An Explanation of Forward Premium Puzzle

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Abstract

This paper focuses on a popular puzzle in the forex market the forward premium puzzle. High interest rate currencies tend to appreciate relative to low-interest-rate currencies. Following Burnside et al. [2009], I argue that adverse selection problems between participants in foreign exchange markets can account for this forward premium puzzle. I present a model in which adverse selection problems between market makers and traders rationalized a negative co-variance between the forward premium and spot rate changes. I first apply the unique order flow data set to test the model from Burnside et al. [2009]. Then, I creatively discuss the transaction between the bond market and spot exchange market to explain the excess return of carry trade.

1 Introduction

UIP illustrates that if investors are risk-neutral and form expectations rationally, exchange rate changes will eliminate any gain arising from the differential in interest rates across countries, and there will be no opportunity to carry trade. According to empirical research, Menkhoff et al. [2012] find that changes in exchange rates will not compensate for interest rate differences, which means the UIP could hardly appear in the currency market. The forward premium puzzle is a public topic in modern international finance. Fama [1984] first argue that carry trades form a profitable investment strategy, violate the UIP, and give rise to the 'forward premium puzzle'. If investments in currencies with high-interest rates deliver low returns during 'bad times' for investors, and then carry trade profits, they are merely compensation for the investors' higher risk-exposure.

During the last few decades, many researchers documented this puzzle, such as Hansen [1982], Fama [1984]. Engel [1984] and Fama [1984] try to explain the puzzle by the existence of the time-varying risk premia. Bansal and Dahlquist [1999] try to find the difference in the risk premia between developed and emerging economies. Londono and Zhou [2017] and Gospodinov [2009] also try to explain the forward premium puzzle through the risk premium method. Burnside et al. [2009] argue that adverse selection problems between the investors in foreign exchange markets can explain the forward premium puzzle. In this paper, I base the adverse selection model on the one suggested by Burnside et al. [2009] to find the main reason for the unresolved forward premium puzzle in international finance.

However, how could the customer earn profit with carry trade? The process in carry trade to get the payoff is discussed below. I first set the domestic currency as the U.S. dollar (USD) and denote the rate of interest on riskless USD denominated securities. I then set the interest rate on riskless foreign denominated securities as i_t^*. Abstracting from transaction costs, the payoff to borrowing one USD, in order to lend the foreign currency, is:

$$(1 + i_t^*)\,\frac{S_{t+1}}{S_t} - (1 + i_t) \tag{1}$$

where S_t denotes the spot exchange rate expressed as USD per foreign currency unit (FCUs). Then, the payoff of the carry trade is:

$$Z_{t+1} = sign\,(i_t^* - i_t)\left[(1 + i_t^*)\,\frac{S_{t+1}}{S_t} - (1 + i_t)\right] \tag{2}$$

Where the Z_{t+1}denotes the payoff in the next period. In period t, the investor has 1 USD and chooses to change it into foreign currency which has interest i_t^*. Then, the investor will obtain $1/S_t$ foreign currency. During the period $t + 1$, the foreign currency would be $(1 + i_t^*)/S_t$ and by changing it into USD the investor would get $(1 + i_t^*) * S_t + 1/S_t$ USD. The investor would just get $(1 + i_t)$ USD if he only let the 1 dollar without any changes. If the investor uses the two ways of arbitrage, the Z_{t+1} would be the payoff of the carry trade strategy. When the USD and the foreign currency do not obey the UIP, the Z_{t+1} would not be zero and excess return would appear. The carry trade could also use the forward rate and spot rate for achieving this strategy. As for the forward premium ($F_t > S_t$), the customer could sell the foreign currency forward. While in the other position ($S_t > F_t$), the customer could earn the profit by purchasing the foreign currency forward. The payoff of the foreign currency forward and spot rate carry trade is:

$$Z_{t+1} = sign\,(F_t - S_t)\left[(1 + i_t)\,\frac{(F_t - S_{t+1})}{F_t}\right] \tag{3}$$

This equation is similar to the equation of interest. When forward premium and discount appear, a carry trade opportunity would arise. For the exchange rate carry trade, the method would be a little different. The investor could sell a forward contract at period t, and change into USDs in period $t + 1$. Then the 1 USD would $(1 + i_t) * S_t + 1/F_t$. While the investor would still get $(1 + i_t)$ USDs if he only let the 1 dollar without any operations. The payoff to this carry trade would be $\frac{(1+i_t)}{F_t}\,(F_t - S_{t+1})$.

Covered interest rate parity (CIP) implies that:

$$\frac{1 + i_t}{1 + i_t^*} = \frac{F_t}{S_t} \tag{4}$$

It could also write as $(1+i_t^*)\,\frac{S_{t+1}}{S_t} = (1-i_t)$, which means the investment for the forward contract of foreign currency would get the same payoff as the investment in domestic currency. When UIP holds, the two way carry trade have the same payoff. While the UIP only holds when the carry trade is not profitable:

$$E\left(Z_{t+1}\right) = E\left(sign\left(i_t^* - i_t\right)\left[\left(1+i_t^*\right)\frac{S_{t+1}}{S_t} - \left(1+i_t\right)\right]\right) = 0 \tag{5}$$

However, carry trade could have a positive profit many times. CIP and UIP together imply that the forward exchange rate is an unbiased forecaster of the future spot exchange rate, i.e. $F_t = E(S_{t+1})$.

The forward premium puzzle can be called the negative correlation between the change of spot exchange rate and the forward premium. If the forward premium exists, domestic currency would depreciate (appreciate) when the nominal interest rate decreases (increases). Consequently, people could apply a simple strategy to earn a profit called carry trade: buy currencies with a higher nominal interest rate and sell the currency with a lower nominal interest rate. Hence, when the carry trade could get excess returns, it could indicate that the forward premium exists.

In this paper, I use the unique order flow data set to test the significance of the model proposed by Burnside et al. [2009]. The generalized method of moments (GMM) helps us find the estimations of those parameters.

There are two main methods to apply order flow data. First, I make a switch (switch method) when I apply the spot rate market order flow which is different from the assumption of Burnside et al. [2009]. I discuss the switch in section 5. Second, I choose to inverse (inverse method) the model from the forward rate to the spot rate, from the model proposed by Burnside et al. [2009]. I discuss the issue of the forward premiums puzzle from a new perspective. My analysis highlights the problem of adverse selection between market makers and investors. To isolate the effects of adverse selection, I use a simple model that was completely abstracted from considering risk. My model is based on the micro-structure method developed by Burnside et al. [2009]. I assume that the forward exchange rate follows an exogenous stochastic process with empirically realistic time series characteristics. My goal explains the forward premium puzzle in the micro-structure method.

The basic structure of my model is as follows: Two main types of risk-neutral traders sign spot rate currencies with competitive, risk-neutral market makers. Informed traders have more information about exchange rate changes than market makers with a signal. Uninformed traders have the same information as market makers. Uninformed traders follow the rules of behavioral trading. According to public information and the change of interest rate, when the pound is expected to appreciate (depreciate), they are more likely to buy (sell) the pound forward.

The emergence of informed agents poses the problem of unfavorable choices for market makers. When the market maker receives the order, he does not know whether the order came from an informed trader or an uninformed trader. However, he can quote different prices for buy and sell orders, and make these prices depend on whether he wants the pound to appreciate or depreciate. My primary result is that adverse selection factors can solve the forward premium puzzle. Specifically, consider a researcher who uses data generated by my model to perform regression analysis on the exchange rate changes of the forward premiums. Under the condition of maintaining regularity, the researcher estimates that the slope coefficient β is negative. This result can be obtained regardless of whether they use the forward exchange rate of the bid (the trader can sell the forward exchange rate of the seller to the market maker) and the forward exchange rate of the asking price (long-term price). The long-term exchange rate that a trader can buy from a market maker is the average of the asking price and the buying price.

Under normal conditions, following the Burnside et al. [2009], require agents to predict the exchange rate based on public information, and the interest rate information to be less than the private information available to informed traders. There is another explanation for this normal situation. As long as it is difficult to use public information to predict the exchange rate, and well-informed traders get a positive expected profit, the forward premium puzzle must exist. The key features of my model is that when agents want to trade based on public information signals, the problem of adverse selection faced by market makers is more serious. To understand why it can be useful to focus on asking prices. Assuming that, based on public information, the pound will depreciate and uninformed traders may sell the pound. Therefore, if the market maker receives a buy order, it is likely to be an order from an informed trader who expects the pound to appreciate. Therefore, market makers offer high purchase orders, that is, high forward exchange rates. When the pound depreciates, the forward premium (assessed by asking price) is higher on average. Therefore, the model captures the negative correlation that defines the difficulty of the forward premiums.

There are two motivations for writing this article concerning the forward premium puzzle. First, Burnside et al. [2009] apply a micro-structure approach to understanding the forward premium puzzle. However, they only discuss the model and the reason for the forward premium puzzle, without estimates of the model. I apply the order flow data which appreciates the adverse selection model. After getting an estimation of the parameters, I try to find the reason for the negative correlation between forward premium and change of spot rate. Second, I add the bond market in the micro-structure model which includes three different markets forward market, spot market, and bond market. I apply the linkage among these markets to discuss the UIP and CIP in the new version using adverse selection.

This paper is structured as follows: the order flow data and the exchange rate data is introduced in the first section; the simple regression between forward premium and the change of spot rate is discussed in the section 3; then, the original model from Burnside et al. [2009] through the exchange rate data set is then estimated; the switch method is discussed in the section 5 and 6; and the inverse method is introduced in section ??. The main results are discussed in the last section.

2 Data

The order flow data I used is from one of the top forex dealers with 12 different pairs of currencies from 2nd Nov 2001 to 23rd Dec 2012. This data set includes exchanges like EURUSD, USDJPY, EURJPY, GBPUSD, EURGBP, USDCHF, EURCHF, AUDUSD, NZDUSD, USDCAD, EURSEK, and EURNOK. The order flow data set have four different kinds of investors: asset managers, corporates, hedge funds, and private clients of spot exchange currencies. I assume that asset managers and hedge funds are informed investors in the forex market, while the corporates and private clients are uninformed traders. The data set also includes bid, ask, and average rate for both forward and spot rates of these 12 exchange currencies from DATASTREAM within the same period.

3 Simple regression

In this section, I test the UIP with simple regression. I apply a simple exploratory model between the forward premium and the change of spot rate as below:

$$s_{t+1} = \alpha + \beta f_t + \varepsilon_{t+1} \tag{6}$$

[Table 1Different period regression is about here]

[Table 2Different period excess return of carry trade strategy is about here]

where α denotes the intercept and β is the slope of the model. The aim to do a simple regression is to test the uncovered interest rate parity in the market. When UIP holds, the α should equal zero and β should equal 1. Then, following Richard and Shu [2000], I apply the Wald F-test with the null hypothesis $H_0 \{\alpha = 0, \beta = 1\}$. The results are given in Table 1 with three different periods - before the financial crisis, during the financial crisis, and after the financial crisis. The financial crisis does not affect the relationship between the forward premium and the change of spot rate for these 12 exchanges in Table 1. Furthermore, it is clear that the value of beta is always close to zero with no significance, and the p-value of the F-test is zero in every case. The results indicate that the UIP cannot hold for these exchanges during these periods. Consequently, I find the reason for the failure of UIP by adding the influence from the interest rate in the model in sections that follow.

I also calculate the annualized mean of the forward premium, rate of depreciation, and excess return for the same period. The excess return of the same exchange has different signs during different periods.

4 Burnside et al. [2009] model

The model from Burnside et al. [2009] assumes that the spot exchange rate follows an exogenous stochastic process, while the forward rate is from the interaction among informed traders, uninformed traders, and market makers. Burnside et al. [2009] attempt to apply adverse selection model to explain the forward premium puzzle. I apply the normal exchange data to estimate the parameters as shown in the results in table 3. Firstly, I will introduce the model from Burnside et al. [2009].

The stochastic process for growth rate of the spot exchange rate was given by:

$$\frac{S_{t+1} - S_t}{S_t} = \phi_t + \varepsilon_{t+1} + \omega_{t+1}. \tag{7}$$

They let S_t be the spot exchange rate expressed as foreign currency units (FCUs) per British pound FCU/USD.

The variable ϕ_t represents the change in the exchange rate that is predictable on the basis of time t, which is public information. At the beginning of time t, all traders observe ϕ_t. For simplicity they assumed that this variable is i.i.d. and obeys:

$$\phi_t = \begin{cases} \phi & \text{with probability } 1/2, \\ -\phi & \text{with probability } 1/2, \end{cases} \tag{8}$$

where $\phi > 0$.

The variable ε_{t+1} is not directly observed at time t, but one group of traders receive advance signals about its value. This variable is i.i.d. and obeys:

$$\varepsilon_{t+1} = \begin{cases} \varepsilon & \text{with probability } 1/2, \\ -\varepsilon & \text{with probability } 1/2, \end{cases} \tag{9}$$

where $\varepsilon > 0$.

Finally, none of the agents in the model has information at time t about the value of ω_{t+1}. The presence of this shock allows the model to generate an exchange rate volatility that is not tied to either private or public information. The variable ω_{t+1} is i.i.d., mean zero, and has variance σ_ω^2. The three shocks ϕ_t, ε_{t+1}, and ω_{t+1} are mutually orthogonal.

If the market maker was selling the pound forward then his profit (in FCUs), and if $\phi_t = \phi$, the market maker's profit from selling one pound forward, π_{t+1}^m, is:

$$\pi_{t+1}^m = F_t^a(\phi) - S_{t+1}. \tag{10}$$

Here, π_{t+1}^m is denominated in FCUs. Since the market maker's expected profit is zero, it follows that:

$$E(\pi_{t+1}^m | \text{buy}, \phi) = F_t^a(\phi) - E(S_{t+1} | \text{buy}, \phi) = 0. \tag{11}$$

Using equation (7) I have:

$$F_t^a(\phi) = S_t \left[1 + \phi + E(\varepsilon_{t+1} | \text{buy}, \phi)\right]. \tag{12}$$

Following the Bayesian rule, I evaluate the expectation of the market maker of ε_{t+1}, based on his information set:

$$E\left(\varepsilon_{t+1} \mid buy, \phi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right)(\varepsilon) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \phi\right)(-\varepsilon) \tag{13}$$

The function given below is implied in the Bayesian rule:

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right) = \frac{Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right)}{Pr\left(buy \mid \phi\right)} \tag{14}$$

When they compute the $Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right)$, they need to consider the informed and uninformed traders separately. When $\phi_t = \phi$, uninformed traders would buy the pound forward. When $\varepsilon_{t+1} = \varepsilon$, informed traders would buy the pound forward with probability q, the signal $\zeta_t = \varepsilon = \varepsilon_{t+1}$.

$$Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right) = 1 - \alpha + \alpha q \tag{15}$$

$$Pr\left(buy \mid \phi\right) = Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right) + Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = -\varepsilon\right) \tag{16}$$

They also need to compute $Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \phi\right)$ in a similar way, and it follows that:

$$Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \phi\right) = 1 - \alpha + \alpha\left(1 - q\right) \tag{17}$$

They use equations 15, 16 and 17 to get the equation below:

$$Pr\left(buy \mid \phi\right) = \left(1 - \alpha + \alpha q\right)\frac{1}{2} + \left[1 - \alpha + \alpha\left(1 - q\right)\right]\frac{1}{2} = 1 - \frac{\alpha}{2} \tag{18}$$

Equations 15, 18 and 14 imply that

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right) = \frac{1 - \alpha\left(1 - q\right)}{2 - \alpha} \tag{19}$$

Since

$$Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \phi\right) = 1 - Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right) \tag{20}$$

They have

$$Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \phi\right) = \frac{1 - \alpha q}{2 - \alpha} \tag{21}$$

By substituting equations 19, 21 and 13, I obtain

$$E\left(\varepsilon_{t+1} \mid buy, \phi\right) = \frac{\alpha}{2 - \alpha}(2q - 1)\varepsilon \tag{22}$$

They obtain from equation above that

$$F_t^a(\phi) = S_t \left[1 + \phi + \frac{\alpha}{2-\alpha}(2q-1)\varepsilon\right] \tag{23}$$

Hence, this is the ask forward rate with positive public information. $F_t^a(\phi)$ would be influenced by the value of ϕ, the proportion of informed traders α, the probability for the signal ζ_t is correct and the value of private information ε. Applying similar methods, I can derive the other three situations as given below[1]:

$$\begin{cases} F_t^a(\phi_t) = \begin{cases} S_t\left[1 + \phi + (2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right] & if\, \phi_t = \phi, \\ S_t\left[1 - \phi + (2q-1)\varepsilon\right] & if\, \phi_t = -\phi, \end{cases} \\ F_t^b(\phi_t) = \begin{cases} S_t\left[1 + \phi - (2q-1)\varepsilon\right] & if\, \phi_t = \phi, \\ S_t\left[1 - \phi - (2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right] & if\, \phi_t = -\phi. \end{cases} \end{cases} \tag{24}$$

[Table 3GMM model-1 results with normal forex data is about here]

Table 3 shows the GMM model estimations with the five moments (model-1). [2] The J-test examines the moments of the GMM models' reasonability. Because the P-values of the J test are all larger than 10%, I indicate that the moments in this model are all appropriate. The public information parameter φ, private information parameter ε, and probability q are all significant in each currency. α also has a low standard error with several exchanges with no significance. The value of public information parameter φ is much lower than that of the private information parameter ε, which indicate that public information has lesser effects on the exchange rate. Although the model has a good estimation, the value of α is still much higher than the assumption with almost 30 estimations of the model. However, I cannot add more parameters and comments in this situation, because of the lack of data. Hence, I use the unique order flow data which includes four different kinds of investors' order flows of spot exchange rate. Since the data set is the order flows of the spot exchange rate. I need to switch the model computing assumption which would be discussed in the next section.

5 Exchange rate in the forward and spot market(switch method)

In this section, I introduce the switch method. The motivation to apply the spot rate order flow data is lacking of data to estimate the micro-structure model. The switch model could help me to apply the spot rate order flow data logically. The main difference between the basic model and switch method is

[1]The complete derivative process is shown in the Appendix. B.

[2]The GMM model has been introduced in appendix.A.

that I consider the expected value of spot rate at term $t+1$ firstly instead of the forward rate.

Given the setup from Burnside et al. [2009], I thought about how the forward rate should be determined. I thought of traders arriving in the forward market and making transactions with a market maker. If the trader wanted to buy (sell) a pound forward, then the market maker would take the opposite position by selling (buying) a pound forward. The basic idea in the model was to have the market maker be risk-neutral, and set the forward rates (the ask and the bid rate) so that the expected profit implicit in the market maker's position should be zero. This occurs when the forward rates for the market maker selling (buying) at time t is equal to the spot rates market maker buying (selling) at time $t+1$[3]. Hence, I can switch from setting the forward rates (the ask and the bid rate) directly to estimating the expectation of spot rates at time $t+1$ in the spot market. I assume that the market maker could also observe the order flow in the spot market at time t. I apply the order flow of the spot rates to forecast the spot rates at time $t+1$. Then, the spot rate order flow data could be applied in estimating the parameters. The model looks similar as the Burnside et al. [2009] model.

If the market maker was selling the pound forward then his profit (in FCUs), and if $\phi_t = \phi$, the market maker's profit from selling one pound forward, π^m_{t+1}, is:

$$\pi^m_{t+1} = F^a_t(\phi) - S_{t+1}. \tag{25}$$

Here, π^m_{t+1} is denominated in FCUs. Since the market maker's expected profit is zero, it follows that:

$$E(\pi^m_{t+1}|\text{buy}, \phi) = F^a_t(\phi) - E(S_{t+1}|\text{buy}, \phi) = 0. \tag{26}$$

Using equation 7 I have:

$$F^a_t(\phi) = S_t\left[1 + \phi + E(\varepsilon_{t+1}|\text{buy}, \phi)\right]. \tag{27}$$

Note that I apply the expected value of S_{t+1} which is in the spot market to estimate the value of $F^a_t(\phi)$ which is in the forward market. I have the order flow data for the spot market which could help us in estimating the expected value of S_{t+1}, since the value of S_{t+1} could be affected by the spot market order flow. As I discussed earlier, the spot rate would follow the exogenous stochastic process. The value of $\varepsilon_{t+1}, \omega_{t+1}$ cannot be observed by any participant in the spot market. Only informed traders receive advance signals about ε_{t+1} value. Hence, I apply the order flow of the spot rate market to estimate the value of the expectation of S_{t+1}, which is consequently equal to the value of $F^a_t(\phi)$.

Following the Bayesian rule, I evaluate the expectation of the market maker of ε_{t+1}, based on his information set:

$$E\left(\varepsilon_{t+1} \mid buy, \phi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right)(\varepsilon) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \phi\right)(-\varepsilon) \tag{28}$$

[3]The equation26 illustrate this assumption

The function given below is implied in the Bayesian rule:

$$Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\phi\right)=\frac{Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\phi\right)Pr\left(\varepsilon_{t+1}=\varepsilon\right)}{Pr\left(buy \mid \phi\right)} \tag{29}$$

When I compute the $Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\phi\right)$, I need to consider the informed and uninformed traders separately. When $\phi_t=\phi$, uninformed traders would buy the pound forward. When $\varepsilon_{t+1}=\varepsilon$, informed traders would buy the pound forward with probability q, the signal $\zeta_t=\varepsilon=\varepsilon_{t+1}$.

$$Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\phi\right)=1-\alpha+\alpha q \tag{30}$$

$$Pr\left(buy \mid \phi\right)=Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\phi\right)Pr\left(\varepsilon_{t+1}=\varepsilon\right)+Pr\left(buy \mid \varepsilon_{t+1}=-\varepsilon,\phi\right)Pr\left(\varepsilon_{t+1}=-\varepsilon\right) \tag{31}$$

I also need to compute $Pr\left(buy \mid \varepsilon_{t+1}=-\varepsilon,\phi\right)$ in a similar way, and it follows that:

$$Pr\left(buy \mid \varepsilon_{t+1}=-\varepsilon,\phi\right)=1-\alpha+\alpha\left(1-q\right) \tag{32}$$

I use equations 30, 31 and 32 to get the equation below:

$$Pr\left(buy \mid \phi\right)=\left(1-\alpha+\alpha q\right)\frac{1}{2}+\left[1-\alpha+\alpha\left(1-q\right)\right]\frac{1}{2}=1-\frac{\alpha}{2} \tag{33}$$

Equations 30, 33 and 29 imply that

$$Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\phi\right)=\frac{1-\alpha\left(1-q\right)}{2-\alpha} \tag{34}$$

Since

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,\phi\right)=1-Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\phi\right) \tag{35}$$

I have

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,\phi\right)=\frac{1-\alpha q}{2-\alpha} \tag{36}$$

By substituting equations 34, 36 and 28, I obtain

$$E\left(\varepsilon_{t+1} \mid buy,\phi\right)=\frac{\alpha}{2-\alpha}(2q-1)\varepsilon \tag{37}$$

I obtain from equation above that

$$F_t^a\left(\phi\right)=S_t\left[1+\phi+\frac{\alpha}{2-\alpha}(2q-1)\varepsilon\right] \tag{38}$$

Hence, this is the ask forward rate with positive public information.$F_t^a\left(\phi\right)$ would be influenced by the value of ϕ, the proportion of informed traders α, the probability for the signal ζ_t is correct and the value of private information

ε. Applying similar methods, I can derive the other three situations as given below[4]:

$$\begin{cases} F_t^a\left(\phi_t\right) = \begin{cases} S_t\left[1+\phi+(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right] & if\ \phi_t = \phi, \\ S_t\left[1-\phi+(2q-1)\varepsilon\right] & if\ \phi_t = -\phi, \end{cases} \\ F_t^b\left(\phi_t\right) = \begin{cases} S_t\left[1+\phi-(2q-1)\varepsilon\right] & if\ \phi_t = \phi, \\ S_t\left[1-\phi-(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right] & if\ \phi_t = -\phi. \end{cases} \end{cases} \tag{39}$$

Substituting equations from 39, I could obtain

$$\ln\left[F_t^a\left(\phi_t\right)/F_t^b\left(\phi_t\right)\right] \cong \frac{2}{2-\alpha}\left(2q-1\right)\varepsilon \tag{40}$$

This equation indicates that the bid ask spread is independent from the public information ϕ_t.

When I consider the regression, like given below, I get the equation as

$$\frac{S_{t+1}-S_t}{S_t} = a + \beta\frac{F_t-S_t}{S_t} + \xi_{t+1} \tag{41}$$

Let $\frac{S_{t+1}-S_t}{S_t} = \delta_{t+1} = \phi_t + \varepsilon_{t+1} + \omega_{t+1}$,and $\frac{F_t-S_t}{S_t} = f_t$.
the slope β could also be computed as follows:

$$plim\hat{\beta} = \frac{cov\left(\delta_{t+1}, f_t\right)}{var\left(f_t\right)} \tag{42}$$

I rewrite the model of f_t as

$$f_t \quad = \quad \begin{cases} \phi-\left(2q-1\right)\left(1-\alpha\right)/\left(2-\alpha\right)\varepsilon & if\phi_t = \phi \\ -\phi+\left(2q-1\right)\left(1-\alpha\right)/\left(2-\alpha\right)\varepsilon & if\phi_t = -\phi \end{cases} \tag{43}$$

then I could compute the variance and co-variance of δ_{t+1} and f_t , and let:

$$\theta = \left(2q-1\right)\left(1-\alpha\right)/\left(2-\alpha\right) \tag{44}$$

$$var\left(f_t\right) = \frac{1}{2}\left(\phi-\theta\varepsilon\right)^2 + \frac{1}{2}\left(-\phi+\theta\varepsilon\right)^2 = \left(\phi-\theta\varepsilon\right)^2 \tag{45}$$

$$cov\left(\delta_{t+1}, f_t\right) = \frac{1}{2}\phi\left(\phi-\theta\varepsilon\right) + \frac{1}{2}\left(-\phi\right)\left(-\phi+\theta\varepsilon\right) = \phi\left(\phi-\theta\varepsilon\right) \tag{46}$$

I then get

$$plin\hat{\beta} = \frac{\phi}{\phi-\theta\varepsilon} \tag{47}$$

and consequently,

[4]The complete derivative process is shown in the Appendix. B.

$$plim\hat{\beta} = \frac{\phi}{\phi - (1-\alpha)(2q-1)\varepsilon/(2-\alpha)} \tag{48}$$

If

$$\phi < \frac{1-\alpha}{2-\alpha}(2q-1)\varepsilon \tag{49}$$

then $plim\hat{\beta} < 0$. I show the estimates of the slope of different currencies from the results of GMM estimation later.

From equations 39, I could obtain

$$\frac{F_t^a(\phi_t) - S_t}{S_t} = \frac{F_t^b(\phi_t) - S_t}{S_t} + \frac{2}{2-\alpha}(2q-1)\varepsilon \tag{50}$$

It is clear that whether I use ask, bid, or the average forward rate in the regression, the effect would be only on the intercept α.

When I set the parameter $q = \frac{1}{2}$(all the traders are uninformed), the ask and bid forward rate would be the same, then

$$\frac{F_t^a(\phi_t) - S_t}{S_t} = \frac{F_t^b(\phi_t) - S_t}{S_t} = \phi_t \tag{51}$$

When I set the $\alpha = 1$ (all traders are informed), the forward premium would be

$$\frac{F_t^a(\phi_t) - S_t}{S_t} = \phi_t + (2q-1)\varepsilon, \tag{52}$$

$$\frac{F_t^b(\phi_t) - S_t}{S_t} = \phi_t - (2q-1)\varepsilon. \tag{53}$$

When I set $q = 1, \varepsilon_{t+1} = \varepsilon, \phi_t = -\phi$, the ask forward rate would be

$$F_t^a(-\phi) = S_t(1 - \phi + \varepsilon) \tag{54}$$

and I obtain the following from the equation, 37 with $q = 1, \varepsilon_{t+1} = \varepsilon$

$$E(\varepsilon_{t+1} \mid buy, \phi) = \frac{\alpha}{2-\alpha}\varepsilon < \varepsilon \tag{55}$$

Consequently, the forward rate would be

$$F_t^a(\phi) = S_t\left(1 + \phi + \frac{\alpha}{2-\alpha}\varepsilon\right) \tag{56}$$

Comparing equation 53, 55 and 49, I have

$$F_t^a(\phi) < F_t^a(-\phi) \tag{57}$$

The market forward rate would follow the $plim\hat{\beta} < 0$

Basically, the rest of the paper works out convenient expressions for $F_t^a(\phi)$, $F_t^b(\phi)$, $F_t^a(-\phi)$, $F_t^b(-\phi)$ by evaluating objects like $E(\varepsilon_{t+1}|\text{buy}, \phi)$ given the differing information sets of traders and market makers, and whether the transaction was a buy or sell of the pound.

[Table 4 GMM model-2 is about here]

[Table 5 GMM model-3 is about here]

Tables 4 and 5 show the results of the estimation of the parameters, while the estimations are appropriate with a reasonable p-value of the J-test. Table 4 (model-2) is the result of the basic model of Burnside et al. [2009], which is the same as model-1. The parameters are almost significant.The public information parameter ϕ has a low value, compared to the private information parameter ε. The correct probability of informed traders q is always higher than 50%, which is consistent with our assumption. The informed trader α remains at a low value indicating that informed traders have a low proportion in the market, which has a much lower and more reasonable value than model-1. Table 5 (model-3) shows the model with a new parameter v. The results show that most uninformed traders choose to believe public information. Estimates of parameter v range from 71% to 100% which is consistent with my assumption.

[Table 10 The slope and profit of the traders is about here]

[Table 24 Characteristics of the data is about here]

[Table 10 The slope and profit of the traders is about here]

Table 10 gives the slope and expected returns of informed traders. When the slope is negative, the forward premium puzzle will exist. Negative slopes from the regression in Table 24 are EURUSD, USDJPY, USDCHF, EURCHF, EURSEK, and EURNOK. I can see from the slope that estimates are negative for currencies for the basic model are EURUSD, USDJPY, EURJPY, USDCHF and USDCAD. All these currencies have positive informed traders' returns, which could explain the forward premium puzzle. In the next section, I consider the relationship between the spot exchange market and bond market.

6 The spot market and bond market(Add UIP in the model)

Burnside et al. [2009] mentioned the interest rate effect in their micro-structure model by using the public information. They argue the interest rate could be included in the public information which could be observed by all participant in the market. However, I think the interest rate should be discussed separately since the UIP and CIP assumption. Hence, I add the bond market in the microstructure model to discuss the relationship between those three market (forward market, spot market and bond market).

When considering the spot market and bond market, I still set the exchange rate as FCU/USD. The stochastic process for the growth rate of the spot exchange rate would be changed to:

$$S_{t+1} = S_t \frac{1+i_t}{1+i_t^*} \left(1 + \varphi_t + \varepsilon_{t+1} + \omega_{t+1}\right). \tag{58}$$

Note that equation 58 is different from the assumption in section5. I consider the UIP when setting the stochastic process.

The variable φ_t represents the change in the exchange Rate, that is predictable on the basis of time t public information. However, the difference between the φ_t and ϕ_t is the φ_t excludes the effect from the interest rate. From the UIP, I strip the interest influence from the ϕ_t, which means the φ_t denotes public information without the interest rate effect. Hence, the $\phi > \varphi$. At the beginning of time t, all traders observe φ_t. For simplicity I assumed that this variable is i.i.d., and obeys:

$$\varphi_t = \begin{cases} \varphi & \text{with probability } 1/2, \\ -\varphi & \text{with probability } 1/2, \end{cases} \tag{59}$$

where $\varphi > 0$.

Then, let us consider the UIP in traders' transactions. Assume the foreign country has a higher interest rate than the US interest rate. Then, the trader wants to exercise the carry trade strategy, between the foreign country and the US, in the spot exchange rate market and bond market. Imagine that at time t the traders have $S_t/(1+i_t)$ USD which would be worth S_t USD in the US bond market at time $t+1$. To get a higher interest rate in the foreign bond market, he could also convert it to $1/(1+i_t)$ FCUs in the spot market by using USD to buy FCU at spot rate S_t, and then earn at the interest rate i_t^* in the foreign bond market. This means the traders have $\frac{1+i_t^*}{1+i_t}$ FCUs at $t+1$. Hence, the terminated value of the trader in the foreign bond market at time $t+1$ is $S_{t+1}\frac{1+i_t^*}{1+i_t}$ USD, when he sells the FCUs to USDs. According to the UIP, the trader should have the same value with S_t and $S_{t+1}\frac{1+i_t^*}{1+i_t}$ at time $t+1$, and the profit from carry trade in this circumstance should be zero:

$$\tilde{\pi}_{t+1}^m = S_{t+1}\frac{1+i_t^*}{1+i_t} - S_t^a \tag{60}$$

I then consider the market maker who should enter in the opposite party, in this circumstance. Hence the profit of market maker should be equal to:

$$\tilde{\pi}_{t+1}^m = S_t^a - S_{t+1}\frac{1+i_t^*}{1+i_t} \tag{61}$$

But notice that if I modified equation 58 to say that

$$S_{t+1} = S_t \frac{1+i_t}{1+i_t^*} \left(1+\varphi_t+\varepsilon_{t+1}+\omega_{t+1}\right) \tag{62}$$

then you would have just an equally useful expression. I would then have

$$\tilde{\pi}_{t+1}^m = S_t^a - S_t \left(1+\varphi_t+\varepsilon_{t+1}+\omega_{t+1}\right) \tag{63}$$

If UIP hold, the expected value of $\tilde{\pi}_{t+1}^m$ should be zero. The effect of the interest rate would have been counteracted. The ask exchange spot rate, then, should be equal to

$$S_t^a = S_t \left(1+\varphi_t+E\left(\varepsilon_{t+1}\right)\right) \tag{64}$$

The difference between S_t^a and F_t^a is the difference between φ_t and ϕ_t.

No agents could observe the fact ε_{t+1}, however, public information φ_t is available for all participants in the market. Hence I have 4 different spot rate $S_t^a(\varphi)$, $S_t^a(-\varphi)$, $S_t^b(\varphi)$, and $S_t^b(-\varphi)$.

When $\varphi_t = \varphi$, the market maker would get the profit from selling one pound spot, π_{t+1}^m, is

$$\pi_{t+1}^m = S_t^a(\varphi) - S_t \left(1+\varphi_t+\varepsilon_{t+1}+\omega_{t+1}\right) \tag{65}$$

The expected profit of the market maker should be zero, hence

$$E\left(\pi_{t+1}^m \mid buy, \varphi\right) = S_t^a(\varphi) - E\left(S_{t+1} \mid buy, \varphi\right) = 0 \tag{66}$$

By applying the equation above, I get the equation given below

$$S_t^a\left(\varphi\right) = S_t \left[1+\varphi+E\left(\varepsilon_{t+1} \mid buy, \varphi\right)\right] \tag{67}$$

Following the Bayesian rule, I evaluate the expectations of the market maker from ε_{t+1}, based on his information set:

$$E\left(\varepsilon_{t+1} \mid buy, \varphi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \varphi\right)\left(\varepsilon\right) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \varphi\right)\left(-\varepsilon\right) \tag{68}$$

The function given below is implied in the Bayesian rule:

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \varphi\right) = \frac{Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \varphi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right)}{Pr\left(buy \mid \varphi\right)} \tag{69}$$

When I compute the $Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \varphi\right)$, I need to consider informed and uninformed traders separately. When $\varphi_t = \varphi$, uninformed traders would buy the pound spot. When $\varepsilon_{t+1} = \varepsilon$, informed traders would buy the pound spot with probability q, the signal $\zeta_t = \varepsilon = \varepsilon_{t+1}$.

$$Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \varphi\right) = 1 - \alpha + \alpha q \tag{70}$$

$$Pr\left(buy \mid \varphi\right) = Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \varphi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right) + Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \varphi\right) Pr\left(\varepsilon_{t+1} = -\varepsilon\right) \tag{71}$$

I also need to compute $Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \varphi\right)$ by the similar way, and it follow that:

$$Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \varphi\right) = 1 - \alpha + \alpha\left(1 - q\right) \tag{72}$$

I use equations 70, 71 and 72 to get the equation below:

$$Pr\left(buy \mid \varphi\right) = \left(1 - \alpha + \alpha q\right)\frac{1}{2} + \left[1 - \alpha + \alpha\left(1 - q\right)\right]\frac{1}{2} = 1 - \frac{\alpha}{2} \tag{73}$$

Equations 70, 73 and 69 imply that

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \varphi\right) = \frac{1 - \alpha\left(1 - q\right)}{2 - \alpha} \tag{74}$$

Since

$$Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \varphi\right) = 1 - Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \varphi\right) \tag{75}$$

I have

$$Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \varphi\right) = \frac{1 - \alpha q}{2 - \alpha} \tag{76}$$

By substituting equations 74, 76 and 68, I obtain

$$E\left(\varepsilon_{t+1} \mid buy, \varphi\right) = \frac{\alpha}{2 - \alpha}(2q - 1)\varepsilon \tag{77}$$

I obtain from equation67

$$S_t^a\left(\varphi\right) = S_t\left[1 + \varphi + \frac{\alpha}{2 - \alpha}(2q - 1)\varepsilon\right] \tag{78}$$

Hence, this is the ask spot rate with positive public information. $S_t^a\left(\varphi\right)$ would be influenced by the value of φ, the proportion of informed traders α, the probability for the signal ζ_t is correct and the value of private information ε. Applying similar methods, I can derive the other three situations as below:

$$\begin{cases} S_t^a\left(\varphi_t\right) = \begin{cases} S_t\left[1 + \varphi + (2q - 1)\varepsilon\alpha/\left(2 - \alpha\right)\right] & if\ \varphi_t = \varphi, \\ S_t\left[1 - \varphi + (2q - 1)\varepsilon\right] & if\ \varphi_t = -\varphi, \end{cases} \\ S_t^b\left(\varphi_t\right) = \begin{cases} S_t\left[1 + \varphi - (2q - 1)\varepsilon\right] & if\ \varphi_t = \varphi, \\ S_t\left[1 - \varphi - (2q - 1)\varepsilon\alpha/\left(2 - \alpha\right)\right] & if\ \varphi_t = -\varphi. \end{cases} \end{cases} \tag{79}$$

Since I consider the effects of interest rate on the transaction between bond market and spot market, I have separated the interest rate information from public information. Because I have already considered the impact from interest rate to the spot exchange rate, I do not consider the order flow affected by the interest rate information. The reason why the UIP cannot be found is that informed traders get a positive profit from the UIP transaction.

If the UIP holds between the bond market and spot market, no one could get a positive profit through carry trade, and the expected profit should be equal to zero.

When I found that the interest rate effect has been counteracted, I realized that the interest rate mainly influences the exchange rate of the forward and term t+1 spot rate, which is consistent with the UIP and CIP. Furthermore, the order flow is also a factor, which has been proven in the literature.

[Table 6 GMM model-4 is about here]

[Table 7 GMM model-5 is about here]

Tables 6(model-4) and 7(model-5) show the results of the estimation of the parameters. I see that the public information parameter φ without interest rate information is much lower than the public information parameter ϕ. For instance, the value of parameter ϕ of EURUSD in model-2 and model-3 is 0.0003, while the value of the parameter φ is 0.0001. This is because I got rid of this effect of the interest rate. These results could indicate that the interest rate information plays an important role in public information.

6.1 Overestimate of the effect of the uninformed traders

Let us consider a stricter circumstance. According to the UIP and CIP, I know that the interest rate influences the exchange rate a lot. The interest rate is also known as public information, which can be observed at time t. Hence the interest rate information is a part of the public information ϕ. When I add the UIP in the stochastic process for the growth rate of the spot exchange rate, I need to get rid of the effect of interest information from public information. Then, I have a new public information parameter φ. However, I ignore the uninformed traders, who follow the interest rate and whose order flow has already been reflected in the UIP. Hence, I add a new parameter ϱ in this section, to get rid of the order flow of the interest rate.

$$S_t^a(\varphi) = S_t\left[1 + \varphi + E\left(\varepsilon_{t+1} \mid buy, \varphi\right)\right] \tag{80}$$

Following the Bayesian rule, I evaluate the expectation of the market maker from ε_{t+1}, based on his information set:

$$E\left(\varepsilon_{t+1} \mid buy, \varphi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \varphi\right)(\varepsilon) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \varphi\right)(-\varepsilon) \tag{81}$$

The function given below is implied in the Bayesian rule:

$$Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\varphi\right)=\frac{Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\varphi\right)Pr\left(\varepsilon_{t+1}=\varepsilon\right)}{Pr\left(buy \mid \varphi\right)} \tag{82}$$

When I compute the $Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\varphi\right)$, I need to consider the informed and uninformed traders separately. When $\varphi_t=\varphi$, uninformed traders would buy the pound spot. When $\varepsilon_{t+1}=\varepsilon$, informed traders would buy the pound spot with probability q, the signal $\zeta_t=\varepsilon=\varepsilon_{t+1}$. I set ϱ as the uninformed traders who follow the interest rate.

$$Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\varphi\right)=1-\alpha-\varrho+\alpha q \tag{83}$$

$$Pr\left(buy \mid \varphi\right)=Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,\varphi\right)Pr\left(\varepsilon_{t+1}=\varepsilon\right)+Pr\left(buy \mid \varepsilon_{t+1}=-\varepsilon,\varphi\right)Pr\left(\varepsilon_{t+1}=-\varepsilon\right) \tag{84}$$

I also need to compute $Pr\left(buy \mid \varepsilon_{t+1}=-\varepsilon,\varphi\right)$ by the similar way, and it follow that:

$$Pr\left(buy \mid \varepsilon_{t+1}=-\varepsilon,\varphi\right)=1-\alpha-\varrho+\alpha\left(1-q\right) \tag{85}$$

I use equations 83, 84 and 85 to get the equation below:

$$Pr\left(buy \mid \varphi\right)=\left(1-\alpha-\varrho+\alpha q\right)\frac{1}{2}+\left[1-\alpha-\varrho+\alpha\left(1-q\right)\right]\frac{1}{2}=1-\varrho-\frac{\alpha}{2} \tag{86}$$

Equations 83, 86 and 82 imply that

$$Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\varphi\right)=\frac{1-\varrho-\alpha\left(1-q\right)}{2-2\varrho-\alpha} \tag{87}$$

Since

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,\varphi\right)=1-Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\varphi\right) \tag{88}$$

I have

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,\varphi\right)=\frac{1-\varrho-\alpha q}{2-2\varrho-\alpha} \tag{89}$$

By substituting equations 87, 89 and 81, I obtain

$$E\left(\varepsilon_{t+1} \mid buy,\varphi\right)=\frac{\alpha}{2-2\varrho-\alpha}(2q-1)\varepsilon \tag{90}$$

I obtain from equation 80

$$S_t^a\left(\varphi\right)=S_t\left[1+\varphi+\frac{\alpha}{2-2\varrho-\alpha}(2q-1)\varepsilon\right] \tag{91}$$

Hence, this is the ask spot rate with the positive public information. $S_t^a\left(\varphi\right)$ would be influenced by the value of φ, the proportion of informed traders α, the probability for the signal ζ_t is correct and the value of private information ε. Applying similar methods, I can derive the other three situations as shown below:

$$\begin{cases} S_t^a(\varphi_t) = \begin{cases} S_t\left[1+\varphi+(2q-1)\varepsilon\alpha/\left(2-2\varrho-\alpha\right)\right] & if\ \varphi_t=\varphi, \\ S_t\left[1-\varphi+(2q-1)\varepsilon\right] & if\ \varphi_t=-\varphi, \end{cases} \\ S_t^b(\varphi_t) = \begin{cases} S_t\left[1+\varphi-(2q-1)\varepsilon\right] & if\ \varphi_t=\varphi, \\ S_t\left[1-\varphi-(2q-1)\varepsilon\alpha/\left(2-2\varrho-\alpha\right)\right] & if\ \varphi_t=-\varphi. \end{cases} \end{cases} \tag{92}$$

[Table 8 GMM model-6 is about here]

Table 8 shows the results of the estimation of the parameters. The parameter ϱ has a large range from 0.1530 to 0.9372, with non-significant. It seems that the setting of moments have some problems. Hence, I discuss the parameter ϱ later in model-7, which is be estimated in the next subsection.

[Table 9 Comparison of public information in different models is about here]

Table 9 (model-6) illustrates the comparative difference in public information parameters between the three models. It is not surprising to see that the public information parameter has the lowest value by getting the rid of the full effect of the interest rate.

$$\frac{S_t^a(\varphi_t)-S_t}{S_t} = \frac{S_t^b(\varphi_t)-S_t}{S_t} + \frac{2-2\varrho}{2-2\varrho-\alpha}(2q-1)\,\varepsilon \tag{93}$$

$$\ln\left[S_t^a(\varphi_t)/S_t^b(\varphi_t)\right] \cong \frac{2}{2-2\varrho-\alpha}(2q-1)\,\varepsilon \tag{94}$$

I can see that the bid-ask spread of the spot rate is not affected by public information, since this is known by all the participants in the market. The higher the proportion of informed traders, the higher correct probability for the signal and more important the private information that would increase the bid-ask spread. If more uninformed traders follow the interest rate information, the bid-ask spread would increase. In the next subsection, I consider the three markets together.

6.2 Discussion of the spot rate and forward rate

To relate the spot and forward rate, it is simpler to start from the UIP and CIP. If the CIP holds, equation 61 and 25 would help us to have:

$$S_{t+1} = S_t^a(\varphi_t)\frac{1+i_t}{1+i_t^*} = F_t^a(\phi_t) \tag{95}$$

Then, I get the equations below:

$$
\begin{aligned}
\tfrac{1+i_t}{1+i_t^*}S_t\left[1+\varphi+(2q-1)\varepsilon\alpha/\left(2-2\varrho-\alpha\right)\right] &= S_t\left[1+\phi+(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right]\ if\ \varphi_t=\varphi,\phi_t=\phi\\
\tfrac{1+i_t}{1+i_t^*}S_t\left[1-\varphi+(2q-1)\varepsilon\right] &= S_t\left[1-\phi+(2q-1)\varepsilon\right]\ if\ \varphi_t=-\varphi,\phi_t=-\phi\\
\tfrac{1+i_t}{1+i_t^*}S_t\left[1+\varphi-(2q-1)\varepsilon\right] &= S_t\left[1-\phi+(2q-1)\varepsilon\right]\ if\ \varphi_t=\varphi,\phi_t=\phi\\
\tfrac{1+i_t}{1+i_t^*}S_t\left[1-\varphi-(2q-1)\varepsilon\alpha/\left(2-2\varrho-\alpha\right)\right] &= S_t\left[1-\phi-(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right]\ if\ \varphi_t=-\varphi,\phi_t=-\phi
\end{aligned}
\tag{96}
$$

I eliminate S_t for both side, and get:

$$
\begin{aligned}
\tfrac{1+i_t}{1+i_t^*}\left[1+\varphi+(2q-1)\varepsilon\alpha/\left(2-2\varrho-\alpha\right)\right] &= \left[1+\phi+(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right]\ if\ \varphi_t=\varphi,\phi_t=\phi\\
\tfrac{1+i_t}{1+i_t^*}\left[1-\varphi+(2q-1)\varepsilon\right] &= \left[1-\phi+(2q-1)\varepsilon\right]\ if\ \varphi_t=-\varphi,\phi_t=-\phi\\
\tfrac{1+i_t}{1+i_t^*}\left[1+\varphi-(2q-1)\varepsilon\right] &= \left[1-\phi+(2q-1)\varepsilon\right]\ if\ \varphi_t=\varphi,\phi_t=\phi\\
\tfrac{1+i_t}{1+i_t^*}\left[1-\varphi-(2q-1)\varepsilon\alpha/\left(2-2\varrho-\alpha\right)\right] &= \left[1-\phi-(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right]\ if\ \varphi_t=-\varphi,\phi_t=-\phi
\end{aligned}
\tag{97}
$$

[Table 11 GMM model-7 is about here]

I found that the parameter q, α, ε should be the same in sections 5 and 6.1 through the equation 97. Then, I estimate the moments in those two sections together, to see the precise value of two different public information ϕ and φ. Table 11(model-7) shows the results of the estimates. I see that the ϕ is still higher than the φ. It is interesting to estimate all the moments among the three different markets together. The results show that the moments are more appropriate than model-6. The value of the parameter ϱ will be more stable and significant with a value of around 20%. It indicates that around 20% uninformed traders follow public information. The parameter φ is always smaller than the parameter ϕ which is evidence for the effect from interest rate.

Once equation 95 holds, the difference between $S_t^a(\varphi_t)$ and $F_t^a(\phi_t)$ is the interest rate. From this, I can indicate that the exchange rate could be affected by both interest rate and order flow from market participants. In the next section, I apply the inverse method to estimate the models. The CIP and UIP should hold when the exchange rates are adjusted by the order flow.

7 Conclusion

In this paper, I present a model in which adverse selection problems between market makers and traders rationalize a negative co-variance between the forward premium and spot rate changes. I apply the unique order flow data in two different ways: switch to consider the spot rate at term $t+1$, or the inverse of the forward rate as the exogenous value. In the first method, UIP exists between the forward rate and spot rate after the adjustment of the order flow. The informed traders always have positive profit, in line with my hypothesis. With the second method, when increasing the number of parameters, the models become much closer to reality. Most of the models could have significant estimations with reasonable value. Adding uncovered interest rate parity helps us to explain the failure of UIP. The results show that the main reason for the failure of UIP and CIP is the effect of private information. Overall, the adverse selection could generate the forward premium puzzle.

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Appendix

Appendix.A GMM models

I will give a sample of GMM model in the practice. Let's show an example of the GMM model. Consider there is a Population Moment Condition. Let θ_0 be a vector of unknown parameters which are to be estimated, v_t be a vector of random variables and $f(.)$ a vector of functions then a population moment condition takes the form

$$E[f(v_t, \theta_0)] = 0 \tag{98}$$

for all t.

When I want to give a example of the population moment, the researchers suggest estimating the parameter vector through the value implied by the corresponding sampling moment. I can abstract in generality and focus only on specific members, namely the normal distribution. This distribution depends on just two parameters: the population mean, μ_0 , and the population variance,σ_0^2 . These two parameters satisfy the population moment conditions

$$E[v_t] - \mu_0 = 0 \tag{99}$$

$$E[v_t^2] - (\sigma_0^2 + \mu_0^2) = 0 \tag{100}$$

In the first step to create a GMM model, I need to find the moments related to the parameters which need to be estimated in the GMM model. In this circumstance, the moment condition can be obtained by putting

$$f(v_t, \theta) = \begin{bmatrix} v_t - \mu_0 \\ v_t^2 - \left(\sigma_0^2 + \mu_0^2\right) \end{bmatrix}$$

where $\theta_0 = (\mu_0, \sigma_0^2)$.

Just as in Minimum Chi-Square, GMM involves choosing parameter estimators to minimize a quadratic form in a weighting matrix, W_T, and the sample moment $T^{-1} \sum\limits_{t=1}^{T} f(v_t, \theta)$.

Generalized Method of Moments could help to estimate the value of the parameters based on the below equation which minimizes :

$$Q_T(\theta) = T^{-1} \sum_{t=1}^{T} f(v_t, \theta)' W_T T^{-1} \sum_{t=1}^{T} f(v_t, \theta) \tag{101}$$

where W_T is a positive semi-definite matrix that may depend on the data but converges in probability to a positive definite matrix of constants. The restrictions on the weighting matrix are required to ensure that $Q_T(\theta)$ is a

Table 1: Different period regression

I present the estimation of the forward premium and the depreciation of spot rate. α is the intercept of the regression while the β denotes the slope of the regression. The F-statistics is for the Wald test of nul hypothesis: $H_0\{\alpha = 0, \beta = 1\}$. The $p - value$ are showed in the parenthesis for both estimations and F-test.

	2005 Aug-2007 July			2007 Aug-2009 July			2009 Aug-2011 July		
	α	β	F	α	β	F	α	β	F
EURUSD	-0.0004	0.0001	2.0077E+06	0.0001	0.0008	7.9161E+05	0.0001	0.0001	4.8277E+06
	(0.0000)	(0.8413)	(0.0000)	(0.0000)	(0.4986)	(0.0000)	(0.0000)	(0.9019)	(0.0000)
USDJPY	0.0009	0.0012	2.7207E+06	0.0004	0.0010	4.4037E+05	0.0001	0.0003	2.5986E+07
	(0.0000)	(0.0585)	(0.0000)	(0.0000)	(0.4977)	(0.0000)	(0.0000)	(0.1437)	(0.0000)
EURJPY	0.0006	0.0004	1.4196E+06	0.0005	0.0013	8.3853E+05	0.0001	0.0001	7.7708E+06
	(0.0000)	(0.6190)	(0.0000)	(0.0000)	(0.2317)	(0.0000)	(0.0000)	(0.7804)	(0.0000)
GBPUSD	0.0000	0.0012	2.0234E+06	-0.0003	0.0017	1.2311E+06	0.0000	0.0019	2.1529E+05
	(0.4610)	(0.09890	(0.0000)	(0.0000)	(0.0647)	(0.0000)	(0.3591)	(0.3907)	(0.0000)
EURGBP	-0.0004	0.0007	2.0863E+06	0.0004	0.0017	9.7960E+05	0.0001	0.0013	9.4002E+05
	(0.0000)	(0.3325)	(0.0000)	(0.0000)	(0.0943)	(0.0000)	(0.0071)	(0.2205)	(0.0000)
USDCHF	0.0007	0.0002	2.8440E+06	0.0002	0.0005	6.5731E+05	0.0001	-0.0007	1.0877E+07
	(0.0000)	(0.7732)	(0.0000)	(0.0000)	(0.6953)	(0.0000)	(0.0000)	(0.0206)	(0.0000)
EURCHF	0.0003	-0.0017	2.0535E+06	0.0003	-0.0010	4.0210E+05	0.0001	-0.0004	4.9270E+06
	(0.0000)	(0.0169)	(0.0000)	(0.0000)	(0.5320)	(0.0000)	(0.0000)	(0.3894)	(0.0000)
AUDUSD	-0.0002	0.0006	5.5651E+06	-0.0006	0.0008	1.9321E+06	-0.0008	0.0002	4.2543E+06
	(0.0000)	(0.1888)	(0.0000)	(0.0000)	(0.2705)	(0.0000)	(0.0000)	(0.6533)	(0.0000)
NZDUSD	-0.0005	0.0003	4.4851E+06	-0.0008	0.0022	1.2181E+06	-0.0005	0.0000	2.2254E+07
	(0.0000)	(0.4630)	(0.0000)	(0.0000)	(0.0176)	(0.0000)	(0.0000)	(0.9366)	(0.0000)
USDCAD	0.0002	0.0001	7.5141E+06	-0.0001	0.0008	1.8961E+06	-0.0001	0.0001	3.5316E+06
	(0.0000)	(0.8919)	(0.0000)	(0.0000)	(0.2769)	(0.0000)	(0.0000)	(0.8175)	(0.0000)
EURSEK	0.0001	0.0004	5.6658E+06	-0.0001	-0.0111	4.5844E+04	-0.0001	0.0015	8.2797E+05
	(0.0000)	(0.3571)	(0.0000)	(0.1770)	(0.0207)	(0.0000)	(0.0000)	(0.1843)	(0.0000)
EURNOK	0.0000	-0.0010	2.5381E+06	-0.0003	-0.0060	3.3389E+05	-0.0003	0.0003	4.4585E+06
	(0.0000)	(0.1157)	(0.0000)	(0.0000)	(0.0008)	(0.0000)	(0.0000)	(0.5326)	(0.0000)

Table 2: Different period excess return of carry trade strategy

I present the annualized mean value of forward premium, rate of depreciation and excess return of carry trade and the esitmated value of $\hat{\beta}$.

	2005 Aug-2007 July				2007 Aug-2009 July				2009 Aug-2011 July			
	forward premium	rate of depreciation	excess return	$\hat{\beta}$	forward premium	rate of depreciation	excess return	$\hat{\beta}$	forward premium	rate of depreciation	excess return	$\hat{\beta}$
EURUSD	-0.0189	-0.0516	0.0308	0.0001	0.0064	-0.0217	0.0275	0.0008	0.0026	0.0487	-0.0160	0.0001
USDJPY	0.0477	-0.0200	0.0748	0.0012	0.0192	0.1247	-0.0893	0.0010	0.0026	0.0945	-0.0857	0.0003
EURJPY	0.0288	-0.0755	0.1057	0.0004	0.0256	0.1023	-0.0619	0.0013	0.0052	0.1403	-0.1017	0.0001
GBPUSD	0.0004	0.0473	-0.0538	0.0012	-0.0136	-0.0921	0.0905	0.0017	-0.0013	-0.0225	0.0126	0.0019
EURGBP	-0.0192	-0.0877	0.0847	0.0007	0.0200	0.1066	-0.0630	0.0017	0.0040	0.0864	-0.0285	0.0013
USDCHF	0.0345	0.0247	0.0164	0.0002	0.0082	0.0808	-0.0533	0.0005	0.0037	0.0749	-0.0894	-0.0007
EURCHF	0.0157	-0.0325	0.0473	-0.0017	0.0146	0.0454	-0.0258	-0.0010	0.0063	0.1143	-0.1054	-0.0004
AUDUSD	-0.0095	0.0461	-0.0443	0.0006	-0.0329	0.0407	-0.0515	0.0008	-0.0419	0.0702	-0.1474	0.0002
NZDUSD	-0.0259	0.0119	-0.0286	0.0003	-0.0425	0.0215	-0.0303	0.0022	-0.0258	0.0563	-0.1168	0.0000
USDCAD	0.0101	0.0653	-0.0499	0.0001	-0.0042	-0.0046	0.0110	0.0008	-0.0047	0.0256	-0.0497	0.0001
EURSEK	0.0059	0.0035	0.0094	0.0004	-0.0046	-0.0356	0.0408	-0.0111	-0.0045	0.0441	-0.0774	0.0015
EURNOK	-0.0014	0.0008	-0.0013	-0.0010	-0.0157	-0.0446	0.0250	-0.0060	-0.0149	0.0501	-0.0824	0.0003

Table 3: GMM model-1 results with normal forex data

I firstly test the original model from Burnside et al. [2009]. The parameters of the basic model are $\varphi, \varepsilon, q, \alpha$. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	J-test	P value of J-test
EURUSD	0.0002	0.0050	0.5806	0.4049	0.0705	0.7906
	(0.0000)	(0.0008)	(0.0112)	(0.1443)		
USDJPY	0.0001	0.0050	0.5896	0.3727	0.1514	0.6972
	(0.0000)	(0.0006)	(0.0141)	(0.1936)		
EURJPY	0.0001	0.0050	0.6045	0.3176	0.1037	0.7474
	(0.0000)	(0.0008)	(0.0226)	(0.2381)		
GBPUSD	0.0004	0.0050	0.6561	0.3817	0.0309	0.8605
	(0.0000)	(0.0008)	(0.0033)	(0.0412)		
EURGBP	0.0003	0.0050	0.5745	0.3160	0.1032	0.7480
	(0.0000)	(0.0007)	(0.0118)	(0.1466)		
USDCHF	0.0002	0.0050	0.5853	0.3065	0.0906	0.7634
	(0.0000)	(0.0007)	(0.0113)	(0.1327)		
EURCHF	0.0003	0.0050	0.5785	0.3058	0.1035	0.7476
	(0.0000)	(0.0007)	(0.0106)	(0.0496)		
AUDUSD	0.0005	0.0050	0.6588	0.0971	0.0537	0.8167
	(0.0000)	(0.0004)	(0.0068)	(0.0459)		
NZDUSD	0.0006	0.0050	0.6490	0.0523	0.1387	0.7096
	(0.0000)	(0.0007)	(0.0132)	(0.0922)		
USDCAD	0.0002	0.0050	0.5795	0.2982	0.1147	0.7349
	(0.0000)	(0.0006)	(0.0051)	(0.0547)		
EURSEK	0.0002	0.0050	0.6216	0.3025	0.0853	0.7703
	(0.0000)	(0.0007)	(0.0098)	(0.0724)		
EURNOK	0.0004	0.0050	0.7278	0.2572	0.0624	0.8027
	(0.0000)	(0.0008)	(0.0217)	(0.0496)		

Table 4: GMM model-2

I firstly test the original model from Burnside et al. [2009]. The parameters of the basic model are $\phi, \varepsilon, q, \alpha$. ϕ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate. The standard error of the estmation are given in the parenthesis.

	ϕ	ε	q	α	J-test	P value of J-test
EURUSD	0.0003	0.0050	0.6344	0.0648	0.0912	0.9990
	(0.0000)	(0.0005)	(0.0120)	(0.0022)		
USDJPY	0.0004	0.0065	0.6783	0.0880	0.5953	0.9636
	(0.0000)	(0.0005)	(0.0125)	(0.0026)		
EURJPY	0.0004	0.0054	0.6380	0.1052	0.1329	0.9979
	(0.0000)	(0.0006)	(0.0142)	(0.0039)		
GBPUSD	0.0004	0.0072	0.5047	0.0860	0.0822	0.9992
	(0.0000)	(0.0006)	(0.0012)	(0.0030)		
EURGBP	0.0003	0.0051	0.5325	0.1154	0.0431	0.9998
	(0.0000)	(0.0011)	(0.0079)	(0.0036)		
USDCHF	0.0004	0.0079	0.6457	0.0840	0.2010	0.9953
	(0.0000)	(0.0006)	(0.0099)	(0.0027)		
EURCHF	0.0005	0.0073	0.5274	0.1007	0.7307	0.9475
	(0.0000)	(0.0004)	(0.0020)	(0.0028)		
AUDUSD	0.0005	0.0085	0.5002	0.1237	0.0858	0.9991
	(0.0000)	(0.0008)	(0.0004)	(0.0048)		
NZDUSD	0.0005	0.0094	0.5001	0.1950	0.0774	0.9993
	(0.0000)	(0.0007)	(0.0003)	(0.0072)		
USDCAD	0.0003	0.0050	0.5905	0.1495	0.0715	0.9994
	(0.0000)	(0.0005)	(0.0087)	(0.0061)		
EURSEK	0.0004	0.0050	0.5423	0.2363	0.0574	0.9996
	(0.0000)	(0.0005)	(0.0075)	(0.0067)		
EURNOK	0.0004	0.0053	0.5790	0.2776	0.0667	0.9995
	(0.0000)	(0.0006)	(0.0086)	(0.0091)		

Table 5: GMM model-3

I then test the model from Burnside et al. [2009]. The parameters of the basic model are $\phi, \varepsilon, q, v, \alpha$. ϕ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The new paramater v is the proportion of uninformed traders who choose to follow the public information. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate.The standard error of the estmation are given in the parenthesis.

	ϕ	ε	q	α	v	J-test	P value of J-test
EURUSD	0.0003	0.0051	0.6356	0.0657	0.8599	0.1018	0.9916
	(0.0000)	(0.0007)	(0.0198)	(0.0024)	(0.0482)		
USDJPY	0.0004	0.0057	0.6706	0.0876	0.8642	0.6064	0.8950
	(0.0000)	(0.0006)	(0.0201)	(0.0026)	(0.0366)		
EURJPY	0.0005	0.0070	0.6386	0.1049	0.8224	0.1314	0.9878
	(0.0000)	(0.0008)	(0.0228)	(0.0039)	(0.0676)		
GBPUSD	0.0004	0.0072	0.5054	0.0860	0.9890	0.0823	0.9939
	(0.0000)	(0.0006)	(0.0221)	(0.0030)	(0.2578)		
EURGBP	0.0003	0.0053	0.5332	0.1154	0.9871	0.0448	0.9975
	(0.0000)	(0.0013)	(0.0210)	(0.0036)	(0.0614)		
USDCHF	0.0004	0.0064	0.6435	0.0847	0.8953	0.1933	0.9787
	(0.0000)	(0.0007)	(0.0202)	(0.0028)	(0.0318)		
EURCHF	0.0005	0.0057	0.5307	0.1005	0.9800	0.7232	0.8677
	(0.0000)	(0.0004)	(0.0214)	(0.0028)	(0.0577)		
AUDUSD	0.0005	0.0085	0.5006	0.1238	0.7107	0.0863	0.9934
	(0.0001)	(0.0008)	(0.0263)	(0.0048)	(30.0332)		
NZDUSD	0.0005	0.0093	0.5003	0.1942	0.7132	0.0778	0.9944
	(0.0001)	(0.0008)	(0.0240)	(0.0074)	(64.8890)		
USDCAD	0.0003	0.0053	0.6124	0.1507	0.8591	0.0569	0.9964
	(0.0000)	(0.0006)	(0.0201)	(0.0061)	(0.0630)		
EURSEK	0.0004	0.0050	0.5423	0.2363	0.9966	0.0575	0.9964
	(0.0000)	(0.0006)	(0.0243)	(0.0067)	(0.1179)		
EURNOK	0.0005	0.0050	0.5591	0.2746	0.9747	0.0699	0.9952
	(0.0001)	(0.0006)	(0.0223)	(0.0091)	(0.1082)		

Table 6: GMM model-4

I test the original model of spot and bond market. The parameters of the basic model are $\varphi, \varepsilon, q, \alpha$. φ denotes the public information without the interest rate information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	J-test	P value of J-test
EURUSD	0.0001	0.0010	0.6278	0.0675	0.0119	1.0000
	(0.0000)	(0.0011)	(0.6676)	(0.0888)		
USDJPY	0.0000	0.0011	0.6307	0.1049	0.0515	0.9997
	(0.0002)	(0.0027)	(0.5099)	(0.0855)		
EURJPY	0.0002	0.0037	0.5307	0.1139	0.0575	0.9996
	(0.0001)	(0.0012)	(0.6535)	(0.0854)		
GBPUSD	0.0002	0.0021	0.5176	0.1008	0.0648	0.9995
	(0.0002)	(0.0036)	(0.5061)	(0.1247)		
EURGBP	0.0001	0.0026	0.5070	0.1937	0.0416	0.9998
	(0.0002)	(0.0025)	(0.6177)	(0.1466)		
USDCHF	0.0003	0.0047	0.5439	0.2327	0.0569	0.9996
	(0.0003)	(0.0049)	(0.5536)	(0.2699)		
EURCHF	0.0005	0.0073	0.5274	0.1007	0.0627	0.9995
	(0.0000)	(0.0004)	(0.0020)	(0.0028)		
AUDUSD	0.0005	0.0085	0.5002	0.1237	0.0623	0.9995
	(0.0000)	(0.0008)	(0.0004)	(0.0048)		
NZDUSD	0.0005	0.0094	0.5001	0.1950	0.0644	0.9995
	(0.0000)	(0.0007)	(0.0003)	(0.0072)		
USDCAD	0.0003	0.0050	0.5905	0.1495	0.0199	1.0000
	(0.0000)	(0.0005)	(0.0087)	(0.0061)		
EURSEK	0.0004	0.0050	0.5423	0.2363	0.0321	0.9999
	(0.0000)	(0.0005)	(0.0075)	(0.0067)		
EURNOK	0.0004	0.0053	0.5790	0.2776	0.0486	0.9997
	(0.0000)	(0.0006)	(0.0086)	(0.0091)		

Table 7: GMM model-5

I add the parameter v based on the model-4. The parameters of the basic model are $\varphi, \varepsilon, q, v, \alpha$. φ denotes the public information without the interest rate information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The new paramater v is the proportion of uninformed traders who choose to follow the public information. The J-test is aim to test the moments of GMM model. If the $p-value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate.The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	v	J-test	P value of J-test
EURUSD	0.0001	0.0033	0.6482	0.0662	0.8288	0.0154	0.9995
	(0.0008)	(0.0501)	(0.0191)	(0.0032)	(4.1505)		
USDJPY	0.0001	0.0010	0.6414	0.0865	0.9600	0.0560	0.9965
	(0.0012)	(0.0844)	(0.0207)	(0.0029)	(8.0604)		
EURJPY	0.0000	0.0014	0.6306	0.1049	0.8258	0.0577	0.9964
	(0.0021)	(0.0860)	(0.0231)	(0.0047)	(19.8534)		
GBPUSD	0.0002	0.0039	0.5070	0.0856	0.9929	0.0644	0.9957
	(0.0000)	(0.0450)	(0.0274)	(0.0032)	(0.8077)		
EURGBP	0.0002	0.0040	0.5382	0.1142	0.9506	0.0448	0.9975
	(0.0003)	(0.0650)	(0.0203)	(0.0034)	(2.0648)		
USDCHF	0.0002	0.0012	0.6536	0.0818	0.9656	0.0493	0.9971
	(0.0009)	(0.0583)	(0.0185)	(0.0042)	(4.0667)		
EURCHF	0.0002	0.0024	0.5182	0.1008	0.9650	0.0629	0.9959
	(0.0002)	(0.0650)	(0.0200)	(0.0039)	(2.9354)		
AUDUSD	0.0001	0.0035	0.5111	0.1246	0.9011	0.0634	0.9958
	(0.0002)	(0.0877)	(0.0340)	(0.0056)	(5.9036)		
NZDUSD	0.0001	0.0030	0.5054	0.1938	0.9888	0.0644	0.9957
	(0.0002)	(0.0862)	(0.0377)	(0.0080)	(5.65980)		
USDCAD	0.0001	0.0048	0.6186	0.1479	0.7625	0.0182	0.9993
	(0.0024)	(0.0621)	(0.0219)	(0.0072)	(6.7040)		
EURSEK	0.0003	0.0050	0.5513	0.2313	0.9981	0.0294	0.9987
	(0.0005)	(0.0299)	(0.0266)	(0.0063)	(1.0438)		
EURNOK	0.0003	0.0047	0.5780	0.2677	0.8422	0.0443	0.9976
	(0.0028)	(0.0683)	(0.0228)	(0.0100)	(7.2889)		

Table 8: GMM model-6

I consider the affect from the interest rate and add the new parameter ϱ. Since I only have the spot exchange curreny order flow data, I set the forward rate as the endogenous variable. The parameters of the basic model are $\varphi, \varepsilon, q, v, \alpha, \varrho$. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The new paramater v is the proportion of uninformed traders who choose to follow the public information. ϱ is the uninformed traders who follow the interest rate. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate.The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	ϱ	J-test	P value of J-test
EURUSD	0.0001	0.0010	0.6280	0.0676	0.1530	0.0115	0.9997
	(0.0090)	(0.0350)	(0.0190)	(0.0032)	(706.5261)		
USDJPY	0.0001	0.0011	0.6645	0.0886	0.3226	0.0516	0.9969
	(0.0100)	(0.0304)	(0.0202)	(0.0028)	(266.8670)		
EURJPY	0.0000	0.0013	0.6178	0.1052	0.3581	0.0589	0.9963
	(0.0088)	(0.0374)	(0.0235)	(0.0048)	(206.8867)		
GBPUSD	0.0002	0.0027	0.5096	0.0854	0.4978	0.0647	0.9957
	(0.0009)	(0.0434)	(0.0267)	(0.0032)	(97.9335)		
EURGBP	0.0000	0.0019	0.5255	0.1129	0.8968	0.0409	0.9978
	(0.0035)	(0.0696)	(0.0200)	(0.0033)	(3.0434)		
USDCHF	0.0001	0.0011	0.6552	0.0855	0.5724	0.0565	0.9965
	(0.0094)	(0.0304)	(0.0187)	(0.0035)	(104.7801)		
EURCHF	0.0001	0.0011	0.5141	0.1008	0.9185	0.0624	0.9959
	(0.0019)	(0.0642)	(0.0198)	(0.0039)	(2.9155)		
AUDUSD	0.0001	0.0032	0.5000	0.1251	0.9372	0.0611	0.9961
	(0.0003)	(0.0879)	(0.0329)	(0.0056)	(0.1568)		
NZDUSD	0.0001	0.0024	0.5159	0.1921	0.4610	0.0706	0.9951
	(0.0027)	(0.0776)	(0.0375)	(0.0079)	(87.7411)		
USDCAD	0.0002	0.0023	0.6172	0.1460	0.4988	0.0201	0.9992
	(0.0098)	(0.0419)	(0.0208)	(0.0077)	(52.5869)		
EURSEK	0.0000	0.0049	0.5297	0.2301	0.7920	0.0208	0.9992
	(0.0017)	(0.0294)	(0.0256)	(0.0064)	(0.9940		
EURNOK	0.0002	0.0041	0.5538	0.2659	0.6820	0.0412	0.9978
	(0.0086)	(0.0808)	(0.0221)	(0.0100)	(8.6987)		

Table 9: Compare the difference between the public information

I compare the public information parameters of different models in this table. While the parameter ϕ is for model-1, parameter φ is for model-3 and model-5.

	model-2	model-4	model-6
EURUSD	0.0003	0.0001	0.0001
	(0.0000)	(0.0000)	(0.0090)
USDJPY	0.0004	0.0000	0.0001
	(0.0000)	(0.0002)	(0.0100)
EURJPY	0.0004	0.0002	0.0000
	(0.0000)	(0.0001)	(0.0088)
GBPUSD	0.0004	0.0002	0.0002
	(0.0000)	(0.0002)	(0.0009)
EURGBP	0.0003	0.0001	0.0000
	(0.0000)	(0.0002)	(0.0035)
USDCHF	0.0004	0.0003	0.0001
	(0.0000)	(0.0003)	(0.0094)
EURCHF	0.0005	0.0005	0.0001
	(0.0000)	(0.0000)	(0.0019)
AUDUSD	0.0005	0.0005	0.0001
	(0.0000)	(0.0000)	(0.0003)
NZDUSD	0.0005	0.0005	0.0001
	(0.0000)	(0.0000)	(0.0027)
USDCAD	0.0003	0.0003	0.0002
	(0.0000)	(0.0000)	(0.0098)
EURSEK	0.0004	0.0004	0.0000
	(0.0000)	(0.0000)	(0.0017)
EURNOK	0.0004	0.0004	0.0002
	(0.0000)	(0.0000)	(0.0086)

Table 10: The slope and profit of the traders

This table show the estimates of value of $plim\hat{\beta}$ and expected return of informed traders π_i^e for other models.

		model-2	model-3
EURUSD	$plim\hat{\beta}$	-0.7282	1.6531
	π_i^e	0.0007	0.0012
USDJPY	$plim\hat{\beta}$	-0.5897	2.0151
	π_i^e	0.0011	0.0016
EURJPY	$plim\hat{\beta}$	-1.6474	1.5987
	π_i^e	0.0007	0.0016
GBPUSD	$plim\hat{\beta}$	1.0827	1.0757
	π_i^e	0.0000	0.0000
EURGBP	$plim\hat{\beta}$	1.9617	1.7402
	π_i^e	0.0002	0.0002
USDCHF	$plim\hat{\beta}$	-0.6450	2.1581
	π_i^e	0.0011	0.0015
EURCHF	$plim\hat{\beta}$	1.6655	1.3482
	π_i^e	0.0002	0.0002
AUDUSD	$plim\hat{\beta}$	1.0027	1.0011
	π_i^e	0.0000	0.0000
NZDUSD	$plim\hat{\beta}$	1.0011	1.0009
	π_i^e	0.0000	0.0000
USDCAD	$plim\hat{\beta}$	-3.7622	2.6260
	π_i^e	0.0004	0.0009
EURSEK	$plim\hat{\beta}$	1.8190	1.7775
	π_i^e	0.0002	0.0002
EURNOK	$plim\hat{\beta}$	6.8196	1.8997
	π_i^e	0.0004	0.0003

Table 11: GMM model-7

I then test the forward, spot and bond market tegethor. The parameters of the basic model are $\varphi, \varepsilon, q, v, \alpha, \varrho, \phi$. φ denotes the public information without interest information, ϕ denotes the public information within interest information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The new paramater v is the proportion of uninformed traders who choose to follow the public information.ϱ is the uninformed traders who follow the interest rate. The J-test is aim to test the moments of GMM model. If the $p-value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate.The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	ϱ	ϕ	J-test	P value of J-test
EURUSD	0.0001	0.0013	0.6325	0.0668	0.2414	0.0002	0.0500	1.0000
	(0.0000)	(0.0002)	(0.0168)	(0.0024)	(0.0889)	(0.0000)		
USDJPY	0.0001	0.0012	0.6646	0.0907	0.2135	0.0003	0.0563	1.0000
	(0.0000)	(0.0001)	(0.0192)	(0.0026)	(0.1325)	(0.0000)		
EURJPY	0.0001	0.0012	0.6238	0.1041	0.2336	0.0003	0.0598	1.0000
	(0.0000)	(0.0002)	(0.0207)	(0.0044)	(0.2519)	(0.0000)		
GBPUSD	0.0002	0.0013	0.5087	0.0869	0.0243	0.0003	0.0700	1.0000
	(0.0000)	(0.0004)	(0.0054)	(0.0031)	(1.2225)	(0.0000)		
EURGBP	0.0002	0.0038	0.5204	0.1155	0.0031	0.0003	0.0494	1.0000
	(0.0000)	(0.0009)	(0.0077)	(0.0033)	(0.4883)	(0.0000)		
USDCHF	0.0002	0.0013	0.6483	0.0865	0.2171	0.0003	0.0597	1.0000
	(0.0000)	(0.0002)	(0.0176)	(0.0031)	(0.1210)	(0.0000)		
EURCHF	0.0002	0.0014	0.5262	0.1011	0.2605	0.0003	0.0651	1.0000
	(0.0000)	(0.0003)	(0.0111)	(0.0035)	(0.6538)	(0.0000)		
AUDUSD	0.0001	0.0013	0.5014	0.1211	0.3202	0.0003	0.0666	1.0000
	(0.0000)	(0.0007)	(0.0024)	(0.0048)	(57.3197)	(0.0000)		
NZDUSD	0.0001	0.0013	0.5010	0.1943	0.3024	0.0003	0.0667	1.0000
	(0.0000)	(0.0007)	(0.0019)	(0.0073)	(38.3224)	(0.0000)		
USDCAD	0.0002	0.0039	0.5977	0.1558	0.1884	0.0003	0.0485	1.0000
	(0.0000)	(0.0004)	(0.0110)	(0.0069)	(0.0514)	(0.0000)		
EURSEK	0.0002	0.0039	0.5218	0.2343	0.0000	0.0003	0.0663	1.0000
	(0.0000)	(0.0005)	(0.0101)	(0.0059)	(0.1955)	(0.0000)		
EURNOK	0.0002	0.0036	0.5744	0.2685	0.1951	0.0003	0.0527	1.0000
	(0.0000)	(0.0004)	(0.0121)	(0.0094)	(0.0667)	(0.0000)		

Table 12: Inversion model-8 results with new parameter v

I then test the model from Burnside et al. [2009]. Since I only have the spot exchange curreny order flow data, I set the forward rate as the endogenous variable. The parameters of the basic model are $\varphi, \varepsilon, q, v, \alpha$. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The new paramater v is the proportion of uninformed traders who choose to follow the public information. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate.The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	α	J-test	P value of J-test
EURUSD	0.0005	0.0582	0.6336	0.7363	0.0661	0.2433	0.9986
	(0.0000)	(0.0087)	(0.0199)	(0.0173)	(0.0024)		
USDJPY	0.0002	0.0501	0.5052	1.0000	0.0772	2.0467	0.8426
	(0.0000)	(0.2058)	(0.0213)	(0.0064)	(0.0027)		
EURJPY	0.0002	0.0500	0.5248	0.8890	0.0870	1.2108	0.9438
	(0.0000)	(0.0484)	(0.0239)	(0.0101)	(0.0044)		
GBPUSD	0.0003	0.1508	0.5009	0.6884	0.1381	1.1182	0.9525
	(0.0000)	(3.7279)	(0.0223)	(0.1643)	(0.0041)		
EURGBP	0.0009	0.1625	0.5023	0.7218	0.1175	0.1145	0.9998
	(0.0000)	(1.4595)	(0.0208)	(0.1569)	(0.0035)		
USDCHF	0.0005	0.0568	0.6437	0.7449	0.0893	0.4687	0.9932
	(0.0000)	(0.0078)	(0.0198)	(0.0164)	(0.0027)		
EURCHF	0.0004	0.1532	0.5140	0.8259	0.1025	0.3377	0.9969
	(0.0000)	(0.2347)	(0.0214)	(0.0107)	(0.0029)		
AUDUSD	0.0005	0.0750	0.5004	0.9952	0.1210	0.0995	0.9998
	(0.0000)	(4.3490)	(0.0254)	(0.1436)	(0.0048)		
NZDUSD	0.0005	0.1316	0.5002	0.7279	0.1953	0.0867	0.9999
	(0.0000)	(11.8890)	(0.0211)	(1.2468)	(0.0068)		
USDCAD	0.0000	0.0512	0.5113	0.8057	0.1531	0.7142	0.9822
	(0.0000)	(0.0954)	(0.0209)	(0.0272)	(0.0057)		
EURSEK	0.0004	0.1507	0.5009	0.6892	0.1411	3.6552	0.6000
	(0.0000)	(4.0282)	(0.0241)	(0.3289)	(0.0074)		
EURNOK	0.0001	0.1726	0.5030	0.9971	0.2955	0.6475	0.9857
	(0.0000)	(0.9268)	(0.0161)	(0.0081)	(0.0091)		

Table 13: Inversion model-9 results with new parameter h

I then add a new parameter h. Since I only have the spot exchange curreny order flow data, I set the forward rate as the endogenous variable. The parameters of the basic model are $\varphi, \varepsilon, q, v, \alpha$. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The paramater v is the proportion of uninformed traders who choose to follow the public information. The new parameter h denotes the informed traders who choose to follow the private information signal. The J-test is aim to test the moments of GMM model. If the $p - value$ of the J-test is larger than the significant level (1%, 5% and 10%) I could indicate the moments are all appropriate. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	α	h	J-test	P value of J-test
EURUSD	0.0005	0.0242	0.6373	0.7600	0.0639	0.7585	0.1852	0.9993
	(0.0000)	(16.6096)	(0.0199)	(0.0247)	(0.0024)	(17.9234)		
USDJPY	0.0005	0.0196	0.6670	0.5052	0.0905	0.7589	0.3202	0.9972
	(0.0000)	(154.3690)	(0.02000	(0.1266)	(0.0027)	(73.1974)		
EURJPY	0.0001	0.0266	0.6689	0.9585	0.1044	0.7764	1.0275	0.9603
	(0.0000)	(0.8521)	(0.0227)	(0.0089)	(0.0040)	(0.9255)		
GBPUSD	0.0006	0.0200	0.5011	0.7365	0.0893	0.8872	0.1096	0.9998
	(0.0000)	(4.5369)	(0.0215)	(0.0220)	(0.0028)	(25.0584)		
EURGBP	0.0009	0.0179	0.5100	0.6238	0.1192	0.8854	0.1334	0.9997
	(0.0000)	(11.5118)	(0.0206)	(0.0557)	(0.0035)	(61.1571)		
USDCHF	0.0005	0.0280	0.6534	0.5046	0.0902	0.7692	0.4781	0.9929
	(0.0000)	(357.3861)	(0.0203)	(0.12550	(0.0026)	(51.0413)		
EURCHF	0.0005	0.0196	0.5170	0.7784	0.0969	0.7897	0.4841	0.9927
	(0.0000)	(2.4022)	(0.0214)	(0.0104)	(0.0028)	(21.7768)		
AUDUSD	0.0005	0.0240	0.5164	0.7376	0.1201	0.8417	0.1064	0.9998
	(0.0000)	(6.4649)	(0.0264)	(0.0203)	(0.0037)	(34.0741)		
NZDUSD	0.0005	0.0291	0.5886	0.7330	0.1994	0.7101	0.1218	0.9997
	(0.0000)	(4.0262)	(0.0227)	(0.0149)	(0.0044)	(19.2923)		
USDCAD	0.0004	0.0193	0.5956	0.7644	0.1420	0.7874	0.1673	0.9994
	(0.0000)	(3.1899)	(0.0209)	(0.0160)	(0.0054)	(8.6125)		
EURSEK	0.0005	0.0270	0.5266	0.7383	0.2373	0.8164	0.1682	0.9994
	(0.0000)	(2.4913)	(0.0238)	(0.0239)	(0.0064)	(12.3036)		
EURNOK	0.0004	0.0274	0.6121	0.9574	0.2780	0.8395	0.2730	0.9981
	(0.0000)	(0.2481)	(0.0222)	(0.0139)	(0.0091)	(0.2035)		

Table 14: Inversion model-10 results with only UIP

I only test the uncovered interest parity in my model with one parameter φ. I assume the market just have public information which is also interest rate information. The standard error of the estmation are given in the parenthesis.

	φ	J-test	P value of J-test
EURUSD	0.0001 (0.0000)	0.1498	0.9853
USDJPY	0.0001 (0.0000)	0.0898	0.9930
EURJPY	0.0001 (0.0000)	0.1484	0.9854
GBPUSD	0.0001 (0.0000)	0.1109	0.9905
EURGBP	0.0485 (0.0059)	0.0304	0.9986
USDCHF	0.0001 (0.0000)	0.1154	0.9899
EURCHF	0.0001 (0.0000)	0.1706	0.9822
AUDUSD	0.0001 (0.0000)	0.2371	0.9714
NZDUSD	0.0001 (0.0000)	0.0949	0.9924
USDCAD	0.0239 (0.0034)	0.0179	0.9994
EURSEK	0.0085 (0.0012)	0.0195	0.9993
EURNOK	0.0597 (0.0065)	0.0380	0.9981

Table 15: Inversion model-11 results with three kinds of investors with new parameter i

I have 6 parameters in this model. I add new market participant in this model by parameter γ. I set the model-4 as the basic model and add the parameters back which I discuss in model-1.φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	γ	i	J-test	P value of J-test
EURUSD	0.0005	0.0945	0.6272	0.0657	0.3312	0.0061	0.0642	1.0000
	(0.0002)	(0.0131)	(0.0164)	(0.0023)	(0.0500)	(0.0001)		
USDJPY	0.0005	0.0767	0.6711	0.0916	0.3640	0.0013	0.0677	1.0000
	(0.0000)	(0.0086)	(0.0188)	(0.0026)	(0.0568)	(0.0000)		
EURJPY	0.0005	0.0834	0.6239	0.1034	0.3077	0.0005	0.0631	1.0000
	(0.0000)	(0.0140)	(0.0205)	(0.0044)	(0.0353)	(0.0000)		
GBPUSD	0.0005	0.2458	0.5002	0.0868	0.6967	0.0165	0.0623	1.0000
	(0.0006)	(26.8039)	(0.0197)	(0.0029)	(0.2283)	(0.0003)		
EURGBP	0.0005	0.1586	0.5074	0.1183	0.5845	0.0002	0.0591	1.0000
	(0.0000)	(0.4047)	(0.0189)	(0.0035)	(0.0361)	(0.0000)		
USDCHF	0.0005	0.0792	0.6518	0.0891	0.2984	0.0018	0.0627	1.0000
	(0.0000)	(0.0088)	(0.0168)	(0.0033)	(0.0336)	(0.0000)		
EURCHF	0.0005	0.2045	0.5164	0.1021	0.3043	0.0004	0.0630	1.0000
	(0.0000)	(0.2860)	(0.0229)	(0.0034)	(0.0295)	(0.0000)		
AUDUSD	0.0006	0.1085	0.5004	0.1213	0.1574	0.0101	0.0625	1.0000
	(0.0004)	(5.9031)	(0.0235)	(0.0046)	(0.2746)	(0.0002)		
NZDUSD	0.0005	0.1823	0.5002	0.1974	0.1408	0.0052	0.0627	1.0000
	(0.0002)	(20.9954)	(0.0214)	(0.0078)	(0.3792)	(0.0001)		
USDCAD	0.0007	0.4114	0.5321	0.0000	0.0000	0.0005	2.0412	0.9960
	(0.0000)	(0.2410)	(0.0184)	(0.0065)	(3136.7605)	(0.0000)		
EURSEK	0.0005	0.1634	0.5032	0.2383	0.2545	0.0108	0.0611	1.0000
	(0.0004)	(1.1719)	(0.0232)	(0.0058)	(0.0443)	(0.0003)		
EURNOK	0.0005	0.1218	0.5535	0.2667	0.2830	0.0034	0.0623	1.0000
	(0.0001)	(0.0499)	(0.0215)	(0.0089)	(0.0489)	(0.0001)		

Table 16: Inversion model-12 results with three kinds of investors and parameter v

I have 7 parameters in this model. I set the model-4 as the basic model and add the parameters back which I discuss in model-2.φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The paramater v is the proportion of uninformed traders who choose to follow the public information. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	α	γ	i	J-test	P value of J-test
EURUSD	0.0005	0.2188	0.6423	0.7522	0.0658	0.3242	0.0056	0.0628	1.0000
	(0.0002)	(0.0274)	(0.0164)	(0.0124)	(0.0023)	(0.0200)	(0.0001)		
USDJPY	0.0004	0.3396	0.5681	0.7924	0.0935	0.0960	0.0010	0.1778	1.0000
	(0.0000)	(0.0949)	(0.0185)	(0.0097)	(0.0026)	(0.0199)	(0.0000)		
EURJPY	0.0005	0.1780	0.6247	0.7437	0.1032	0.2642	0.0004	0.0631	1.0000
	(0.0000)	(0.0301)	(0.0205)	(0.0168)	(0.0044)	(0.0339)	(0.0000)		
GBPUSD	0.0008	0.0548	0.5010	0.5135	0.0869	0.0141	0.0167	0.0641	1.0000
	(0.0006)	(1.0718)	(0.0197)	(2.6669)	(0.0028)	(7.3702)	(0.0003)		
EURGBP	0.0005	0.1994	0.5062	0.7562	0.1179	0.2956	0.0002	0.0629	1.0000
	(0.0000)	(0.6088)	(0.0189)	(0.1789)	(0.0035)	(0.4126)	(0.0000)		
USDCHF	0.0005	0.1470	0.6843	0.7254	0.0912	0.3313	0.0015	0.0718	1.0000
	(0.0000)	(0.0152)	(0.0169)	(0.0244)	(0.0033)	(0.0768)	(0.0000)		
EURCHF	0.0005	0.2575	0.5135	0.7438	0.1021	0.3511	0.0004	0.0630	1.0000
	(0.0000)	(0.4309)	(0.0224)	(0.0348)	(0.0034)	(0.1009)	(0.0000)		
AUDUSD	0.0006	0.1946	0.5003	0.7373	0.1207	0.1419	0.0102	0.0627	1.0000
	(0.0004)	(18.8731)	(0.0246)	(22.2224)	(0.0043)	(21.2324)	(0.0002)		
NZDUSD	0.0005	0.1566	0.5003	0.6963	0.1996	0.2702	0.0052	0.0631	1.0000
	(0.0002)	(12.9608)	(0.0215)	(1.5601)	(0.0079)	(4.2699)	(0.0001)		
USDCAD	0.0005	0.2670	0.5774	0.7610	0.1520	0.2645	0.0005	0.0704	1.0000
	(0.0000)	(0.0592)	(0.0173)	(0.0145)	(0.0066)	(0.0521)	(0.0000)		
EURSEK	0.0005	0.1604	0.5032	0.7207	0.2378	0.3476	0.0108	0.0612	1.0000
	(0.0004)	(1.1570)	(0.0231)	(0.0408)	(0.0059)	(0.1514)	(0.0003)		
EURNOK	0.0005	0.1372	0.5652	0.7425	0.2611	0.2584	0.0034	0.0671	1.0000
	(0.0001)	(0.0451)	(0.0213)	(0.0121)	(0.0098)	(0.0364)	(0.0001)		

Table 17: Inversion model-13 results with three kinds of investors and parameter h

I have 8 parameters in this model. I set the model-4 as the basic model and add the parameters back which I discuss in model-3.φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The paramater v is the proportion of uninformed traders who choose to follow the public information. The parameter h denotes the informed traders who choose to follow the private information signal. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	α	γ	h	i	J-test	P value of J-test
EURUSD	0.0027	0.3612	0.6507	0.7677	0.0663	0.3029	0.7923	0.0053	0.0630	1.0000
	(0.0002)	(4187.0431)	(0.0171)	(0.2527)	(0.0023)	(0.5948)	(277.5363)	(0.0001)		
USDJPY	0.0000	0.2149	0.5083	0.5439	0.0792	0.1109	1.0000	0.0000	6.6965	0.5697
	(0.0000)	(8.5502E+04)	(0.0186)	(0.5379)	(0.0026)	(1.5144)	(6471.1762)	(0.0000)		
EURJPY	0.0029	0.2758	0.6270	0.7600	0.1032	0.2745	0.8054	0.0004	0.0627	1.0000
	(0.0001)	(6.7283E+05)	(0.0211)	(0.7948)	(0.0042)	(1.6687)	(1.9452E+04)	(0.0001)		
GBPUSD	0.0049	0.4508	0.5122	0.6991	0.1297	0.2961	0.9359	0.0168	0.4091	0.9999
	(0.0005)	(162.9241)	(0.0199)	(0.0713)	(0.0033)	(0.1628)	(14.5682)	(0.0002)		
EURGBP	0.0030	0.0749	0.5106	0.7495	0.1169	0.2547	0.6667	0.0002	0.0604	1.0000
	(0.0001)	(495.7177)	(0.0189)	(0.1241)	(0.0035)	(0.2231)	(2069.8324)	(0.0001)		
USDCHF	0.0001	0.0270	0.6373	0.5019	0.0015	0.9950	0.9170	0.0001	5.8036	0.6692
	(0.0000)	(451.4853)	(0.0174)	(0.1376)	(0.0028)	(0.8389)	(2215.4144)	(0.0000)		
EURCHF	0.0027	0.0616	0.5106	0.5000	0.0974	0.0488	0.5107	0.0000	1.0104	0.9982
	(0.0000)	(742.6417)	(0.0222)	(0.0869)	(0.0032)	(0.1168)	(5643.0737)	(0.0000)		
AUDUSD	0.0032	0.1376	0.5623	0.5014	0.1231	0.0859	0.7132	0.0096	0.1774	1.0000
	(0.0002)	(2.4185E+06)	(0.0226)	(0.0904)	(0.0046)	(0.1786)	(3.0930E+06)	(0.0001)		
NZDUSD	0.0037	0.4157	0.6889	0.7332	0.2100	0.1827	0.6979	0.0050	0.2006	1.0000
	(0.0001)	(3.5135E+07)	(0.0223)	(0.1116)	(0.0086)	(0.1178)	(2.3510E+06)	(0.0001)		
USDCAD	0.0027	0.0396	0.6039	0.5234	0.1422	0.0369	0.7887	0.0001	0.0715	1.0000
	(0.0001)	(2338.1697)	(0.0169)	(0.7803)	(0.0066)	(1.3722)	(2321.2356)	(0.0001)		
EURSEK	0.0033	0.2543	0.6122	0.6896	0.2376	0.3002	0.7771	0.0110	0.1053	1.0000
	(0.0003)	(233.4782)	(0.0234)	(0.0501)	(0.0057)	(0.1079)	(36.3772)	(0.0002)		
EURNOK	0.0029	0.3100	0.5942	0.6175	0.2834	0.0081	0.8246	0.0026	0.1037	1.0000
	(0.0001)	(1024.6304)	(0.0220)	(0.1523)	(0.0096)	(0.0847)	(55.5704)	(0.0001)		

Table 18: Inversion model-14 results with three kinds of investors with new parameter i

I have 7 parameters in this model. I add new market participant in this model by parameter θ. I set the model-4 as the basic model and add the parameters back which I discuss in model-1.φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. θ is the proportion of the traders who follow the carry trade strategy. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	γ	i	θ	J-test	P value of J-test
EURUSD	0.0005	0.2205	0.6416	0.0657	0.2741	0.0053	0.2548	0.0628	1.0000
	(0.0001)	(0.0283)	(0.0165)	(0.0023)	(0.0133)	(0.0001)	(0.0137)		
USDJPY	0.0003	0.3384	0.5844	0.0961	0.2227	0.0010	0.4959	0.2072	1.0000
	(0.0000)	(0.0775)	(0.0188)	(0.0026)	(0.0042)	(0.0000)	(0.0613)		
EURJPY	0.0005	0.1320	0.6785	0.1056	0.2654	0.0004	0.2677	0.0773	1.0000
	(0.0000)	(0.0165)	(0.0205)	(0.0044)	(0.0107)	(0.0000)	(0.0185)		
GBPUSD	0.0005	0.0994	0.5006	0.0855	0.3972	0.0167	0.2838	0.0658	1.0000
	(0.0006)	(3.1927)	(0.0197)	(0.0029)	(2.9329)	(0.0003)	(0.9364)		
EURGBP	0.0005	0.1377	0.5098	0.1178	0.2799	0.0002	0.2746	0.0592	1.0000
	(0.0000)	(0.2629)	(0.0189)	(0.0035)	(0.0342)	(0.0000)	(0.0317)		
USDCHF	0.0006	0.2501	0.6039	0.0851	0.6925	0.0015	0.1641	0.2140	1.0000
	(0.0000)	(0.0419)	(0.0167)	(0.0032)	(0.0127)	(0.0000)	(0.0040)		
EURCHF	0.0005	0.1890	0.5196	0.1020	0.2342	0.0004	0.2295	0.0632	1.0000
	(0.0000)	(0.2230)	(0.0229)	(0.0034)	(0.0076)	(0.0000)	(0.0188)		
AUDUSD	0.0006	0.2309	0.5002	0.1207	0.2242	0.0101	0.2991	0.0627	1.0000
	(0.0004)	(28.5098)	(0.0238)	(0.0044)	(23.9091)	(0.0002)	(41.3294)		
NZDUSD	0.0009	0.1474	0.5679	0.0000	0.2718	0.0051	0.4133	2.1577	0.9950
	(0.0002)	(28.5323)	(0.0214)	(0.0068)	(19.4888)	(0.0001)	(50.1916)		
USDCAD	0.0005	0.1656	0.6092	0.1428	0.2651	0.0004	0.2674	0.0624	1.0000
	(0.0000)	(0.0264)	(0.0170)	(0.0068)	(0.0156)	(0.0000)	(0.0265)		
EURSEK	0.0005	0.1597	0.5034	0.2383	0.2517	0.0108	0.2499	0.0611	1.0000
	(0.0004)	(1.0891)	(0.0231)	(0.0058)	(0.0369)	(0.0003)	(0.0383)		
EURNOK	0.0006	0.1280	0.5337	0.2193	0.1455	0.0012	0.1343	0.1448	1.0000
	(0.0000)	(0.0825)	(0.0215)	(0.0101)	(0.0096)	(0.0000)	(0.0115)		

Table 19: Inversion model-15 results with three kinds of investors and parameter v

I have 8 parameters in this model.φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The paramater v is the proportion of uninformed traders who choose to follow the public information. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. θ is the proportion of the traders who follow the carry trade strategy. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	α	γ	i	θ	J-test	P value of J-test
EURUSD	0.0004	0.1513	0.7080	0.7185	0.0687	0.2277	0.0053	0.2409	0.0972	1.0000
	(0.0001)	(0.0139)	(0.0170)	(0.0627)	(0.0024)	(0.0828)	(0.0001)	(0.0298)		
USDJPY	0.0005	0.2267	0.6391	0.6345	0.0914	0.3234	0.0010	0.2433	0.0730	1.0000
	(0.0000)	(0.0335)	(0.0192)	(0.1186)	(0.0027)	(0.0309)	(0.0000)	(0.0253)		
EURJPY	0.0005	0.2007	0.6265	0.7549	0.1032	0.2621	0.0004	0.2549	0.0630	1.0000
	(0.0000)	(0.0352)	(0.0206)	(0.0499)	(0.0044)	(0.1111)	(0.0000)	(0.0943)		
GBPUSD	0.0005	0.0775	0.5005	0.6795	0.0872	0.5283	0.0167	0.1206	0.0636	1.0000
	(0.0006)	(3.4442)	(0.0197)	(6.2926)	(0.0032)	(13.9695)	(0.0003)	(3.8201)		
EURGBP	0.0005	0.1643	0.5081	0.6872	0.1175	0.2652	0.0002	0.2762	0.0607	1.0000
	(0.0000)	(0.3799)	(0.0188)	(0.3745)	(0.0035)	(0.2671)	(0.0000)	(0.2936)		
USDCHF	0.0005	0.3879	0.5768	0.7036	0.0867	0.1813	0.0014	0.0903	0.1462	1.0000
	(0.0000)	(0.0870)	(0.0168)	(0.0208)	(0.0033)	(0.0676)	(0.0000)	(0.0455)		
EURCHF	0.0005	0.1740	0.5215	0.7540	0.1019	0.2522	0.0004	0.2447	0.0631	1.0000
	(0.0000)	(0.1837)	(0.0229)	(0.0712)	(0.0034)	(0.0477)	(0.0000)	(0.0340)		
AUDUSD	0.0005	0.1732	0.5003	0.6430	0.1209	0.3048	0.0101	0.0710	0.0626	1.0000
	(0.0004)	(12.9789)	(0.0232)	(6.5917)	(0.0048)	(34.8342)	(0.0002)	(6.8605)		
NZDUSD	0.0005	0.1659	0.5003	0.7297	0.1996	0.2344	0.0052	0.2403	0.0632	1.0000
	(0.0002)	(14.3896)	(0.0218)	(6.4478)	(0.0080)	(9.2405)	(0.0001)	(8.2974)		
USDCAD	0.0004	0.1549	0.6154	0.7235	0.1425	0.1117	0.0004	0.2009	0.0680	1.0000
	(0.0000)	(0.0247)	(0.0179)	(0.0571)	(0.0068)	(0.0901)	(0.0000)	(0.0505)		
EURSEK	0.0007	0.1206	0.5020	0.5499	0.2440	0.2663	0.0003	0.3042	6.5235	0.6866
	(0.0000)	(1.3954)	(0.0235)	(3.8725)	(0.0059)	(4.7548)	(0.0000)	(1.8301)		
EURNOK	0.0006	0.1370	0.5266	0.7692	0.2364	0.5261	0.0011	0.0749	0.1788	1.0000
	(0.0000)	(0.1190)	(0.0218)	(0.0881)	(0.0105)	(0.1039)	(0.0000)	(0.0393)		

Table 20: Inversion model-16 results with three kinds of investors and parameter h

I have 9 parameters in this model. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The paramater v is the proportion of uninformed traders who choose to follow the public information. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. θ is the proportion of the traders who follow the carry trade strategy. h denotes the informed traders who choose to follow the private information signal. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	α	γ	i	θ	h	J-test	P value of J-test
EURUSD	0.0001	0.4363	0.5763	0.7420	0.0911	0.1419	0.0010	0.7569	0.8680	3.4539	0.9027
	(0.0000)	(1.0675E+05)	(0.0172)	(4276.3968)	(0.0023)	(98.8367)	(0.0000)	(80.0123)	(98.9311)		
USDJPY	0.0026	0.4069	0.6681	0.9164	0.0905	0.0565	0.0010	0.0526	0.7499	0.0610	1.0000
	(0.0001)	(1141.7909)	(0.0199)	(1.8236)	(0.0028)	(0.9678)	(0.0001)	(0.9015)	(4.2653)		
EURJPY	0.0029	0.2560	0.6255	0.6576	0.1036	0.2863	0.0004	0.3382	0.7900	0.0628	1.0000
	(0.0001)	(1.4544E+04)	(0.0204)	(3.0065)	(0.0045)	(0.8021)	(0.0001)	(0.6662)	(528.2677)		
GBPUSD	0.0049	0.3213	0.6814	0.8039	0.1005	0.2530	0.0165	0.3121	0.6506	0.2918	1.0000
	(0.0004)	(3552.9456)	(0.0202)	(0.1719)	(0.0032)	(0.1090)	(0.0003)	(0.0411)	(920.2485)		
EURGBP	0.0031	0.2813	0.5258	0.7890	0.1172	0.2738	0.0002	0.2719	0.8404	0.0605	1.0000
	(0.0001)	(1.1148E+04)	(0.0189)	(0.1608)	(0.0036)	(0.2075)	(0.0001)	(0.1877)	(4383.3404)		
USDCHF	0.0027	0.3693	0.6446	0.7568	0.0926	0.2375	0.0014	0.2502	0.7696	0.0676	1.0000
	(0.0001)	(9501.9713)	(0.0181)	(0.9126)	(0.0031)	(1.1225)	(0.0001)	(1.2149)	(158.2888)		
EURCHF	0.0027	0.0645	0.5734	0.9708	0.1224	0.0888	0.0003	0.1132	0.6388	0.4495	0.9999
	(0.0000)	(163.4989)	(0.0231)	(0.0399)	(0.0033)	(0.0462)	(0.0001)	(0.0517)	(591.5039)		
AUDUSD	0.0047	0.2544	0.5669	0.7272	0.1212	0.2465	0.0104	0.3038	0.7538	0.0804	1.0000
	(0.0003)	(504.2045)	(0.0246)	(0.2880)	(0.0048)	(0.1379)	(0.0002)	(0.1280)	(253.9973)		
NZDUSD	0.0038	0.2726	0.6021	0.7539	0.2054	0.2285	0.0052	0.2483	0.7580	0.1022	1.0000
	(0.0001)	(933.2531)	(0.0220)	(0.1512)	(0.0080)	(0.1068)	(0.0001)	(0.0841)	(247.9677)		
USDCAD	0.0032	0.0591	0.6187	0.8670	0.1101	0.1812	0.0008	0.0280	0.7131	0.3666	1.0000
	(0.0001)	(61.7136)	(0.0172)	(0.1700)	(0.0064)	(0.2712)	(0.0001)	(0.0478)	(99.3052)		
EURSEK	0.0031	0.2975	0.5289	0.7728	0.2371	0.2141	0.0109	0.2666	0.8815	0.0647	1.0000
	(0.0003)	(1.1059E+04)	(0.0235)	(0.1776)	(0.0060)	(0.1262)	(0.0003)	(0.0707)	(2372.1182)		
EURNOK	0.0036	0.1684	0.6321	0.7896	0.2609	0.2439	0.0033	0.2226	0.7461	0.1013	1.0000
	(0.0002)	(4893.9867)	(0.0222)	(0.3163)	(0.0100)	(0.1972)	(0.0002)	(0.1314)	(1304.5137)		

Table 21: Inversion model-17 results with 4 kinds of investors and parameter h

I have 10 parameters in this model. I add market participant in this model by parameter $A\&H$. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. The paramater v is the proportion of uninformed traders who choose to follow the public information. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. θ is the proportion of the traders who follow the carry trade strategy. h denotes the informed traders who choose to follow the private information signal. A denotes the proportion of the asset managers, while H is the proportion of the Hedge funds in the forex market.The standard error of the estmation are given in the parenthesis.

	φ	ε	q	v	A	γ	i	θ	h	H	J-test	P value of J-test
EURUSD	0.0026	0.2486	0.6421	0.7552	0.0333	0.2545	0.0051	0.2662	0.7539	0.0346	0.0608	1.0000
	(0.0001)	(9464.8552)	(0.0170)	(0.0313)	(0.0016)	(0.0260)	(0.0002)	(0.0274)	(7813.6715)	(0.0017)		
USDJPY	0.0023	0.0684	0.7797	0.6526	0.0457	0.3575	0.0010	0.2239	0.9629	0.0482	0.1780	1.0000
	(0.0021)	(1.0573E+07)	(0.2381)	(13.8205)	(0.0266)	(18.7038)	(0.0008)	(11.9080)	(1.0819E+08)	(0.0066)		
EURJPY	0.0030	0.4961	0.6600	0.7500	0.0544	0.2486	0.0004	0.2479	0.5976	0.0508	0.0699	1.0000
	(0.0001)	(4.7609E+05)	(0.0268)	(1.8111)	(0.0031)	(1.5039)	(0.0000)	(1.5058)	(6.3681E+04)	(0.0026)		
GBPUSD	0.0040	0.4948	0.5212	0.7605	0.0684	0.2862	0.0135	0.2447	0.8741	0.0210	0.6834	0.9996
	(0.0001)	(147.2703)	(0.0196)	(0.0019)	(0.0023)	(0.0041)	(0.0003)	(0.0021)	(21.6412)	(0.0017)		
EURGBP	0.0029	0.2964	0.5457	0.7544	0.0731	0.2384	0.0002	0.2439	0.7375	0.0464	0.0686	1.0000
	(0.0001)	(2.0714E+04)	(0.0189)	(0.4302)	(0.0030)	(0.3517)	(0.0000)	(0.3567)	(8784.0724)	(0.0020)		
USDCHF	0.0026	0.4644	0.6787	0.7407	0.0420	0.2595	0.0014	0.2487	0.5627	0.0495	0.0713	1.0000
	(0.0001)	(1.2269E+04)	(0.0176)	(0.1831)	(0.0019)	(0.1586)	(0.0000)	(0.1558)	(3584.5175)	(0.0027)		
EURCHF	0.0029	0.3918	0.5220	0.7422	0.0464	0.2633	0.0004	0.2663	0.7837	0.0557	0.0632	1.0000
	(0.0000)	(2.3321E+04)	(0.0234)	(0.2005)	(0.0025)	(0.1656)	(0.0000)	(0.1649)	(7350.6893)	(0.0021)		
AUDUSD	0.0043	0.4049	0.5137	0.7555	0.0771	0.2595	0.0093	0.2290	0.8368	0.0773	0.1529	1.0000
	(0.0003)	(7.7876E+05)	(0.0369)	(4.6168)	(0.0179)	(3.5909)	(0.0005)	(3.2514)	(2.1092E+05)	(0.0045)		
NZDUSD	0.0039	0.3552	0.5063	0.7528	0.0934	0.2208	0.0051	0.2442	0.8454	0.1044	0.0628	1.0000
	(0.0001)	(1.7128E+04)	(0.0220)	(0.2544)	(0.0041)	(0.1740)	(0.0001)	(0.1857)	(6183.6195)	(0.0061)		
USDCAD	0.0027	0.3719	0.5969	0.7249	0.0739	0.2441	0.0004	0.2346	0.7151	0.0770	0.0561	1.0000
	(0.0002)	(1.3065E+04)	(0.0195)	(0.3789)	(0.0042)	(0.3319)	(0.0000)	(0.3227)	(1640.0261)	(0.0048)		
EURSEK	0.0001	0.4824	0.5485	0.5001	0.0602	0.5677	0.0000	0.0000	0.7319	0.1372	6.1581	0.6295
	(0.0000)	(170.0294)	(0.0243)	(0.0342)	(0.0047)	(0.4584)	(0.0000)	(0.0207)	(7.7624)	(0.0050)		
EURNOK	0.0035	0.2971	0.5509	0.7544	0.1443	0.2089	0.0031	0.2138	0.7880	0.1276	0.0619	1.0000
	(0.0002)	(1.3606E+06)	(0.0276)	(4.7164)	(0.0290)	(2.9519)	(0.0002)	(3.0252)	(1.7321E+05)	(0.0156)		

Table 22: Inversion model-18 results with three kinds of investors with new parameter i

I consider the carry trade influence here. I have 7 parameters in this model. φ denotes the public information, while ε is the private information. q is the probability of the informed traders have the right private information signal, and α is the proportion of the informed trader in the market. γ is the propotion of the traders who only focus on the opportunities for UIP arbitrage. i denotes the interest rate information. The standard error of the estmation are given in the parenthesis.

	φ	ε	q	α	γ	i	θ	J-test	P value of J-test
EURUSD	0.0005	0.2397	0.6069	0.0732	0.2086	0.0118	0.2119	0.1955	1.0000
	(0.0000)	(0.0643)	(0.0178)	(0.0022)	(0.0573)	(0.0083)	(0.0573)		
USDJPY	0.0005	0.1747	0.6761	0.0934	0.6103	0.0001	0.2345	0.1829	1.0000
	(0.0000)	(0.0204)	(0.0192)	(0.0026)	(0.0371)	(0.0000)	(0.0164)		
EURJPY	0.0005	0.1907	0.6247	0.1065	0.2755	0.0037	0.2779	0.0670	1.0000
	(0.0000)	(0.0346)	(0.0208)	(0.0044)	(0.0177)	(0.0032)	(0.0175)		
GBPUSD	0.0005	0.0992	0.5001	0.0870	0.0287	0.0227	0.0292	0.0630	1.0000
	(0.0000)	(14.6173)	(0.0189)	(0.0031)	(2.3655)	(0.0052)	(2.3657)		
EURGBP	0.0005	0.2010	0.5065	0.1178	0.2499	0.0169	0.2491	0.0700	1.0000
	(0.0000)	(0.5858)	(0.0189)	(0.0035)	(0.0378)	(0.0119)	(0.0370)		
USDCHF	0.0005	0.2734	0.6101	0.0871	0.2642	0.0132	0.2661	0.0842	1.0000
	(0.0000)	(0.0435)	(0.0168)	(0.0033)	(0.0045)	(0.0050)	(0.0046)		
EURCHF	0.0005	0.1924	0.5182	0.1023	0.2509	0.0014	0.2511	0.0636	1.0000
	(0.0000)	(0.2397)	(0.0225)	(0.0032)	(0.0074)	(0.0038)	(0.0081)		
AUDUSD	0.0005	0.1621	0.5004	0.1208	0.2735	0.0143	0.2740	0.0631	1.0000
	(0.0000)	(8.8054)	(0.0207)	(0.0047)	(6.3138)	(0.0051)	(6.3140)		
NZDUSD	0.0005	0.1545	0.5003	0.1992	0.2606	0.0075	0.2614	0.0632	1.0000
	(0.0000)	(12.5479)	(0.0217)	(0.0075)	(1.1452)	(0.0049)	(1.1452)		
USDCAD	0.0005	0.1929	0.5921	0.1485	0.2601	0.0145	0.2610	0.0704	1.0000
	(0.0000)	(0.0372)	(0.0177)	(0.0069)	(0.0049)	(0.0073)	(0.0050)		
EURSEK	0.0005	0.1670	0.5007	0.2369	0.2607	0.0154	0.2599	0.0627	1.0000
	(0.0000)	(5.2796)	(0.0233)	(0.0056)	(0.0938)	(0.0059)	(0.0938)		
EURNOK	0.0006	0.1341	0.5277	0.2691	0.1154	0.0081	0.1162	0.0639	1.0000
	(0.0000)	(0.1037)	(0.0212)	(0.0095)	(0.0182)	(0.0063)	(0.0181)		

Table 23: $plim\hat{\beta}$ and expected return of informed traders π_i^e

Since model-4 just have one parameter φ and only one investor typle UIP arbitrager, I only estimate the value of $plim\hat{\beta}$ and expected return of informed traders π_i^e for other models.

		model-7	model-8	model-9	model-11	model-12	model-13	model-14	model-15	model-16	model-17	model-18
EURUSD	$plim\hat{\beta}$	-1.3352	-22.1746	0.9356	0.5576	0.7713	0.9908	0.8770	0.8941	0.9757	0.9929	0.0372
	π_i^e	0.0002	0.0143	-0.0007	0.0226	0.0568	0.0102	0.0575	0.0590	0.0002	0.0004	0.0462
USDJPY	$plim\hat{\beta}$	1.0011	-11.6236	1.0004	-0.1672	0.1140	0.0020	0.1698	0.3027	1.0005	0.9444	0.0387
	π_i^e	0.0000	0.0003	0.0002	0.0241	0.0405	0.0033	0.0509	0.0577	0.0007	0.0002	0.0548
EURJPY	$plim\hat{\beta}$	-0.6861	-3.3000	-1.1085	-0.1196	0.0542	0.9960	0.0894	0.1828	0.9793	0.9738	0.0608
	π_i^e	0.0004	0.0020	0.0007	0.0187	0.0387	0.0024	0.0414	0.0459	-0.0027	0.0009	0.0418
GBPUSD	$plim\hat{\beta}$	-3.1801	1.0563	0.8400	1.0008	1.0000	0.9950	1.0000	1.0000	1.0227	0.9985	0.9997
	π_i^e	0.0005	0.0002	-0.0020	0.0001	0.0001	-0.0157	0.0001	0.0001	-0.0332	-0.0009	0.0000
EURGBP	$plim\hat{\beta}$	-3.3843	1.0489	0.9483	0.2693	0.8931	0.7702	0.9513	1.0234	0.8109	0.9557	0.9261
	π_i^e	0.0006	0.0006	-0.0015	0.0021	0.0021	-0.0204	0.0024	0.0024	-0.0292	-0.0006	0.0022
USDCHF	$plim\hat{\beta}$	1.0002	-2.0377	1.0002	-0.1951	0.2073	0.0360	0.1779	0.4859	0.9947	0.9449	0.0415
	π_i^e	0.0000	0.0145	0.0001	0.0220	0.0479	0.0039	0.0458	0.0542	-0.0027	0.0012	0.0541
EURCHF	$plim\hat{\beta}$	-2.7717	-25.2575	0.6855	-0.3539	0.6206	0.9973	0.7184	0.9343	0.6294	0.9791	0.6789
	π_i^e	0.0006	0.0036	-0.0031	0.0061	0.0060	-0.0266	0.0065	0.0068	-0.0143	-0.0007	0.0061
AUDUSD	$plim\hat{\beta}$	-2.4229	1.0623	0.7419	1.0014	1.0000	0.9992	1.0000	1.0000	1.0236	0.9957	0.9999
	π_i^e	0.0007	0.0000	-0.0027	0.0001	0.0001	-0.0239	0.0001	0.0001	-0.0330	-0.0010	0.0001
NZDUSD	$plim\hat{\beta}$	-6.5353	1.0101	0.5452	1.0023	1.0000	0.9492	1.0000	0.9996	0.9926	0.9862	0.9999
	π_i^e	0.0006	0.0000	-0.0037	0.0001	0.0001	-0.0121	0.0200	0.0001	-0.0193	-0.0011	0.0001
USDCAD	$plim\hat{\beta}$	-1.6051	-0.5699	0.8211	-0.0863	0.0370	1.0000	0.0937	0.1819	0.9596	0.9911	0.0594
	π_i^e	0.0006	0.0009	-0.0010	0.0264	0.0336	-0.0016	0.0304	0.0310	-0.0059	0.0004	0.0296
EURSEK	$plim\hat{\beta}$	-0.5988	1.0396	0.5861	1.0171	0.9999	0.9873	1.0000	1.0136	1.0354	0.0082	0.9989
	π_i^e	0.0004	0.0002	-0.0027	0.0008	0.0007	-0.0090	0.0008	0.0004	-0.0158	0.0002	0.0002
EURNOK	$plim\hat{\beta}$	-0.8882	-0.1492	2.2555	0.6168	0.7192	0.9940	0.5228	0.5446	0.9827	0.9963	0.1524
	π_i^e	0.0008	0.0004	0.0004	0.0099	0.0125	-0.0044	0.0061	0.0051	-0.0072	-0.0004	0.0048

Table 24: Characteristics of the data

	Median bid-ask spread	Std of bid-ask spread	Std of Rate of depreciation	Std of Forward premium	Ratio	regression $\hat{\beta}$	MSE_S/MSE_F	$MSE_S - MSE_F$	estimate of $MSE_S - MSE_F$
EURUSD	0.0002	0.0001	0.0143	0.0002	0.0172	-0.0002	0.9992	0.0000	0.0002
USDJPY	0.0000	0.0000	0.0146	0.0003	0.0224	-0.0001	1.0015	0.0000	0.0002
EURJPY	0.0000	0.0000	0.0173	0.0002	0.0139	0.0000	0.9996	0.0000	0.0003
GBPUSD	0.0004	0.0001	0.0142	0.0003	0.0183	0.0009	1.0006	0.0000	0.0002
EURGBP	0.0002	0.0001	0.0262	0.0004	0.0171	0.0005	1.0003	0.0000	0.0007
USDCHF	0.0005	0.0001	0.0158	0.0002	0.0156	-0.0005	1.0009	0.0000	0.0003
EURCHF	0.0006	0.0002	0.0094	0.0001	0.0150	-0.0016	0.9983	0.0000	0.0001
AUDUSD	0.0000	0.0001	0.0198	0.0003	0.0127	0.0003	0.9951	0.0000	0.0004
NZDUSD	0.0000	0.0000	0.0204	0.0002	0.0101	0.0008	0.9958	0.0000	0.0004
USDCAD	0.0005	0.0002	0.0142	0.0002	0.0130	0.0004	0.9999	0.0000	0.0002
EURSEK	0.0001	0.0000	0.0095	0.0003	0.0367	-0.0053	0.9880	0.0000	0.0001
EURNOK	0.0001	0.0000	0.0107	0.0003	0.0239	-0.0020	0.9944	0.0000	0.0001
AVERAGE	0.0002	0.0001	0.0155	0.0003	0.0180	-0.0006	0.9978	0.0000	0.0003

meaningful measure of distance. Notice that the positive semi-definiteness of W_T ensures both that $Q_T(\theta) \geq 0$ for any θ , and also that $Q_T(\hat{\theta}_T) = 0$ if $T^{-1} \sum_{t=1}^{T} f(v_t, \theta)$. Hansen [1982] referrers to the estimator as Generalized Method of Moments, and that is the name by which the method is known in econometric.

Appendix.B the basic model of section 5

Follow the previous literature, I assume the hedge funds and asset managers are informed investors. The spot rate S_{t+1} at term $t+1$ include the public information for term t and private information for term $t+1$. Hence the relationship between S_{t+1} and S_t would be as below:

$$\frac{S_{t+1} - S_t}{S_t} = \phi_t + \varepsilon_{t+1} + \omega_{t+1} \tag{102}$$

where φ_t is the public information influence at term t, which could be observed by all trades. I assume the influence would be positive or negative in the same probability.

$$\phi_t = \begin{cases} \phi \, with \, probability & 1/2, \\ -\phi \, with \, probability & 1/2. \end{cases} \tag{103}$$

where ε_{t+1} is not observed directly at time t which could be observed by informed investors as a signal $\zeta_t \in \{\varepsilon, -\varepsilon\}$.

$$\varepsilon_{t+1} = \begin{cases} \varepsilon \, with \, probability & 1/2, \\ -\varepsilon \, with \, probability & 1/2. \end{cases} \tag{104}$$

the value of the influence from public and private information (ϕ, ε) are both positive. Finally, ω_{t+1} denotes the information which no agents in the market would observe, while variable ω_{t+1} independently and identically follows the normal distribution with the mean zero and variance σ_ω^2. The three information parameters $(\phi_t, \varepsilon_{t+1}, \omega_{t+1})$ in the model are mutually orthogonal.

At the beginning of term t, informed traders could observe the private information signal ζ_t which could be positive or negative. The probability for informed traders getting the correct private information is q. Hence I have the function as below:

$$Pr\left(\zeta_t = \varepsilon \mid \varepsilon_{t+1} = \varepsilon\right) = Pr\left(\zeta_t = -\varepsilon \mid \varepsilon_{t+1} = -\varepsilon\right) = q > \frac{1}{2} \tag{105}$$

I assume the informed traders could use a better technique to get ζ_t or use the special method to access private information signal with the correct probability q which is higher than half.

No agents could observe the fact ε_{t+1}, however, public information φ_t is available for all participants in the market. Hence I could have 4 different forward rate $F_t^a(\phi)$, $F_t^a(-\phi)$, $F_t^b(\phi)$, and $F_t^b(-\phi)$.

When $\phi_t = \phi$, the market maker would get the profit from selling one pound forward, π^m_{t+1}, is

$$\pi^m_{t+1} = F^a_t(\phi) - S_{t+1} \tag{106}$$

The expected profit of market maker should be zero, hence

$$E\left(\pi^m_{t+1} \mid buy, \phi\right) = F^a_t(\phi) - E\left(S_{t+1} \mid buy, \phi\right) = 0 \tag{107}$$

By applying the equation 102, I get the below equation:

$$F^a_t(\phi) = S_t\left[1 + \phi + E\left(\varepsilon_{t+1} \mid buy, \phi\right)\right] \tag{108}$$

$$E\left(\varepsilon_{t+1} \mid buy, \phi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right)(\varepsilon) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid buy, \phi\right)(-\varepsilon) \tag{109}$$

the below function is implied in Bayesian rule,

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right) = \frac{Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right)}{Pr\left(buy \mid \phi\right)} \tag{110}$$

When I compute the $Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right)$, I need to consider the informed and uninformed traders separately. When $\phi_t = \phi$, uninformed traders would buy the pound forward. When $\varepsilon_{t+1} = \varepsilon$, informed traders would buy the pound forward with probability q, the signal $\zeta_t = \varepsilon = \varepsilon_{t+1}$.

$$Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right) = 1 - \alpha + \alpha q \tag{111}$$

$$Pr\left(buy \mid \phi\right) = Pr\left(buy \mid \varepsilon_{t+1} = \varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right) + Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = -\varepsilon\right) \tag{112}$$

I also need to compute $Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \phi\right)$ by the similar way, and it follow that:

$$Pr\left(buy \mid \varepsilon_{t+1} = -\varepsilon, \phi\right) = 1 - \alpha + \alpha(1 - q) \tag{113}$$

I use equations 111, 112 and 113 to obtain the equation below:

$$Pr\left(buy \mid \phi\right) = (1 - \alpha + \alpha q)\frac{1}{2} + \left[1 - \alpha + \alpha(1 - q)\right]\frac{1}{2} = 1 - \frac{\alpha}{2} \tag{114}$$

Equations 111, 114 and 110 imply that

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid buy, \phi\right) = \frac{1 - \alpha(1 - q)}{2 - \alpha} \tag{115}$$

Since

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,\phi\right)=1-Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,\phi\right) \tag{116}$$

I have

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,\phi\right)=\frac{1-\alpha q}{2-\alpha} \tag{117}$$

By substituting equations 115, 117 and 109, I obtain

$$E\left(\varepsilon_{t+1} \mid buy,\phi\right)=\frac{\alpha}{2-\alpha}(2q-1)\varepsilon \tag{118}$$

I obtain from equation 108

$$F_t^a\left(\phi\right)=S_t\left[1+\phi+\frac{\alpha}{2-\alpha}(2q-1)\varepsilon\right] \tag{119}$$

The ask rate when the public signal is negative. $F_t^a\left(-\phi\right)$ is equal to the market maker's expectation of S_{t+1} conditional on having received a buy order and on $\phi_t=-\phi$

Follow the Bayesian rule, I could evaluate the expectation of market maker of ε_{t+1}, based on his information set:

When $\phi_t=-\phi$, the market maker would get the profit from selling one pound forward, π_{t+1}^m, is

$$\pi_{t+1}^m=F_t^a\left(-\phi\right)-S_{t+1} \tag{120}$$

The expected profit of market maker should be zero, hence

$$E\left(\pi_{t+1}^m \mid buy,-\phi\right)=F_t^a\left(-\phi\right)-E\left(S_{t+1} \mid buy,-\phi\right)=0 \tag{121}$$

applying the equation 102, I could get the below equation:

$$F_t^a\left(-\phi\right)=S_t\left[1-\phi+E\left(\varepsilon_{t+1} \mid buy,-\phi\right)\right] \tag{122}$$

$$E\left(\varepsilon_{t+1} \mid buy,-\phi\right)=Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,-\phi\right)\left(\varepsilon\right)+Pr\left(\varepsilon_{t+1}=-\varepsilon \mid buy,-\phi\right)\left(-\varepsilon\right) \tag{123}$$

the below function is implied in Bayesian rule,

$$Pr\left(\varepsilon_{t+1}=\varepsilon \mid buy,-\phi\right)=\frac{Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,-\phi\right)Pr\left(\varepsilon_{t+1}=\varepsilon\right)}{Pr\left(buy \mid -\phi\right)} \tag{124}$$

When I compute the $Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,-\phi\right)$, I need to consider the informed and uninformed traders separately. When $\phi_t=-\phi$, uninformed traders would sell the pound forward. When $\varepsilon_{t+1}=\varepsilon$, informed traders would buy the pound forward with probability q, the signal $\zeta_t=\varepsilon=\varepsilon_{t+1}$.

$$Pr\left(buy \mid \varepsilon_{t+1}=\varepsilon,-\phi\right)=\alpha q \tag{125}$$

$$Pr\,(buy \mid -\phi) = Pr\,(buy \mid \varepsilon_{t+1} = \varepsilon, -\phi)\, Pr\,(\varepsilon_{t+1} = \varepsilon) + Pr\,(buy \mid \varepsilon_{t+1} = -\varepsilon, -\phi)\, Pr\,(\varepsilon_{t+1} = -\varepsilon) \tag{126}$$

I also need to compute $Pr\,(buy \mid \varepsilon_{t+1} = -\varepsilon, -\phi)$ by the similar way, and it follow that:

$$Pr\,(buy \mid \varepsilon_{t+1} = -\varepsilon, -\phi) = \alpha\,(1-q) \tag{127}$$

I could use equations 125, 126 and 127 to get the equation below:

$$Pr\,(buy \mid -\phi) = (\alpha q)\,\frac{1}{2} + [\alpha\,(1-q)]\,\frac{1}{2} = \frac{\alpha}{2} \tag{128}$$

Equations 125, 128 and 124 imply

$$Pr\,(\varepsilon_{t+1} = \varepsilon \mid buy, -\phi) = q \tag{129}$$

Since

$$Pr\,(\varepsilon_{t+1} = -\varepsilon \mid buy, -\phi) = 1 - Pr\,(\varepsilon_{t+1} = \varepsilon \mid buy, -\phi) \tag{130}$$

I have

$$Pr\,(\varepsilon_{t+1} = -\varepsilon \mid buy, -\phi) = 1 - q \tag{131}$$

By substituting equations 129, 131 and 123, I obtain

$$E\,(\varepsilon_{t+1} \mid buy, -\phi) = (2q-1)\,\varepsilon \tag{132}$$

I obtain from equation 122

$$F_t^a\,(-\phi) = S_t\left[1 - \phi + \frac{\alpha}{2-\alpha}(2q-1)\varepsilon\right] \tag{133}$$

The bid rate when the public signal is positive.$F_t^b\,(\phi)$ is equal to the market maker's expectation of S_{t+1} conditional on having received a buy order and on $\phi_t = \phi$

Follow the Bayesian rule, I could evaluate the expectation of market maker of ε_{t+1}, based on his information set:

When $\phi_t = \phi$, the market maker would get the profit from selling one pound forward, π_{t+1}^m, is

$$\pi_{t+1}^m = F_t^b\,(\phi) - S_{t+1} \tag{134}$$

The expected profit of market maker should be zero, hence

$$E\left(\pi_{t+1}^m \mid sell, \phi\right) = F_t^b\,(\phi) - E\,(S_{t+1} \mid sell, \phi) = 0 \tag{135}$$

By applying the equation 102, I obtain the below equation:

$$F_t^b\,(\phi) = S_t\,[1 + \phi + E\,(\varepsilon_{t+1} \mid sell, \phi)] \tag{136}$$

$$E\left(\varepsilon_{t+1} \mid sell, \phi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid sell, \phi\right)(\varepsilon) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid sell, \phi\right)(-\varepsilon) \tag{137}$$

the below function is implied in Bayesian rule,

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid sell, \phi\right) = \frac{Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right)}{Pr\left(sell \mid \phi\right)} \tag{138}$$

When I compute the $Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, \phi\right)$, I need to consider the informed and uninformed traders separately. When $\phi_t = \phi$, uninformed traders would buy the pound forward. When $\varepsilon_{t+1} = \varepsilon$, informed traders would buy the pound forward with probability q, the signal $\zeta_t = \varepsilon = \varepsilon_{t+1}$.

$$Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, \phi\right) = 1 - \alpha q \tag{139}$$

$$Pr\left(sell \mid \phi\right) = Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right) + Pr\left(sell \mid \varepsilon_{t+1} = -\varepsilon, \phi\right) Pr\left(\varepsilon_{t+1} = -\varepsilon\right) \tag{140}$$

I also need to compute $Pr\left(sell \mid \varepsilon_{t+1} = -\varepsilon, \phi\right)$ by the similar way, and it follow that:

$$Pr\left(sell \mid \varepsilon_{t+1} = -\varepsilon, \phi\right) = 1 - \alpha\left(1 - q\right) \tag{141}$$

I use equations 139, 140 and 141 to obtain the equation below:

$$Pr\left(sell \mid \phi\right) = \left(1 - \alpha q\right)\frac{1}{2} + \left[1 - \alpha\left(1 - q\right)\right]\frac{1}{2} = 1 - \frac{\alpha}{2} \tag{142}$$

Equations 139, 142 and 138 imply that

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid sell, \phi\right) = 1 - q \tag{143}$$

Since

$$Pr\left(\varepsilon_{t+1} = -\varepsilon \mid sell, \phi\right) = 1 - Pr\left(\varepsilon_{t+1} = \varepsilon \mid sell, \phi\right) \tag{144}$$

I have

$$Pr\left(\varepsilon_{t+1} = -\varepsilon \mid sell, \phi\right) = q \tag{145}$$

By substituting equations 143, 145 and 137, I obtain

$$E\left(\varepsilon_{t+1} \mid sell, \phi\right) = -(2q - 1)\varepsilon \tag{146}$$

I obtain from equation 136

$$F_t^b\left(\phi\right) = S_t\left[1 + \phi - (2q - 1)\varepsilon\right] \tag{147}$$

The bid rate when the public signal is negative. $F_t^a(-\phi)$ is equal to the market maker's expectation of S_{t+1} conditional on having received a buy order and on $\phi_t = -\phi$

Follow the Bayesian rule, I could evaluate the expectation of market maker of ε_{t+1}, based on his information set:

When $\phi_t = -\phi$, the market maker would get the profit from selling one pound forward, π_{t+1}^m, is

$$\pi_{t+1}^m = F_t^b(-\phi) - S_{t+1} \tag{148}$$

The expected profit of market maker should be zero, hence

$$E\left(\pi_{t+1}^m \mid sell, -\phi\right) = F_t^b(-\phi) - E\left(S_{t+1} \mid sell, -\phi\right) = 0 \tag{149}$$

By applying the equation 102, I get the below equation:

$$F_t^b(-\phi) = S_t\left[1 - \phi + E\left(\varepsilon_{t+1} \mid sell, -\phi\right)\right] \tag{150}$$

$$E\left(\varepsilon_{t+1} \mid sell, -\phi\right) = Pr\left(\varepsilon_{t+1} = \varepsilon \mid sell, -\phi\right)(\varepsilon) + Pr\left(\varepsilon_{t+1} = -\varepsilon \mid sell, -\phi\right)(-\varepsilon) \tag{151}$$

the below function is implied in Bayesian rule,

$$Pr\left(\varepsilon_{t+1} = \varepsilon \mid sell, -\phi\right) = \frac{Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, -\phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right)}{Pr\left(sell \mid -\phi\right)} \tag{152}$$

When I compute the $Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, -\phi\right)$, I need to consider the informed and uninformed traders separately. When $\phi_t = -\phi$, uninformed traders would sell the pound forward. When $\varepsilon_{t+1} = \varepsilon$, informed traders would buy the pound forward with probability q, the signal $\zeta_t = \varepsilon = \varepsilon_{t+1}$.

$$Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, -\phi\right) = 1 - \alpha q \tag{153}$$

$$Pr\left(sell \mid -\phi\right) = Pr\left(sell \mid \varepsilon_{t+1} = \varepsilon, -\phi\right) Pr\left(\varepsilon_{t+1} = \varepsilon\right) + Pr\left(sell \mid \varepsilon_{t+1} = -\varepsilon, -\phi\right) Pr\left(\varepsilon_{t+1} = -\varepsilon\right) \tag{154}$$

I also need to compute $Pr\left(sell \mid \varepsilon_{t+1} = -\varepsilon, -\phi\right)$ by the similar way, and it follow that:

$$Pr\left(sell \mid \varepsilon_{t+1} = -\varepsilon, -\phi\right) = 1 - \alpha\left(1 - q\right) \tag{155}$$

I use equations 153, 154 and 155 to obtain the equation below:

$$Pr\left(sell \mid -\phi\right) = \left(1 - \alpha q\right)\frac{1}{2} + \left[1 - \alpha\left(1 - q\right)\right]\frac{1}{2} = 1 - \frac{\alpha}{2} \tag{156}$$

Equations 153, 156 and 152 imply that

$$Pr\left(\varepsilon_{t+1}=\varepsilon \mid sell,-\phi\right)=\frac{1-\alpha\left(1-q\right)}{2-\alpha} \tag{157}$$

Since

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid sell,-\phi\right)=1-Pr\left(\varepsilon_{t+1}=\varepsilon \mid sell,-\phi\right) \tag{158}$$

I have

$$Pr\left(\varepsilon_{t+1}=-\varepsilon \mid sell,-\phi\right)=\frac{1-\alpha q}{2-\alpha} \tag{159}$$

By substituting equations 157, 159 and 151, I obtain

$$E\left(\varepsilon_{t+1} \mid sell,-\phi\right)=-\frac{\alpha}{2-\alpha}(2q-1)\varepsilon \tag{160}$$

I obtain from equation 150

$$F_t^b\left(-\phi\right)=S_t\left[1-\phi-\frac{\alpha}{2-\alpha}(2q-1)\varepsilon\right] \tag{161}$$

I then have forward exchange rate as:

$$\begin{cases} F_t^a\left(\phi_t\right)=\begin{cases} S_t\left[1+\phi+(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right] & if\ \phi_t=\phi, \\ S_t\left[1-\phi+(2q-1)\varepsilon\right] & if\ \phi_t=-\phi, \end{cases} \\ F_t^b\left(\phi_t\right)=\begin{cases} S_t\left[1+\phi-(2q-1)\varepsilon\right] & if\ \phi_t=\phi, \\ S_t\left[1-\phi-(2q-1)\varepsilon\alpha/\left(2-\alpha\right)\right] & if\ \phi_t=-\phi. \end{cases} \end{cases} \tag{162}$$