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The Forward Premium Puzzle: Is the Carry Trade the explanation?

22 April 2009
Word count: 4,971

ABSTRACT:

The high-yielding currencies appreciate and low-yielding currencies depreciate in time. This empirical phenomenon is in direct contradiction with the mainstream economic theory. It makes the currency forwards consistently biased estimates of future spots. The problem is known as a Forward Premium Puzzle and has not yet been resolved. In this paper we test the most recent perspective where carry trade – a speculative strategy which benefits from the phenomenon – is itself a source of the discrepancy. We apply panel regression techniques on the data from eleven currencies. Our results generally confirm the expected relationship between the carry trade and the forward premium. However, they are not statistically strong enough to prove the carry trade as the sole driver of the forward premium puzzle.

CONTENTS:

I. INTRODUCTION

The fundamental building block of most models in mainstream international macroeconomics is the Uncovered Interest Parity condition (UIP). The condition implies that the currencies with higher interest rates (positive interest rate differentials) depreciate in time, whereas currencies with low interest rates appreciate. This relationship is derived from the assumption of no arbitrage.

The empirical evidence, however, does not support the UIP. A large volume of empirical literature shows that on average there is no tendency for the high-yielding currencies to depreciate. Conversely, many studies show that the relationship is reversed – high yielding currencies appreciate (Fama (1984), Bansal and Dahlquist (1999)). The phenomenon, known as the Forward Premium Puzzle (FPP), has been the subject of intensive research in the last quarter-century. Though, there is no generally accepted explanation of the FPP currently available.

This paper takes the perspective of one of the most recent strands of research in the field of FPP – the importance of the carry trade. When a currency investor borrows in a low-yielding currency, exchanges the proceeds and invests in a high-yielding currency, hoping that the exchange rate will remain constant, he employs a speculative strategy known as the carry trade (Plantin and Shin, 2006). This strategy generates profits when the exchange rates deviate from the UIP.

The carry trade has the properties of a self-fulfilling prophecy. The higher the volume of carry trading, the further the target currency appreciates, the further the UIP relationship between currencies is distorted and the more profitable the carry trade is. Buying high-yielding currencies exerts an upward pressure on them. Hence, each carry trade has a positive externality for other carry trades on that currency.

The carry trade has become a highly popular strategy in recent years. Institutional investors, like hedge funds and investment banks have been very highly involved in carry transactions. Their positions in yen-funded carry trades were extremely high throughout the 2000's, giving rise to concern over their impact on the Japanese macroeconomics.

An even more risky phenomenon is the "retail" carry trade – household borrowing in foreign currency to fund investments at home. The most spectacular manifestation of this is in Poland, where over 60% of all mortgages are denominated in Swiss frank (CHF). A result is a massive overhang of foreign currency liability on the economy, which may cause a systemic crisis in the case of an upward swing of CHF.

The impact of the carry trade on exchange rates is extremely important for understanding the risks of the global economy. This paper tests the hypothesis that the carry trade is a significant cause of the deviations from the UIP. As carry trades are virtually indistinguishable from other currency transactions and hence unobservable, we use other variables as proxies of attractiveness of currencies for the carry trade.

The paper is organised as follows: section II includes a more rigorous lay out of the Forward Premium Puzzle, section III briefly discusses the existing literature on the subject of FPP, section IV explains the theory of carry trade dynamics, section V discusses the method used to test the specified hypotheses, section VI presents the data and carries out a visual analysis, section VII includes the results and interpretation of the econometric analysis and verifies the hypotheses of the study, finally section VIII states the conclusion, evaluation and possible policy implications.

II. THE FORWARD PREMIUM PUZZLE

The interest parity condition is a central feature of virtually every linearized general-equilibrium open-economy models (Burnside, et al. 2006). It relates the interest rates to the exchange rates. The Covered Interest Parity (CIP) is expressed as follows:

$$(1+i_{\$}) = (F/S)(1+i_{CCY})$$

Or:

$$F = S\frac{1+i_{\$}}{1+i_{CCY}}$$

The covered interest parity is a non-arbitrage condition. It postulates that "the returns from borrowing in one currency, exchanging the proceeds into the other currency and investing in that currency, while at the same time holding the forward contract to exchange back the currency, are equal to the returns from investing in the primary currency". In other words, the difference in the interest rates of two countries is

exactly reflected in the difference between the spot and forward exchange rate. Otherwise it would be possible to earn risk free returns.

The Uncovered Interest Parity (UIP) is an addition to the CIP:

$$(1+i_{\$}) = \frac{E(S_{+1})}{S}(1+i_{CCY})$$

The UIP means that there is no risk premium to holding currency and it implies that the forward rate is the best expectation of the future spot rate:

$$F = E(S_{+1})$$

The tests of the UIP are usually performed on the regression:

$$(S_{t+1} - S_t)/S_t = \alpha + \beta(F_t - S_t)/S_t + \varepsilon_{t+1}$$

If the UIP holds α should be zero and β should be equal to unity. For the purpose of this study we define the Forward Bias as 1- β.

A large volume of studies show that β does not in practice equal unity. Usually β is less than one and often negative. This means that the currencies which have high interest rates appreciate with time. The forward prices are consistently biased predictors of future spot prices. The phenomenon is known in literature as the Forward Premium Puzzle (FPP).

III. LITERATURE REVIEW

There is a large volume of literature documenting and attempting to solve the FPP. However, no academic consensus has yet emerged on the explanation of the phenomenon. The appreciation of high-yielding currencies was first noted in the seminal work by Fama (1984). His study, as well as other papers in the first generation of FPP related papers (McCullum 1994, Froot and Thaler 1989), attempted to attribute the forward bias to exchange rate risk premia. The bias however proved to be too large to be solely explained by the risk premia.

The second generation of studies employed a variety of innovative approaches to solving the FPP. The explanations included non-cointegration of spot and forward rates (Roll and Yan, 2000), statistical considerations (Lewis, 1995), biases in

expectations (Frankel and Rose, 1994) and costs of actively managing foreign exchange portfolios (Bacchetta and Van Wincoop, 2006). The most promising however are the two most recent approaches: 1) analysis of the market microstructure and 2) analysis of the impact of carry speculation. The latter is the approach tested in this paper.

The market microstructure approach focuses on the way the market is built in order to derive the forward bias. Burnside, Eichenbaum, and Rebelo (2007) offer a model where the market maker uses both public information and upcoming orders to set his bid and offer prices. His reaction, however, is different when orders go in line with public expectations and different when they go against them. Using this model Burnside et al. derive a bias on the UIP.

This study focuses on the carry trade approach to explaining the FPP. Plantin and Shin (2006) develop a model which explains the dynamics of the carry speculation. The interrelation of carry trade and the FPP is presented below. This study attempts to test the significance of the carry trade by verifying if the size of the forward bias of different currencies is correlated with the attractiveness of the currency for carry speculators.

IV. CARRY TRADE DYNAMICS

The theoretical underpinning of the dynamics of the carry speculation is present in Plantin and Shin (2006). We will use this model to carry out an empirical analysis of the impact of carry trade on forward bias.

One of the properties of every financial assets is it's 'resiliency', the measure of how easily its price is brought back to the fundamental value after a shock. Some assets, like short-maturity government bonds are very strongly anchored to their financial values. Other assets, including exchange rates, take much longer to revert to their fundamental values. Hence for these assets hypothetically the price can remain away from its fundaments for an extended period of time. The prices of these assets are therefore influenced by short term considerations and by expectations of other traders' actions.

Plantin and Shin offer a model where the change in the price of the asset is determined by (i) the inflow of funds for the assets and (ii) random arbitrary reversals of the price to its fundamental value. The probability of a reversal acts as the measure of the resiliency of the asset.

The model implies that if there are no costs (or benefits) of the carry then for however low resiliency the dominance-solvable equilibrium (of the game played by the traders) the price always remains equal to the fundamental value.

This captures the notion of the *stabilizing* role of speculation (Friedman 1953). Speculation generates two kinds of externality. The positive externality of buying an asset is that the future value of the asset will be high. The negative externality is that the asset is currently expensive. In the absence of carry costs the negative externality outweighs the positive externality. There is no incentive for the trader to join in to push the price away from fundamentals (Plantin and Shin, 2006). Contrary, speculators will sell overpriced assets and buy underpriced assets, generating price stability. Therefore low resiliency alone is not enough for the prices to remain unnaturally low or high.

However, introducing carry costs (or benefits) drastically changes this result. In the foreign exchange market, a trader who initiates a carry trade (borrows in low-yielding currency, exchanges the proceeds and invests in a high-yielding currency) earns a profit (the interest rate differential) even when the exchange rate remains constant. In other words, just holding the position is *ceteris paribus* profitable. Moreover, every carry trade increases the value of the high-yielding currency, making other carry trades more profitable (positive externality).

The carry speculator acknowledges that there is risk of the price reverting to the mean, but his expected profit from maintaining a position may be bigger than the expected loss in case of price reversal. As traders maintain a position that brings carry profit other traders join in. This causes the price to deviate further from the fundamental value. All traders reason to the conclusion of maintaining a carry position and all traders know that others reason to this conclusion. The positive externality (maintaining positions increase their profitability) outweighs the negative externality (the risk of a reversal is high for already high deviation from

fundamentals). Therefore a price of a currency can remain remote from its fundamentals.

The risk of the carry trade is that a sharp reversal of the price to the fundamentals occurs. This happens in the case of a large random shock, in the case of panic or in the case of a public intervention. For example when the specific exchange rate becomes a monetary policy target, the risk of maintaining the positions outweighs the expected profit and suddenly the carry positions are rapidly unwound. This causes an immediate reversal to the fundamental value, which can wipe out the carry profits. For this reason the carry trade has been compared to picking up nickels in front of a steamroller.

This model is reflected by the real price-paths of exchange rates. This is summarized in traders' jargon as "going up by the stairs and down in the elevator" (Plantin and Shin 2006).

This paper aims to test how much weight the carry trades have in deviating the exchange rates from the UIP-implied fundamental values. We will use the following variables which are related to the attractiveness of a currency for carry speculation as a proxy for the carry trade volumes:

IV.1 Interest rate differential. The size of the interest rate differential is the measure of profitability of a carry trade in the case when the exchange rate remaining stable. It is ubiquitous for the carry speculators to ignore the UIP and treat the spot exchange rates as martingales:

$$E(S_{t+1}) = S_t$$

Therefore traders use the interest rate differential as an expected profit and form their trading decisions on that basis. Therefore the high interest rate differential should be correlated with the carry trade and should have a positive impact on the forward bias.

IV.2 Exchange rate volatility. The high volatility of a currency introduces a risk for carry trade that the price will drop to a level where a carry trade brings loss or that a reversal to fundamental value occurs. Hence, high volatility should be negatively correlated with the carry trade and negatively correlated with the forward bias.

IV.3 Interest rate volatility. The model developed by Plantin and Shin can be extended to a situation where the fundamental value of the exchange rate is itself a stochastic process. The implication of this adjustment is that speculation again stabilizes the price. When the interest rate is stochastic, the theoretical exchange rate is also stochastic and hence there is a risk that this theoretical exchange rate of the currency randomly moves nearer to the actual-value exchange rate and hence increases the probability of a reversal of the exchange rate to fundamentals. Therefore the currencies which have higher interest rate volatility should be less attractive for carry speculation. Hence, interest volatility should be negatively correlated both with carry trade and with deviation from UIP.

V. THE METHOD

The aim of this paper is to measure the differences in the forward premium between currencies and then to test how much of these differences is explained by the carry trade related variables: interest rate differential, interest rate volatility and spot price volatility. The hypotheses implied by the theory of carry trade are:

Hypothesis 1: Forward Premium ($\hat{\beta}_i$) is positively related to exchange rate volatility.

Hypothesis 2: Forward Premium ($\hat{\beta}_i$) is negatively related to interest rate differential.

Hypothesis 3: Forward Premium ($\hat{\beta}_i$) is positively related to interest rate volatility.

The method is as follows: first the financial data series for 11 currencies for 01.01.1999-31.12.2007 are divided into one year periods. For each period the coefficient β is estimated using the regression of:

$$(S_{t+1} - S_t)/S_t = \alpha + \beta(F_t - S_t)/S_t + \varepsilon_{t+1}$$

If the UIP holds the β coefficient is equal to unity. If the spot price is a martingale than $\hat{\beta}_i$ should be zero. If the high-yielding currency appreciates then $\hat{\beta}_i$ is negative.

The $\hat{\beta}_i$ coefficient for each period and each currency is recorded. The $\hat{\beta}_i$'s are then regressed on the explanatory variables *r_diff, vol* and *r_vol:*

$$\hat{\beta}_i = \delta_0 + \delta_1 \cdot r\_diff_i + \delta_2 vol_i + \delta_3 r\_vol_i + \varepsilon_i$$

This regression is estimated using various panel data techniques, including: Fixed Effects estimator (Within), Between estimator, Random Effects estimator and OLS estimation.

VI. THE DATA SET

First, we present the forward and spot prices time series, which are used for calculation of the forward premium ($\hat{\beta}_i$). We discuss their summary statistics and graphical time paths. This is followed by a description of the explanatory variables – interest rates, volatilities and interest rate volatilities.

VI.1 Forward and Spot prices.

To estimate the forward premiums we use the time series from the DataStream. We use the spot and 3-month forward rates for eleven currencies against the British Pound (GBP). The currencies chosen are eight developed countries currencies (USD, EUR, JPY, AUD, NZD, SEK, NOK, CHF) and three emerging currencies (PLN, INR and HUF). The dataset includes daily observations of the currencies over 9 years: from 01.01.1999 to 31.12.2007. By using the most recent data to obtain the estimates of the forward premium we contribute to the documentation of the time variation of the forward premium. The additional benefit of using the recent data is that in the last decade the carry trade reached highest proliferation and became a mature trading strategy.

In the context of the FPP JPY, CHF, AUD and NZD are particularly interesting. Japanese Yen and (to lesser extent) Swiss Frank are conventionally known as the carry trade funding currencies. Australian Dollar and New Zealander Dollar are popularly known as the typical target currencies. This study will examine whether their statistical attractiveness for carry trade is matched by high forward bias (negative forward premium).

In Table 1 we report summary statistics for the 3 month spot exchange rates changes at daily frequency for GBP against 11 currencies and the interest rate differentials of

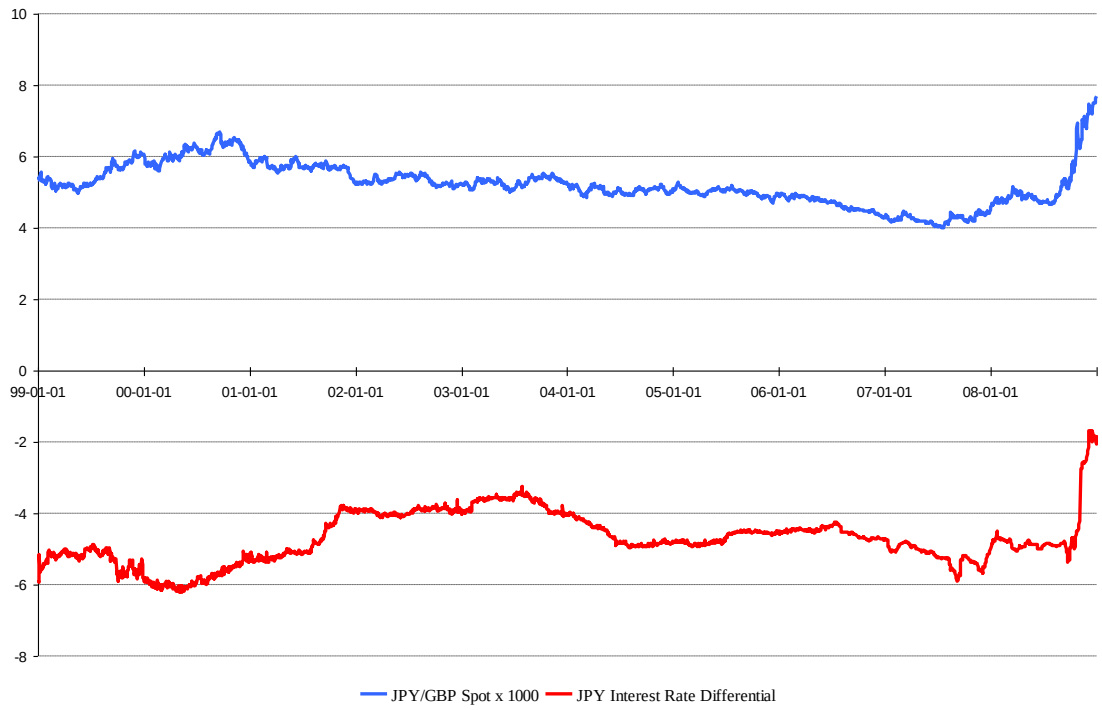
these currencies (this is equivalent to a normalized Forward Premium). We observe that GBP has depreciated against most of the currencies. The average forward premia are positive for six currencies and negative for five currencies. According to the FPP the forward premiums should move in tandem with the FX changes. The UIP states otherwise.

Table 1. Exchange rate changes and forward premia.

	Spot exchange rate change (GBP/CCY)		Forward Premium (GBP/CCY)	
	Mean	Std. Dev	Mean	Std. Dev
AUD	-0,28%	4,72%	-0,59%	0,69%
NOK	-0,43%	3,75%	0,10%	1,90%
EUR	-0,61%	3,54%	1,66%	0,73%
CHF	-0,72%	4,06%	3,37%	0,69%
JPY	-0,64%	6,45%	4,73%	0,66%
NZD	-0,19%	4,90%	-1,46%	1,13%
PLN	-0,56%	5,39%	-3,98%	4,87%
SEK	-0,18%	3,36%	1,63%	1,00%
HUF	-0,36%	4,39%	-4,70%	2,54%
INR	0,17%	4,24%	-2,71%	1,69%
USD	-0,15%	4,71%	1,27%	1,28%

Table 1 suggests that the forward bias is not extensive, given that eight of the currencies moved as predicted by the UIP. However, the visual inspection of the time paths of the currencies reveals something different. In Graph 1 we see the behaviour of the Japanese Yen (GBP/JPY).

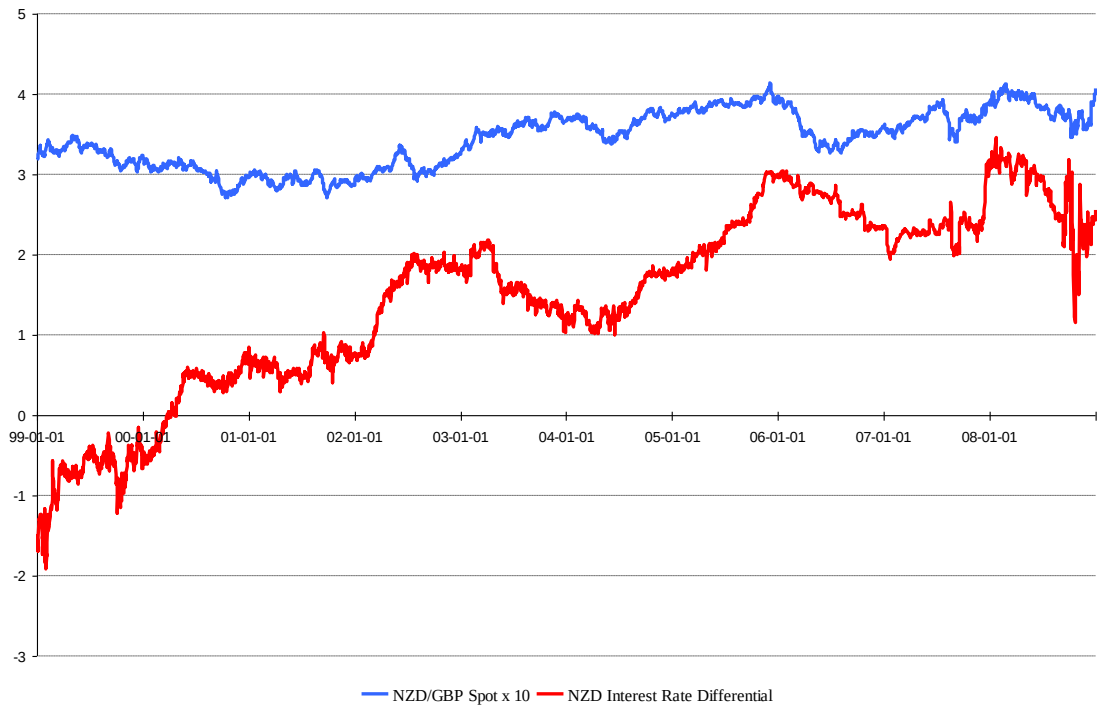
Graph 1. JPY/GBP and JPY interest rate differential vs. time.



We see that the interest rate differential (RJPY-RGBP) is negative for the entire period and that the price of JPY is on average falling between 2001 and 2008. Therefore for almost the whole period JPY was behaving contrary to the UIP. Moreover, the price path of JPY is a classical example of "up by the stairs, down by the elevator" pattern. This is consistent with the conventional perception of JPY as the carry trade funding currency. Hypothetically, carry transactions pushed JPY down during the 2001-2007 period and then were abruptly unwound.

Graph 2 allows us to consider a typical carry trade target currency – New Zealander Dollar (NZD).

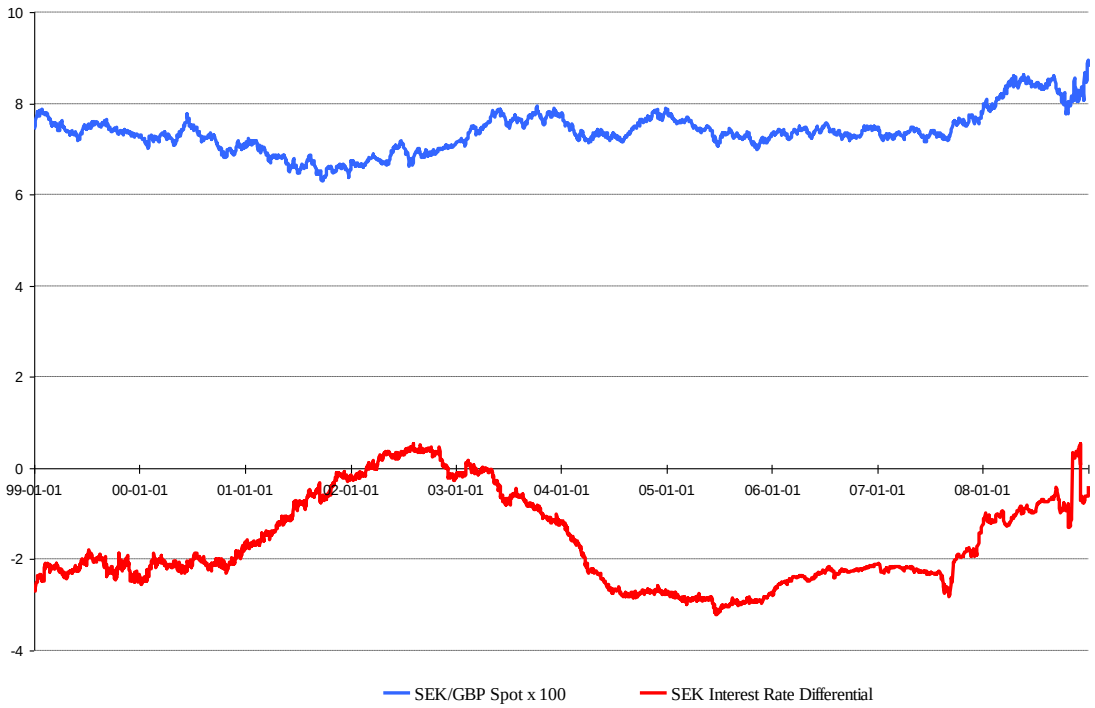
Graph 2. NZD/GBP and NZD interest rate differential vs. time.



NZD initially, until about 2002, is on a falling trend when the interest rate differential is negative (with a one year lag). After this period NZD is increasing, while the interest rate differential is positive. Therefore the price path of NZD is roughly compliant with the FPP prediction. Again, we see the "up by the stairs, down by the elevator" pattern, with a long steady growth followed by a sudden drops in periods 2002-2006 and 2006-2007.

Finally we consider a currency which is not conventionally associated with carry trade – Swedish Krona (SEK)

Graph 3. SEK/GBP and SEK interest rate differential vs. time.



Here, again, we see some FPP resembling properties. SEK depreciates in the period 1999-2002 when the interest rate differential is negative and appreciates when it is close to zero or positive in 2002-2003. However, after 2003 there is no distinct trend and no clear relationship between spot and interest rate differential. We also do not observe sharp increases in the spot price which could be interpreted as sudden unwinding of carry trades.

Basing on this analysis, in the econometric estimations in the later section of this paper we are going to use 1 year period for calculation of the forward premium. This should facilitate capturing the periods of appreciation of carry target currencies (against the UIP) as well as the sudden depreciations (in line with UIP).

VI.2 The independent variables.

The explanatory variables which we use in this paper to proxy the attractiveness of a currency for carry trade (and hence to proxy the volume of carry trade) are spot volatility, interest rate differential and interest volatility.

Table 2. Historical Volatilities for 1999-2008.

Currency	Volatility
Australian dollar (AUD)	7,50%
Euro (EUR)	6,85%
Swiss frank (CHF)	6,46%
Japanese yen (JPY)	11,10%
New Zealander dollar (NZD)	10,20%
Norwegian krone (NOK)	6,89%
Polish zloty (PLN)	10,75%
Swedish krona (SEK)	5,65%
Hungarian forint (HUF)	8,00%
Indian rupee (INR)	8,79%
US dollar (USD)	11,20%

We calculate the historical volatility as the standard deviation of the observations for each time series. The Table 2 shows significant differences between the volatilities of the currencies analysed. The emerging currencies (PLN) have generally very high volatility, whereas less traded G10 currencies (SEK, NOK) are the most stable. Analogically, Table 3 shows that there are large differences in volatility for the same currency at different periods of time:

Table 3. Yearly volatilities.

	AUD	NOK	EUR	CHF	JPY	NZD	PLN	SEK	HUF	INR	USD
1999	2,64%	1,57%	3,10%	3,11%	5,68%	3,13%	4,68%	1,95%	3,67%	1,64%	1,89%
2000	3,08%	1,75%	2,23%	2,51%	4,12%	4,56%	2,52%	2,61%	2,76%	2,38%	4,35%
2001	3,11%	1,05%	1,60%	2,15%	2,23%	2,47%	3,17%	3,29%	2,45%	2,01%	1,74%
2002	3,01%	4,40%	1,85%	2,03%	2,19%	3,51%	4,14%	2,20%	2,42%	3,84%	3,69%
2003	5,33%	2,68%	2,49%	1,81%	2,28%	3,38%	3,06%	2,86%	2,75%	2,48%	2,16%
2004	3,38%	3,17%	1,90%	2,21%	1,90%	3,28%	5,85%	2,62%	3,06%	2,21%	2,83%
2005	2,06%	1,74%	1,33%	1,23%	2,01%	2,03%	2,54%	2,76%	2,22%	2,79%	3,04%
2006	2,17%	3,06%	1,06%	1,80%	4,38%	4,93%	1,90%	1,09%	3,75%	5,34%	3,76%
2007	3,19%	3,64%	2,20%	1,91%	2,68%	3,20%	4,23%	1,98%	2,49%	2,86%	2,13%
2008	5,60%	3,43%	4,04%	5,75%	12,28%	4,04%	5,61%	2,93%	6,13%	4,34%	4,16%

This provides evidence for significant volatility clustering, which may make a currency less attractive for carry trade at some points in time and more attractive at different points. For example Japanese Yen varies in volatility between less than 4% in some years to over 10% in other. In the later section we will analyse how this variability impacts the forward premium.

Interest rate differential and interest rate differential volatility are the next variables used. We calculate the interest rate differential as the difference between the 3-month Eurocurrency rate denominated in the London interbank market as reported by FT on a daily basis for the period between 01.01.1999 and 31.12.2007.

Table 4. Interest rate differentials.

	AUD	NOK	EUR	CHF	JPY	NZD	PLN	SEK	HUF	INR	USD
1999	-0,56	0,95	-	-4,13	-5,29	-0,76	8,86	-2,20	9,66	-	-0,09
2000	-0,06	0,54	-1,73	-3,07	-5,81	0,24	12,4	-2,10	5,29	4,16	0,38
2001	-0,19	2,16	-0,72	-2,07	-4,82	0,64	10,9	-0,93	6,00	3,75	-1,23
2002	0,64	2,79	-0,71	-2,86	-3,95	1,55	4,85	0,17	5,10	3,35	-2,24
2003	1,11	0,33	-1,36	-3,38	-3,70	1,63	1,93	-0,53	4,77	1,72	-2,51
2004	0,81	-2,68	-2,49	-4,14	-4,61	1,40	1,52	-2,35	6,79	0,31	-3,01
2005	0,84	-2,61	-2,54	-3,94	-4,68	2,28	0,52	-2,91	2,42	1,04	-1,18
2006	1,10	-1,83	-1,75	-3,33	-4,52	2,67	-0,66	-2,35	2,18	-	0,37
2007	0,72	-0,46	-1,62	-	-4,48	1,80	2,37	-1,58	4,13	-	-1,52
2008	1,58	0,58	-0,91	-	-4,54	2,78	0,67	-0,84	3,21	-	-2,53

In Table 4 we observe large differences between currencies' interest rate differentials. Some of the currencies have a consistently high, positive differential (HUF), some have consistently negative differential (CHF, JPY) and some have a volatile differential (NOK, USD).

Finally, in Table 5 we see the interest rate volatility. For some currencies in the period there have been large changes in the interest rate. The cross-country differences do not necessarily follow the lines of emerging-developed division – NOK, SEK and USD had highly volatile interest rate periods.

Table 5. Yearly interest rate volatilities.

	AUD	NOK	EUR	CHF	JPY	NZD	PLN	SEK	HUF	INR	USD
1999	-0,45	0,63	-	-0,06	-0,05	-0,46	0,17	-0,08	0,07	-	-4,28
2000	-4,86	1,25	-0,36	-0,18	-0,05	1,61	0,07	-0,07	0,14	0,21	0,77
2001	-1,30	0,18	-0,22	-0,09	-0,11	0,22	0,14	-0,55	0,05	0,14	-0,53
2002	0,45	0,12	-0,17	-0,13	-0,02	0,27	0,28	1,29	0,12	0,27	-0,07
2003	0,16	3,84	-0,20	-0,06	-0,05	0,17	0,22	-0,76	0,42	0,36	-0,07
2004	0,45	-0,14	-0,12	-0,04	-0,07	0,17	0,22	-0,22	0,17	1,16	-0,10
2005	0,19	-0,13	-0,08	-0,05	-0,03	0,17	1,28	-0,03	0,36	0,46	-0,60
2006	0,09	-0,08	-0,09	-0,03	-0,03	0,08	-0,44	-0,06	0,27	-	0,63
2007	0,30	-0,73	-0,08	-	-0,06	0,09	0,09	-0,15	0,15	-	-0,31
2008	0,30	0,83	-0,48	-	-0,20	0,16	1,29	-0,48	0,54	-	-0,26

In the econometric analysis in the next section we use the final daily spot and forward rates to calculate the yearly forward premiums for each currency. These are then regressed on yearly volatility, interest rate differential and interest volatility. One limitation of this method is the fact that the explanatory variables are derived from the same basic datasets as the dependent variables – spots, forwards and interest rates. This limitation has to be acknowledged and the errors of the regression have to be taken with caution.

VII. EMPIRICAL ANALYSIS

VII.1 The Forward Bias.

We divide the 11 currency time series into one year periods from 1999 to 2007. This gives 99 time series. In order to estimate the forward premiums we regress the normalized difference between initial spot and the 3-month spot on the normalized difference between initial 3-month forward and initial spot:

$$(S_{i,t+1} - S_{i,t}) / S_{i,t} = \alpha_i + \beta_i (F_{i,t} - S_{i,t}) / S_{i,t} + \varepsilon_{i,t+1}$$

The forward bias is equal to 1- β_i . We report the summary statistics for the β_i coefficients in Table 6., the full record of the coefficients is included in Table 1 of the Appendix.

Table 6. Summary statistics of β_i (Forward Premiums).

Variable	Mean	Std. Dev.	Min	Max	Observations
β_i overall	-0,09596	5,2757	-18,971	16,362	N=99
β_i between		1,2801	-2,4431	1,9655	N=9
β_i within		5,1244	-21,032	16,053	T=11

We see that the mean $\hat{\beta}_i$ is approximately -0.096. This means that on average the forward prices, which are calculated using the UIP, are biased. Not only the spot prices do not on average move in the direction expected by the forwards (which

would be the case if $\beta_i \in (0,1)$), but they tend to move in the opposite direction ($\beta_i < 0$) .

VII.2 Explaining the bias.

In order to test the hypotheses outlined in Section V we estimate the impact of the variables *vol, rate_diff,* and *rate_vol* on the *forward_premium* using a series of panel regression techniques.

VII.3 Pooling Estimator (OLS)

First we regress the variables using the pooling technique (Ordinary Least Squares) to observe the general, whole-sample relationship between the variables.

$$\beta_{it} = \alpha + \delta Vol_{it} + \delta Rate\_diff_{it} + \delta Rate\_vol_{it} + \varepsilon_{t+1}$$

Table 7. Pooling (OLS) regression of β_{it}

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Vol.	0.05175	0.16009	0.32	0.747
Rate Diff.	-0.7849	0.62256	-1.26	0.210
Rate Vol.	-33.006	50.3801	-0.66	0.514
Constant	-.79258	1.4522	0.55	0.597
R^2	0.0216	F-Statistic(3,95)	0.70	
Sample size	99	Prob(F-Stat)	0.554	

The pooling estimation shows an increasing relationship between volatility and β_i. This is in line with the hypothesis that high volatility should deter the carry speculators and hence should make the currency follow the UIP more accurately. The reported coefficient on the interest rate differential is negative, which also matches the hypothesis. It means that the bias is larger for these currencies which have a larger interest rate differential. These currencies attract more carry speculation, as the size of the interest rate differential is equal to expected profits, for those who assume a martingale property of the spot prices. Finally, the negative coefficient on the interest rate volatility goes against the carry trade theory.

All the reported coefficients are not statistically significant under 5% significance level. Therefore these results do not provide strong evidence for carry trade driving the forward bias.

VII.4 Fixed Effects (Within) Estimator

The Fixed Effects estimator explains the differences in time within the analysed currencies. We estimate:

$$\beta_{it} - \overline{\beta}_i = \alpha + \delta(Vol_{it} - \overline{Vol_i}) + \delta(Rate\_diff_{it} - \overline{Rate\_diff_i}) + \delta(Rate\_vol_{it} - \overline{Rate\_vol_i}) + \varepsilon_{t+1}$$

Table 8. Fixed Effects (within) regression of $\hat{\beta}_i$.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Vol.	0.07052	0.1683	0.42	0.676
Rate Diff.	-0.6308	0.6323	-0.95	0.343
Rate Vol.	-29.92	53.43	-0.56	0.577
Constant	0.7076	1.5325	0.46	0.645

R^2 within	0.0146	F-Statistic(3,87)	0.43
Sample size	99	Prob(F-Stat)	0.7325
Number of groups	9	Observations per group	11

The coefficients reported by the Fixed-effects estimation are similar to those found by the Pooled estimation, with positive relationship for volatility and negative for rate differential and rate volatility. This means that the changes in volatility and interest rate differential for the same currency cause the carry traders to move in and out of their positions on the currency. This is consistent with the property of the carry trades being easily influenced and subsequently unwound due to changes in the volatility of the currency. Again, the relationships are not statistically significant.

VII.5 Between Estimator.

We use the between estimator to examine the differences in the bias between the currencies. We use the model:

$$\overline{\beta}_i = \alpha + \delta\overline{Vol_i} + \delta\overline{Rate\_diff_i} + \delta\overline{Rate\_vol_i} + \varepsilon_{t+1}$$

Table 9. Between regression of $\hat{\beta}_i$.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Vol.	-0.9053	0.4912	-1.84	0.125
Rate Diff.	-4.316	1.585	-2.72	0.042
Rate Vol.	5.4002	117.5	0.05	0.965
Constant	-0.1579	3.159	-0.05	0.962
R^2 between	0.636	F-Statistic(3,5)	3.91	
Sample size	99	Prob(F-Stat)	0.1397	
Number of groups	9	Observations per group	11	

The Between estimation gives partially different results to these estimated above. Firstly, it reports a negative coefficient on volatility, although statistically insignificant. This would suggest that the carry traders do not consider volatility when making their decisions which currency to invest in. Combined with the Fixed-effects estimation, it suggests that increasing volatility makes the currency traders flee from their carry positions (opposite is true for decreasing volatility), but a move from low to high volatility does not necessarily attract investors to a given currency (or the inverse).

The estimation reports a statistically significant negative coefficient on interest rate, which is consistent with the hypothesis – carry traders use the interest rate differential to choose between currencies. There is no statistically significant relationship between rate volatility and the bias.

VIII. CONCLUSION AND EVALUATION

VIII.1 The Results of Tests of Hypotheses.

The estimation results give a mixed outlook on the hypotheses tested.

Hypothesis 1: The study provides some arguments for a positive relationship between volatility and forward premium (hence, negative relationship between volatility and forward bias). Such relationship was found by the Pooled, Random-effects and Fixed-effects estimators. However the relationship is not statistically significant for these tests.

Hypothesis 2: There are relatively strong arguments for a negative relationship between interest rate differential and forward premium. All the estimators for this relationship gave negative coefficients. The coefficient for the Between estimator was statistically significant. This may suggest that is a strong impact of interest rate differential on carry speculators choice of currencies.

Hypothesis 3: No significant relationship is found between interest rate volatility and forward premium.

Hence in summary, the empirical evidence gives some support for our central hypothesis that carry speculation drives the forward biases in the foreign exchange market, however this evidence is not strong and cannot be deemed conclusive.

VIII.2 Limitations

There are several limitations of this study. Firstly, the major difficulty lies in the use of proxy variables to estimate carry trade attractiveness. In order to be able to accurately interpret the results we should have data on the carry trade volumes that we could use as an independent variable in the forward premium regression. Secondly, the division of the sample into one year periods to estimate forward premia is arbitrary. A different division may yield slightly different results. Finally, as expressed earlier, the explanatory variables are derived from the same sample as the dependant variable. That may introduce some bias. These limitations partially originate in the novelty of the carry-trade-based strand of research of the FPP.

VIII.3 Policy Implications

The evidence of the importance of the carry trade for determination of future exchange rates suggests some possible implications for the monetary policymakers.

The observation that the carry trades generate “up by the stairs, down by the elevator” dynamics of the exchange rate can incentivize the central banker to attempt to manage the carry trade volumes and directions. The relationship, shown in this paper, between carry trade, interest rates and forward premium gives the central banker an instrument for manipulating the carry trade.

We consider a high yielding currency with a central banker whose objective is to prevent drastic shocks to the exchange rate. If he observes exchange rate appreciation he may suspect a built-up of carry positions. Expecting that this is a growing bubble he may want to burst it before it becomes large enough to be risky for the economy. Hence, he may decrease the interest rate (decreasing the interest rate differential) in order to provoke unwinding of carry positions.

Analogically, a central banker with a low-yielding currency which has been depreciating may provoke a sharp appreciation of his currency by increasing the interest rate.

Interestingly, our study found that mere volatility of the interest rate differential does not imply lesser forward bias. This suggests that in order to wind up carry trade positions the market must become convinced that the change in the interest rate differential is not very temporary.

This leads to possible “time inconsistency” problems. The central banker changes the interest rate to provoke a carry trade unwinding but has an incentive to revert to previous levels of interest rate if the previous levels where optimal for other monetary policy objectives. If the carry speculators collectively sense that the other objectives of the central banker allow only for a very short-lived interest rate change they may cling to their positions.

VIII.4 Future directions

The future extensions of the research should address the limitations discussed above. Highly desirable would be a use of time series data of the distilled volumes of carry trade. The application of more advanced statistical techniques should also provide more convincing results.

The study of carry trade is extremely important for the understanding of the risks of global economy and is a very promising source of explanation of the puzzles of international macroeconomics.

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APPENDIX

Table 1. Yearly estimated β_{it} for the 11 currencies for 1999-2007. This is the dependent variable in the panel regressions.

	AUS	EUR	CHF	JPY	NZD	NOK	PLN	SEK	HUF	INR	USD
1999	7,8553	-4,6664	-2,9953	1,8418	-2,4999	2,7050	0,7730	-2,7204	-0,0407	-0,0026	11,014
2000	-0,7240	0,3107	2,4132	-0,0722	16,362	-5,8024	-0,9524	-1,4873	-0,0032	0,0074	-7,7081
2001	8,1649	-4,9340	0,3103	-1,8200	-1,6326	-1,1192	-0,0619	-8,6689	0,0170	-0,0058	0,2620
2002	0,0373	13,756	3,1820	-0,2569	-7,8233	-4,0104	1,7315	-12,265	0,0265	-0,0261	-5,1859
2003	-9,0104	-0,5062	-1,7790	-1,1671	-4,4369	-2,2241	5,2218	-9,2645	-0,0164	-0,0226	-3,6692
2004	8,5219	1,0975	0,8304	-0,0769	-2,3486	2,5170	-12,567	1,8559	0,0243	0,0008	-0,3958
2005	-2,1387	-0,5133	-0,4751	-0,7922	1,1593	0,8657	9,2312	-1,4357	-0,0162	0,0150	1,1679
2006	4,2414	-1,3610	-1,8658	-3,0579	3,1490	-2,3257	-3,6843	-0,2705	-0,0055	-0,0282	1,1499
2007	-18,970	7,4319	3,4285	2,3099	-4,8283	11,772	15,124	4,5840	0,0302	0,0227	0,7162

Table 2. Random Effects regression of β_{it}.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Vol.	0.05175	0.1601	0.32	0.746
Rate Diff.	-0.785	0.6226	-1.26	0.207
Rate Vol.	-33.01	50.38	-0.66	0.512
Constant	0.7926	1.4522	0.55	0.55

R^2	0.0216	Wald chi^2 (3)	2.10
Sample size	99	Prob(chi^2)	0.5518
Number of groups	9	Observations per group	11