The existence and severity of the forward premium puzzle during tranquil and turbulent periods: developed versus developing country currencies

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Abstract

In this paper we investigate the forward premium bias (FPB) puzzle for a number of developed and developing country currencies. Our main objective is to examine the possible variations in the existence and severity of the bias for different currency sets over two sample periods which can be categorized as calm and turbulent periods. We find significant evidence that the FBP tend to vary over time and across currency sets. We also find that the global financial crisis has been a turning point in the variation of the existence and severity of the bias for our currency sets. The results show that different currency sets have been affected by the crisis in different patterns. While the bias disappeared prominently for developed country currencies with the peak of the crisis, it survived and became more pronounced for some high-yielding developing country currencies. The results imply that the FPB is time-varying and its existence and severity vary across and within currency sets depending on the time period under consideration. Overall, the findings of the paper suggest that both time period-specific characteristics as well as currency-specific factors play a vital role for the existence and severity of the FPB.

Keywords: Forward premium bias; Foreign exchange; Global financial crises; Covered and uncovered interest rate parities; Advanced and emerging market currencies; Currency carry trades

***JEL* classification:** F31; G15

1. Introduction

The forward premium bias (FPB) is one of longstanding puzzles in the field of exchange rate economics. The FPB puzzle is simply the empirical failure of the unbiasedness hypothesis (UH) and uncovered interest rate parity (UIP) alike. Assuming covered interest rate parity (CIP) to hold, and under the assumptions of UIP and rational expectations, the UH states that currency forward rates should be unbiased predictors of future spot rates. Accordingly, one way for testing the UH involves the regression of future realized exchange rate changes against current forward premium. Practically, one central condition for the UH to hold is that the slope coefficient of this regression must be equal to one. Slope coefficient of one means that low (high) interest rate currencies are expected to appreciate (depreciate) by a rate equal to forward premium (discount). Nevertheless, most empirical findings show that the slope coefficient of the UH test regression equation tends to consistently take on values of less than one, and more puzzling less than zero[1].

There is almost no agreement in literature on one conclusive explanation for the existence of the FPB puzzle (For useful surveys see e.g., Engel, 1996. 2016; Sarno, 2005; Chinn, 2006; Jongen et al., 2008). Generally speaking, the explanations provided can be classified into four categories where the FPB can be attributed to: first, the existence of time-variant risk premium component in forward rates (e.g., Hodrick and Srivastava, 1986; Frankel and Chinn; 1993, Verdelhan, 2010; Kumar, 2020; Abankwa and Blenman; 2021), second, the existence of systematic errors in market participants' expectations of future currency values (e.g., Lewis, 1989; Froot and Frankel 1989; Engel and Hamilton, 1990; Kaminsky, 1993; Yu, 2013), third, the existence of statistical and econometrical issues in the UH test regression equation (e.g., Baillie and Bollerslev, 2000; Baillie and Kilic, 2006; Gospodinov, 2009; Pippenger, 2011; Ho and Mo, 2016) and fourth, the effects of currency trading strategies which attempt to exploit the bias in forward rates (e.g., Gagnon and Chaboud, 2007; Bacchetta and Wincoop, 2010; Hochrald and Wagner, 2010; Plantin and Shin, 2011; Spronk et al., 2013; Breedon et al., 2016; Cho et. al., 2019; Czech, 2020).

Despite that the FPB puzzle is well established in the literature, there is no consensus on its existence and severity when different currency sets and different sample periods are considered. More precisely, it is found that the FPB tends to behave differently over different time periods and across different currency samples. For example, the FPB is found to exist over some time periods but not in other time periods (e.g., Bansal and Dahlquist, 2000; Flood and Rose, 2002; Zhou and Kutan, 2005; Lee, 2011, 2013; Lothian and Wu, 2011; Grossmann et al., 2014; Czech, 2020; Miah and Altiti, 2020). In addition, its severity is found to vary amongst different currencies (e.g., Bansal and Dahlquist, 2000; Frankel and Poonawala, 2010; Loring and Lucey, 2013; Grossmann et al., 2014; Miah and Altiti, 2020). This paper is motivated by this strand of literature. Indeed, the results of such studies are varying and less of agreement especially when investigating the FPB across different currency sets and types, and over different sample periods. This situation makes room for further research. The findings and conclusions of this branch of research, to which this study belongs, are

[1] E.g., Froot and Thaler (1990) report an average slope coefficient of -0.88 for 75 published studies.

particularly relevant. This is because they can provide further insights and reveal additional aspects of the forward premium anomaly and its behaviour which, in turn, can expand our perspective of it. Importantly, a better understanding of the anomaly can help in developing more realistic and proper models.

The crux of the paper is to investigate the existence and severity of the FPB for several developed and developing country currencies with an emphasis on its behaviour during two sample periods which can be characterised as calm and turbulent periods. As a representative turbulent period, we focus on the most recent one which comprises two major crises; the global financial crisis which starts in 2007, and the European sovereign debt crisis which starts in 2010. So, we confine our analysis to the sample period up to 2014. We identify the calm period to extend from the beginning of the sample up to 2006, just before the start of the global financial crisis. We then identify the turbulent period to extend from 2007 to 2014. Our objective is to examine the possible changes in the behaviour of the FPB in developed and developing currency sets over the turbulent period compared to the prior period given the major developments which our identified turbulent period has seen. These major developments can be summarised by; increased volatility and illiquidity, record-low interest rates for many countries especially developed ones in an attempt to revive their economies, and the movement of capital flows to some high-yielding emerging markets[2] (e.g., Mishra et al., 2014; Nechio, 2014; Aizenman et al., 2016; Eichengreen and Gupta, 2015; Ahmed and Zlate, 2014; kim, 2015). With this in mind, we examine the FPB during the two periods, and over time during our whole sample period with the aim of identifying any possible differences in its behaviour across our currency samples.

Our currency samples consist of 10 advanced market and 11 emerging market exchange rates against the US dollar. We examine the FPB for forward contracts of 1-month horizon. By and large, the existing literature which examines the variation of the FPB focuses either on the variation of the bias over different time periods or on the variation of the bias across different currency sets. In this paper we consider the variation of the existence and severity of the FPB both over time for different currency sets and across and within currency sets over different time periods. In addition, rather than just dividing the whole sample periods into sub-periods or excluding specific time periods from the full sample period, we employ the techniques of rolling regressions which enable us to track the variation in the behaviour of the bias over time during the full sample period. Furthermore, our analysis involves the investigation of the FPB variation in terms of currency carry trade returns.

The paper contributes to the literature by providing significant evidence on the variability of the FPB whether over time or across currency sets. Our investigation proceeds in various analysis procedures. Namely, country-by-country analysis, pooled data analysis with dummy variables, rolling regression analysis and currency carry trade return analysis. Our analysis shows that the FPB is not permanent finding but rather its existence and severity tend to vary significantly during different time periods and across different currency samples. Also, our

[2] According to the Financial Times May 7, 2015; from July 2009 until the end of June 2014, a net total of $2.2tn in capital was received by 15 emerging markets.

analysis particularly shows the effect of the global financial crisis. We find that the crisis constituted a turning point for the variation of the existence and severity of the bias. We find that the existence and severity of the FPB in our different currency sets have been affected in different patterns during the crisis. Importantly, our results suggest that the existence and severity of the bias tend to vary across different currency sets and from one time period to another depending on both period-specific characteristics as well as currency-specific factors. In other words, the results suggest that forward premium is driven by time-varying and country-specific factors. Moreover, as many of the existing studies focus on currencies of developed countries, our results provide more insights into the FPB regarding the developing country currencies.

The rest of the paper is organized as follows: in section 2 we review related literature; in section 3 we describe the data set; in section 4 we provide the empirical analysis and results; in section 5 we discuss the findings and conclude the paper.

2. Related literature

Covered interest rate parity (CIP), Uncovered interest rate parity (UIP) and unbiasedness hypothesis (UH) are amongst the very important parities and hypotheses in international finance. CIP involves that interest rate differentials between currencies should be offset by forward premiums (discounts), i.e.

$$i_{t,k} - i^*_{t,k} = [f_t^k - s_t] \quad (1)$$

where i and i^* are the k-period nominal interest rates for the quote and base currency, respectively, f_t^k is the natural logarithm of the k-period forward exchange rate and s_t is the natural logarithm of the spot exchange rate. UIP involves that interest rate differentials between currencies should be offset by exchange rate movements, i.e.

$$E_t(s_{t+k} - s_t) = i_{t,k} - i^*_{t,k} \quad (2)$$

where $E_t(s_{t+k} - s_t)$ is the expected change in the spot exchange rate from time t to $t+k$ conditioned on all relevant information at time t. Under the assumptions of rational expectations and risk neutrality, the UIP can be tested for through the regression equation of

$$s_{t+k} - s_t = \alpha + \beta\left(i^*_{t,k} - i_{t,k}\right) + \varepsilon_{t+k} \quad (3)$$

where s is the natural logarithm of the realized spot exchange rate and ε_{t+k} is an error term. For the UIP to hold, the null hypothesis involves that $\alpha = 0$, $\beta = 1$ and ε_{t+k} is a white noise process. By assuming CIP to hold, where the interest rate differential can be replaced with the forward premium (discount), UH involves that forward exchange rates should be unbiased predictors of future spot exchange rates, i.e.

$$E_t(s_{t+k} - s_t) = [f_t^k - s_t] \quad (4)$$

and it can be tested for through the regression equation of

$$s_{t+k} - s_t = \alpha + \beta\left(f_t^k - s_t\right) + \varepsilon_{t+k} \text{ (5)}$$

with the null hypothesis of $\alpha = 0$, $\beta = 1$ and ε_{t+k} is a white noise process.

β coefficients of one in equations (3) and (5) mean that high (low) interest rate currencies are expected to depreciate (appreciate) by a rate equal to interest rate differential or forward discount (premium). This implies that interest rate differentials amongst currencies cannot be exploited for achieving positive currency excess returns. For more than four decades, the validity of the UIP and UH has been examined widely. The puzzling conclusion of empirical evidence is that forward exchange rates are mostly found to be downward-biased predictors of future spot rates. Particularly, the forward premium bias (FPB) puzzle indicates to the failure of the UIP/UH in the way that β coefficient estimates are found to consistently have values of less than unity with a closeness to zero, or more puzzling less than zero. This means that, contrary to the UIP/UH perditions, high interest rate currencies are either expected to depreciate against low interest rate currencies by a rate lower than forward discount, or not to depreciate at all but rather appreciate.

Broadly speaking, early studies examine the FPB over a relatively limited time span and/or for a limited number of advanced market currencies (e.g., Fama, 1984; Hodrick and Srivastava, 1986; Frankel and Chinn, 1993; Kaminsky, 1993). Later, the increase in observations as time goes by allow for examining the FBP over extended time periods and different sub-periods. In addition, the increase in the number of currencies which got well representation in the forward currency market, especially emerging market currencies, allow for examining the FBP for different currency sets and types.

Some studies examine the bias in relation to some certain characteristics of countries and exchange rate types. Bansal and Dahlquist (2000) discuss that country-specific characteristics can play significant role in the existence of the FPB. They use a data set of exchange rates of 16 developed countries and 12 developing countries over the period from January 1976 to May 1998. They find that the FPB tends to exist for countries with high income, low inflation volatility, and high credit rating and only when the US dollar is the higher interest rate currency. However, during the turbulent period of 1990s and for 23 developing and developed countries, Flood and Rose (2002) find no significant difference between high- and low-income countries, and that UIP works well for high inflation countries especially at short forecast horizons. They also find that the performance of the UIP is systematically worse for both fixed and flexible exchange rate countries when compared to crisis countries. Lee (2011) examines the UIP on a cross-sectional basis for 37 developed and developing countries over the period from 1974 to 2004. He finds evidence that the failure of the UIP is more pronounced for high inflation countries compared to low inflation ones.

Some research investigates the FPB in relation to currency types. Frankel and Poonawala (2010) examine the UIP for a set of 21 developed and 14 emerging country currencies against the US dollar over the period from 1996 to 2004. They find that the FPB is more pronounced for developed country currencies than for emerging ones. They argue that because emerging country currencies are riskier and their trend of movement is easily identifiable compared to developed market currencies, these results are in favour of systematic expectational errors-based explanations of the bias and against time variant risk-based explanations. In contrast, Loring and Lucey (2013) extend the sample period used by Frankel and Poonawala (2010) and examine the FPB from 2004 to 2011 for 13 developed and 14 emerging country currencies against the US dollar. They dismiss the results that the bias is more pronounced for developed country currencies. Further, their results give some evidence that the bias is more pronounced for emerging country currencies. Lee (2013) introduces the notion of "key currency bias". He examines the UIP for a large set of advanced and emerging country currencies. He finds that the FPB tends to exist for the main currencies of US Dollar, Euro (Deutschmark before the Euro), Japanese yen and U.K. pound against other currencies.

Yet, some authors focus on investigating the FPB by examining it over extended time periods and for different sub-periods of time. Lothian and Wu (2011) argue that small sample sizes can be a reason for the bias in the forward rate predictions. So, they examine the UIP for US dollar, French franc and pound sterling over a period of two centuries - almost from 1800 to 1999. Over this extended period, they find supportive evidence for the parity in the case of French franc/pound sterling. Zhou and Kutan (2005) examine the FPB over the period from September 1977 to June 1998 for US dollar exchange rates against six major currencies. They first find evidence on the existence of the FPB over the whole sample period. However, they find no evidence supporting the existence of the FPB when they exclude the sup-period of 1980-1987 from their full sample period. Grossmann et al. (2014) examine the FPB for EURO and British pound exchange rates against 10 advanced market currencies and 14 emerging market currencies over the period from 1999 to 2013. They divide the whole sample period into three sub-periods: 1999-2007, 2008-2013 and 2010-2013. They find that the FPB exists for the period 1999-2007, but it does not for the period 2008-2013. For the period 2010-2013 they find evidence on the FPB for advanced market currencies in the case of British pound only. For emerging market currencies, they find that the FPB does not exist for the period 2010-2013 in both cases of EURO and British pound. Miah and Altiti (2020) examine the 3 and 12-month FPB for 27 developed and developing exchange rates against the US Dollar over the period 2007-2016. They divided their sample period into two sub-periods of crisis (2007M2-2011M11) and non-crisis (2011M12-2016M01). They find that over non-crisis period the FPB is higher for developed country currencies than for developing ones. For developed country currencies, they find that over crisis period the bias is higher compared to non-crisis period for 3-month forward rates, but it is lower for 12-month forward rates. For developing country currencies, the bias is found lower over crisis period compared to non-crisis period for 3-month forward rates, but it is slightly higher for 12-month forward rates.

3. Data

We obtained our data set from DataStream. It consists of the World Market Reuters (WMR) series of the mid bilateral spot exchange rates and one-month forward exchange rates of the

US dollar against 21 currencies. We set the US dollar as the base currency for both spot and forward exchange rate quotations i.e., other currency units per 1 US dollar. So, the increase in the exchange rate implies the appreciation of the US dollar against other currencies and vice versa.

We divide our 21 currency sample into two groups; developed country currency group with 10 countries, and developing country currency group with 11 countries. The group of developed countries includes Australia (AUD), Canada (CAD), Switzerland (CHF), Denmark (DKK), EURO, U.K. (GBP), Japan (JPY), Norway (NOK), New Zealand (NZD) and Sweden (SEK). The group of developing countries includes Czech Republic (CZK), Hong Kong (HKD), Hungary (HUF), India (INR), Kuwait (KWD), Mexico (MXN), Singapore (SGD), Thailand (THB), Turkey (TRY), Taiwan (TWD) and South Africa (ZAR)[3].

The starting point of our sample period for every currency pair is restricted by the availability of data on forward exchange rates. Our sample period for all currency pairs starts from December 1996 (except for EURO, HUF and INR). The sample period for EURO starts from January 1999, and for HUF and INR it starts from October 1997. We confine our analysis to the sample period up to 2014 and divide it into two sub-periods. The first one represents a calm period and extends from the beginning of the sample up to 2006, just before that start of the global financial crisis. The second one represents the most recent turbulent period which encompasses the global financial crisis, which start in 2007, and the European sovereign debt crisis, which start in 2010. So, we identify our turbulent period to extend from 2007 to 2014.

Our empirical analysis is at monthly frequency. We create the monthly observations by taking the quote of the spot and forward exchange rates at the end (last working day) of each month. We believe that this is essential to keep the match between the forward rate and the corresponding future spot rate.

Figure 1 depicts the time series of spot rates for each currency, while Table 1 reports the means and standard deviations of the monthly changes in spot exchange rates and 1-month forward premiums. On average, the value of US dollar decreased against developed country currencies over the whole sample period except for GBP, NOK and SEK; while it increased against developing country currencies except for CZK, KWD and SGD. Looking at the standard deviations we note that spot returns are much more volatile than forward premium. For all developed countries the standard deviations of spot returns are higher over the turbulent period compared to the calm period. In contrast, for the vast majority of currencies forward premiums are less volatile over the turbulent period.

[3] Our selection of currencies included in each country sample is based on the availability of forward rates data. The currencies of developed countries are, more or less, ranked within the top 20 in the list of foreign exchange turnover by currency according to the 2019 triennial survey of the Bank for International settlements (BIS). For currencies of developing countries, they are, more or less, ranked within the top 30 of the list. Some important developing currencies which ranked relatively high are not included because either the data is not available, or the data is available but with late starting point. For example, there is no WMR forward rates data for Brazilian real against the USD. For Russian ruble, the data is available from 2004M03. For South Korean won and Polish zloty the data is available from 2002M02. For Indonesian rupiah, we noticed that the one-month forward rate is constant almost over 2001-2008.

4. Empirical analysis and results

The objective of the paper is to examine the variation of the existence and severity[4] of the FPB for different sets of developed and developing country currencies during different time periods defined as calm and turbulent periods. To this end, we begin our analysis by examining the FPB on country-by-country basis. We then employ the pooled data analysis. Next, we examine the FPB over time by using rolling regression techniques. Finally, we examine the FPB in terms of currency carry trade returns.

4.1. Country-by-country analysis

We stick to the standard method of testing UH so that our results will be comparable with related studies. The below workhorse regression of testing the UH, which is known as Fama's regression[5], is estimated for every currency against the USD;

$$s_{t+k} - s_t = \alpha + \beta(f_t^{1M} - s_t) + \varepsilon_{t+k} \quad (6)$$

where s_t (s_{t+k}) is the natural log of the spot exchange rate at time t ($t + k$ i.e., one month ahead), f_t^{1M} is the natural log of the 1-month forward exchange rate time t, and ε_{t+k} is the error term. α and β are the coefficients to be estimated. The reported standard errors of the parameter estimates are the Newey-West robust standard errors which are corrected for heteroscedasticity and autocorrelation in error terms.

Practically and to be consistent with the literature, we examine the FPB by focusing on the significance of β estimates, and importantly whether they are equal to the theoretical value of unity according to the null hypothesis of $\beta = 1$.

Table 2 reports the estimation results of the UH test regression over the whole sample period for developed and developing country currencies. For all countries the average of β estimates is -0.67. For developed and developing countries the average of β estimates is -1.62 and 0.19 respectively. For the 10 developed countries β is less than unity for all countries, and it is negative for 8 countries. At the conventional significance levels, β is significantly negative for DKK and EURO. However, the null hypothesis of $\beta = 1$ can be rejected for 5 countries. For the 11 developing countries β is less than unity for 10 countries, and it is negative for 7 countries. None of the less than unity β estimates is significant. However, for the β estimates of less than unity the null hypothesis that $\beta = 1$ can be rejected for 6 countries. To summarize, the regression estimates are not much supportive to the UH over the whole sample period. β estimates are less than unity for all currencies except for KWD, and they are negative for 15 countries out of 21. For the less than unity β estimates, the null hypothesis of $\beta = 1$ can be rejected for 11 countries. In addition, for countries where the null

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[4] We define the severity of the FPB as follows: the lower (than unity) the value of β estimates in the UH test regression, the more sever and pronounced the FPB is.

[5] This regression, in difference specifications, was first introduced by Tryon (1979), but became extensively in use after the influential work of Fama (1984).

hypothesis cannot be rejected none of the β estimates is really close to theoretical value of one[6]. For the countries where the FPB exists, the results show that it is more pronounced for developed country currencies.

Table 3 reports the estimation results over the calm and turbulent periods for developed and developing country currencies. For the calm period the average of β estimates is -1.66 for all countries. For developed and developing countries the average of β estimates is -3.42 and -0.06 respectively. For the 10 developed country currencies β estimates are all negative, and they are significant for 8 countries. The null hypothesis of $\beta = 1$ can be rejected for all currencies except for GPB and JPY. For the 11 developing countries β estimates are all less than unity, and they are negative for 5 countries. None of the β estimates is significant. However, the null hypothesis of $\beta = 1$ can be rejected for 6 currencies.

For the turbulent period the average of β estimates is 2.57 for all countries. For developed and developing countries the average of β estimates is 4.75 and 0.59 respectively. 11 countries out of 21 have β estimates greater than one[7]. For the 10 developed countries β estimates are greater than unity for the vast majority of currencies, and they are significant for 3 currencies. The null hypothesis of $\beta = 1$ cannot be rejected for all currencies except for NOK and NZD where β estimates are significantly greater than unity. For the 11 developing countries β estimates are less than unity for 7 currencies, and they are negative for 4 currencies. β is significant only in the case of KWD where it is greater than one. For β estimates of less than unity the null hypothesis of $\beta = 1$ can be rejected for 2 currencies.

The results during calm and turbulent periods reveal different patterns of the existence and severity of the FPB. For the calm period the evidence is strong on the existence of the FPB for both developed and developing countries. In addition, it is obvious that the FPB is more pronounced for developed country currencies than for developing country currencies. This finding is consistent with the results of Frankel and Poonawala (2010). In contrast, there is no evidence on the existence of the FPB, and it evidently disappeared for developed country currencies over the turbulent period. For developing country currencies it is hard to come up with one definite conclusion on the existence and severity of the FPB over the turbulent period. Although the FPB disappeared or has been alleviated for some currencies, β estimates remained negative or even took lower values for the currencies of HUF, INR, TRY and ZAR. For example, in the case of HUF β estimate decreased from 0.16 over the calm period to -4.38 over the turbulent period. Similarly, in the case of TRY β estimate decreased from -0.01 to -0.92. In the cases of INR and ZAR β estimates did not change much and remained negative[8]. These results suggest that the change in the existence and severity of the FPB over

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[6] It is worth mentioning that the inability of rejecting the UH is apparently due to the large standard errors of the parameter estimates rather than the closeness of β estimates to the hypothesized value of unity, especially for developed countries.

[7] This is consistent with the results of Clarida et al. (2009) and Coudert and Mignon (2013) who find that Fama regression tends to produce greater than unity slope coefficients in turbulent periods.

[8] Although these negative estimates are not statistically significant, and the null hypothesis of $\beta = 1$ cannot statistically be rejected, these inferences should be taken with caution. This is because the standard errors of the estimates are quite large especially over the turbulent period.

the calm and turbulent periods does not exhibit one specific patten that can be simply generalised to all currency sets.[9]

4.2. Pooled data analysis

From statistical perspective, small sample sizes are proposed as an explanation to the existence of the FPB. Moreover, we note from the previous section that hypothesis testing is hardly reliable because of the large standard errors of the parameter estimates[10]. Therefore, in this section, the cross-currency and time series information is incorporated by employing the pooled data analysis techniques where the sample sizes can be increased, and the parameters in the regression equation can be estimated with more accuracy. In addition, we employ dummy variable techniques which enable us to test for whether the difference in slope coefficient estimates for the different currency samples and the different time periods is statistically significant. Specifically, we estimate the following two balanced pooled time-series, cross-section regressions:

$$s_{i,t+k} - s_{i,t} = \alpha_1 D_{i,t}^{Deve.} + \alpha_2 D_{i,t}^{Emer.} + \beta^{Deve.}\left(f_{i,t}^{1M} - s_{i,t}\right)D_{i,t}^{Deve.} + \beta^{Emer.}\left(f_{i,t}^{1M} - s_{t,i}\right)D_{i,t}^{Emer.} + \varepsilon_{i,t+k} \quad (7)$$

$$s_{i,t+k} - s_{i,t} = \alpha_1 D_{i,t}^{Calm} + \alpha_2 D_{i,t}^{Turb} + \beta^{Calm}\left(f_{i,t}^{1M} - s_{i,t}\right)D_{i,t}^{Calm} + \beta^{Turb}\left(f_{i,t}^{1M} - s_{t,i}\right)D_{i,t}^{Turb} + \varepsilon_{i,t+k} \quad (8)$$

where $s_{i,t}$ is the natural log of the spot exchange rate of the i_{th} currency against the USD at time t , $s_{i,t+k}$ is the natural log of the spot exchange rate of the i_{th} currency against the USD at time $t+k$ i.e. one month ahead, $f_{i,t}^{1M}$ is the natural log of the 1-month forward exchange rate of the i_{th} currency against the USD at time t , $D_{i,t}^{Deve.}$ is a dummy variable which takes the value of one if the currency i_{th} is developed country currency and zero otherwise, $D_{i,t}^{Emer.}$ is a dummy variable which takes the value of one if the currency i_{th} is developing country currency and zero otherwise, $D_{i.t}^{Calm}$ is a dummy variable which takes the value of one when the observation date of the i_{th} currency belongs to tranquil period and zero otherwise, $D_{i.t}^{Turb}$ is a dummy variable which takes the value of one when the observation date of the i_{th} currency belongs to turbulent period and zero otherwise, and $\varepsilon_{i,t+k}$ is the error term. α_s and

[9] It is worth mentioning that HUF and TRY had changing exchange rate regimes during our sample period. TRY was pegged to a basket of currencies before 2001 and freely floats after 2001. HUF had crawling peg until 2001, then loosely pegged (+/-15%) to the Euro until it freely floats since 2008. To check whether changing regimes would affect the results we estimate the regression for HUF over the period 2001-2014 which excludes the period of crawling peg. β estimate is -2.86*** with a standard error of (1.085). We also estimate the regression over calm period of 2001-2006. β estimate is -1.87* with a standard error of (1.108). In addition, we estimate the regression over turbulent period of 2008-2014. β estimate is -7.151** with a standard error of (2.966). For TRY, we estimate the regression over the period 2001-2014 which exclude the period of currency-basket peg. β estimate is -0.04 with a standard error of (0.033). Also, we estimate the regression over calm period of 2001-2006. β estimate is -0.04 with a standard error of (0.034). We note that the results are qualitatively the same after accounting for changing regimes.

[10] Chinn and Frankel (2014) argue that it is difficult to obtain precise parameter estimates from the pure time series as they are oftentimes uninformative.

β_s are the coefficients to be estimated[11]. The reported standard errors of the parameter estimates are the White period standard errors which are robust to arbitrary heteroscedasticity and serial correlation in the residuals.

Table 4 presents the estimation results of the pooled data regression as specified in equation (7) over the whole sample period, calm period and turbulent period. Over the whole sample period and calm period, $\beta^{Deve.}$ and $\beta^{Emer.}$ estimates indicate to the existence of the FPB for both developed and developing currency sets. $\beta^{Deve.}$ and $\beta^{Emer.}$ estimates are significantly negative and the null hypotheses of $\beta^{Deve.} = 1$ and $\beta^{Emer.} = 1$ can be rejected at the conventional significance levels. The results also show that the FPB is significantly more pronounced for the developed currency set compared to the developing currency set where the null hypothesis of $\beta^{Deve.} = \beta^{Emer.}$ can be rejected. Moving to the turbulent period, we note that the FPB disappeared for the developed currency set and the UH turned out to hold as the significant $\beta^{Deve.}$ estimate of 1.89 is not statistically different from the theoretical value of unity. On the other hand, for the developing currency set the results imply evidence on the downward-bias of forward rates as the significant $\beta^{Emer.}$ estimate of 0.64 is significantly different from unity. Note also that the difference between $\beta^{Deve.}$ and $\beta^{Emer.}$ is statistically significant. Comparing $\beta^{Deve.}$ estimates over the whole sample period and calm period implies that the FPB of the developed currency set is more severe over the calm period compared to the whole period which reflects the effect of the turbulent period. Note that this does not apply to the developing currency set. These results show that the FPB tends to vary significantly across currency sets.

Table 5 presents the estimation results of the pooled data regression as specified in equation (8) for all currencies, developed currency set and developing currency set. For the three currency sets, β^{Calm} estimates indicate to the existence of the FPB over the calm period. β^{Calm} estimates are all significantly negative and the null hypotheses of $\beta^{Calm} = 1$ can be rejected at 1 percent significance level. On the other hand, for all currencies and the developed currency set the FPB disappeared and the UH turned out to hold over the turbulent period as implied by the estimates of β^{Turb}. β^{Turb} estimates are significantly positive and the null hypotheses of $\beta^{Turb} = 1$ can not be rejected. Again, there is evidence on the downward-bias in forward rates for the developing currency set over the turbulent period where the β^{Turb} estimate of .64 is significant and significantly different from unity. For the three currency sets the difference in the FPB between calm and turbulent periods is statistically significant as the null hypotheses of $\beta^{Calm} = \beta^{Turb}$ can be rejected. These results show that the FPB tends to vary significantly over the different time periods.

The difference in the FPB between the developed currency set and developing currency set over the turbulent period is consistent with the findings of Loring and Lucey (2013) who conclude that the FPB is less pronounced for developed currencies compared to developing currencies over the period May 2004-September 2011. This outcome can reflect our results in

[11] The analysis is thoroughly maintained with balanced pooled data. So, the estimation period starts either from January 1999 whenever EURO is included, or from October 1997 whenever HUF and/or INR are included but not the EURO.

the previous section where β estimates for some developing country currencies (HUF, INR, TRY and ZAR) remained negative or became more negative over turbulent period. A common factor for these currencies is that they represent high-yielding developing country currencies.

We thus take a further step in our analysis by analysing these currencies separately from other developing country currencies. In other words, we split developing country currencies into two groups; the first one includes only 7 developing country currencies without HUF, INR, TRY and ZAR, and the other group includes only these currencies (HITZ group). Table 6 presents the estimation results of the pooled data regressions for these two currency sets. β estimates in Panel A and β^{Calm} estimates in panel B imply evidence on the downward-bias of forward rates over the whole and calm periods for the two currency sets where the null hypotheses of $\beta = 1$ and $\beta^{Calm} = 1$ can be rejected for the resulting less than unity estimates. Over the turbulent period, different conclusions can be noticed for the two currency sets. For the 7 developing country set the FPB disappeared and the UH turned out to hold over the turbulent period where the null hypothesis of $\beta^{Turb} = 1$ cannot be rejected for the significant β^{Turb} estimate of 1.23. On the other hand, for the HITZ group the FPB remained existent, and yet it became more sever over the turbulent period (β^{Turb} is -0.68) compared to the calm periods (β^{Calm} is -0.03). It is worth noting that the variation in the FPB patterns over calm and turbulent periods is statistically significant where the hypothesis of $\beta^{Calm} = \beta^{Turb}$ can be rejected at the conventional significance levels for the two currency sets.

The results of the pooled data analysis show that the FPB is not a constant phenomenon but rather it varies significantly across currency sets and time periods. The existence and severity of the bias tend to vary across and within currency sets depending on the time period under investigation. In addition, the results indicate that different currency sets have been affected in different ways during the turbulent period. While the FPB disappeared and the UH turned out to hold for developed and several developing country currencies over the turbulent period, the bias became more severe for some high-yielding developing country currencies. These results strongly suggest that time period and currency-specific characteristics should be taken into account when analysing the existence and severity of the FPB across different currency sets and over different time periods.

4.3. Rolling regressions analysis

In order to shed more light on the time varying behaviour of the FPB across currency sets we investigate the bias over time by employing the techniques of rolling regressions. Specifically, we estimate the following pooled data regression for the different currency sets based on rolling regressions with a fixed window size of six years starting from January 1999 whenever the EURO is included, or from October 1997 whenever HUF and/or INR are included but not the EURO. Then, with every rolling regression the estimation window moves forward by one month.

$$s_{i,t+k} - s_{i,t} = \alpha + \beta\left(f_{i,t}^{1M} - s_{i,t}\right) + \varepsilon_{i,t+k} \quad (9)$$

Table 7 reports some descriptive statistics for the resulting rolling slope coefficients for the developed and developing country currency sets. Minimum values and standard deviations suggest that β estimates tend to take lower values, and they are more varying for developed countries compared to developing countries.

Figure 2 depicts the rolling slope coefficients for four currency sets. Namely, developed country currency set, developing country currency set, 7 developing country currency set (without HUF, INR, TRY and ZAR), and HITZ group. Consistent with the results in the previous sections, over the calm period the existence of the FPB is evident for all currency sets, and the bias is more pronounced for developed countries. Over the turbulent period, the vast majority of rolling β estimates are positive for all currency sets except for HITZ group. Generally, for the developed currency set we can note that almost from mid-2008 the rolling β estimates go up quite sharply to the value of unity. On the other hand, in case of the developing currency set we note that the rolling β estimates increase in a gradual from. This gradual increase can reflect the effect of HITZ group.

More specifically, for the developed country set the rolling β estimates start to take persistent positive values from August 2008. 96 percent of these positive estimates are not significantly different from unity. For the developing country set the rolling β estimates start to take persistent positive values from April 2009. Only 25 percent of these positive estimates are not significantly different from unity. But, with the exclusion of HITZ group from the developing country set the rolling β estimates start to take persistent positive values from September 2007 with 92 percent of these positive estimates are not significantly different from unity. For the HITZ group the pattern of the rolling β estimates is remarkably different. Specifically, we note that the rolling β estimates are negative and much lower over the turbulent period compared to the calm one.

The importance of the rolling regressions analysis is that it enables us to identify when the change in the FPB has taken place. Moreover, the analysis particularly shows the effect of the 2007-2008 crisis. The results show that the 2007-2008 global financial crisis has been a turning point for the existence and severity of the FPB. Moreover, our rolling regressions exercise shows that the existence and severity of the FBP in different currency sets have been affected by the crisis in different ways. Specifically, almost coinciding with the peak of the crisis we note that the FPB disappeared for developed and several developing country currencies. On the contrary, for some high-yielding developing county currencies the FPB turned out to be more pronounced over the turbulent period.

4.4. Carry trade returns analysis

In this section we examine the FBP puzzle in terms of currency carry trade returns. Currency carry trades involve borrowing low interest rate currencies for financing investments in high interest rate currencies[12]. The existence of the FPB means that such trades are expected to generate positive returns on average. This is because the FPB implies that high interest rate currencies are expected to either appreciate against low interest rate currencies or insufficiently depreciate to fully offset the interest rate differentials. So, the positive and good performance of currency carry trades is just the flipside of the existence and severity of the FPB while the negative and poor performance of currency carry trades reflect the disappearance (or the low severity) of the FBP.

Under the assumption of CIP, carry trades can be executed in forward exchange markets by selling forward currencies which are traded at forward premiums and buying forward currencies which are traded at forward discounts. With the USD being the base currency, we construct three equally-weighted carry trade portfolios. Namely, portfolio P_1^{AllC} which consists of all currencies, portfolio $P_2^{Deve.C}$ which consists of developed country currencies and portfolio $P_3^{Emer.C}$ which consists of developing country currencies. We set the investment horizon to be on month and so portfolios are rebalanced monthly by allocating positions based on the USD forward premium/discount against the constituent currencies of the respective portfolio. Specifically, at the end of every month t we sort currencies based on forward premiums. Then, 1-month USD long (short) positions are taken at the end of every month against the other currencies in the respective portfolio which are at forward premiums (discounts) against the USD. The monthly return of each portfolio is the average return of the taken positions.

The carry trade return on short positions is computed as

$$CR_{t+1M}^{S} = f_t^{1M} - s_{t+1M} \equiv fp_t^{1M} - (s_{t+1M} - s_t) \equiv fp_t^{1M} - \Delta s_{t+1M} \quad (10)$$

where fp_t^{1M} is the 1-month forward premium calculated as $f_t^{1M} - s_t$. The carry trade return on long positions is computed as

$$CR_{t+1M}^{L} = s_{t+1M} - f_t^{1M} \equiv (s_{t+1M} - s_t) - fp_t^{1M} \equiv \Delta s_{t+1M} - fp_t^{1M} \quad (11)$$

Table 8 presents the descriptive statistics for each portfolio returns over the whole sample period, calm period and turbulent period. The results just mirror and further support the results of regression analysis reported in the previous sections. Over the whole sample period and calm period, the three portfolios have positive average returns and positive Sharpe ratios which is consistent with the existence of the FPB. The average returns over the whole sample period range from 3.05 percent to 3.09 percent, while Sharpe ratios range from 0.49 to 0.61. Over the calm period the average returns range from 4.80 percent to 6.24 percent, while Sharpe rations range from 1.22 to 1.77. The higher average returns over the calm period compared to the whole sample period reflect the greater severity of the FPB over the calm period. In addition, the higher average returns for the portfolio of developed currencies ($P_2^{Deve.C}$) compared to the portfolio of developing currencies ($P_3^{Emer.C}$) reflect the greater severity of the FPB in developed currencies especially over the calm period.

[12] Frankel (2008) and McCauley and McGuire (2009) argue that currency carry trades can be defined more generally as the shift in investments from lower yielding currencies toward higher yielding currencies.

Moving to the turbulent period, we note that the portfolio of all currencies (P_1^{AllC}) and the portfolio of developed currencies ($P_2^{Deve.C}$) have negative average returns and negative Sharpe ratios which is consistent with the disappearance of the FPB. On the other hand, and consistent with our previous finding, the portfolio of developing currencies ($P_3^{Emer.C}$) has positive average return and positive Sharpe ratio even though they decreased considerably. By comparing the average return and Sharpe ratio of the developed currencies portfolio with those of the developing currencies portfolio we note that the former one has been much affected during the crisis period. Compared to the whole sample period, the average return over the turbulent period is lower by -131.07% for the developed currencies portfolio, while the average return is lower by -74.10% for the developing currencies portfolio. Similarly, the Sharpe ratio is lower by -126.53% over the turbulent period compared to the whole sample period for the developed currencies portfolio, while the Sharpe ratio is lower by -78.33% for the developing currencies portfolio.

5. Discussions and conclusions

Through our various analysis procedures, we find that the existence and severity of the FPB vary significantly across different currency samples and time periods. Over the calm period the FPB is found to evidently exist for both developed and developing currencies. In addition, the bias is found to be more pronounced for developed currency set than for developing currency set. In contrast, the results are significantly different over the turbulent period. Specifically, our result show that the 2007-2008 global financial crisis constituted a turning point for the variation of the existence and severity of the bias. We find that coinciding with the peak of the crisis the FPB disappeared prominently and the UH turned out to hold especially for the developed currency set. However, for some high-yielding developing currency set the FPB survived during the crisis period and yet became more severe compared to the calm period.

Our results and findings can be linked to two important strands of recent literature. On the one hand, the disappearance of the FPB over the turbulent period is consistent with the findings of recent research on currency carry trades. Specifically, currency carry trades are found to perform poorly and even generate negative returns during turbulent periods. In addition, it is found that investors tend to unwind their carry trade positions in periods of low market liquidity, resulting in substantial losses in currency carry trades. Note that the poor performance and negative returns of currency carry trades is just the flipside of the disappearance of the FPB. In this context, the vanishing of the FPB over the turbulent period gives rise to the branch of literature that attributes the FPB anomaly to the existence of time-varying risk premium in currency forward rates. Examples of those risk factors, which are found to significantly explain the excess return of currency carry trades, include currency crash risk and high liquidity constraints (Brunnermeier et al., 2009; Kumar, 2020; Abankwa, 2020), realized and implied exchange rate volatility (Clarida et al., 2009), monetary policy volatility (Moore and Roche, 2012; Berg and Mark, 2019), global FX volatility (Menkhhoff et al., 2012) and downside market risk (Dobrynskaya, 2014). This, in turn, suggests that the specific characteristics of the sample period under consideration can play important role in the existence of the FPB phenomenon.

On the other hand, the survival of the FPB with more severity for some high-yielding emerging market currencies over the turbulent period can be associated with the effects of carry trade flows[13]. In the study of Ahmed and Zlate (2014) the relatively high interest rates are found statistically and economically significant driver of the capital inflows received by emerging markets over the period followed the global financial crisis. Note that carry trade flows create a demand pressure on high-yielding currencies leading to rising their values. This just contradicts the predictions of the UH. Consequently, as shown by Gagnon and Chaboud (2007) and Bacchetta and Wincoop (2010), the gradual building up of carry positions along with the infrequent changes in portfolio positions can result in “delayed overshooting”, which in turn can lead to continuous appreciation of the high interest rate currencies for a prolonged time. This suggests that carry trade flows and currency-specific factors can impact the existence and severity of the FPB[14].

Overall, the results suggest that the FPB anomaly can be related to the existence of risk factors, which can affect the predictions of forward exchange rates, and to the intensity and movements of currency carry trades. The results also show that the FPB is not a constant and permanent finding. It rather varies over time, and across and within currency sets depending on the sample period. Accordingly, time-period characteristics and currency-specific factors play important role in the existence and severity of the bias. In other words, the existence and severity of the FPB are closely related to both period-specific characteristics as well as currency-specific factors. Examples of those characteristics and factors may include volatility, liquidity, capital movements, rare events, monetary policy and forward premium sizes. Investigating the effect of such characteristic and factors on the existence and severity of the downward bias in the predictions of forward exchange rates are sensible topics for future research.

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[13] Mishra et al. (2014), Nechio (2014), Aizenman et al. (2016), Eichengreen and Gupta (2015), Kim (2015) argue that in the wake of the global financial crisis high-yielding emerging markets were promising investment destinations, and that they were subject to waves of carry trade flows through the global search for yield.

[14] Shehadeh et al. (2016) analyze a data set of US dollar forward positions against several developed and developing country currencies taken by Commodity Trading Advisors (CTAs) over the period followed the financial crisis. They find evidence on carry trade pattern for developing market currencies but not for developed market ones.

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Table 1 Descriptive Statistics

Panel A: Developed Countries

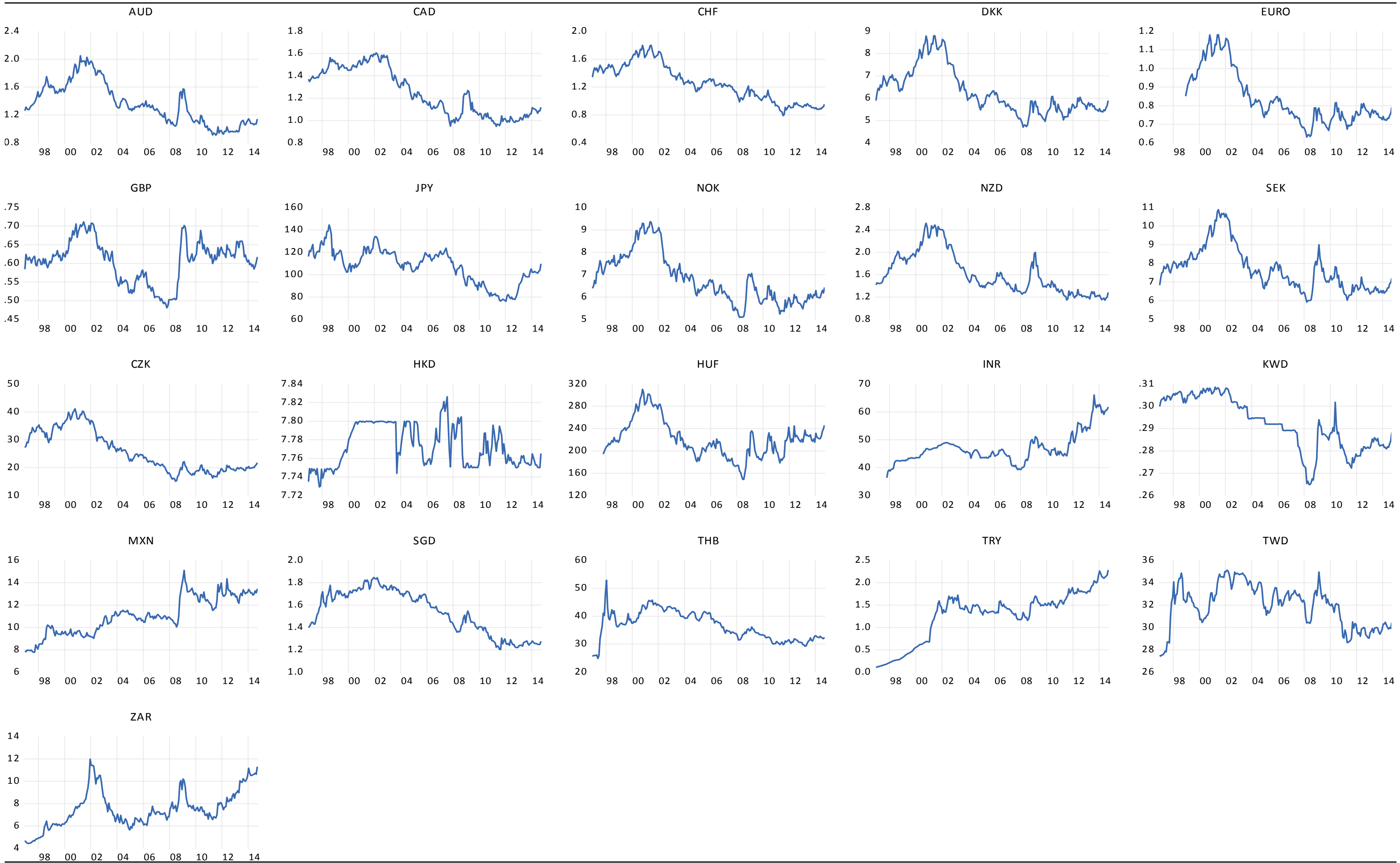
	Period	N	ΔS Mean%	ΔS SD%	fp Mean%	fp SD%
AUD	Whole[1]	213	-0.05	3.73	0.18	0.15
	Calm[2]	121	0.02	2.94	0.11	0.15
	Turbulent[3]	92	-0.13	4.59	0.27	0.10
CAD	Whole	213	-0.10	2.47	0.004	0.09
	Calm	121	-0.12	1.88	-0.02	0.10
	Turbulent	92	-0.06	3.10	0.03	0.05
CHF	Whole	213	-0.16	3.12	-0.16	0.13
	Calm	121	-0.06	2.78	-0.22	0.13
	Turbulent	92	-0.29	3.53	-0.07	0.08
DKK	Whole	213	0.000	2.94	-0.03	0.12
	Calm	121	-0.02	2.64	-0.05	0.13
	Turbulent	92	0.03	3.31	0.01	0.09
EURO	Whole	188	-0.06	2.99	-0.02	0.11
	Calm	96	-0.14	2.64	-0.04	0.14
	Turbulent	92	0.03	3.33	0.000	0.07
GBP	Whole	213	0.03	2.44	0.08	0.09
	Calm	121	-0.11	2.17	0.10	0.10
	Turbulent	92	0.20	2.75	0.04	0.07
JPY	Whole	213	-0.03	3.12	-0.23	0.19
	Calm	121	0.03	3.26	-0.33	0.15
	Turbulent	92	-0.11	2.94	-0.10	0.14
NOK	Whole	213	0.003	3.26	0.09	0.17
	Calm	121	-0.02	2.89	0.06	0.21
	Turbulent	92	0.03	3.70	0.12	0.08
NZD	Whole	213	-0.05	3.87	0.22	0.14
	Calm	121	0.02	3.13	0.19	0.16
	Turbulent	92	-0.14	4.68	0.26	0.09
SEK	Whole	213	0.03	3.25	-0.01	0.14
	Calm	121	0.02	2.84	-0.05	0.16
	Turbulent	92	0.04	3.73	0.05	0.09

Panel B: Developing Countries

	Period	N	ΔS Mean%	ΔS SD%	fp Mean%	fp SD%
CZK	Whole	213	-0.10	3.72	0.10	0.35
	Calm	121	-0.19	3.36	0.18	0.45
	Turbulent	92	0.01	4.15	-0.004	0.09
HKD	Whole	213	0.000	0.12	-0.004	0.12
	Calm	121	0.01	0.11	0.01	0.15
	Turbulent	92	-0.01	0.14	-0.03	0.03
HUF	Whole	203	0.12	4.12	0.51	0.28
	Calm	111	0.01	3.02	0.63	0.31
	Turbulent	92	0.24	5.16	0.37	0.15
INR	Whole	203	0.26	2.17	0.37	0.24
	Calm	111	0.18	1.24	0.28	0.20
	Turbulent	92	0.36	2.92	0.48	0.24
KWD	Whole	213	-0.02	0.74	0.05	0.11
	Calm	121	-0.03	0.37	0.06	0.05
	Turbulent	92	0.000	1.04	0.047	0.15
MXN	Whole	213	0.25	2.85	0.63	0.52
	Calm	121	0.28	2.36	0.87	0.58
	Turbulent	92	0.21	3.41	0.33	0.16
SGD	Whole	213	-0.04	1.79	-0.08	0.13
	Calm	121	0.08	1.70	-0.10	0.15
	Turbulent	92	-0.20	1.91	-0.04	0.09
THB	Whole	213	0.11	3.38	0.21	0.45
	Calm	121	0.25	4.22	0.27	0.58
	Turbulent	92	-0.07	1.75	0.13	0.14
TRY	Whole	213	1.43	4.84	-0.65	13.37
	Calm	121	2.12	5.35	-1.70	17.7
	Turbulent	92	0.52	3.91	0.72	0.27
TWD	Whole	213	0.05	1.62	-0.08	0.28
	Calm	121	0.15	1.70	-0.02	0.29
	Turbulent	92	-0.09	1.52	-0.15	0.25
ZAR	Whole	213	0.41	4.65	0.59	0.25
	Calm	121	0.36	4.56	0.64	0.31
	Turbulent	92	0.48	4.79	0.53	0.14

Notes: the table reports the mean and standard deviation (SD) of the monthly spot exchange rate changes (ΔS), and 1-month forward premium (fp). $\Delta S = s_{t+1M} - s_t$, $fp = f_t^{1M} - s_t$ where s is the natural log of spot exchange rate, f^{1M} is the natural log of 1-month forward rate. US dollar is the base currency. N is the number of monthly observations. 1: Whole sample period starts from Dec. 1996 to 2014; expect for EURO where it starts from Jan. 1999, and for HUF and INR where it starts from Oct. 1997. 2: Calm period extends from the beginning of the sample period to Dec. 2006. 3: Turbulent period extends from 2007 to the end of the sample period. End of month quotes of spot and forward exchange rates are taken to generate monthly observations.

Figure 1
Spot Rate Series



Notes: the figure presents time series of spot rates of each currency against the USD. USD is the base currency.

Table 2

1-Month Unbiasedness Hypothesis Test: $s_{t+k} - s_t = \alpha + \beta(f_t^{1M} - s_t) + \varepsilon_{t+k}$

Whole Sample Period§

Panel A: Developed Countries	N	β	$F\ \beta = 1$	$\bar{R}^2$	Panel B: Developing Countries	N	β	$F\ \beta = 1$	$\bar{R}^2$
AUD	213	-2.14 (1.469)	4.58**	0.00	CZK	213	0.56 (0.498)	0.76	0.00
CAD	213	-2.11 (2.041)	2.32	0.00	HKD	213	-0.04 (0.042)	>99***	0.00
CHF	213	-1.81 (1.417)	3.94**	0.00	HUF	203	-0.62 (0.857)	3.60*	0.00
DKK	213	-3.27**(1.596)	7.16***	0.01	INR	203	-0.14 (0.667)	2.91*	0.00
EURO	188	-3.23* (1.751)	5.84**	0.01	KWD	213	2.91***(0.634)	9.12***	0.17
GBP	213	-1.49 (1.914)	1.69	0.00	MXN	213	-0.07 (0.318)	11.39***	0.00
JPY	213	0.41 (1.226)	0.23	0.00	SGD	213	-0.03 (0.886)	1.34	0.00
NOK	213	-1.04 (1.378)	2.20	0.00	THB	213	0.96 (0.688)	0.00	0.01
NZD	213	0.38 (2.467)	0.06	0.00	TRY	213	-0.02 (0.032)	>99***	0.00
SEK	213	-1.92 (1.439)	4.11**	0.00	TWD	213	0.54 (0.335)	1.92	0.00
Average		-1.62		0.00	ZAR	213	-1.97 (1.352)	4.83**	0.01
					Average		0.19		0.02
Average all countries		-0.67		0.01					

Notes: OLS estimates of the regression of 1-month spot exchange rate change on 1-month forward premium with Newey-West robust standard errors. The USD is the base currency. Standard errors in parentheses. N is the number of monthly observations. *F* is the *F*-statistic of the null hypothesis that β=1. ***, ** and * denote the significance of β and the rejection of the null hypothesis of $\beta=1$ at 1%, 5% and 10% significance levels, respectively.
§Whole sample period 1996M12-2014 except for EURO from 1999, and HUF and INR from 1997M10.

Table 3
1-Month Unbiasedness Hypothesis Test: $s_{t+k} - s_t = \alpha + \beta(f_t^{1M} - s_t) + \varepsilon_{t+k}$
Calm Versus Turbulent Periods

		Calm Period 1996M12-2006§				Turbulent Period 2007-2014			
		N	β	$F\ \beta = 1$	$\bar{R}^2$	N	β	$F\ \beta = 1$	$\bar{R}^2$
Panel A: Developed Countries	AUD	121	-4.65^{**} (1.914)	8.71^{***}	0.05	92	3.11 (4.153)	0.26	-0.01
	CAD	121	-3.30^{*} (1.676)	6.60^{**}	0.02	92	1.43 (12.032)	0.00	-0.01
	CHF	121	-3.97^{**} (1.786)	7.74^{***}	0.03	92	4.98 (3.986)	1.00	0.00
	DKK	121	-4.53^{**} (1.746)	10.02^{***}	0.04	92	-0.74 (5.075)	0.12	-0.01
	EURO	96	-4.61^{**} (1.917)	8.56^{***}	0.05	92	0.56 (6.119)	0.01	-0.01
	GBP	121	-1.71 (1.802)	2.26	0.00	92	0.94 (5.394)	0.00	-0.01
	JPY	121	-1.33 (1.727)	1.82	0.00	92	5.11^{**}(2.528)	2.64	0.05
	NOK	121	-2.49^{**} (1.166)	8.94^{***}	0.03	92	10.50^{**}(4.585)	4.30^{**}	0.05
	NZD	121	-3.82^{**} (1.845)	6.82^{**}	0.03	92	17.90^{***}(6.619)	6.52^{**}	0.11
	SEK	121	-3.81^{***}(1.434)	11.27^{***}	0.04	92	3.68 (2.905)	0.85	0.00
Average			-3.42		0.03		4.75		0.02
Panel B: Developing Countries	CZK	121	0.56 (0.475)	0.85	0.00	92	4.45 (4.313)	0.64	0.00
	HKD	121	-0.06 (0.043)	$>99^{***}$	0.00	92	0.20 (0.468)	2.90^{*}	-0.01
	HUF	111	0.16 (0.821)	1.04	-0.01	92	-4.38 (3.041)	3.13^{*}	0.00
	INR	111	-0.52 (0.627)	5.87^{**}	0.00	92	-0.24 (1.307)	0.90	-0.01
	KWD	121	0.34 (0.585)	1.29	-0.01	92	3.36^{***}(0.544)	18.92^{***}	0.22
	MXN	121	-0.31 (0.344)	14.57^{***}	0.00	92	2.66 (2.616)	0.40	0.01
	SGD	121	0.11 (1.012)	0.77	-0.01	92	0.90 (2.254)	0.00	-0.01
	THB	121	0.91 (0.682)	0.02	0.01	92	1.38 (1.241)	0.09	0.00
	TRY	121	-0.01(0.030)	$>99^{***}$	-0.01	92	-0.92 (1.842)	1.08	-0.01
	TWD	121	0.25 (0.397)	3.55^{*}	-0.01	92	0.84 (0.529)	0.09	0.01
	ZAR	121	-2.06 (1.477)	4.29^{**}	0.01	92	-1.80 (4.284)	0.43	-0.01
Average			-0.06		0.00		0.59		0.02
Average all countries			-1.66		0.01		2.57		0.02

Notes: OLS estimates of the regression of 1-month spot exchange rate change on 1-month forward premium with Newey-West robust standard errors. The USD is the base currency. Standard errors in parentheses. N is the number of monthly observations. *F* is the *F*-statistic of the null hypothesis that $\beta=1$. ***, ** and * denote the significance of β and the rejection of the null hypothesis of $\beta=1$ at 1%, 5% and 10% significance levels, respectively. §except for EURO from 1999M01, and HUF and INR from 1997M10.

Table 4

Pooled Data Unbiasedness Hypothesis Test: Difference between currency sets

$$s_{i,t+k} - s_{i,t} = \alpha_1 D_{i,t}^{Deve.} + \alpha_2 D_{i,t}^{Emer.} + \beta^{Deve.}(f_{i,t}^{1M} - s_{i,t})D_{i,t}^{Deve.} + \beta^{Emer.}(f_{i,t}^{1M} - s_{t,i})D_{i,t}^{Emer.} + \varepsilon_{i,t+k}$$

	$\beta^{Deve.}$	F $\beta^{Deve.} = 1$	$\beta^{Emer.}$	F $\beta^{Emer.} = 1$	F $\beta^{Deve.} = \beta^{Emer.}$	N	$\bar{R}^2$
Whole sample period	-0.58** (0.241)	42.85***	-0.04*** (0.001)	>99***	5.02**	3948	0.00
Calm period	-1.88*** (0.335)	73.80***	-0.04*** (0.003)	>99***	30.08***	2016	0.02
Turbulent period	1.89*** (0.584)	2.35	0.64*** (0.154)	5.35**	4.29**	1932	0.00

Notes: Pooled time series, cross-section estimates with White period robust standard errors. The USD is the base currency. Standard errors in parentheses. F is the F-statistic for the null hypotheses that $\beta=1$ and $\beta^{Deve.} = \beta^{Emer.}$. N is the number of observations. ***, ** and * denote the significance of β and the rejection of the null hypotheses of $\beta=1$ and $\beta^{Deve.} = \beta^{Emer.}$ at 1%, 5% and 10% significance levels, respectively. For the definition of the individual developed and developing countries included see tables 2 and 3.

Table 5
Pooled Data Unbiasedness Hypothesis Test: Difference between time periods

$$s_{i,t+k} - s_{i,t} = \alpha_1 D_{i,t}^{Calm} + \alpha_2 D_{i,t}^{Turb.} + \beta^{Calm}\left(f_{i,t}^{1M} - s_{i,t}\right)D_{i,t}^{Calm} + \beta^{Turb.}(f_{i,t}^{1M} - s_{t,i})D_{i,t}^{Turb.} + \varepsilon_{i,t+k}$$

	β^{Calm}	F $\beta^{Calm} = 1$	β^{Turb}	F $\beta^{Turb} = 1$	F $\beta^{Calm} = \beta^{Turb}$	N	$\bar{R}^2$
All currencies	-0.04*** (0.004)	>99***	0.87*** (0.183)	0.519	24.23***	3948	0.00
Developed country currencies	-1.88*** (0.335)	73.79***	1.89*** (0.584)	2.35	42.96***	1880	0.01
Developing country currencies	-0.03*** (0.001)	>99***	0.64*** (0.154)	5.35**	18.90***	2233	0.00

Notes: Pooled time series, cross-section estimates with White period robust standard errors. The USD is the base currency. Standard errors in parentheses. *F* is the *F*-statistic for the null hypotheses that $\beta=1$ and $\beta^{Calm} = \beta^{Turb}$. N is the number of observations. ***, ** and * denote the significance of β and the rejection of the null hypotheses of $\beta=1$ and $\beta^{Calm} = \beta^{Turb}$ at 1%, 5% and 10% significance levels, respectively. For the definition of the individual developed and developing countries included see tables 2 and 3.

Table 6

Pooled Data Unbiasedness Hypothesis Test: Developing countries without HITZ and HITZ group

Panel A

$s_{i,t+k} - s_{i,t} = \alpha + \beta\left(f_{i,t}^{1M} - s_{i,t}\right) + \varepsilon_{i,t+k}$

	N	β	F $\beta = 1$	$\bar{R}^2$
Developing countries without HITZ	1421	0.18^{**} (0.074)	$>99^{***}$	0.00
HITZ group	812	-0.03^{***} (0.003)	$>99^{***}$	0.00

Panel B

$s_{i,t+k} - s_{i,t} = \alpha_1 D_{i,t}^{Calm} + \alpha_2 D_{i,t}^{Turb} + \beta^{Calm}\left(f_{i,t}^{1M} - s_{i,t}\right)D_{i,t}^{Calm} + \beta^{Turb}(f_{i,t}^{1M} - s_{t,i})D_{i,t}^{Turb} + \varepsilon_{i,t+k}$

	β^{Calm}	F $\beta^{Calm} = 1$	β^{Turb}	F $\beta^{Turb} = 1$	F $\beta^{Calm} = \beta^{Turb}$
Developing countries without HITZ	0.01 (0.080)	$>99^{***}$	1.23^{***} (0.275)	0.70	20.35^{***}
HITZ group	-0.03^{***} (0.004)	$>99^{***}$	-0.68^{**} (0.267)	39.31^{***}	6.01^{**}

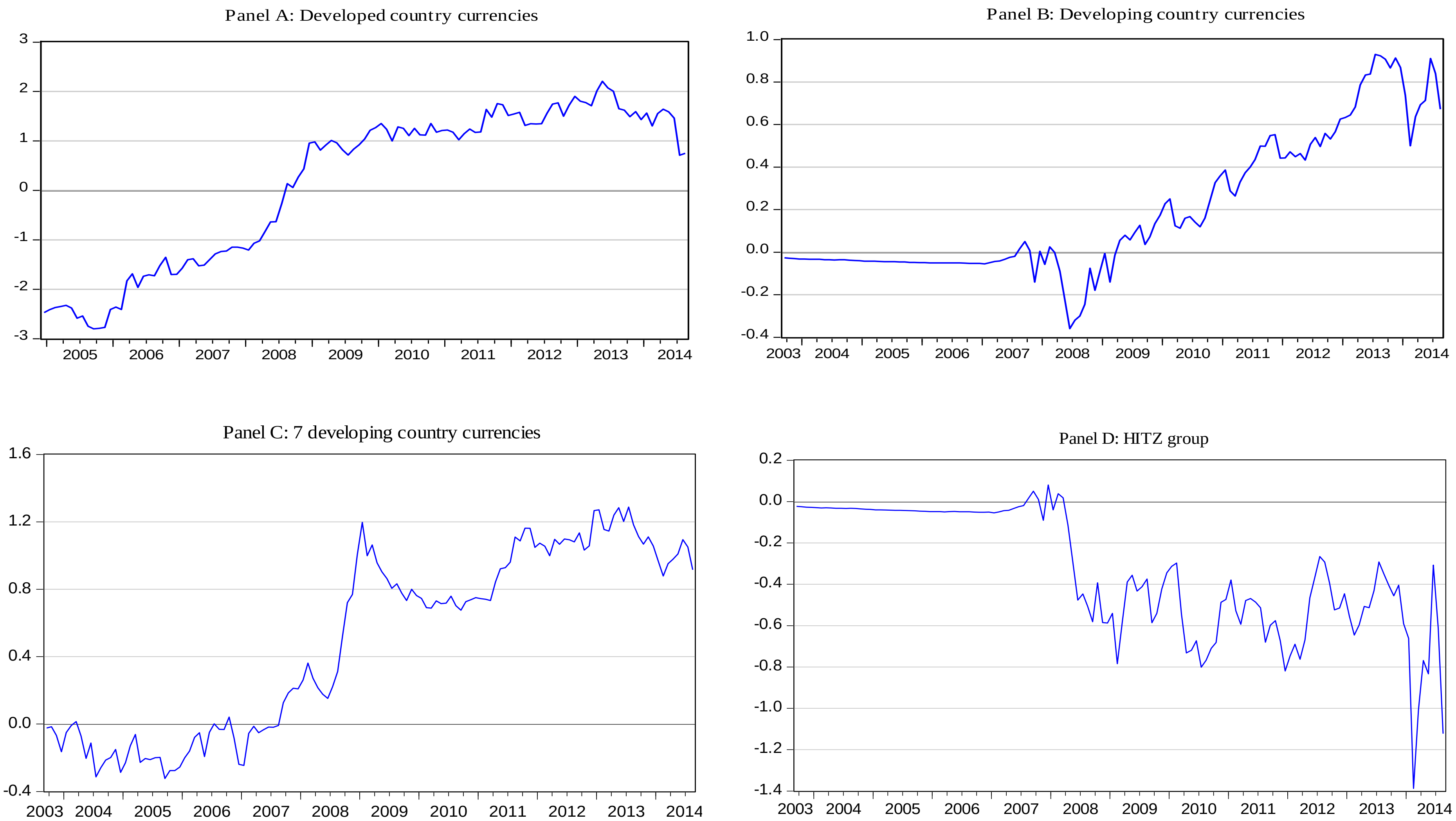
Notes: Pooled time series, cross-section estimates with White period robust standard errors. The USD is the base currency. Standard errors in parentheses. HITZ group includes HUF, INR, TRY and ZAR. F is the F-statistic for the null hypotheses that $\beta=1$ and $\beta^{Calm} = \beta^{Turb}$. N is the number of observations. ***, ** and * denote the significance of β and the rejection of the null hypotheses of $\beta=1$ and $\beta^{Calm} = \beta^{Turb}$ at 1%, 5% and 10% significance levels, respectively. For the definition of the individual developing country currencies see tables 2 and 3.

Table 7 Descriptive Statistics for the rolling Slope Coefficients βs

	Panel A: Developed country currencies	Panel B: Developing country currencies
Minimum	-2.80	-0.36
Maximum	2.21	0.93
Mean	0.16	0.19
Median	0.98	0.03
Std.Dev.	1.57	0.33
N	117	132

Notes: the table reports some descriptive statistics for the resulting rolling slope coefficients βs from the rolling regressions of the pooled time series, cross-section regression equation of the UH test $(s_{i,t+1M} - s_{i,t} = \alpha + \beta(f_{i,t}^{1M} - s_{i,t}) + \varepsilon_{i,t+1M})$ with a window size of six years starting from 1999M01 for the developed country currencies, and from 1997M10 for the developing country currencies. N is the number of the rolling βs.

Figure 2
Rolling Slope Coefficients βs



Notes: the figure depicts the resulting rolling slope coefficients βs from the rolling regressions of the pooled time series, cross-section regression equation of the UH test ($s_{i,t+k} - s_{i,t} = \alpha + \beta(f_{i,t}^{1M} - s_{i,t}) + \varepsilon_{i,t+k}$) with a window size of six years starting from 1999M01 for the developed country set, and from 1997M10 for the other currency sets.

Table 8
Carry Trade Return Analysis

	Whole sample period			Calm period			Turbulent period		
	P_1^{AllC}	$P_2^{Deve.C}$	$P_3^{Emer.C}$	P_1^{AllC}	$P_2^{Deve.C}$	$P_3^{Emer.C}$	P_1^{AllC}	$P_2^{Deve.C}$	$P_3^{Emer.C}$
Mean%	3.08	3.09	3.05	5.50	6.24	4.80	-0.04	-0.96	0.79
Median%	4.74	5.17	3.67	6.00	8.32	3.82	3.29	0.49	2.92
Std.Dev.%	5.04	6.26	5.10	3.11	4.83	3.93	6.67	7.59	6.25
Skew.	-1.25	-1.12	-0.69	-0.13	-0.44	0.15	-0.91	-1.03	-0.73
Kurt.	8.85	8.34	5.63	3.34	3.49	4.74	5.85	7.43	4.40
SR	0.61	0.49	0.60	1.77	1.29	1.22	-0.01	-0.13	0.13
Diff. Mean				78.57%	101.94%	57.38%	-101.30%	-131.07%	-74.10%
Diff. SR				190.16%	163.27%	103.33%	-101.64%	-126.53%	-78.33%

Notes: the table reports the descriptive statistics of the annualized monthly carry trade returns for three portfolios over three times periods. P_1^{AllC} is the carry trade portfolio which encompasses all currencies. $P_2^{Deve.C}$ is the carry trade portfolio which encompasses developed country currencies only. $P_3^{Emer.C}$ is the carry trade portfolio which encompasses developing country currencies only. SR stands for Sharpe Ratio. Diff. Mean represents the percentage difference in mean return of the respective time period relative to the mean return of the whole sample period for each portfolio. Diff. SR represents the percentage difference in Sharpe Ratio of the respective time period relative to the Sharpe Ratio of the whole sample period for each portfolio. Given that carry trade portfolios are zero-investment portfolios, Sharpe Ratio is computed as Mean/Std.Dev.