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Forward Bias Trading in Emerging Markets

Manuel Mayer*

Abstract

This paper investigates the returns to forward bias-trading in dynamic multi–currency strategies in order to empirically assess the limits to speculation hypothesis in foreign exchange markets. The results suggest that bias–trading strategies allow for economically significant excess returns, represent attractive diversification devices, and contain low downside risk. Furthermore, enriching carry–trade portfolios with emerging market currencies results in large diversification gains. Overall, the findings are in line with the widespread use of bias–trading strategies among market professionals and challenge the concept of limits to speculation as an explanation for the forward bias puzzle.

Keywords:
Exchange rates, forward bias, limits to speculation, trading strategies, emerging market currencies.

* I thank Stefan Pichler, Alois Geyer, Christian Wagner, and Markus Hochradl for their helpful comments and suggestions. Phone: +43-1-31336-6334; E-mail: manuel.mayer@vgsf.ac.at; Web: http://www.vgsf.ac.at/vgsf/students/mmayer; Vienna Graduate School of Finance - Heiligengärtnerstraße 46, 1190 Vienna, Austria
1. Introduction

Uncovered interest parity (UIP) postulates that the expected change in the exchange rate compensates for the interest rate differential. Provided that covered interest parity and rational expectations hold, UIP implies that the forward exchange rate is an unbiased predictor of the future spot exchange rate. However, starting with the seminal work by Hansen & Hodrick (1980), Bilson (1981), and Fama (1984), empirical research provides evidence of a biased forward exchange rate. Proposed explanations for this ‘forward bias puzzle’ include risk premia, statistical considerations such as peso problems, as well as learning and biases in expectations. Surveys of the literature can be found in Hodrick (1987), Engel (1996), and Sarno (2005).

Since past attempts to solve the forward bias puzzle have met with limited success, recent research focuses on the microstructure of foreign exchange markets. Evans & Lyons (2002) suggest that order flow drives exchange rates and provide strong empirical evidence supporting their point. Lyons (2001) builds on that idea and argues that the forward bias is too small to attract speculative capital, i.e. the bias may be statistically but not economically significant. This limits to speculation hypothesis states that traders do not exploit the forward bias because Sharpe ratios are too small compared to other investment opportunities. It is argued that speculative capital is allocated to bias-trading strategies only if Sharpe ratios exceed a certain threshold. Inspired by the idea of limits to speculation, Sarno et al. (2006) show in a smooth transition regression framework that there are non-linearities in deviations from uncovered interest parity. Burnside et al. (2006) suggest that transaction costs and price pressure limit the extent to which traders exploit the forward bias.

In contrast to the concept of limits to speculation, market evidence and strategy reports published by financial institutions suggest that the forward bias is massively traded and that bias-trading might even be a key driver for the surge in foreign exchange trading over the last few years; see Galati et al. (2007) and Galati & Melvin (2004). While returns to single-currency bias-trading strategies appear to be economically small, Corte et al. (2008) and Hochradl & Wagner (2010) show that dynamic multi-currency strategies yield large economic gains.

The objective of this paper is to assess the limits to speculation hypothesis empirically by measuring the economic significance of the forward bias. This is done by implementing investment strategies explicitly aimed at exploiting the bias. While past research investigated bias-trading almost entirely in developed economies, this paper takes a large set of emerging market currencies into account. In particular, optimally-weighted carry-trade portfolios covering up to 38 currencies are implemented.
The results suggest that bias–trading strategies can be viewed as attractive investment opportunities. They yield Sharpe ratios considerably higher than the US stock market, contain low downside risk, and represent attractive diversification devices (no systematic risk). Furthermore, it turns out that there are large diversification gains from enriching carry–trade portfolios with emerging market currencies.

Overall, this paper challenges the concept of limits to speculation as an explanation for the forward bias puzzle. The remainder of this paper is organized as follows. Section 2 reviews the related literature on the forward bias puzzle and the limits to speculation hypothesis. Section 3 introduces investment strategies exploiting the forward bias. Section 4 reports the returns to bias–trading and discusses their economic significance. Section 5 concludes.
2. Forward Bias Puzzle

2.1 Uncovered Interest Parity

Uncovered interest parity (UIP) postulates that the expected change of the spot exchange rate compensates for the interest rate differential or, given that covered interest parity (CIP) holds, the forward premium. UIP is frequently stated in the following way:

\[ E_t[s_{t+1}] - s_t = i_t^* - i_t = f_{t,1} - s_t \]  

(1)

Here \( s_t \) and \( f_{t,1} \) denote the natural logarithm of the spot exchange rate and the one period forward exchange rate at time \( t \), with \( t \in \mathbb{N} \) and equidistant time intervals \([t; t + 1]\) for all \( t \). The variables \( i_t \) and \( i_t^* \) are the effective one period domestic and foreign interest rates, and the operator \( E_t \) denotes the expectation based on time \( t \) information. If UIP, CIP, and rational expectations \( s_{t+1} = E_t [s_{t+1}] + \varepsilon_{t+1} \) hold, then the forward exchange rate is an unbiased predictor of the future spot exchange rate, i.e. forward rate unbiasedness (FRU) holds:

\[ s_{t+1} = f_{t,1} + \varepsilon_{t+1} \]  

(2)

Where \( \varepsilon_{t+1} \) represents a disturbance term. Since empirical evidence strongly suggest that CIP holds, testing UIP is usually based on fitting the Fama (1984) regression which relates the change of the spot exchange rate to a constant and the forward premium:

\[ s_{t+1} - s_t = \alpha + \beta (f_{t,1} - s_t) + \varepsilon_{t+1} \]  

(3)

Under the hypothesis that forward rate unbiasedness holds \( \alpha \) is equal to zero, \( \beta \) is equal to one, and the disturbance term \( u_{t+1} \) is serially uncorrelated. Under UIP the domestic currency on average appreciates when it is at a forward premium.

The common finding in the literature, however, is that \( \beta \) is significantly different from one and in many cases negative. This empirical observation is called the forward bias puzzle and implies that the domestic currency actually tends to depreciate when it is at a forward premium. Or stated in terms of interest rates: Low interest rate currencies tend to depreciate.
The results of fitting equation (3) to data by using mid–quotes of spot and forward exchange rates can be found in the appendix. Table 2 presents estimated Fama–Regressions for the period from January 1999 to July 2009 whereas Table 3 presents the results for the sample ending in December 2006. In line with the literature, a majority of currencies show negative estimates of β.

2.2 Data

The data set used to evaluate parity conditions and currency speculation strategies was obtained from Datastream and consists of daily observations of bid and ask spot and one week forward exchange. Original data represent quotes taken from the Reuters system. The data set covers the period from January 1999 to July 2009 and all exchange rates are quoted as foreign currency units per US dollar. The ask (bid) exchange rate is the rate at which an investor can buy (sell) US dollars. Daily data is converted into weekly observations by sampling on every Friday. A complete list of the 38 currencies studied in this paper can be found in the appendix. In addition to spot and forward exchange rates, the data set covers the weekly US stock market premium and the weekly Treasury–bill rate obtained from Kenneth French’s data library. Stock market returns are value weighted covering all NYSE, AMEX, and NASDAQ firms.

Table 1 presents the median bid–ask spreads for spot and forward exchange rates in percentage points. It turns out that bid–ask spreads in forward markets are slightly larger than those in spot markets and that bid–ask spreads in emerging markets are substantially higher than those in developed economies.

2.3 Limits to Speculation Hypothesis

There is an extensive literature aimed at explaining the forward bias. One way to address the problem is to introduce risk premia as in Fama (1984). A key result in this area of research is that models of risk–premia suggest unrealistically high degrees of risk aversion. Other proposed explanations involve the interaction of risk premia and monetary policy in McCallum (1994), peso problems in Lewis (1995), non–cointegration of forward and spot rates in Roll & Yan (2000), and learning and biases in expectations in Frankel & Rose (1994).

Recent research focuses on a microstructure approach to exchange rates. Evans & Lyons (2002) provide strong empirical evidence that exchange rates are driven by order–flow. Consequently, investigating the trading behaviour of market participants who generate order–flow may offer deeper insight into the driving factors behind the forward bias. The limits to speculation hypothesis by Lyons (2001) is based on this idea. It is argued that even though the forward bias is statistically significant it is economically insignificant, in the sense that it is too small to attract speculative capital. It is a key feature of this argument that financial institutions with a comparative advantage in exploiting the forward bias, typically allocate speculative capital based on Sharpe ratios. They do so
not because this behaviour is rational in a theoretical sense, but because Lyons (2001) considers this as an empirical fact, based on interviews with proprietary traders at banks and hedge funds.

Lyons (2001) further argues that the willingness of traders to take up an investment strategy is limited to strategies with Sharpe ratios above the minimum threshold of 0.5, which turns out to be the annual average Sharpe ratio of the US market over the last 50 years. Analyzing bias-trading strategies for six USD exchange rates, he finds Sharpe ratios – after approximating transaction costs – between 0.37 and 0.41 and thus support for his hypothesis.

In contrast to the concept of limits to speculation Galati et al. (2007), Galati & Melvin (2004) provide evidence that capital is allocated to bias-trading strategies and that bias-trading might even be a key driver for the surge in foreign exchange trading over the last years. Corte et al. (2008) and Hochradl & Wagner (2010) showed that while single-currency bias-trading strategies generate economically small payoffs, dynamic multi-currency strategies yield large economic gains. The widespread use of bias-exploiting strategies among market professionals and evidence that bias-trading has grown significantly over the last years suggests a certain degree of economic significance.

The objective of this paper is to assess the limits to speculation hypothesis empirically by measuring the economic significance of the forward bias in the sense suggested by Lyons (2001). In the following investment strategies explicitly aimed at exploiting the forward bias will be implemented to investigate whether they have the potential to attract speculative capital. While past research is almost entirely focused on small portfolios covering developed economy currencies only, this paper studies large multi-currency strategies including up to 38 emerging market and developed economy currencies.

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3. Bias Trading Strategies

The bias–trading strategies considered in this paper are simple carry–trades, which are well known to practitioners. Naturally, by selecting more complicated strategies, in–sample Sharpe ratios can always be raised to arbitrarily high levels. Because of the simplicity and popularity of carry–trades, their payoffs can be considered as conservative estimates of the returns to bias–trading, not generated from data snooping.

The carry–trade strategy consists of selling the domestic currency forward when it is at a forward premium ($F_t - S_t$) and buying the domestic currency forward when it is at a forward discount ($F_t < S_t$). Let $S_t$ denote the spot exchange rate, $F_t$ the forward exchange rate, and $x_t$ the number of domestic currency units sold forward. Assume that the investor bets one unit of domestic currency every period, then the decision rule of the carry–trade can be stated in the following way:

$$x_t = +1 \quad \text{if} \quad F_t > S_t$$

$$x_t = -1 \quad \text{if} \quad F_t < S_t$$

The payoff to this strategy denoted in domestic currency units is given by:

$$x_t \left( \frac{F_t}{S_{t+1}} - 1 \right)$$

(4)

If bid–ask spreads are taken into account, which turns out to be vital for the profitability of carry–trades, the decision rule changes to:

$$x_t = +1 \quad \text{if} \quad \frac{F_t^b}{S_t^b} > 1$$

$$x_t = -1 \quad \text{if} \quad \frac{F_t^a}{S_t^a} < 1$$

$$x_t = 0 \quad \text{otherwise}$$

Where the ask (bid) exchange rate is the rate at which an investor can buy (sell) the domestic currency. The payoff to the carry–trade taking transaction costs into account is:

$$x_t \left( \frac{F_t^b}{S_{t+1}^b} - 1 \right) \quad \text{if} \quad x_t > 0$$

$$x_t \left( \frac{F_t^a}{S_{t+1}^a} - 1 \right) \quad \text{if} \quad x_t < 0$$

$$0 \quad \text{if} \quad x_t = 0$$
It is implicit in the decision rule of the carry-trade that the expected future spot exchange rate is equal to the spot rate today, i.e. that the spot exchange rate is a martingale.

It is natural to implement carry-trades not only for single currencies but also for portfolios of currencies. In the following, a small portfolio covering only currencies of major developed economies and a large portfolio consisting of developed economy and emerging market currencies are studied. For both portfolios this paper implements equally- and optimally weighted strategies. The latter involves choosing portfolio weights such that at each time $t$ the following expression is minimized:

$$\min_{\omega_t} \omega_t^T V_t \omega_t$$

subject to $\sum_{i=1}^n w_{it} E_t[z_{it+1}] = z_p$, $\sum_{i=1}^n w_{it} = 1$, $w_{it} \geq 0$

The variable $w_{it}$ is the time $t$ portfolio weight of currency $i$, and $\omega_t$ represents the vector of portfolio weights. The expected payoff associated with the speculation strategy applied to currency $i$ is given by $E_t[z_{it+1}]$, while $z_p$ denotes the time $t$ expectation of the payoff to the portfolio at time $t + 1$. The matrix $V_t$ is obtained as a recursive estimate of the covariance matrix of the one-step ahead forecast errors of the returns, where it is assumed that the true value of $V_t$ is time invariant. The forecast error is computed as the difference between the actual payoff and the agent's expected payoff.

\[\text{A list of the currencies covered by the small and large portfolio can be found in the appendix}\]
4. Returns to Bias Trading

4.1 Basic Results

This section studies the payoffs to the bias–trading strategies defined above. It turns out that bid–ask spreads have a significant impact on the profitability of currency speculation. Since bid–ask spreads are small it is sometimes argued that it is reasonable to ignore them. However, in the sense relevant to bias–trading bid–ask spreads are large. They are approximately of the same size as the expected payoffs to currency speculation. As shown in Burnside et al. (2006) and Burnside et al. (2007), approximating or even ignoring bid–ask spreads leads to grossly misleading inference about the profitability of currency speculation. For this reason, this paper implements strategies that take true bid–ask spreads into account.

Table 6 shows the annualized mean, standard deviation, Sharpe ratio, 5% historical Value at Risk, CAPM–β, and the standard error of β of the weekly returns to the optimally–weighted carry–trade portfolios for three different periods: a full sample ranging from January 1999 to July 2009, a somewhat shorter sample ending in December 2006, and a third subsample from January 2007 to July 2009. To put results into perspective Table 6 also contains the US stock market premium calculated as the difference between weekly US stock market returns and Treasury–bill rates obtained from Kenneth French's data library.

It turns out that for all sample periods carry–trade portfolios outperform the US stock market significantly. For the full sample period annualized Sharpe ratios amount to 0.6 and 1.8, reflecting the particularly small standard deviation of carry–trade returns. Downside risk measured in terms of 5% historical Value at Risk is much lower than that in the US stock market and comparing the CAPM–β's with their standard errors suggests that they are not significantly different from zero, indicating that the risk contained in carry–trades is largely diversifiable.

As expected, Sharpe ratios considerably increase when looking at the second subsample ending in December 2006, i.e. excluding data on the current financial crisis. For the third sample starting in 2007 all Sharpe ratios turn out to be negative, though carry–trades considerably outperform the benchmark. Downside risk is much lower than in the US stock market and the CAPM–β's still suggest insignificant correlation with the benchmark.

Comparing the small portfolio to the large one shows that Sharpe ratios can be increased considerably by enriching carry–trade portfolios with emerging market currencies. The findings suggest that the standard deviation of the returns to the large portfolio is lower than that of the small one. Even though returns to single–currency carry–trades are much more volatile in emerging markets than in developed economies, the higher diversification in the large portfolio compensates for this. Another important feature of emerging market currencies is that for about one fourth of the currencies in the large portfolio there are less than 50 trades over the whole sample period. The reason is that bid–ask spreads are much higher in emerging markets than in
developed economies and consequently, the decision rule of the carry-trade more often suggests not to trade. Comparing the returns of optimally-weighted portfolios to their equally-weighted pendants shows that the simple portfolio optimization implemented in this paper is able to reduce standard deviations between 15 to 20 percent. The returns to single-currency carry-trades are presented in Tables 4 and 5.

Summing up, bias-trading yields Sharpe ratios considerably higher than the US stock market and the minimum threshold of 0.5 stated by Lyons (2001). Furthermore, it contains low downside risk and represents an attractive diversification device (virtually no systematic risk). Finally, there are large diversification gains from enriching carry-trade portfolios with emerging market currencies.

This paper studies the period from January 1999 to July 2009, but it turns out that the main results stated above are robust with respect to changes of the sample period. They agree with those of Burnside et al. (2006) who study the period from 1979 to 2005, using optimally-weighted carry-trade portfolios of developed economy currencies. Burnside et al. (2007) establish the same findings for the period from 1997 to 2006, implementing equally-weighted portfolios covering developed economy as well as emerging market currencies. Also the results of Hochradl & Wagner (2010) who study the period from 1990 to 2005 for optimally-weighted portfolios consisting of developed economy currencies match those found in this paper.

4.2 Cumulative Returns

This section looks at the cumulative returns to bias-trading. It is assumed that an agent starts with one dollar in his bank account at the beginning of the sample period and bets that dollar on the carry-trade. From that point forward the agent bets the balance of his bank account. The resulting payoffs are deposited or withdrawn from the agent’s account. Since the carry-trade is a zero-cost investment, the agent’s net balances stay in the bank and accumulate interest at the Treasury-bill rate. It turns out that the bank account balance never becomes negative in the sample.

Figure 1 depicts the weekly cumulative returns to the optimally-weighted carry-trade portfolios, the US stock market as obtained from Kenneth French’s data library, and the Treasury-bill rate for the period from January 1999 to July 2009. As expected, the large carry-trade portfolio outperforms the small one and both outperform the US stock market.

The volatility of carry-trade returns is much smaller than that of the stock market. Especially during the crisis currency speculation payoffs turn out to be more stable than the stock market. This result
is true for an the up-to-date data set used in this paper as well as for sample periods starting in the 80’s studied in Burnside et al. (2006).

4.3 Trader’s Problem

So far this paper has emphasized the mean and variance of the returns to currency speculation. One way to introduce an alternative performance measure besides Sharpe ratios, downside risk, and covariance is to confront a hypothetical trader with the possibility of investing in the US stock market and wagering bets on the carry-trade. It is assumed that the trader has power utility defined over an infinite stream of consumption. In this attractively simple infinite-horizon model portfolio choice depends on preferences and state variables but not on time. Even though it is somewhat implausible to let the terminal date to go to infinity, the effective investment horizon can be varied by changing the time discount factor that determines the relative weights investors place on the near-term future versus the distant future. The trader’s problem is given by:

$$\max_{c_t, x_t, x'_t} U = E_0 \sum_{t=0}^{\infty} \delta^t (\frac{C_t^{1-\gamma}}{1-\gamma})$$

s.t. $C_t = Y_t + X_{t-1}^s (1 + r_t^s) + X_{t-1}^c r_t^c - X_t^s$

Here $C_t$ denotes consumption, $Y_t$ is an exogenous income endowment normalized to one at time zero and assumed to grow at an annual rate of 1.4%$, X_t^s$, and $X_t^c$ represent investments in the US stock market and the carry-trade, and the variables $r_t^s$ and $r_t^c$ denote the realized real returns to the US stock market and the carry-trade, respectively$. It is assumed that the variables $r_t^s$ and $r_t^c$ are generated by the joint empirical distribution of returns to the US stock market and the carry-trade portfolios. The trader chooses constant ratios

$$X_t^s = \frac{X_t^s}{Y_t}$$

and $$X_t^c = \frac{X_t^c}{Y_t}$$

for all $t$.

Table 8 presents the numerical solutions based on setting the risk aversion parameter $\gamma$ to five for the small and large carry-trade portfolios, for the full sample period and the period ending in December 2006. As expected, investments in the US stock market are much higher for the shorter sample period excluding the current financial crisis and investments in the small portfolio are lower than investments in the large one. For both sample periods, investments in carry-trades are considerably higher than investments in the US stock market.

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3 Real growth rate of US per capita GDP obtained from IMF WEO database.
4 Real returns are calculated using US consumer price inflation.
4.4 Crisis Scenario

The data set used in this paper covers the Turkish currency crisis in February 2001 which is represented by the large spike in Figure 3 at the beginning of the sample period. Due to data availability issues, the Argentine Peso and the Brazilian Real are not included in the large portfolio. Consequently, the currency crisis in Argentina in 2002 and in Brazil in 1999 are not reflected in the returns bias–trading. This section is intended to adjust for the occurrence of these crises. To be conservative, the Korean crisis in 1997 and the Russian crisis in 1998 are also taken into account even though they lie outside the sample period studied in this paper.

It is assumed that at time \( t - 1 \) an agent invests a fraction of \( 1/n \) in the currency exhibiting a crisis at time \( t \), where \( n \) denotes the number of currencies in the large portfolio. For all other points in time, the trader does not take any position in the currency. Currency crises that lie outside the sample period are assumed to occur at the beginning of the sample. Using this procedure the crises in Argentina, Brazil, Korea, and Russia are incorporated in the large portfolio.

Burnside et al. (2007) show that these currencies depreciated by 29%, 23%, 32%, and 56% within a week. As argued in Burnside et al. (2007), penalizing the large portfolio by the full extent of the currency depreciation between \( t - 1 \) and \( t \) can be viewed as a conservative estimate of the crisis impact on carry–trade profitability.

Table 7 presents the crisis–adjusted returns to the optimally–weighted large portfolio for the full sample and the period ending in December 2006. While the one–time losses stated above are very large, the high degree of diversification in the large portfolio limits their impact on the overall portfolio payoff. It turns out that even under the conservative assumptions made above, effects of currency crisis can be reasonably diversified in the large portfolio.
5. Conclusion

The concept of limits to speculation as put forward by Lyons (2001) suggests that even though the forward bias is statistically significant, it is economically insignificant. In particular, it is argued that the bias is too small to attract speculative capital, since other investment opportunities yield higher Sharpe ratios. Lyons (2001) argues that the willingness of traders to take up an investment strategy is limited to strategies with Sharpe ratios above 0.5 and that bias-trading yields Sharpe ratios below this minimum threshold. Consequently, traders do not exploit the bias which remains statistically persistent. However, market evidence strongly suggests that the forward bias is traded in practice and that bias-trading might even be a key driver for the surge in foreign exchange trading over the last years. While returns to single-currency strategies appear to be economically small, the literature suggests that multi-currency strategies yield large economic gains.

The objective of this paper is to assess the limits to speculation hypothesis empirically by measuring the economic significance of the forward bias in the sense suggested by Lyons (2001). This is done by implementing investment strategies explicitly aimed at exploiting the bias in developed economies as well as emerging markets. It turns out that bias-trading strategies can be viewed as attractive investment opportunities. They yield Sharpe ratios considerably higher than that of the US stock market and the minimum threshold stated by Lyons (2001), contain low downside risk measured in terms of Value at Risk, and represent useful diversification devices (no systematic risk). Furthermore, there are large diversification gains from enriching carry-trade portfolios with emerging market currencies, resulting in even higher Sharpe ratios. Even though, returns to single-currency carry-trades are much more volatile in emerging markets than in developed economies, the higher diversification in the large portfolio compensates for this.

Since the results of this paper are based on the empirical distribution of returns, the forward bias can be rationalized by a peso problem, i.e. when agents decide whether to take up an investment strategy they place positive weight on very large tail events that have not materialized in the sample. As a consequence, agents might not be willing to trade even though the empirical distribution of returns looks attractive. This argument is challenged by Galati et al. (2007) and Galati & Melvin (2004) who provide evidence that the bias is massively traded in practice. Furthermore, even though the peso problem can provide an explanation for the persistence of the forward bias it is inconsistent with the limits to speculation hypothesis since it is a key feature of this argument that financial institutions allocate speculative capital based on Sharpe ratios derived from historical payoffs.

Overall, the findings of this paper suggest that dynamic multi-currency strategies applied to emerging market as well as developed economy currencies generate economically significant excess returns.
Results are in line with the widespread use of bias-trading strategies among market professionals and challenge the concept of limits to speculation hypothesis as an explanation for the forward bias puzzle.
References


Appendix

Carry Trade Portfolios

Small portfolio: Euro, UK Pound, Japanese Yen, Swiss Franc, Canadian Dollar, and Australian Dollar.

Large portfolio: Euro (EUR), UK Pound (GBP), Japanese Yen (JPY), Swiss Franc (CHF), Canadian Dollar (CND), Australian Dollar (AUD), Danish Krone (DKK), Swedish Krona (SEK), Norwegian Krone (NOK), Czech Koruna (CZK), Hong Kong Dollar (HKD), Hungarian Forint (HUF), Indian Rupee (INR), Indonesian Rupiah (IDR), Kuwaiti Dinar (KWD), Mexican Peso (MXN), New Zealand Dollar (NZD), Philippine Peso (PHP), Polish Zloty (PLN), Saudi Riyal (SAR), Singapore Dollar (SGD), South Korean Won (KRW), Taiwan Dollar (TWD), Thai Baht (THB), New Turkish Lira (TRY), UAE Dirham (AED), Bulgarian Lev (BGN), Croatian Kuna (HRK), Egyptian Pound (EGP), Estonian Kroon (EEK), Icelandic Krona (ISK), Kazakhstani Tenge (KZT), Latvian Lat (LVL), Lithuanian Lita (LTL), Maltese Lira (MTL), Moroccan Dirham (MAD), Qatari Rial (QAR), and South African Rand (ZAR).

Tables and Figures

Table 1 presents median bid—ask spreads for spot and forward exchange rates for the period from 01.01.1999 to 10.07.2009. Bid—Ask spreads are given in percent: (ASK/BID − 1) × 100.

Tables 2 and 3 present the estimated coefficients (α, β) and corresponding standard errors (σα, σβ) of the Fama—regression (3) fitted to the sample periods from 01.01.1999 to 10.07.2009 and 01.01.1999 to 29.12.2006.

Tables 4 and 5 present the annualized mean, standard deviation and Sharpe ratio of the payoffs to the single—currency carry—trades for the sample periods from 01.01.1999 to 10.07.2009 and 01.01.1999 to 29.12.2006. Since carry—trades are zero—cost investments Sharpe ratios are calculated as mean divided by standard deviation.

Table 6 presents the annualized mean, standard deviation, Sharpe ratio, 5% historical Value at Risk, CAPM—β, and standard error of β of the weekly returns to the optimally—weighted carry—trade portfolios for the periods: 30.07.1999 to 10.07.2009, 30.07.1999 to 29.12.2006, and 01.01.2007 to 10.07.2009. To estimate the variance—covariance matrix Vt, 30 observations are used.


Table 8 presents the solutions Xs and Xc to the trader’s problem as given in section 4.3 for the small and large optimally—weighted carry—trade portfolios for the periods: 30.07.1999 to 10.07.2009 and 30.07.1999 to 29.12.2006.
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<th>Country</th>
<th>Spot</th>
<th>Forward</th>
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* data is available for the period from 02.04.2004 – 10.07.2009 only.
Table 5: Payoffs to Carry-Trade 01.01.1999 - 20.12.2006

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<td>Kazakhstani T. *</td>
<td>0.0017</td>
<td>0.0023</td>
<td>0.7365</td>
</tr>
<tr>
<td>Latvian Lats*</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Lithuanian Litas*</td>
<td>-0.0145</td>
<td>0.0559</td>
<td>-0.3663</td>
</tr>
<tr>
<td>Maltese Lira*</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Moroccan Dirham*</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Qatari Riyal*</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>South African Rand*</td>
<td>-0.0204</td>
<td>0.0831</td>
<td>-0.3173</td>
</tr>
</tbody>
</table>

* data is available for the period from 02.04.2004 – 10.07.2009 only.
### Table 6: Optimally-Weighted Carry-Trade Portfolio

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Mean</th>
<th>SD</th>
<th>SR</th>
<th>VaR</th>
<th>$\beta_{APM}$</th>
<th>$SE_{\beta}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation Period: 30.07.09 – 16.07.09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>0.0177</td>
<td>0.0307</td>
<td>0.5764</td>
<td>-0.3485</td>
<td>-0.0010</td>
<td>0.0086</td>
</tr>
<tr>
<td>Large</td>
<td>0.0234</td>
<td>0.0182</td>
<td>1.3302</td>
<td>-0.0149</td>
<td>0.0054</td>
<td>0.0043</td>
</tr>
<tr>
<td>US</td>
<td>-0.0166</td>
<td>0.2062</td>
<td>(-0.0184)</td>
<td>-2.2820</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation Period: 30.07.09 – 25.12.09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>0.0356</td>
<td>0.0283</td>
<td>1.2965</td>
<td>-0.2946</td>
<td>-0.0010</td>
<td>0.0085</td>
</tr>
<tr>
<td>Large</td>
<td>0.0447</td>
<td>0.0195</td>
<td>2.9267</td>
<td>-0.0537</td>
<td>0.0028</td>
<td>0.0050</td>
</tr>
<tr>
<td>US</td>
<td>0.0200</td>
<td>0.1752</td>
<td>0.1135</td>
<td>-1.8873</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation Period: 01.01.07 – 16.07.09</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>-0.0956</td>
<td>0.0366</td>
<td>(-0.5047)</td>
<td>-0.4068</td>
<td>0.0012</td>
<td>0.0145</td>
</tr>
<tr>
<td>Large</td>
<td>-0.0002</td>
<td>0.0129</td>
<td>(-0.0185)</td>
<td>-0.1543</td>
<td>0.0085</td>
<td>0.0071</td>
</tr>
<tr>
<td>US</td>
<td>-0.1258</td>
<td>0.2702</td>
<td>(-0.4506)</td>
<td>-3.2588</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 7: Crisis Scenario: Optimally-Weighted Carry-Trade Portfolio

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Mean</th>
<th>SD</th>
<th>SR</th>
<th>VaR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation Period: 30.07.09 – 16.07.09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large-Crisis</td>
<td>0.0287</td>
<td>0.0182</td>
<td>1.5452</td>
<td>-0.1102</td>
</tr>
<tr>
<td>Large</td>
<td>0.0334</td>
<td>0.0182</td>
<td>1.3302</td>
<td>-0.0949</td>
</tr>
<tr>
<td>US</td>
<td>-0.0186</td>
<td>0.2062</td>
<td>(-0.0804)</td>
<td>-2.2820</td>
</tr>
<tr>
<td><strong>Evaluation Period: 30.07.09 – 25.12.09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large-Crisis</td>
<td>0.0287</td>
<td>0.0267</td>
<td>1.9460</td>
<td>-0.0631</td>
</tr>
<tr>
<td>Large</td>
<td>0.0447</td>
<td>0.0185</td>
<td>2.2937</td>
<td>-0.0637</td>
</tr>
<tr>
<td>US</td>
<td>0.0260</td>
<td>0.1752</td>
<td>0.1143</td>
<td>-1.8873</td>
</tr>
</tbody>
</table>
Table 8: Trader’s Problem

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>$X^*$</th>
<th>$X''$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Period: 30.07.08 – 10.07.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Portfolio</td>
<td>0.0085</td>
<td>0.2132</td>
</tr>
<tr>
<td>Large Portfolio</td>
<td>0.0063</td>
<td>2.1345</td>
</tr>
<tr>
<td>Evaluation Period: 30.07.08 – 26.12.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Portfolio</td>
<td>0.2047</td>
<td>0.6737</td>
</tr>
<tr>
<td>Large Portfolio</td>
<td>0.2583</td>
<td>0.7155</td>
</tr>
</tbody>
</table>
Figure 1: Cumulative Returns to Carry-Trade, US Stock Market, and T-bill rate: 30.07.1999 – 10.07.2009
Figure 2: Returns to Small Optimally-Weighted Carry-Trade Portfolio: 30.07.1999 – 10.07.2009

Figure 3: Returns to Large Optimally-Weighted Carry-Trade Portfolio: 30.07.1999 – 10.07.2009
Forecast Based Strategies

This section discusses the BGT strategy according to Backus et al. (1993) which is a forecast-based extension of the carry-trade. The BGT strategy uses a regression similar to the Fama–Regression (3) to obtain forecasts of future spot rates. It consists of selling (buying) the domestic currency forward when the payoff predicted by the rolling regression (6) is positive (negative):

\[
\frac{F_t - S_{t+1}}{S_t} = a + b \frac{F_t - S_t}{S_t} + \epsilon_{t+1}
\]  

(6)

Note that if one assumes that \(1/S_t\) is a martingale then (6) is approximately equivalent to:

\[
\frac{F_t - S_{t+1}}{S_t} = a + b \frac{F_t - S_t}{S_t} + \epsilon_{t+1}
\]  

(7)

Which can be rearranged to show that: \(a = -\alpha\) and \(b = 1 - \beta\), where \(\alpha\) and \(\beta\) are the intercept and slope in the Fama–Regression (3). Ignoring bid–ask spreads the decision rule of the BGT strategy is given by:

\[
x_t = +1 \quad \text{if} \quad E_t(F_t/S_{t+1}) > 1
\]

\[
x_t = -1 \quad \text{if} \quad E_t(F_t/S_{t+1}) < 1
\]

The expectation is constructed as follows:

\[
E_t(F_t/S_{t+1}) = 1 + \hat{\alpha}_t + \hat{\beta}_t(F_t - S_t)/S_t
\]

The variables \(\hat{\alpha}_t\) and \(\hat{\beta}_t\) denote the recursive estimates of the coefficients in regression (6). When taking transaction costs into account the expectation changes to:

\[
E_t(F_t/S_{t+1}) = [1 + \hat{\alpha}_t + \hat{\beta}_t(F_t - S_t)/S_t] \frac{P_t}{F_t} \frac{S_t}{S_{t+1}}
\]

\[
E_t(F_t/S_{t+1}) = [1 + \hat{\alpha}_t + \hat{\beta}_t(F_t - S_t)/S_t] \frac{P_t}{F_t} \frac{S_t}{S_{t+1}}
\]

The corresponding decision rule of the BGT strategy with transaction costs is given by:

\[
x_t = +1 \quad \text{if} \quad E_t(F_t/S_{t+1}) > 1
\]

\[
x_t = -1 \quad \text{if} \quad E_t(F_t/S_{t+1}) < 1
\]

\[
x_t = 0 \quad \text{otherwise}
\]
The tables in the appendix do not report the returns to the BGT strategy. For both portfolios and all sample periods studied the BGT strategy performs not better than carry-trades. This result is quite surprising but agrees with Burnside et al. (2006). The main reason for the bad performance of the BGT strategy is the bad fit of the forecast regression (6). It turns out that the forecast quality is worse than that of a no change forecast which is inherent in carry–trades. This finding is quite robust to stretching and squeezing the rolling window of the forecast regression.

Another example of forecast-based bias–trading can be found in Hochradl & Wagner (2010) who use recursive VEC models for the spot and forward rate to forecast future spot exchange rates. Like the BGT strategy, VEC models cannot beat carry–trades. In general it can be said that the forecast models that have been implemented in the literature so far to obtain short term forecast of future spot exchange rates, typically do not outperform carry–trades.
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