# Testing Speculative Efficiency of Currency Markets*

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**Abstract**

Motivated by the concept of limits to speculation, we investigate the *economic* significance of deviations from uncovered interest parity (UIP) and the *speculative* efficiency of currency markets. Based on the 'Fama-regression', we suggest an alternative approach for testing UIP, encompassing static strategies, carry-trades, and a link to technical trading rules. Doing so reveals that the regression constant, $\alpha$, - while commonly disregarded - plays an important role. To judge economic significance, we derive trader inaction ranges implied by limits to speculation. Our empirical results suggest that the foreign exchange market is speculatively efficient and that neglecting $\alpha$ misleads conclusions about economic significance.

**Keywords:** Exchange rates; Uncovered interest parity; Limits to speculation;

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# 1 Introduction

Tests of foreign exchange market efficiency are typically based on an assessment of uncovered interest rate parity (UIP). UIP postulates that the expected change in a bilateral exchange rate is equal to the forward premium, i.e., given that covered interest rate parity holds, it compensates for the interest rate differential. However, empirical research provides evidence that the forward rate is a biased estimate of the future spot rate, finding that the higher interest rate currency tends to not depreciate as much as predicted by UIP or even appreciates. This result implies apparent predictability of excess returns over UIP. Attempts to explain the forward bias using, among others, risk premia, consumption-based asset pricing theories, and term-structure models have not been able to convincingly solve the puzzle. In a recent microstructural approach, Lyons (2001) argues that while the forward bias might be statistically significant, the failure of UIP might not be substantial in economic terms due to limits to speculation. Compared to other investment opportunities, the Sharpe ratios realizable from currency trading strategies are too small to attract traders' capital, who consequently leave the bias unexploited and persistent. The presumption that traders allocate capital only if Sharpe ratios exceed a certain threshold implies a range of trader inaction for small UIP deviations. Based on the traditional 'Fama-regression', we motivate an alternative approach for investigating UIP. Aiming at testing the speculative efficiency of currency markets, we start by assessing whether static long or short positions in the foreign currency allow for non-zero excess returns. Subsequently, we propose to test whether the carry-trade strategy, a widely used trading rule aimed at exploiting the forward bias, generates excess returns significantly different from zero. In formulating the testable hypotheses we find that the constant from the standard regression test - while commonly disregarded in related research - plays an important role in assessing speculative efficiency. In fact, neglecting the parameter might mislead conclusions about the relevance of UIP deviations substantially. To judge the economic significance of the statistical failure of UIP we derive trader inaction ranges as motivated by the concept of limits to speculation. Again, disregarding the constant potentially distorts the evaluation of speculative efficiency due to inaccurate inaction ranges resulting from the omission of the parameter.

Apart from trading approaches explicitly aimed at exploiting deviations from UIP, we also investigate a technical trading strategy. Using a basic momentum rule we motivate that a link between the extent to which UIP is valid and the profitability of trend extrapolating strategies exists. While (a sequence of) short-lived trends might be overlooked, long and pronounced trends leading to high profits of momentum trading should be captured by the parameters of the Fama-regression. Thus, periods in which UIP tests reject the null hypotheses, are more likely to be characterized by trends and therefore higher profitability of momentum trading.

Overall, our empirical results suggest that the foreign exchange market is speculatively efficient and that deviations from UIP are not important in economic terms. In particular we find that while standard UIP tests might reject the null hypothesis, our approach indicates that trading on these deviations is not significant economically. However, if one disregarded the regression constant in the analysis, one is mislead towards concluding that exploiting UIP deviations is attractive. With respect to momentum-trading, we find higher profitability in periods in which the UIP relationship weakens.

The remainder of the paper is organized as follows. We briefly review the related literature on UIP and limits to speculation in section 2. In section 3, we describe our approach for testing speculative efficiency by relating the profitability of currency speculation strategies to the standard UIP regression. To judge economic significance of UIP deviations, we derive trader inaction ranges as motivated by Lyons (2001) in section 4. Section 5 presents an empirical analysis and section 6 offers a conclusion.

## 2 Related Literature on UIP and Limits to Speculation

A standard procedure to test uncovered interest rate parity (UIP) is the Fama (1984) regression

$$\Delta s_{t+1} = \alpha + \beta \left(f_t^1 - s_t\right) + \varepsilon_{t+1} \tag{1}$$

where $s_t$ denotes the logarithm of the spot exchange rate at time $t$, $f_t^1$ the logarithm of the one-period forward rate, and $\Delta$ a one-period change. The null hypothesis that UIP holds is represented by $\alpha$ being zero and $\beta$ equalling unity. The common finding that empirical research over the last decades provided and concentrated on is that $\beta$ is typically lower than unity and often even negative. This indicates that the higher interest rate currency tends to not depreciate as much as predicted by UIP, and if negative, the higher interest rate currency evend tends to appreciate, implying the apparent predictability of excess returns over UIP. For surveys of this evidence see e.g. Hodrick (1987), Froot and Thaler (1990), Lewis (1995), Taylor (1995), Engel (1996), Sarno and Taylor (2003).

From an economic perspective the statistical rejection of the UIP might point at a risk premium or at market inefficiency. Attempts to explain the forward bias using models of risk premia, however, have met with limited success, especially for plausible degrees of risk aversion, see e.g. Frankel and Engel (1984), Domowitz and Hakkio (1985), Hodrick (1987), Cumby (1988), Hodrick (1989), Mark (1988), Engel (1996), Mark and Wu (1997), and Chinn and Frankel (2002). Moreover, research based on (among others) explanations such as learning, peso problems and bubbles, see e.g. Lewis (1995), consumption-based asset pricing theories, see e.g. Backus, Gregory, and Telmer (1993), Bansal, Gallant, Hussey, and Tauchen (1995), Bekaert (1996), expected utility theory, see e.g. Frankel and Froot (1987) and Bekaert, Hodrick, and Marshall (1997), and term-structure models, see e.g. Backus, Foresi, and Telmer (2001), has not been able to convincingly explain the forward bias.

Lyons (2001) suggests a microstructural approach based on the finding that order flow drives exchange rates, see Evans and Lyons (2002). He takes a "practitioner's perspective" and builds on institutional realities: Traders only allocate capital to currency speculation if they expect a higher Sharpe ratio than from other investment opportunities, i.e. some threshold in terms of the Sharpe ratio has to be exceeded.[1] Lyons (2001) outlines that the return from currency speculation depends on how far $\beta$ deviates from unity, while the standard deviation is independent thereof. Hence, for minor deviations from the UIP implied value of unity, Sharpe ratios are only small, in fact too small to attract speculative capital, thereby implying a range of inaction around UIP. Lyons (2001) states that $\beta$s around -1 or 3 are necessary to achieve a Sharpe ratio of 0.4, the long run performance of a buy-and-hold strategy in US equities. Regarding this as the lower bound for Sharpe ratio thresholds, Lyons (2001), p. 215, states "[...] I feel safe in asserting that there is limited interest at these major institutions in allocating capital to strategies with Sharpe ratios below 0.5.". Accordingly, he suggests that range of $\beta$-values between approximately -1 and 3 characterizes the trader inaction band.

Recent papers find evidence consistent with the LSH. Inspired by the LSH, Sarno, Valente, and Leon (Forthcoming) and Baillie and Kiliç (2006) investigate the relationship between spot and forward rates in a smooth transition regression (STR) framework. Both report evidence for such a non-linear relationship, allowing for a time-varying forward bias. The empirical results of both suggest that UIP does not hold most of the time because expected deviations from UIP are economically insignificant, i.e. too small to attract capital. Note, however, that while the STR is motivated by the LSH, the possibility that the actual source of the non-linearity is a reason other than limits to speculation can not be precluded.

[1] Lyons (2001) stresses that speculative capital is allocated based on Sharpe ratios in practice. It is this empirical reality that is important for the concept rather than a theoretical rational for why such a behavior arises.

Recent empirical work (related to our paper) suggests that trading strategies aimed at exploiting the forward bias might be attractive investment and diversification opportunities for traders. Villanueva (Forthcoming) finds that the forward premium has directional predictability and that corresponding trading rules allow for statistically significant profits. Motivated by the concept of limits to speculation, Hochradl and Wagner (2006) compare the performance of constrainedly optimized deposit portfolios across multiple currencies to that of reasonable benchmarks and find that the portfolios yield higher Sharpe ratios than buy-and-hold stock or bond-index investments. Consequently, they conclude that bias-trading approaches should have the potential to attract speculative capital, being consistent with empirical evidence on the behavior of market participants.

## 3 Currency Speculation and Uncovered Interest Parity

The aim of the present paper is to investigate the speculative efficiency of currency markets. In doing so we are inspired by the concept of limits to speculation as put forward by Lyons (2001) which was outlined in the previous section. In the remainder of this section, we motivate new hypotheses to be tested on the parameters of the Fama-regression to investigate the profitability of the following currency trading approaches: (i) a permanent long (or short) position in the foreign currency, which can be viewed as a lower bound for speculative efficiency. (ii) the carry-trade, a widely used approach aimed exploiting the forward bias. (iii) a momentum-based technical trading rule, commonly used by practitioners, in particular over short horizons. While the performance of the first two can be derived directly from the Fama-regression, the later cannot but still allows for establishing a link.

At this point it is instructive to recall, that the existing literature typically concentrates on the role of $\beta$ in the Fama regression while it tends to disregard discussion on the constant $\alpha$

when interpreting results and drawing conclusions; see the previous section. In such a way, Lyons (2001) suggests that $\beta$ might vary within some range as long as deviations do not allow for attractive Sharpe ratios. While he does not mention $\alpha$, this could also be argued for the constant. It is not entirely clear why previous literature neglects $\alpha$, though. Presumably, one reason is that estimates over longer horizons are typically small and not always significant; but neither are the coefficients on the forward premium always significant. Furthermore, the performance of trading strategies aimed at exploiting UIP indicates that $\beta$ is not the only parameter to look at: while these speculative approaches are explicitly designed as to capitalize on situations in which $\beta < 1$, large profits can also be generated in periods with $\beta \geq 1$. Analogously, periods with $\beta$ being far below unity do not necessarily result in profits. Corresponding evidence is outlined in the empirical analysis below. This suggest to consider the regression constant as well and therefore, we explicitly take $\alpha$ into account and highlight the consequences of presuming $\alpha = 0$.

At the outset, we concretize the terminology that we adopt for the remainder of the paper. Having set the aim of investigating speculative efficiency, we adopt the following definition:

***Definition:*** *The currency market is speculatively efficient if excess returns from currency speculation are not economically significant.*

In the context of the Fama-regression we mean by ***speculative efficiency*** that $\alpha$ and $\beta$ do not always have to correspond to the standardly hypothesized values but rather that deviations of one or both might occur as long as these do not allow for large profit opportunities. By ***economic significance*** we mean that a pure statistical rejection of the null hypothesis, i.e. finding that excess returns are significantly different from zero, might not be enough in economic terms. The profits might be strictly positive but still too small to attract capital. Rather, traders compare currency speculation approaches to other investment opportunities, e.g. a buy-and-hold equity investment. Speculative capital would only be allocated to currency strategies for which a higher Sharpe ratio than for other investments is expected. If that were not the case, no capital would be allocated, thus no order flow produced, and hence the bias be left unexploited and persistent consequently being visible statistically but without economic relevance.

Thus, speculative efficiency would be rejected if excess-returns from currency speculation are not only significantly different from zero but also higher than traders' Sharpe ratio thresholds and currency strategies therefore capable of attracting speculative capital. In the remainder of this section we describe the procedure to test whether excess returns are different from zero while trader inaction ranges applied to judge the economic significance are derived in the next section.

### 3.1 Deviations from Uncovered Interest Parity: Static Trading Approach

The limits to speculation hypothesis suggests to judge the economic significance of UIP deviations by the profitability of currency speculation in terms of its Sharpe ratio. To consider the Sharpe ratio of currency speculation, it is instructive to reparameterize equation (1) in terms of excess returns resulting from UIP deviations; this approach was also investigated by e.g. Bilson (1981), Fama (1984), and Backus, Gregory, and Telmer (1993). For brevity we set $p_t^1 = \left(f_t^1 - s_t\right)$. Defining the excess return by the difference between the exchange rate return and the lagged premium, $ER_{t+1} \equiv \Delta s_{t+1} - p_t^1 \equiv s_{t+1} - f_t^1$, yields

$$\begin{aligned} ER_{t+1} &= \alpha + (\beta - 1)\, p_t^1 + \varepsilon_{t+1}. \\ \overline{ER} &= \alpha + (\beta - 1)\, \overline{p} \end{aligned} \tag{2}$$

$ER_{t+1}$ corresponds to the payoff of a long forward position in the foreign currency entered at time $t$ and maturing at $t+1$. Analogously, $-ER_{t+1}$ corresponds to a short position. $\overline{ER}$ is the average excess return that enters the numerator of the Sharpe ratio with $\overline{p}$ denoting the mean of the lagged forward premium. Note that, since the Fama-regression is usually estimated by OLS, the average residual is zero by assumption. If UIP holds, excess returns should not be significantly different from zero. This is typically tested by investigating whether the restriction $\beta = 1$ holds, sometimes jointly tested with $\alpha = 0$. Clearly, an average excess return of zero does not only result if $\alpha$ and $\beta$ exactly correspond to their theoretical values but for any values that satisfy $\alpha = -(\beta - 1)\overline{p}$. Hence, both parameters might deviate from their hypothesized values but still not allow for a non-zero excess return. In fact, this illustrates that if one of the parameters deviates from its theoretical value, the other one should do so as well such that the excess return growing with the deviation of the first parameter is reduced by an opposing deviation of the other one. This offsetting relationship suggests that as a minimum in periods with $\beta < 1$, $\alpha$ should have the same sign as the forward premium, while the sign of $\alpha$ should be opposite if $\beta > 1$. For judging whether speculation profits on UIP deviations by static trading positions are significantly different from zero, one might rather test whether $\alpha$ and $\beta$ satisfy the aforementioned condition, i.e. whether $\beta = 1 - \alpha/\overline{p}$, instead of $\beta = 1$ and $\alpha = 0$

***Test 1:*** *For the parameters of the Fama-regression* (1), *we test the hypothesis* $\beta = 1 - \alpha/\overline{p}$. *If this restriction does not hold, non-zero excess returns can be generated by a static long or short position in the foreign currency.*

Furthermore, given the evidence that $\beta$ varies widely over time, see e.g. Baillie and Bollerslev (2000), this should also indicate that variability in $\alpha$ is found. In terms of speculative efficiency, one should find that $\alpha$ and $(\beta - 1)\overline{p}$ are negatively correlated.

Given that the hypothesized relationship between $\alpha$ and $(\beta - 1)\overline{p}$ holds, disregarding $\alpha$ in the analysis of speculative efficiency leads to overestimation of UIP deviations since the offsetting effect of $\alpha$ on $(\beta - 1)\overline{p}$ would be neglected.

***Prediction 1a:*** *Given that the null hypothesis of Test 1 holds, disregarding $\alpha$ leads to overestimation of excess returns from UIP deviations. If the hypothesis is rejected, underestimation occurs.*

Thus, neglecting the constant in the analysis might cause misleading conclusions about economic significance.

### 3.2 Exploiting the Forward Bias: Carry-Trade

As a next step we investigate a simple but widely used trading strategy aimed at exploiting the forward bias. The finding of previous research that the Fama-regression $\beta$ is usually below unity suggests, together with presuming that $\alpha = 0$, to base speculative trading strategies on the sign of the forward premium. Evidence of the slope coefficient being less than unity, indicates that the higher interest rate currency tends to not depreciate as much as predicted by UIP or might even appreciate. A simple approach aiming at exploiting this finding is to go long in the higher interest rate currency and short in the low interest rate currency. This strategy, often termed 'carry-trade', is very popular among market participants as talking to practitioners and reading research and strategy reports published by financial institutions reveals.[2] Even more, in a document published by the Bank for International Settlements, Galati and Melvin (2004) provide evidence that carry trades are a key driver for the surge in foreign exchange trading.

[2] In particular, we rely on conversations with practitioners and reports from Deutsche Bank and Lehman Brothers. Further references outlining that the bias is viewed as exploitable by traders are given in e.g. Chinn (2006), p.10.

Excess returns from the carry-trade can be written in terms of $ER$: one would sell forward the foreign currency at time $t$ if $p_t^1 > 0$ and realize a payoff of $-ER_{t+1}$ at $t+1$; a long position is entered if $p_{t+1} < 0$ yielding a payoff of $ER_{t+1}$. To indicate that a variable $i$ is adjusted for the position taken, with the position being opposite to the sign of the forward premium, we use the superscript $'$, that is $i' = -\text{sgn}\left[p_t^1\right] i$ with $\text{sgn}\left[\cdot\right]$ denoting the signum function. Hence, the excess return from the carry trade and can be written as

$$\begin{aligned} CT_{t+1} &= ER'_{t+1} = \alpha' + (\beta - 1)\left(p_t^1\right)' + \varepsilon'_{t+1} \\ \overline{CT} &= \overline{\alpha'} + (\beta - 1)\,\overline{p'} + \overline{\varepsilon'} \end{aligned} \tag{3}$$

Note that, if over the investigated period the sign of the premium changes at least once, $\alpha'$ is not a constant and the mean of $\varepsilon'$ is not zero. Therefore, the respective means are components of the average carry.trade excess return, $\overline{CT}$, which is the numerator of the Sharpe ratio. Excess returns from the carry-trade are not significantly different from zero if the restriction $\beta = 1 - (\overline{\alpha'} + \overline{\varepsilon'})/\overline{p'}$ holds on the parameters in regression (1).

***Test 2:*** *For the parameters of the Fama-regression* (1)*, we test the hypothesis* $\beta = 1 - (\overline{\alpha'} + \overline{\varepsilon'})/\overline{p'}$. *If this restriction does not hold, non-zero excess returns can be generated by the carry-trade.*

Note that also if (one sets) $\alpha = 0$, one would not necessarily test for whether $\beta = 1$. If the minimum relationship between $\alpha$ and $(\beta-1)\overline{p}$ hypothesized in the previous subsection holds, i.e. in periods with $\beta < 1$, $\alpha$ has the same sign as the forward premium, while the sign of $\alpha$ is opposite if $\beta > 1$, the following can be said for $\overline{CT}$ in general: in periods with $\beta < 1$, it turns out that $\overline{\alpha'} < 0$, $\overline{p'} < 0$, and therefore $(\beta - 1)\overline{p'} > 0$, again highlighting the offsetting relationship between the first and the last term. Thus, one generates profits from $\beta$ being lower than unity, but profits are eroded by the constant. Note, that if $\beta > 1$ the reverse is true, but that it is not necessarily the case that one makes a loss even though the strategy is motivated by trading on a $\beta < 1$. If the minimum requirement for $\alpha$ and $(\beta - 1)\overline{p}$ does not hold, underestimation of carry-trade excess returns occurs if $\beta < 1$ and overestimation if $\beta > 1$.

***Prediction 2a:*** *Depending on whether (i) the minimum requirement for the relationship between $\alpha$ and $(\beta - 1)\overline{p}$ holds and (ii) the sign of $\beta$, disregarding $\alpha$ leads to an incorrect assessment of excess returns. In particular, if the relationship holds, one would overestimate (underestimate) carry-trade excess returns if $\beta < 1$ ($\beta > 1$). The opposite occurs if the relationship does not hold.*

Again, neglecting the constant potentially causes misleading conclusions about speculative efficiency.

### 3.3 Technical Trading Rules: Momentum

While the value of technical analysis is heavily doubted by many financial economists, empirical evidence on decision rules employed by professional foreign exchange market participants suggests that chartist approaches are widely used in practice, in particular for short horizons; see e.g. Taylor and Allen (1992), Menkhoff (1997), and Cheung and Chinn (2001). Related research concentrates on widely used trend-following approaches based on filters, moving averages, and momentum. The majority of evidence suggests the profitability of such trading rules; for recent work see e.g. Osler (2001), Okunev and White (2003), Schulmeister (2006) and the references therein.

In the present paper, we rely on the basic momentum rule with the $k$-days momentum being defined as the difference in the current exchange rate and the price $k$ days ago: $M_t^k = s_t - s_{t-k}$.

The trading rule is to go long in the foreign currency when $M_t^k$ turns from negative to positive and to go short when momentum becomes negative. Thus, unlike the carry-trade discussed in the previous subsection, the momentum rule does not explicitly aim at exploiting deviations from UIP and its performance cannot be directly inferred from the UIP regression. However, since momentum trading decisions are based on the extrapolation of trends from past prices, a link between the profitability of momentum trading and UIP can be established. Long and pronounced trends leading to high profits of momentum trading should be captured by the parameters of the Fama-regression while (a sequence of) short-lived trends, which traders might still be able to capitalize on, might not be captured since opposing trends cancel out over time. One approach to improve on this issue might be to investigate UIP using higher frequency data than typically applied and a shorter observation period.

Looking at the regressions (1) and (2), shows that whether a trend in the exchange rate evolves depends on $\alpha$ and $\beta$. Starting from the standard UIP test, $\alpha = 0$ and $\beta = 1$, suggests that as long as the null hypothesis holds, trends allowing for non-zero excess returns are less pronounced. However, based only on this test, rejecting the null is not necessarily indicative of a trend. As outlined above, both $\alpha$ and $\beta$ might deviate from the hypothesized values but might (and even should) exhibit offsetting effects. A trend and therefore non-zero excess returns from trend-chasing can therefore be only expected if one can (also) reject the speculative UIP test proposed above, i.e. $\beta = 1 - \alpha/\overline{p}$. Thus, in general, momentum profits are expected to be larger in periods in which the UIP tests are rejected than in periods in which they are not. In particular, the speculative UIP test should be better suited for identifying high profit periods.

***Prediction 3:*** *Momentum-trading is less profitable in periods in which standard and speculative UIP tests indicate that the null hypotheses hold as compared to situations in which they* *can be rejected. The speculative UIP test is better capable of identifying periods of high profits.*

# 4 Deriving Trader Inaction Ranges

In this section we extend the analysis of the trading approaches directly linked to the UIP regression, i.e. the static long (short) position and the carry-trade. For assessing the economic significance of excess returns we derive trader inaction ranges implied by limits to speculation in currency markets as suggested by Lyons (2001). First, we directly follow Lyons (2001) in that we restrict the analysis to investigating the role of $\beta$. Subsequently we derive the bounds for UIP deviations including $\alpha$ and highlight the consequences of disregarding the constant. Technical details are left for appendix Appendix A. Furthermore, we derive the bounds of the inaction range for the carry-trade strategy and again highlight the consequences of (dis-)regarding $\alpha$. Since the technical details are lengthy but straightforward and along the arguments for the UIP deviation bounds, we do not present them within the paper.

## 4.1 Inaction Range as Motivated by Lyons (2001)

In this subsection we derive the trader inaction range following the verbal description of Lyons (2001). Thus, for the moment we only consider $\beta$ and disregard $\alpha$. In this case, the excess return from UIP deviations, see equation (2), solely depends on how far $\beta$ deviates from unity. Given a positive forward premium, i.e. the domestic interest rate being higher than the foreign, $ER_{t+1}$ will be positive if $\beta > 1$ and negative if $\beta < 1$. A long (short) position in the foreign currency becomes increasingly profitable the further $\beta$ is above (below) unity. The reverse is true if the forward premium is negative. Hence, the arguments of Lyons (2001) suggest that, given that the forward premium is positive (negative), a long position attracts speculative capital if $\beta$ overshoots (undershoots) some upper (lower) bound, while a short position is attractive if $\beta$ undershoots (overshoots) the lower (upper) bound. Periods in which $\beta$ is within the bounds are characterized by trader inaction.

Apart from explicitly taking $\alpha$ into account below, we also consider the forward bias explicitly in the standard deviation of $ER$ and hence in the denominator of the Sharpe ratio. The variance of excess returns from UIP deviations is given by

$$\sigma^2_{ER} = (\beta - 1)^2\sigma^2_p + \sigma^2_\varepsilon + 2(\beta - 1)\mathrm{cov}_{p,\varepsilon} \tag{4}$$

with $\sigma_i$ denoting the standard deviation of variable $i$ and $\mathrm{cov}_{j,k}$ the covariance of variables $j$ and $k$. Since the Fama-regression parameters are estimated by OLS, the residuals are orthogonal to the premium by assumption. Setting $\alpha = 0$ and combining equations (2) and (4), the Sharpe ratio, being defined as the fraction of excess return per standard deviation, can be written as

$$SR^{ER,\alpha=0} = \frac{(\beta - 1)\,\overline{p}}{\sqrt{(\beta - 1)^2\sigma^2_p + \sigma^2_\varepsilon}}. \tag{5}$$

Looking at the Sharpe ratio, the numerator changes with $\beta$ deviating from unity proportionally to $\overline{p}$. However, $\beta$ also enters the denominator and the standard deviation increases as $\beta$ deviates from the theoretical value of unity. Thus, for increasing deviations of $\beta$, the Sharpe ratio changes monotonically but only decreasingly, and therefore, from a pure mathematical point of view, one could say that speculation is limited since the Sharpe ratio is bounded; for the partial derivatives and the limits see appendix A.1. It is an empirical matter whether the limiting Sharpe ratios as well as the $\beta$s necessary to come close the limits are economically reasonable.

In the spirit of Lyons (2001), we derive bounds for the inaction range in terms of $\beta$. From equation (7) one can derive the $\beta$s necessary to achieve a certain Sharpe ratio threshold, $SR_{th}$, by rearranging and solving the resulting quadratic equation.

$$\beta\left[SR_{th}, \alpha = 0\right] = \frac{\pm SR_{th}\sigma_\varepsilon}{\sqrt{\left(\overline{p}^2 - SR_{th}^2\sigma_p^2\right)}} + 1. \tag{6}$$

The resulting inaction range exhibits the following interesting features. Considering the $\beta$ for which the Sharpe ratio is zero, which we call the center of the range $\beta^c[0, \alpha = 0]$, corresponds to the theoretic value of unity. Around this value the upper and lower bound are symmetric, as suggested by Lyons (2001). The width of the inaction range increases with the Sharpe ratio threshold, due to the aforementioned effect of $\beta$ also entering the denominator; see appendix A.1. for the partial derivatives. Note that for very small $|\overline{p}|$ the bounds might not be defined, i.e. the Sharpe ratio threshold might be unreachable high.

## 4.2 Inaction Range for UIP Deviations

Along our arguments outlined in section 3, we stress the importance of including $\alpha$ in the assessment of economic significance. Thus, the excess return from UIP deviations is as given in equation (2) and the standard deviation can be taken from equation (4) since $\alpha$ as a constant has no impact on the variance. The Sharpe ratio therefore is

$$SR^{ER} = \frac{\alpha + (\beta - 1)\,\overline{p}}{\sqrt{(\beta - 1)^2\sigma_p^2 + \sigma_\varepsilon^2}}. \tag{7}$$

Compared to presuming $\alpha = 0$, a non-zero $\alpha$ impacts the Sharpe ratio by a change proportional to the standard deviation; see appendix A.2.. Given that the relationship between $\alpha$ and $(\beta - 1)\overline{p}$ formulated in Test 1 holds, the Sharpe ratios implied by equation (7) will be lower than those from equation (5) where $\alpha$ was set to zero; see above Prediction 1a.

Furthermore, the Sharpe ratio is not a monotonic function of $\beta$ anymore; while the Sharpe ratio is still bounded (with the same limits), the Sharpe ratio does not converge to its extremes with $\beta$ approaching plus or minus infinity, rather the global optimum occurs when $\beta = (\overline{p}\sigma_\varepsilon)/(\alpha\sigma_p) + 1$. This might be important for periods in which the premium is very low in terms of absolute values.

For a given Sharpe ratio threshold, $SR_{th}$, the respective $\beta$-bounds of the inaction range can be calculated from rearranging equation (7) and solving the resulting quadratic equation. The bounds are given by

$$\beta\left[SR_{th}, \alpha\right] = \frac{-\alpha\overline{p} \pm SR_{th}\sqrt{\alpha^2\sigma_p^2 + \sigma_\varepsilon^2\left(\overline{p}^2 - SR_{th}^2\sigma_p^2\right)}}{\overline{p}^2 - SR_{th}^2\sigma_p^2} + 1. \tag{8}$$

We now find that the center of the range, i.e. the $\beta$ for which the Sharpe ratio is zero, corresponds to $\beta^c[0, \alpha] = 1 - \alpha/\overline{p}$. Hence, for non-zero values of $\alpha$, the inaction range is not centered around unity, the UIP-theoretical value for $\beta$. Rather the center of the inaction range corresponds to the $\beta$-value that we argued in section 3 to be the hypothesized value for testing UIP deviations.

Furthermore, the bands are not symmetric around the center, i.e. the distance of the upper bound to the center can be different from the distance between the lower bound to the center. For the technical details of the aforementioned see appendix A.2. Finally, as for the bounds derived in the previous subsection, it might be possible that the Sharpe ratio threshold is unreachable, resulting in the inaction range to be undefined.

The arguments put forward above suggest that neglecting $\alpha$ might have an impact on the interpretation of economic significance. Comparing the bounds derived with $\alpha = 0$ to those derived using the Fama-$\alpha$, a misinterpretation of economic significance might arise due to the fact that the inaction range the former differs from the latter in terms of the level of the range as well with respect to its shape. In combination with Prediction 1a we expect

***Prediction 1b:*** *Given that the null hypothesis of Test 1 holds, disregarding $\alpha$ might lead to incorrectly rejecting the trader inaction range bounds since excess returns are overestimated. If the hypothesis does not hold excess returns are underestimated and therefore rejection might not occur although it should.*

### 4.3 Inaction Range for the Carry-Trade

In section 3 we have introduced the widely-used 'carry-trade' strategy: based on the finding of past research that the Fama-$\beta$ is below unity and often even negative, one goes long a high interest rate currency and shorts a low interest rate currency. As in the previous subsection, we consider the Sharpe ratio and derive the trader inaction range therefrom. However, we abstain from presenting the technical details since the procedure is analogue to the previous subsection and the expressions are lengthy.

The excess return from the carry-trade was presented in equation (3) and corresponding variance is given by

$$\sigma^2_{CT} = \sigma^2_{\alpha'} + (\beta - 1)^2 \sigma^2_{p'} + \sigma^2_{\varepsilon'} + 2(\beta - 1)\mathrm{cov}_{\alpha',p'} + 2\mathrm{cov}_{\alpha',\varepsilon'} + 2(\beta - 1)\mathrm{cov}_{p',\varepsilon'}. \qquad (9)$$

Note that if the sign of the premium changes at least once, $\alpha'$ is not a constant and therefore also impacts on the standard deviation of carry trade returns. Furthermore, the covariances can be different from, although will typically be close to, zero. The Sharpe ratio of the carry-trade is thus given by $SR^{CT} = \overline{CT}/\sigma_{CT}$.

The bounds of the carry-trade inaction range for a given Sharpe ratio threshold can be calculated from rearranging $SR^{CT}$ and solving the following quadratic equation:

$$\begin{aligned}&(\beta-1)^2\left\{\overline{p'}^2 - SR_{th}^2\sigma_{p'}^2\right\} + (\beta-1)\left\{2\Big(\overline{\alpha' p'} + \overline{p'\varepsilon'} - SR_{th}^2\left(\text{cov}_{\alpha',p'} + \text{cov}_{p',\varepsilon'}\right)\Big)\right\}\\ &+\left\{\overline{\alpha'}^2 + \overline{\varepsilon'}^2 + 2\overline{\alpha'\varepsilon'} - SR_{th}^2\left(\sigma_{\alpha'}^2 + \sigma_{\varepsilon'}^2 + 2\text{cov}_{\alpha',\varepsilon'}\right)\right\}.\end{aligned} \tag{10}$$

The center of the inaction range is given by $\beta^c\,[0,\alpha] = 1 - (\overline{\alpha'} + \overline{\varepsilon'})/\overline{p'}$. This corresponds to the above argued value that one should test for to assess whether the carry-trade yields profits significantly different from zero. Note that the center of the range can also be different from zero even if $\alpha = 0$. Analogously to the inaction range derived in the previous subsection, the bounds can be asymmetric. Setting $\alpha$, and thereby also the corresponding covariances, to zero again impacts on the assessment of economic significance. Looking at the centers of the inaction ranges shows that the difference is $\beta^c[0,\alpha] - \beta^c[0,\alpha=0] = -\overline{\alpha'}/\overline{p'}$. Given that the minimum requirement for $\alpha$ and $(\beta-1)\overline{p}$ outlined in motivating Test 1 holds (i.e. in periods with $\beta < 1$, $\alpha$ has the same sign as the forward premium, while the sign of $\alpha$ is opposite if $\beta > 1$), results in $\beta^c[0,\alpha] < \beta^c[0,\alpha=0]$ if $\beta < 1$ and $\beta^c[0,\alpha] > \beta^c[0,\alpha=0]$ if $\beta > 1$. The reverse is true if the relationship does not hold. Thus, the levels of the inaction ranges resulting from setting $\alpha = 0$ and using the Fama-$\alpha$ might be substantially different and therefore mislead conclusions about economic significance. Based on previous empirical evidence that $\beta$ is typically less than unity, and given that offsetting effects between $\alpha$ and $(\beta-1)\overline{p}$ exist, this might be indicative that neglecting $\alpha$ results in an inaction range on a too high level and that therefore economic significance might be indicated although this is in fact not true. Based on the aforementioned and Prediction 2a, we expect

***Prediction 2b:*** *Disregarding $\alpha$ causes misleading conclusions with respect to the economic significance of carry-trade excess returns depending on (i) whether the minimum requirement for the relationship between $\alpha$ and $(\beta-1)\overline{p}$ holds and (ii) the sign of $\beta$. If the relationship* *holds, for periods in which $\beta < 1$, excess-returns would be overestimated potentially leading to incorrectly indicating that the lower bound is violated. If $\beta > 1$ excess-returns are under-estimated if disregarding $\alpha$, thereby potentially failing to indicate economic significance. The reverse is true if the relationship does not hold.*

# 5 Empirical Analysis

For our empirical analysis we use daily and monthly spot exchange rates and one-month forward premia provided by the Bank for International Settlements. The exchange rates considered are the US Dollar (USD) versus the Canadian Dollar (CAD), Swiss Franc (CHF), British Pound (GBP), Japanese Yen (JPY), Danish Krone (DKK), and German Mark (DEM).[3]
For the DEM the time series covers the period from December 1978 to December 1998, for all other currencies September 1977 to December 2005. Following arguments put forward in Lyons (2001) we use a Sharpe ratio threshold of 0.5 and assume that transaction costs are ten basis points per transaction.

## 5.1 Results

Table 1 reports results of the Fama-regression as commonly reported in previous literature. Standard tests of UIP suggest that $\alpha = 0$ is rejected for three out of six currencies, $\beta = 1$ for all currencies, and the joint hypothesis also for all currencies, at least at the 5 percent level. In contrast, Test 1, $\beta = 1 - \alpha/\overline{p}$, to assess whether UIP holds in a speculative sense, does not reject UIP in a single case. This indicates that the hypothesized offsetting relationship between $\alpha$ and $(\beta - 1)\overline{p}$ exists. Assessing the significance of carry-trade excess returns as proposed in Test 2, reveals mixed evidence: excess-returns are significantly different from zero

[3] We comment on other currencies in the subsection on the robustness of our results.

for CAD, GBP, and DKK while not so for the other currencies.

[Insert Table 1 about here.]

Based on previous evidence that $\beta$ varies over time, this should also be true for $\alpha$ if a relationship as hypothesized for Test 1 exists; in particular, $\alpha$ and $(\beta - 1)\overline{p}$ were argued to be negatively correlated. Based on rolling 60 month periods, Table 2 provides evidence that the Fama-regression estimates of both $\alpha$ and $\beta$ vary substantially over time. Furthermore, we find that $\alpha$ and $(\beta - 1)\overline{p}$ indeed exhibit high negative correlation, supporting that speculative efficiency concept.

[Insert Table 2 about here.]

Considering the relationship of between UIP deviations and the profitability of momentum trading reveals support for Prediction 3, as reported in Table 3. Schulmeister (2006) argues that typical lengths considered for such momentum rules vary between 3 and 40 days; we present results for a horizon of 20 days, however, the results are robust to changes in the specification. Based on daily data we analyze rolling 20-day windows (Panel A) and monthly aggregates over 60-month rolling windows (Panel B). We perform the standard UIP test ($\alpha = 0, \beta = 1$) and the speculative version ($\beta = 1 - \alpha/\overline{p}$) over the respective periods. As outlined above, the standard test is sufficient to identify some of the no-trend periods, but rejection is not necessarily indicative for a trend. Given the just presented evidence that an offsetting relationship between $\alpha$ and $\beta$ exists, $\alpha$ and $\beta$ might deviate from their theoretical values without allowing for speculative excess returns. Based on the standard test we report average daily profits over the rolling 20-day periods (Panel A) and the average annualized Sharpe ratios for rolling 60-month periods (Panel B), depending on whether in the respective periods the null hypothesis cannot be rejected (p-value $> 0.1$, $\overline{R^{std}_{p>0.1}}$, $\overline{SR^{std}_{p>0.1}}$) or can be rejected (p-value $\leq 0.1$, $\overline{R^{std}_{p\leq 0.1}}$, $\overline{SR^{std}_{p\leq 0.1}}$). Analogously, we do so far the speculative UIP test, denoted by superscript *spec*. The results of both categorizations suggest that momentum trading is more profitable in periods in which the UIP tests reject the null-hypothesis. However, as argued above, the speculative test performs better in identifying the high profit periods. Overall the results of the 20-day rolling period analysis suggests that the largest part of momentum trading profits is generated in periods in which UIP is rejected, while profits close to zero (*std*) or even losses (*spec*) are incurred if the hypotheses are not rejected. The results of the rolling 60-month analysis exhibit a similar pattern, however, less pronounced; this is due to the aforementioned effect of only capturing long-lived trends but failing to account for (a sequence of) short trends.

[Insert Table 3 about here.]

For assessing the economic significance of UIP deviations, Table 4 reports the corresponding trader inaction ranges. The first two columns repeat the Fama regression estimates, followed by the Sharpe ratios implied when setting $\alpha = 0$, see equation (5), and when using the Fama-$\alpha$, see equation (7). Having found that the speculative UIP test does not reject the null hypothesis, as expected in Prediction 1a, disregarding $\alpha$ leads to overestimating the excess returns realizable from UIP deviations by static long or short positions. The bounds derived when setting $\alpha = 0$ are symmetrically centered around unity while those derived when using the Fama-$\alpha$ are centered asymmetrically around $1 - \alpha/\overline{p}$ and do not even necessarily contain the theoretical value of unity. The differences in the inaction ranges (in particular of the level and less importantly of the shape) lead to inaccurate conclusions with respect to economic significance when disregarding $\alpha$: For $\alpha = 0$, as already reported above, the results always reject non-zero excess returns and indicate for the GBP and JPY even a significant violation of the lower bound, i.e. indicate a Sharpe ratio significantly above 0.5. Looking at the results calculated when taking $\alpha$ into account reveals that this finding is spurious, since using the

Fama-$\alpha$ no rejection of the null-hypotheses is found, i.e. Sharpe ratios are not significantly different from zero and the inaction range bounds hold. Thus, we find support for Prediction 1b that disregarding $\alpha$ cause misleading conclusions about economic significance.

[Insert Table 4 about here.]

This finding is visualized for the CAD in Figure 1. Panels A and B show the 60-month rolling Fama-$\beta$ coefficient and the corresponding bounds, calculated with $\alpha = 0$ and the Fama-$\alpha$ respectively. While the shape of the inaction range for $\alpha = 0$ is driven by the lagged forward premium (see Panel C), one clearly sees the influence of $\alpha$ (see Panel D) on the bounds taking the Fama-$\alpha$ into account.

[Insert Figure 1 about here.]

Overall, these results provide first support for speculative efficiency of currency markets, in that at least static trading positions do not allow for economically significant excess returns. A similar picture evolves when looking at the carry-trade results in table 5. Given the results on the speculative UIP test, as expected in Prediction 2a, disregarding $\alpha$ leads to overestimation of Sharpe ratios when $\beta < 1$. The bounds again differ in level and Shape with these differences resulting in inaccurate assessment of economic significance if $\alpha$ is disregarded: When setting $\alpha = 0$, $\beta = \beta^c$ is rejected for all currencies, while this is only the case for CAD, GBP, and DKK when taking $\alpha$ into account. With respect to the lower bound, the results with $\alpha = 0$ indicate violation for four out of six currencies while this is only true for the DKK. This again highlights the importance of considering $\alpha$ when evaluating the economic significance. Since recent papers provide evidence that diversification across multiple currencies improves the performance of bias-trading strategies, see Villanueva (Forthcoming) and Hochradl and Wagner (2006), we also consider an equally-weighted carry-trade portfolio based on the six currencies. Our results indicate that we cannot reject that the lower bound holds, i.e. the resulting Sharpe ratios are not significantly greater than 0.5. Thus, our findings suggests that the foreign exchange market is largely speculatively efficient as judged by the profitability of carry-trades. At first sight, the DKK seems to be an exception and we therefore take a closer look at the subsample results provided in the next subsection.

[Insert Table 5 about here.]

Thus, overall our results indicate that disregarding $\alpha$ distorts the evaluation of economic significance of UIP deviations. This effect is visualized for the CAD (Panels A and B) and the portfolio (Panels C and D) based on 60-month rolling periods in Figure 2.

[Insert Figure 2 about here.]

In general we find support for the foreign exchange market being speculatively efficient since trading on UIP deviations does not allow for economically significant excess returns.

### 5.2 Robustness

With respect to the robustness of our results we examine whether our conclusions remain the same when investigating other currencies, other forward-maturities, and subsamples.

First, apart from the currencies reported in the present paper, we have also analyzed a variety of others such as the Australian Dollar, New Zealand Dollar, Euro (all have been excluded because of short data availability), other European non-Euro currencies (Norwegian Krone, Swedish Krone), and further European pre-Euro currencies (French Franc, Italian Lira, etc.). The conclusions that can be drawn for these currencies are qualitatively equivalent to those reached in the paper and are therefore not reported due to space considerations.

Second, our conclusion of speculative efficiency is not dependent on the choice of forward rate maturities. The Bank for International Settlements (BIS) also provides data for three, six, and twelve month horizons. Repeating the analysis for this data, again points at speculative efficiency and the importance of taking $\alpha$ into account. Thus, we do not report these results as well.

[Insert Tables 6 and 7 about here.]

Finally, note that our results are robust over time. Tables 6 and 7 report inaction ranges for UIP deviations and carry-trades respectively. The results show, that disregarding $\alpha$ frequently misleads the assessment of economic significance for both trading approaches in that inaccurate rejection/non-rejection of null hypotheses is indicated. In general the conclusion of speculative efficiency is strengthened. With respect to UIP deviations we only find a single violation of the inaction range, the DEM in the first subsample. In periods in which the forward premium is (very close to) zero, the bands become extremely large (see GBP in subsmple 1) or are not defined (see DEM in subsample 2, CAD in subsample 3). Furthermore for the DEM, in subsample 2, the relationship between $\alpha$ and $(\beta - 1)\overline{p}$ does not even fulfill the minimum requirement. As a consequence, the inaction range calculated with the Fama-$\alpha$ results in the lower bound being greater than the upper bound, and the center of the range not lying within the two. Due to the absence of the offsetting relationship, in this situation, the Sharpe ratio of a long positions will be positive for any $\beta$ within the range but negative for $\beta$s outside.[4] The DEM results in the third subsample are relativeley extreme due to the short period of data availability.

Looking at the carry-trade results reveals that the DKK persistently allowed for higher Sharpe ratios than other currencies, however, economic significance can only be found in the first subsample. The carry-trade portfolio performed particularly well over the period from 1995

[4]This is also visible in the graph of the CAD inaction range in Figure 1 in Panel B around 1997/1998.

to 2005, consistent with the findings of Hochradl and Wagner (2006). However, as reported above, taking the full perspective, we do not find serious evidence against speculative efficiency for the equally-weighted portfolio as well.

## 6 Conclusion

Motivated by the concept of limits to speculation, we investigate the *economic* significance of deviations from uncovered interest parity (UIP) and the *speculative* efficiency of currency markets. Based on the 'Fama-regression', we suggest an alternative approach for testing UIP, encompassing static strategies, carry-trades, and a link to technical trading rules. Doing so reveals that the regression constant, $\alpha$, - while commonly disregarded - plays an important role. To judge economic significance, we derive trader inaction ranges implied by limits to speculation.

Overall our results suggest that the foreign exchange market is speculatively efficient. In particular we find that it is not possible to generate economically significant excess returns from UIP deviations, neither by a static trading approach or trading rules explicitly aimed at exploiting the forward bias. Furthermore, profits from trend chasing earned by technical traders are largely generated in relatively few and short subperiods in which UIP is rejected, and Sharpe ratios are not overwhelming over longer horizons.

Equally interesting as supporting that currency markets are speculatively efficient is the finding that the regression constant plays an important role: basing the analysis exclusively on $\beta$ and disregarding $\alpha$ distorts the assessment of economic significance and might mislead to concluding that the foreign exchange market is not speculatively efficient although it is.

# Appendix A. Technical Details

## A.1. Sharpe Ratio and Inaction Range Bounds when $\alpha = 0$

### A.1.a. Sharpe Ratio with $\alpha = 0$

Based on equation (7) we investigate the Sharpe ratio when setting $\alpha = 0$,

$$SR^{DEV} = \frac{(\beta - 1)\,\overline{p}}{\sqrt{(\beta - 1)^2\sigma_p^2 + \sigma_\varepsilon^2}}.$$

The first derivative of the Sharpe ratio with respect to $\beta$ is given by

$$\frac{\partial SR}{\partial \beta} = \frac{\overline{p}\sigma_\varepsilon^2}{\left[\sigma_\varepsilon^2 + (\beta - 1)^2\,\sigma_p^2\right]^{3/2}},$$

i.e. depending on the sign of $\overline{p}$, the Sharpe ratio increases ($\overline{p} > 0$) or decreases ($\overline{p} < 0$) monotonically.

The second derivative,

$$\frac{\partial^2 SR}{\partial \beta^2} = -\frac{3\,(\beta - 1)\,\overline{p}\sigma_\varepsilon^2\sigma_p^2}{\left[\sigma_\varepsilon^2 + (\beta - 1)^2\,\sigma_p^2\right]^{5/2}},$$

shows that, if $\overline{p} > 0$, the Sharpe ratio function is concave ($\frac{\partial^2 SR}{\partial \beta^2} < 0$) for $\beta > 1$, while it is convex ($\frac{\partial^2 SR}{\partial \beta^2} > 0$) for $\beta < 1$. The reverse is true if $\overline{p} < 0$.

Calculating the limits of the Sharpe ratio function with $\beta$ going to plus and minus infinity,

$$\lim_{\beta \to \infty} SR = \frac{\overline{p}\sqrt{\sigma_p^2}}{\sigma_p^2} \qquad \text{and} \qquad \lim_{\beta \to -\infty} SR = -\frac{\overline{p}\sqrt{\sigma_p^2}}{\sigma_p^2},$$

reveals that the Sharpe ratio is bounded.

### A.1.b. Inaction Range Bounds with $\alpha = 0$

Based on equation (6) we investigate the inaction range for UIP deviations when setting $\alpha = 0$,

$$\beta\left[SR_{th}, \alpha = 0\right] = \frac{\pm SR_{th}\sigma_{\varepsilon}}{\sqrt{\left(\overline{p}^{2} - SR_{th}^{2}\sigma_{p}^{2}\right)}} + 1.$$

To investigate the shape of the inaction range bounded by a upper $\beta$, $\beta^{u}$ and a lower $\beta$, $\beta^{l}$, we look at the derivatives with respect to the Sharpe ratio threshold, $SR_{th}$,

$$\text{upper bound:} \quad \frac{\partial \beta^{u}}{\partial SR_{th}} = \frac{\overline{p}^{2}\sigma_{\varepsilon}}{\left[\overline{p}^{2} - \sigma_{p}^{2}SR_{th}^{2}\right]^{3/2}} > 0 \quad \text{and} \quad \frac{\partial^{2}\beta^{u}}{\partial SR_{th}^{2}} = \frac{3\overline{p}^{2}\sigma_{\varepsilon}\sigma_{p}^{2}SR_{th}}{\left[\overline{p}^{2} - \sigma_{p}^{2}SR_{th}^{2}\right]^{5/2}} > 0,$$

$$\text{lower bound:} \quad \frac{\partial \beta^{l}}{\partial SR_{th}} = -\frac{\overline{p}^{2}\sigma_{\varepsilon}}{\left[\overline{p}^{2} - \sigma_{p}^{2}SR_{th}^{2}\right]^{3/2}} < 0 \quad \text{and} \quad \frac{\partial^{2}\beta^{l}}{\partial SR_{th}^{2}} = -\frac{3\overline{p}^{2}\sigma_{\varepsilon}\sigma_{p}^{2}SR_{th}}{\left[\overline{p}^{2} - \sigma_{p}^{2}SR_{th}^{2}\right]^{5/2}} < 0.$$

Thus, the upper bound is an increasing convex function of the Sharpe ratio threshold, while the lower bound is decreasing and concave.

## A.2. Sharpe Ratio and Inaction Range Bounds when using the Fama-$\alpha$

### A.2.a. Sharpe Ratio with Fama-$\alpha$

In order to investigate the change in the Sharpe ratio when incorporating the Fama-$\alpha$ instead of setting $\alpha = 0$, we look at the partial derivatives:

$$\frac{\partial SR}{\partial \alpha} = \frac{1}{\sqrt{\sigma_{\varepsilon}^{2} + (\beta - 1)^{2}\sigma_{p}^{2}}},$$

$$\frac{\partial^{2} SR}{\partial \alpha^{2}} = 0.$$

Hence, depending on the sign of $\alpha$, the Sharpe ratio changes inversely proportional to the standard deviation.

Looking at the partial derivatives of the Sharpe ratio with respect to $\beta$,

$$\frac{\partial SR}{\partial \beta} = \frac{\overline{p}\sigma_\varepsilon^2 - \alpha(\beta-1)\sigma_p^2}{\left[\sigma_\varepsilon^2 + (\beta-1)^2\sigma_p^2\right]^{3/2}},$$

$$\frac{\partial^2 SR}{\partial \beta^2} = -\frac{3(\beta-1)\overline{p}\sigma_\varepsilon^2\sigma_p^2 + \alpha\sigma_p^2[\sigma_\varepsilon^2 - 2(\beta-1)^2\sigma_p^2]}{\left[\sigma_\varepsilon^2 + (\beta-1)^2\sigma_p^2\right]^{5/2}},$$

reveals that the function is non-monotonic. While the Sharpe ratio is still bounded with the same limits as given above (see appendix A.2.a.), the global optimum, i.e. $\partial SR/\partial\beta = 0$, is not reached with $\beta$ going to plus or minus infinity but when $\beta = (\overline{p}\sigma_\varepsilon)/(\alpha\sigma_p) + 1$.

### A.2.b. Inaction Range Bounds with Fama-$\alpha$

To investigate the impact of including $\alpha$ in the assessment of economic significance, we consider the partial derivatives of the inaction range bounds with respect to $\alpha$:

upper bound:

$$\frac{\partial \beta^u}{\partial \alpha} = \frac{-\overline{p} + \frac{\alpha\sigma_p^2 SR_{th}}{\sqrt{\alpha^2\ \sigma_p^2 + \sigma_\varepsilon^2(\overline{p}^2 - \sigma_p^2 SR_{th}^2)}}}{\overline{p}^2 - \sigma_p^2 SR_{th}^2} \qquad \text{and} \qquad \frac{\partial^2 \beta^u}{\partial \alpha^2} = \frac{\sigma_\varepsilon^2\sigma_p^2 SR_{th}}{\left[\sigma_\varepsilon^2(\overline{p}^2 - \sigma_p^2 SR_{th}^2) + \alpha^2\sigma_p^2\right]^{3/2}} > 0$$

lower bound:

$$\frac{\partial \beta^l}{\partial \alpha} = \frac{-\overline{p} - \frac{\alpha\sigma_p^2 SR_{th}}{\sqrt{\alpha^2\ \sigma_p^2 + \sigma_\varepsilon^2(\overline{p}^2 - \sigma_p^2 SR_{th}^2)}}}{\overline{p}^2 - \sigma_p^2 SR_{th}^2} \qquad \text{and} \qquad \frac{\partial^2 \beta^l}{\partial \alpha^2} = -\frac{\sigma_\varepsilon^2\sigma_p^2 SR_{th}}{\left[\sigma_\varepsilon^2(\overline{p}^2 - \sigma_p^2 SR_{th}^2) + \alpha^2\sigma_p^2\right]^{3/2}} < 0.$$

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Table 1: Fama Regression Results and Tests for the Significance of UIP Deviations and Carry Trades

| | $\alpha$ | $(\mathrm{SE}_\alpha)$ | $\beta$ | $(\mathrm{SE}_\beta)$ | $\overline{p}$ | $\beta\overline{p}$ | p$[\alpha=0]$ | p$[\beta=1]$ | p$[\alpha=0,\beta=1]$ | p$[\beta=1-\frac{\alpha}{\overline{p}}]$ | p$[\beta=1-\frac{\overline{\alpha'}+\overline{\varepsilon'}}{\overline{p'}}]$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAD | −0.0012 | (0.0009) | −1.3523 | (0.5609) | −0.0008 | 0.0011 | 0.1988 | 0.0000 | 0.0001 | 0.4511 | 0.0003 |
| CHF | 0.0055 | (0.0026) | −1.3069 | (0.6376) | 0.0028 | −0.0036 | 0.0386 | 0.0003 | 0.0015 | 0.6389 | 0.3677 |
| GBP | −0.0043 | (0.0021) | −2.7655 | (0.7972) | −0.0017 | 0.0047 | 0.0420 | 0.0000 | 0.0000 | 0.2224 | 0.0005 |
| JPY | 0.0094 | (0.0030) | −2.3744 | (0.8001) | 0.0030 | −0.0071 | 0.0020 | 0.0000 | 0.0002 | 0.7454 | 0.2757 |
| DKK | −0.0014 | (0.0020) | −0.9733 | (0.6196) | −0.0012 | 0.0012 | 0.4868 | 0.0016 | 0.0058 | 0.5604 | 0.0000 |
| DEM | 0.0018 | (0.0025) | −0.8440 | (0.7569) | 0.0016 | −0.0014 | 0.4815 | 0.0156 | 0.0458 | 0.5750 | 0.2260 |

Notes: Results are for 09/1977-12/2005 for CAD, CHF, GBP, JPY, DKK, and 12/1978-12/1998 for DEM. $\alpha$ and $\beta$ are the estimates of the Fama-regression with standard errors in parentheses. $\overline{p}$ denotes the average forward premium. p[$\cdot$] denotes the p-value for testing the hypothesis formulated in [$\cdot$]. The first three p-values are for standard hypotheses applied when testing UIP. The fourth corresponds to the test of speculative efficiency proposed in the present paper. The last tests whether excess returns from trading the forward bias are significantly different from zero. Superscript $'$ indicates that a variable is adjusted for the position taken in the strategy; $\varepsilon$ denotes the Fama-regression residual.

Table 2: Distribution of Fama-Regression Parameters over Rolling 60 Month Periods

| | Fama-$\alpha$ | | | Fama-$\beta$ | | | |
|---|---|---|---|---|---|---|---|
| | q=97.5% | q=50% | q=2.5% | q=97.5% | q=50% | q=2.5% | Corr$[\alpha, (\beta-1)\overline{p}]$ |
| CAD | 0.0042 | −0.0022 | −0.0108 | 0.3724 | −2.2937 | −6.3277 | −0.7446 |
| CHF | 0.0432 | 0.0109 | −0.0032 | 1.7490 | −4.1122 | −10.9364 | −0.9269 |
| GBP | 0.0059 | −0.0040 | −0.0233 | 6.5167 | −3.0734 | −9.8881 | −0.8976 |
| JPY | 0.0320 | 0.0088 | −0.0123 | 3.3347 | −2.9261 | −9.4188 | −0.9272 |
| DKK | 0.0151 | 0.0001 | −0.0139 | 3.4544 | −2.8530 | −6.7673 | −0.5903 |
| DEM | 0.0413 | 0.0045 | −0.0037 | 3.3129 | −1.2895 | −12.4177 | −0.9381 |

Notes: Results are for 60 month rolling windows over the period from 09/1977-12/2005 for CAD, CHF, GBP, JPY, DKK, and 12/1978-12/1998 for DEM. $q = (\cdot)\%$ denotes the $(\cdot)\%$-quantile of the distribution of the rolling $\alpha$ and $\beta$ Fama-regression estimates. The last term reports the correlation for the expression in $[\cdot]$, where $\overline{p}$ denotes the average forward premium.

Table 3: Deviations from UIP and the Performance of Momentum-Strategies

Panel A: Rolling 20-days average daily profits of momentum trading depending on whether UIP does or does not hold

| | $\overline{R}$ | | $\overline{R^{std}_{p>0.1}}$ | | $\overline{R^{spec}_{p>0.1}}$ | | $\overline{R^{std}_{p\leq0.1}}$ | | $\overline{R^{spec}_{p\leq0.1}}$ | | z[$\Delta\overline{R^{std}_p}$] | z[$\Delta\overline{R^{spec}_p}$] | z[$\overline{R^{std}_{p\leq0.1}} < \overline{R^{spec}_{p\leq0.1}}$] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAD | 7194 | 0.00007 | 6053 | −0.00001 | 6560 | −0.00008 | 1141 | 0.00047 | 634 | 0.00158 | 4.37 | 12.13 | 6.69 |
| CHF | 7218 | 0.00022 | 5781 | −0.00021 | 6362 | −0.00030 | 1437 | 0.00194 | 856 | 0.00407 | 8.69 | 15.49 | 6.15 |
| GBP | 7218 | 0.00016 | 5822 | −0.00022 | 6331 | −0.00028 | 1396 | 0.00175 | 887 | 0.00334 | 9.66 | 15.37 | 5.48 |
| JPY | 7105 | 0.00034 | 5510 | 0.00000 | 5975 | −0.00022 | 1595 | 0.00153 | 1130 | 0.00335 | 7.98 | 16.66 | 6.96 |
| DKK | 7217 | 0.00024 | 5793 | −0.00009 | 6367 | −0.00023 | 1424 | 0.00157 | 850 | 0.00377 | 7.85 | 16.53 | 7.42 |
| DEM | 5083 | 0.00029 | 3980 | 0.00001 | 4485 | −0.00017 | 1103 | 0.00130 | 598 | 0.00375 | 4.85 | 12.71 | 6.49 |

Panel B: Rolling 60-month Sharpe ratios of momentum trading depending on whether UIP does or does not hold

| | $\overline{SR}$ | | $\overline{SR^{std}_{p>0.1}}$ | | $\overline{SR^{spec}_{p>0.1}}$ | | $\overline{SR^{std}_{p\leq0.1}}$ | | $\overline{SR^{spec}_{p\leq0.1}}$ | | z[$\Delta\overline{SR^{std}_p}$] | z[$\Delta\overline{SR^{spec}_p}$] | z[$\overline{SR^{std}_{p\leq0.1}} < \overline{SR^{spec}_{p\leq0.1}}$] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAD | 280 | 0.3220 | 94 | −0.0209 | 216 | 0.2593 | 186 | 0.4953 | 64 | 0.5337 | 10.01 | 3.86 | 0.55 |
| CHF | 280 | 0.4501 | 124 | 0.2336 | 225 | 0.3623 | 156 | 0.6221 | 55 | 0.8093 | 11.37 | 12.51 | 5.09 |
| GBP | 280 | 0.2746 | 159 | 0.2142 | 247 | 0.2501 | 121 | 0.3540 | 33 | 0.4580 | 4.15 | 5.28 | 2.59 |
| JPY | 280 | 0.7788 | 143 | 0.6804 | 251 | 0.7522 | 137 | 0.8815 | 29 | 1.0086 | 5.80 | 4.61 | 2.15 |
| DKK | 280 | 0.5531 | 156 | 0.3941 | 215 | 0.4367 | 124 | 0.7531 | 65 | 0.9383 | 7.24 | 9.36 | 3.02 |
| DEM | 181 | 0.6157 | 101 | 0.3897 | 149 | 0.4945 | 80 | 0.9009 | 32 | 1.1798 | 10.85 | 13.44 | 5.05 |

Notes: Results are over the period from 09/1977-12/2005 for CAD, CHF, GBP, JPY, DKK, and 12/1978-12/1998 for DEM. The number of periods is given in the first column of each block. *std.* denotes the standard UIP test, i.e. $\alpha = 0, \beta = 1$, *spec* denotes the speculative efficiency UIP test, i.e. $\beta = 1 - \alpha/\overline{p}$. $\alpha$ and $\beta$ are the estimates from the Fama-regression. $\overline{p}$ denotes the average forward premium. p refers to the p-values of the respective tests. z[$\cdot$] denotes the z-statistic for [$\cdot$].

*Panel A:* Rolling 20-days periods are considered.$\overline{R}$ denotes the average profits over the rolling periods. $\Delta\overline{R}$ refers to the difference in profits depending on the categorization based on p.

*Panel B:* Rolling 60-month periods are considered. $\overline{SR}$ denotes the average Sharpe ratio over the rolling periods. $\Delta\overline{SR}$ refers to the difference in Sharpe ratios depending on the categorization based on p.

Table 4: Trader Inaction Ranges and Sharpe Ratios for UIP Deviations

| | Fama-regression | | Implied SR | | Bounds with $\alpha = 0$ | | | Bounds with Fama-$\alpha$ | | | Inference, $\alpha = 0$ / $\alpha$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\alpha$ (SE$_\alpha$) | $\beta$ (SE$_\beta$) | $\alpha = 0$ | Fama-$\alpha$ | $\beta^u$ (p[$\beta < \beta^u$]) | $\beta^c$ (p[$\beta = \beta^c$]) | $\beta^l$ (p[$\beta > \beta^l$]) | $\beta^u$ (p[$\beta < \beta^u$]) | $\beta^c$ (p[$\beta = \beta^c$]) | $\beta^l$ (p[$\beta > \beta^l$]) | $\beta^u$ | $\beta^c$ | $\beta^l$ |
| CAD | −0.0012 | −1.3523 | 0.4108 | 0.1402 | 3.9011 | 1.0000 | −1.9011 | 2.2618 | −0.5492 | −3.6129 | n./n. | r./n. | n./n. |
| | (0.0009) | (0.5609) | | | (1.0000) | (0.0000) | (0.8357) | (0.9994) | (0.4511) | (0.9694) | | | |
| CHF | 0.0055 | −1.3069 | −0.6052 | −0.0870 | 2.8943 | 1.0000 | −0.8943 | 0.8946 | −0.9753 | −2.9493 | n./n. | r./n. | n./n. |
| | (0.0026) | (0.6376) | | | (1.0000) | (0.0003) | (0.259) | (0.999) | (0.6389) | (0.9859) | | | |
| GBP | −0.0043 | −2.7655 | 0.7104 | 0.2250 | 3.6063 | 1.0000 | −1.6063 | 0.9925 | −1.5726 | −4.3044 | n./n. | r./n. | r./n. |
| | (0.0021) | (0.7972) | | | (1.0000) | (0.0000) | (0.0734) | (0.9999) | (0.2224) | (0.93) | | | |
| JPY | 0.0094 | −2.3744 | −0.9958 | −0.0604 | 2.6610 | 1.0000 | −0.6610 | −0.5106 | −2.1697 | −3.9122 | n./n. | r./n. | r./n. |
| | (0.003) | (0.8001) | | | (1.0000) | (0.0000) | (0.0165) | (0.9985) | (0.7454) | (0.9903) | | | |
| DKK | −0.0014 | −0.9733 | 0.2541 | 0.1107 | 5.0729 | 1.0000 | −3.0729 | 3.8325 | −0.1136 | −4.3596 | n./n. | r./n. | n./n. |
| | (0.002) | (0.6196) | | | (1.0000) | (0.0016) | (0.9996) | (0.9984) | (0.5604) | (0.9739) | | | |
| DEM | 0.0018 | −0.8440 | −0.3055 | −0.1252 | 4.0840 | 1.0000 | −2.0840 | 2.9328 | −0.0885 | −3.2642 | n./n. | r./n. | n./n. |
| | (0.0025) | (0.7569) | | | (1.0000) | (0.0156) | (0.9486) | (0.9961) | (0.575) | (0.9485) | | | |

Notes: Results are for 09/1977-12/2005 for CAD, CHF, GBP, JPY, DKK, and 12/1978-12/1998 for DEM. The first two columns give the Fama-regression estimates of $\alpha$ and $\beta$ with standard errors in parentheses. Implied SR denotes the Sharpe ratios of a long position in the foreign currency implied when setting $\alpha = 0$, see equation (5), and using the Fama-$\alpha$, see equation (7); note that the latter corresponds to the realized Sharpe ratio. Based on equation (8) and a Sharpe ratio threshold of 0.5, the upper and lower bound of the inaction range for UIP deviations are calculated, first setting $\alpha = 0$, $\left(\beta^u[0.5, \alpha = 0], \beta^l[0.5, \alpha = 0]\right)$, second using $\alpha$ from the Fama regression, $\left(\beta^u[0.5, \alpha], \beta^l[0.5, \alpha]\right)$. $\beta^c[0, \cdot]$ denotes the center of the range. The values in parentheses are the p-values for the tests formulated in $[\cdot]$. The last three columns summarize the findings by indicating whether the null hypotheses that the bounds hold are rejected (r.) or not (n.) based on using $\alpha = 0$/Fama-$\alpha$.

Table 5: Trader Inaction Ranges and Sharpe Ratios for Carry-Trades

| | Fama-regression | | Implied SR | | Bounds with $\alpha = 0$ | | | Bounds with Fama-$\alpha$ | | | Inference, $\alpha = 0$ / $\alpha$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\alpha$ (SE$_\alpha$) | $\beta$ (SE$_\beta$) | $\alpha = 0$ | Fama-$\alpha$ | $\beta^u$ (p[$\beta < \beta^u$]) | $\beta^c$ (p[$\beta = \beta^c$]) | $\beta^l$ (p[$\beta > \beta^l$]) | $\beta^u$ (p[$\beta < \beta^u$]) | $\beta^c$ (p[$\beta = \beta^c$]) | $\beta^l$ (p[$\beta > \beta^l$]) | $\beta^u$ | $\beta^c$ | $\beta^l$ |
| CAD | −0.0012 | −1.3523 | 0.7198 | 0.6085 | 2.7759 | 1.0868 | −0.5961 | 2.4011 | 0.7093 | −0.9793 | n./n. | r./r. | r./n. |
| | (0.0009) | (0.5609) | | | (1.0000) | (0.0000) | (0.0893) | (1.0000) | (0.0003) | (0.2532) | | | |
| CHF | 0.0055 | −1.3069 | 0.5359 | 0.1826 | 1.9280 | 0.3884 | −1.1907 | 0.8139 | −0.7317 | −2.3319 | n./n. | r./n. | n./n. |
| | (0.0026) | (0.6376) | | | (1.0000) | (0.0082) | (0.4278) | (0.9995) | (0.3677) | (0.9456) | | | |
| GBP | −0.0043 | −2.7655 | 0.9975 | 0.6676 | 3.4693 | 1.3877 | −0.6676 | 2.1045 | 0.0226 | −2.0558 | n./n. | r./r. | r./n. |
| | (0.0021) | (0.7972) | | | (1.0000) | (0.0000) | (0.0044) | (1.0000) | (0.0005) | (0.187) | | | |
| JPY | 0.0094 | −2.3744 | 1.0258 | 0.2759 | 2.4248 | 0.8752 | −0.6818 | 0.0617 | −1.5008 | −3.0960 | n./n. | r./n. | r./n. |
| | (0.003) | (0.8001) | | | (1.0000) | (0.0001) | (0.0176) | (0.9987) | (0.2757) | (0.8161) | | | |
| DKK | −0.0014 | −0.9733 | 0.8864 | 0.8500 | 4.9498 | 2.7134 | 0.6257 | 4.8025 | 2.5633 | 0.4740 | n./n. | r./r. | r./r. |
| | (0.002) | (0.6196) | | | (1.0000) | (0.0000) | (0.0052) | (1.0000) | (0.0000) | (0.0101) | | | |
| DEM | 0.0018 | −0.8440 | 0.3753 | 0.2697 | 2.1134 | 0.4348 | −1.2756 | 1.7534 | 0.0747 | −1.6413 | n./n. | r./n. | n./n. |
| | (0.0025) | (0.7569) | | | (0.9999) | (0.0925) | (0.7155) | (0.9996) | (0.226) | (0.8534) | | | |
| Port. | 0.0017 | −1.7335 | 0.7378 | 0.6483 | 3.1655 | 1.1857 | −0.7819 | 2.8207 | 0.8379 | −1.1383 | n./n. | r./r. | r./n. |
| | (0.0012) | (0.6204) | | | (1.0000) | (0.0000) | (0.0630) | (1.0000) | (0.000) | (0.1690) | | | |

Notes: Results are for 09/1977-12/2005 for CAD, CHF, GBP, JPY, DKK, and 12/1978-12/1998 for DEM. Port. gives the results for an equally weighted portfolio based on the aforementioned currencies. The first two columns give the Fama-regression estimates of $\alpha$ and $\beta$ with standard errors in parentheses. Implied SR denotes the Sharpe ratios of the carry-trade implied when setting $\alpha = 0$ and using the Fama-$\alpha$; note that the latter corresponds to the realized Sharpe ratio. Based on equation (10) and a Sharpe ratio threshold of 0.5, the upper and lower bound of the inaction range for the carry-trade are calculated, first setting $\alpha = 0$, $\left(\beta^u[0.5, \alpha = 0], \beta^l[0.5, \alpha = 0]\right)$, second using $\alpha$ from the Fama regression, $\left(\beta^u[0.5, \alpha], \beta^l[0.5, \alpha]\right)$. $\beta^c[0, \cdot]$ denotes the center of the range. The values in parentheses are the p-values for the tests formulated in $[\cdot]$. The last three columns summarize the findings by indicating whether the null hypotheses that the bounds hold are rejected (r.) or not (n.) based on using $\alpha = 0$/Fama-$\alpha$.

Table 6: Trader Inaction Ranges and Sharpe Ratios for UIP Deviations: Robustness over Subsamples

| | Fama-regression | | Implied SR | | Bounds with $\alpha = 0$ | | | Bounds with Fama-$\alpha$ | | | Inference, $\alpha = 0$ / $\alpha$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\alpha$ ($SE_\alpha$) | $\beta$ ($SE_\beta$) | $\alpha = 0$ | Fama-$\alpha$ | $\beta^u$ ($p[\beta < \beta^u]$) | $\beta^c$ ($p[\beta = \beta^c]$) | $\beta^l$ ($p[\beta > \beta^l]$) | $\beta^u$ ($p[\beta < \beta^u]$) | $\beta^c$ ($p[\beta = \beta^c]$) | $\beta^l$ ($p[\beta > \beta^l]$) | $\beta^u$ | $\beta^c$ | $\beta^l$ |
| Subsample 1: 09/1977-12/1984 | | | | | | | | | | | | | |
| CAD | −0.0030 | −1.8407 | 0.3029 | −0.4542 | 6.1371 | 1.0000 | −4.1371 | −1.4630 | −6.1004 | −15.2296 | n./n. | r./n. | n./n. |
| CHF | 0.0243 | −3.8474 | −2.6580 | −0.6317 | 1.8832 | 1.0000 | 0.1168 | −1.8032 | −2.6954 | −3.6044 | n./n. | r./r. | r./n. |
| GBP | −0.0059 | −3.8659 | 0.1796 | −0.4406 | 89.1037 | 1.0000 | −87.1037 | −2.6386 | −15.8055 | −1621.8850 | n./n. | r./n. | n./n. |
| JPY | 0.0145 | −2.8820 | −1.6129 | −0.2987 | 2.1594 | 1.0000 | −0.1594 | −0.9951 | −2.1631 | −3.3795 | n./n. | r./n. | r./n. |
| DKK | −0.0113 | −2.2039 | 0.6961 | −0.4080 | 3.2266 | 1.0000 | −1.2266 | −1.8133 | −4.0818 | −7.0417 | n./n. | r./n. | n./n. |
| DEM | −0.0010 | −1.5978 | −1.1980 | −1.3059 | 2.0749 | 1.0000 | −0.0749 | 2.3099 | 1.2340 | 0.1599 | n./n. | n./r. | n./r. |
| Subsample 2: 01/1985-12/1994 | | | | | | | | | | | | | |
| CAD | −0.0047 | −2.2727 | 1.6875 | 0.4216 | 1.9329 | 1.0000 | 0.0671 | −0.5167 | −1.4550 | −2.4285 | n./n. | r./n. | r./n. |
| CHF | 0.0057 | 0.3936 | −0.0351 | 0.4778 | 11.4767 | 1.0000 | −9.4767 | 0.7717 | −7.8608 | −24.8800 | n./n. | n./n. | n./n. |
| GBP | −0.0035 | −2.1041 | 0.9569 | 0.6281 | 2.6111 | 1.0000 | −0.6111 | 1.5407 | −0.0668 | −1.6850 | n./n. | n./r. | n./n. |
| JPY | 0.0096 | −1.7463 | −0.3806 | 0.6464 | 4.6335 | 1.0000 | −2.6335 | −2.7728 | −6.4109 | −10.5506 | n./n. | n./r. | n./n. |
| DKK | 0.0086 | 1.6879 | −0.1598 | 0.6696 | 3.1761 | 1.0000 | −1.1761 | 6.9063 | 4.5707 | 2.4097 | n./n. | n./r. | n./n. |
| DEM | 0.0059 | 1.3861 | 0.0004 | 0.5687 | . | . | . | −5.4304 | −519.2500 | 8.2181 | . | . | . |
| Subsample 3: 01/1995-12/2005 | | | | | | | | | | | | | |
| CAD | 0.0017 | −3.3035 | −0.0599 | 0.2550 | . | . | . | . | . | . | . | . | . |
| CHF | 0.0121 | −5.4827 | −1.6548 | −0.2572 | 2.8948 | 1.0000 | −0.8948 | −2.5649 | −4.4751 | −6.4559 | n./n. | r./n. | r./n. |
| GBP | −0.0022 | −2.6505 | 0.6299 | 0.2717 | 3.8840 | 1.0000 | −1.8840 | 1.7869 | −1.0758 | −4.0056 | n./n. | r./n. | n./n. |
| JPY | 0.0055 | −2.0194 | −1.0433 | −0.4822 | 2.4368 | 1.0000 | −0.4368 | 0.8100 | −0.6238 | −2.0713 | n./n. | n./n. | n./n. |
| DKK | 0.0021 | −5.3781 | −0.3173 | −0.0587 | 11.7689 | 1.0000 | −9.7689 | 5.6633 | −4.1991 | −16.6367 | n./n. | r./n. | n./n. |
| DEM | 0.0353 | −21.3988 | −5.0456 | −0.3831 | 3.1243 | 1.0000 | −1.1243 | −17.5087 | −19.6983 | −21.9223 | n./n. | r./n. | r./n. |

Notes: Results are for the periods indicated above the tabulars. Note that for the DEM data is available only for 12/1978-12/1998 for DEM. The first two columns give the Fama-regression estimates of $\alpha$ and $\beta$ with standard errors in parentheses. Implied SR denotes the Sharpe ratios of a long position in the foreign currency implied when setting $\alpha = 0$, see equation (5), and using the Fama-$\alpha$, see equation (7); note that the latter corresponds to the realized Sharpe ratio. Based on equation (8) and a Sharpe ratio threshold of 0.5, the upper and lower bound of the inaction range for UIP deviations are calculated, first setting $\alpha = 0$, $(\beta^u[0.5, \alpha = 0], \beta^l[0.5, \alpha = 0])$, second using $\alpha$ from the Fama regression, $(\beta^u[0.5, \alpha], \beta^l[0.5, \alpha])$. $\beta^c[0, \cdot]$ denotes the center of the range. The last three columns indicate whether the null hypotheses that the bounds hold (as formulated in parentheses) are rejected (r.) or not (n.) based on using $\alpha = 0$/Fama-$\alpha$.

Table 7: Trader Inaction Ranges and Sharpe Ratios for Carry-Trades: : Robustness over Subsamples

| | Fama-regression | | Implied SR | | Bounds with $\alpha = 0$ | | | Bounds with Fama-$\alpha$ | | | Inference, $\alpha = 0$ / $\alpha$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\alpha$ ($SE_\alpha$) | $\beta$ ($SE_\beta$) | $\alpha = 0$ | Fama-$\alpha$ | $\beta^u$ (p[$\beta < \beta^u$]) | $\beta^c$ (p[$\beta = \beta^c$]) | $\beta^l$ (p[$\beta > \beta^l$]) | $\beta^u$ (p[$\beta < \beta^u$]) | $\beta^c$ (p[$\beta = \beta^c$]) | $\beta^l$ (p[$\beta > \beta^l$]) | $\beta^u$ | $\beta^c$ | $\beta^l$ |
| Subsample 1: 09/1977-12/1984 | | | | | | | | | | | | | |
| CAD | −0.0030 | −1.8407 | 0.7673 | 0.5308 | 2.9078 | 1.0491 | −0.8053 | 2.0846 | 0.1931 | −1.7193 | n./n. | r./r. | n./n. |
| CHF | 0.0243 | −3.8474 | 2.6580 | 0.6317 | 1.8832 | 1.0000 | 0.1168 | −1.8032 | −2.6954 | −3.6044 | n./n. | r./n. | r./n. |
| GBP | −0.0059 | −3.8659 | 0.9032 | 0.8236 | 3.0352 | 0.6284 | −1.8055 | 2.7336 | 0.2829 | −2.1942 | n./n. | r./r. | r./n. |
| JPY | 0.0145 | −2.8820 | 1.6338 | 0.4414 | 1.9649 | 0.8629 | −0.2463 | −0.7549 | −1.8724 | −3.0185 | n./n. | r./n. | r./n. |
| DKK | −0.0113 | −2.2039 | 1.4198 | 0.9750 | 3.3763 | 1.8890 | 0.4694 | 2.2366 | 0.6837 | −0.7970 | n./n. | r./r. | r./r. |
| DEM | −0.0010 | −1.5978 | 1.1980 | 1.3059 | 2.0749 | 1.0000 | −0.0749 | 2.3099 | 1.2340 | 0.1599 | n./n. | n./n. | n./n. |
| Port. | 0.0039 | −3.4234 | 1.4262 | 0.8860 | 2.2806 | 0.8437 | −0.6023 | 0.6589 | −0.7790 | −2.2471 | n./n. | r./r. | r./n. |
| Subsample 2: 01/1985-12/1994 | | | | | | | | | | | | | |
| CAD | −0.0047 | −2.2727 | 1.7717 | 0.5335 | 2.0441 | 1.1127 | 0.1875 | −0.3117 | −1.2479 | −2.2072 | n./n. | r./n. | r./n. |
| CHF | 0.0057 | 0.3936 | −0.1329 | −0.1959 | 2.1702 | −0.2558 | −2.7512 | 1.8826 | −0.5720 | −3.0834 | n./n. | n./n. | n./n. |
| GBP | −0.0035 | −2.1041 | 1.0790 | 0.7564 | 2.9728 | 1.3551 | −0.2442 | 1.9408 | 0.3267 | −1.2776 | n./n. | n./n. | n./n. |
| JPY | 0.0096 | −1.7463 | 0.4030 | −0.1046 | 3.1698 | 0.4591 | −2.2854 | 0.4588 | −2.3288 | −5.1432 | n./n. | n./n. | n./n. |
| DKK | 0.0086 | 1.6879 | 0.1899 | 0.8110 | 4.5143 | 2.4406 | 0.4785 | 7.0371 | 4.8764 | 2.8865 | n./n. | n./r. | n./n. |
| DEM | 0.0059 | 1.3861 | −0.2066 | −0.2956 | 2.6047 | 0.5267 | −1.5773 | 2.2413 | 0.1421 | −2.0039 | n./n. | n./n. | n./n. |
| Port. | 0.0054 | 1.4567 | −0.0375 | 0.1437 | 3.5985 | 1.2854 | −1.0060 | 4.4705 | 2.1293 | −0.2384 | n./n. | n./n. | n./n. |
| Subsample 3: 01/1995-12/2005 | | | | | | | | | | | | | |
| CAD | 0.0017 | −3.3035 | 0.7311 | 0.7132 | 4.0528 | 1.0715 | −1.9054 | 3.9748 | 0.9798 | −2.0096 | n./n. | r./r. | n./n. |
| CHF | 0.0121 | −5.4827 | 1.5937 | 0.2281 | 2.6896 | 0.8008 | −1.0990 | −2.6806 | −4.5891 | −6.5744 | n./n. | r./n. | r./n. |
| GBP | −0.0022 | −2.6505 | 0.7093 | 0.4433 | 3.7037 | 1.0805 | −1.5377 | 2.3021 | −0.3206 | −2.9519 | n./n. | r./n. | n./n. |
| JPY | 0.0055 | −2.0194 | 1.0433 | 0.4822 | 2.4368 | 1.0000 | −0.4368 | 0.8100 | −0.6238 | −2.0713 | n./n. | n./n. | n./n. |
| DKK | 0.0021 | −5.3781 | 0.8676 | 0.8046 | 3.7007 | 0.4172 | −2.8963 | 3.2917 | −0.0026 | −3.3229 | n./n. | r./r. | r./n. |
| DEM | 0.0353 | −21.3988 | 5.0456 | 0.3831 | 3.1243 | 1.0000 | −1.1243 | −17.5087 | −19.6983 | −21.9223 | n./n. | r./n. | r./n. |
| Port. | 0.0043 | −4.3445 | 1.3752 | 1.0369 | 3.7107 | 1.5557 | −0.5681 | 2.2930 | 0.0832 | −2.0620 | n./n. | r./r. | r./r. |

Notes: Results are for the periods indicated above the tabulars. Note that for the DEM data is available only for 12/1978-12/1998 for DEM. Port. gives the results for an equally weighted portfolio based on the aforementioned currencies. The first two columns give the Fama-regression estimates of $\alpha$ and $\beta$ with standard errors in parentheses. Implied SR denotes the Sharpe ratios of the carry-trade implied when setting $\alpha = 0$ and using the Fama-$\alpha$; note that the latter corresponds to the realized Sharpe ratio. Based on equation (10) and a Sharpe ratio threshold of 0.5, the upper and lower bound of the inaction range for the carry-trade are calculated, first setting $\alpha = 0$, $\left(\beta^u[0.5, \alpha = 0], \beta^l[0.5, \alpha = 0]\right)$, second using $\alpha$ from the Fama regression, $\left(\beta^u[0.5, \alpha], \beta^l[0.5, \alpha]\right)$. $\beta^c[0, \cdot]$ denotes the center of the range. The last three columns indicate whether the null hypotheses that the bounds hold (as formulated in parentheses) are rejected (r.) or not (n.) based on using $\alpha = 0$/Fama-$\alpha$.

Figure 1: Trader Inaction Ranges for UIP Deviations: CAD, Rolling 60-Month Periods

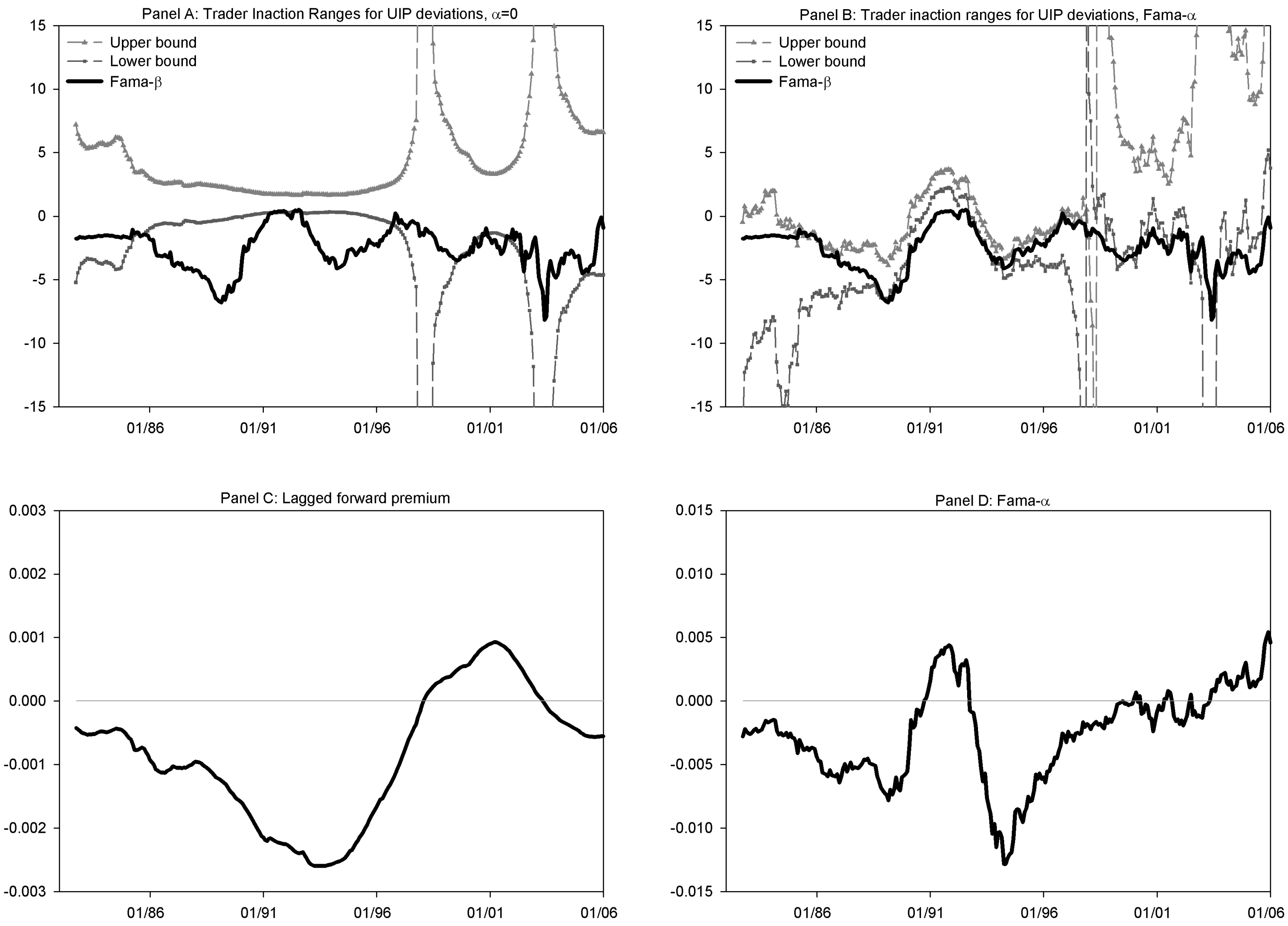

Figure 2: Trader Inaction Ranges for Carry-Trade: CAD and Portfolio, Rolling 60-Month Periods