EFCE
7/21/06
9:00 AM

The Returns to Currency Speculation*

Craig Burnside,[†] Martin Eichenbaum,[‡]
Isaac Kleshchelski,[§] and Sergio Rebelo[¶]
(very preliminary)

May 30, 2006

Abstract

Currencies that are at a forward premium tend to depreciate. This 'forward-premium puzzle' represents an egregious deviation from uncovered interest parity. We document the properties of returns to currency speculation strategies that exploit this anomaly. The first strategy, known as the carry trade, is widely used by practitioners. This strategy involves selling currencies forward that are at a forward premium and buying currencies forward that are at a forward discount. The second strategy relies on a particular regression to forecast the payoff to selling currencies forward. We show that these strategies yield high Sharpe ratios which are not a compensation for risk. However, these Sharpe ratios do not represent unexploited profit opportunities. In the presence of microstructure frictions, spot and forward exchange rates move against traders as they increase their positions. The resulting 'price pressure' drives a wedge between average and marginal Sharpe ratios. We argue that marginal Sharpe ratios are zero even though average Sharpe ratios are positive. We display a simple microstructure model that simultaneously rationalizes 'price pressure' and the forward premium puzzle. The central feature of this model is that market makers face an adverse selection problem that is less severe when the currency is expected to appreciate.

J.E.L. Classification: F31
Keywords: Uncovered interest parity, exchange rates.

*We thank Ravi Jagannathan for numerous discussions and suggestions. We benefited from the comments of David Backus, Lars Hansen, and Barbara Rossi and from conversations with Kent Daniel (Goldman Sachs), Angel Serrat (J.P. Morgan), and Amitabh Arora, Antonio Baldaque and David Mozina (Lehman Brothers). We also thank Andrew Nowobilski for research assistance, and Kevin Ji for assistance with our data set.

†Duke University and NBER

‡Northwestern University, NBER, and Federal Reserve Bank of Chicago.

§Northwestern University.

¶Northwestern University, NBER, and CEPR.

1. Introduction

Currencies that are at a forward premium tend to depreciate. This 'forward-premium puzzle' represents an egregious deviation from uncovered interest parity (UIP). We document the returns to currency speculation strategies that exploit this anomaly. The first strategy, known as the carry trade, is widely used by practitioners. This strategy involves selling currencies forward that are at a forward premium and buying currencies forward that are at a forward discount. The second strategy relies on a particular regression to forecast the payoff to selling currencies forward. We show that these strategies yield high Sharpe ratios which are not a compensation for risk. However, these Sharpe ratios do not represent unexploited profit opportunities. In the presence of microstructure frictions, spot and forward exchange rates move against traders as they increase their positions. The resulting 'price pressure' drives a wedge between average and marginal Sharpe ratios. We argue that marginal Sharpe ratios are zero even though average Sharpe ratios are positive. Using price pressure estimates obtained by Evans and Lyons (2002) we estimate that the expected total monthly payoff to the carry trade is 13.8 million pounds. Obtaining this payoff requires a monthly bet of 2.3 billion pounds. These estimates suggest that, while the statistical failure of uncovered interest parity is striking, the economic significance of this failure is limited.

Easley and O'Hara (1987) show that price pressure can emerge as an equilibrium phenomenon in microstructure models which stress adverse selection problems faced by market makers. The logic of their model extends naturally to exchange rate markets. We show that a simple microstructure model also rationalizes the 'forward premium-depreciation puzzle.' The central feature of this model is that market makers face an adverse selection problem that is less severe when the currency is expected to appreciate.

We review the basic parity conditions in Section 2. In Section 3 we briefly describe statistical evidence on covered and uncovered-interest-parity conditions. We describe the two speculation strategies that we study in Section 4 and characterize the properties of payoffs to currency speculation in Section 5. In Sections 6 and 7 we study whether the payoffs to currency speculation are correlated with risk and macro factors. In Section 8 we examine the consequences of price pressure for the properties of the payoffs to currency speculation. In Section 9 we propose a microstructure model that is consistent with the 'forward-premium puzzle'. Section 10 concludes.

2. Covered and Uncovered Interest Rate Parity

To fix ideas we derive the standard covered and uncovered interest parity conditions using a simple small-open-economy model with an exogenous endowment of a single good, Y_t. This economy is populated by a representative agent who maximizes his lifetime utility:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, M_t/P_t).$$

Here, C_t represents consumption, M_t denotes beginning-of-period money holdings, and P_t denotes the price level. The momentary utility function $u(.)$ is strictly concave, the discount factor, β, is between zero and one, and E_0 is the expectations operator conditional on the information available at the beginning of time zero. It is convenient to express the agent's time t budget constraint in foreign currency units,

$$\begin{aligned} S_t B_{t+1} + B^*_{t+1} &= S_t B_t (1 + R_{t-1}) + B^*_t (1 + R^*_{t-1}) \\ &\quad + S_t (M_t - M_{t+1}) + x_{t-1}(F_{t-1} - S_t) + S_t P_t (Y_t - C_t). \end{aligned} \tag{2.1}$$

Here S_t denotes the spot exchange rate defined as foreign currency units (FCU) per unit of domestic currency. In our data exchange rates are quoted as FCU per British pound. So it is natural for us to take the British Pound as the domestic currency. The variable F_t denotes the forward exchange rate, expressed as FCU per British pound, for forward contracts maturing at time $t+1$. The variables B_t and B^*_t denote beginning-of-period holdings of domestic and foreign bonds, respectively. Bonds purchased at time t yield interest rates of R_t and R^*_t in domestic and foreign currency, respectively. The variable x_t denotes the number of pounds sold forward at time t. To simplify notation we abstract from state-contingent securities.

The agent's first-order conditions imply two well-known parity conditions,

$$(1 + R^*_t) = \frac{1}{S_t} (1 + R_t) F_t, \tag{2.2}$$

$$(1 + R^*_t) = (1 + R_t) \left[E_t \left(\frac{S_{t+1}}{S_t} \right) + \frac{\text{cov}_t (S_{t+1}/S_t, \lambda_{t+1})}{E_t \lambda_{t+1}} \right]. \tag{2.3}$$

Relation (2.2) is known as covered-interest-rate parity. Relation (2.3) is a risk-adjusted version of uncovered interest parity. Here λ_t, the time t marginal utility of a FCU, is the Lagrange multiplier associated with (2.1).

Together (2.2) and (2.3) imply that the forward rate is the expected value of the future spot plus a risk premium,

$$F_t = E_t S_{t+1} + \frac{\text{cov}_t (\lambda_{t+1}, S_{t+1})}{E_t \lambda_{t+1}}. \tag{2.4}$$

We pay particular attention to the case in which the covariance term is zero ($\text{cov}_t(\lambda_{t+1}, S_{t+1}) = 0$) and the forward rate is an unbiased predictor of the future spot rate:

$$F_t = E_t(S_{t+1}). \tag{2.5}$$

There is a large literature, surveyed by Hodrick (1987) and Engel (1996), that rejects the implications of (2.5). There is also a large literature that tests (2.4) under alternative parameterizations of an agent's utility function that allow for risk aversion. As far as we know there is no utility specification which succeeds in generating a risk premium compatible with (2.4) (see Backus, Foresi, and Telmer (1998) for a discussion).

3. Evaluating Parity Conditions

We now describe our data set and use it to show that a version of (2.2) that incorporates bid-ask spreads holds. We also use our data to briefly review the nature of the statistical evidence against (2.5).

Data Our data set, obtained from Datastream, consists of daily observations for bid and ask interbank spot exchange rates, 1-month and 3-month forward exchange rates, and interest rates at 1-month and 3-month maturities. All exchange rates are quoted in units of foreign currency per British pound. The ask (bid) exchange rate is the rate at which a participant in the interdealer market can buy (sell) British pounds from a currency dealer. The ask (bid) interest rate is the rate at which agents can borrow (lend) domestic currency. Daily data were converted into non-overlapping monthly observations (see the appendix for details). Our data set covers the period January 1976 to December 2005 for spot and forward exchange rates and January 1981 to December 2005 for interest rates. The countries included in the data set are Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Switzerland, the U.K., and the U.S.[1]

Table 1 displays median bid-ask spreads for spot and forward exchange rates. The left-hand panel reports median bid-ask spreads in percentage terms ($100 \times \ln(Ask/Bid)$). The right-hand panel reports the difference between ask and bid quotes in units of foreign currency. Three observations emerge from Table 1. First, bid-ask spreads are wider in forward

[1] We focus on developed-country currencies with liquid markets where currency-speculation strategies are most easily implementable. See Bansal and Dahlquist (2000) and Lustig and Verdelhan (2006) for analyses that include emerging markets.

markets than in spot markets. Second, there is substantial heterogeneity across currencies in the magnitude of bid-ask spreads. Third, bid-ask spreads have declined for all currencies in the post-1999 period. This drop partly reflects the advent of screen-based electronic foreign-exchange dealing and brokering systems, such as Reuters' Dealing 2000-2, launched in 1992, and the Electronic Broking System launched in 1993.[2]

Covered Interest Parity To assess whether CIP holds it is critical to take bid-ask spreads into account. We use the following notation: S_t^a and S_t^b denote the ask and bid spot exchange rate, F_t^a and F_t^b denote the ask and bid forward exchange rate, R_t^a and R_t^b denote the ask and bid interest rate in British pounds, and R_t^{*a} and R_t^{*b} denote the ask and bid interest rate in foreign currency.

In the presence of bid-ask spreads equation (2.2) is replaced with the following two inequalities,

$$\pi_{CIP} = S_t^b \left(1 + R_t^{*b}\right) \frac{1}{F_t^a} - \left(1 + R_t^a\right) \leq 0, \tag{3.1}$$

$$\pi_{CIP}^* = \frac{1}{S_t^a} \left(1 + R_t^b\right) F_t^b - \left(1 + R_t^{*a}\right) \leq 0. \tag{3.2}$$

Equation (3.1) implies that there is a non-positive payoff (π_{CIP}) to the "borrowing pounds covered strategy." This strategy consists of borrowing one pound, exchanging the pound into foreign currency at the spot rate, investing the proceeds at the foreign interest rate, and converting the payoff into pounds at the forward rate. Equation (3.2) implies that there is a non-positive payoff (π_{CIP}^*) to the "borrowing foreign currency covered strategy." This strategy consists of borrowing one unit of foreign currency, exchanging the foreign currency into pounds at the spot rate, investing the proceeds at the domestic interest rate, and converting the payoff into foreign currency at the forward rate. Table 2 reports statistics for π_{CIP} and π_{CIP}^* for nine currencies. We compute statistics pertaining to the Euro-legacy currencies over the period January 1981 to December 1998. For all other currencies the sample period is January 1981 to December 2005.

Table 2 indicates that for all nine currencies, the median value for π_{CIP} and π_{CIP}^* is negative. Also the fraction of periods in which π_{CIP} and π_{CIP}^* are negative is small. Even in periods where the payoff is positive, the median payoff is very small. Similar results hold for 3-month horizon investments and the post-1994 time period.

[2] It took a few years for these electronic trading systems to capture large transactions volumes. We break the sample in 1999, as opposed to in 1992 or 1993, to fully capture the impact of these trading platforms.

Our finding that deviations from CIP are small and rare is consistent with the results in Taylor (1987) who uses data collected at 10-minute intervals for a three-day period, Taylor (1989) who uses daily data for selected historical periods of market turbulence, and Clinton (1988) who uses daily data from November 1985 to May 1986.

Uncovered Interest Parity: Statistical Evidence Tests of (2.5) generally focus on the regression:

$$(S_{t+1} - S_t)/S_t = \alpha + \beta(F_t - S_t)/S_t + \xi_{t+1}. \tag{3.3}$$

Under the null hypothesis that (2.5) holds, $\alpha = 0$, $\beta = 1$, and ξ_{t+1} is orthogonal to time t information. The rejection of this null hypothesis has been extensively documented. Table 3 reports the estimates of α and β that we obtain using our data for both 1-month and 3-months horizons. We run these regressions using the average of bid and ask spot and forward exchange rates. Consistent with the literature, we find that β is consistently different from 1. We also confirm the existence of the 'forward-premium puzzle,' i.e. point estimates of β are negative. Under the null hypothesis (2.5), the pound should, on average, appreciate when it is at a forward premium ($F_t > S_t$). The negative point estimates of β imply that the pound actually tends to depreciate when it is at a forward premium.

There is a large literature aimed at explaining the failure of (2.5) and the forward premium puzzle. Proposed explanations include the importance of risk premia (Fama (1984)), the interaction of risk premia and monetary policy (McCallum (1994)), statistical considerations such as peso problems (Lewis (1995)) and non-cointegration of forward and spot rates (Roll and Yan (2000) and Maynard (2003)). Additional explanations include learning (Lewis (1995)) and biases in expectations (Frankel and Rose (1994)). More recently, Alvarez, Atkeson, and Kehoe (2006) stress the importance of time-varying risk premia resulting from endogenous market segmentation, while Bachetta and Van Wincoop (2006) emphasize the implications of rational inattention for the failure of UIP.

For now we do not focus on explaining the failure of UIP. Instead our goal is to measure the economic significance of this failure. Our metric for significance is the amount of money that can be made by exploiting deviations from UIP.

4. Two Currency-Speculation Strategies

We consider two strategies that exploit the failure of UIP. The first strategy, known to practitioners as the "carry trade," involves borrowing low-interest-rate currencies, lending high-interest-rate currencies, and not hedging the exchange rate risk. The second strategy, suggested by Backus, Gregory, and Telmer (1993), relies on a particular regression to predict the payoff to selling currency forward. We refer to this strategy as the BGT strategy.

The Carry-Trade Strategy To describe this strategy we abstract, for the moment, from bid-ask spreads. The carry trade consists of borrowing the low-interest-rate currency and lending the high-interest-rate currency,

$$y_t = \begin{cases} >0 & \text{if } R_t < R_t^*, \\ <0 & \text{if } R_t^* < R_t. \end{cases} \tag{4.1}$$

where y_t is the amount of pounds borrowed. The payoff to this strategy, denominated in pounds, is:

$$\text{Payoff}_1 = y_t \left[S_t(1+R_t^*)\frac{1}{S_{t+1}} - (1+R_t) \right]. \tag{4.2}$$

An alternative version of the carry-trade strategy consists of selling the pound forward when it is at a forward premium ($F_t > S_t$) and buying the pound forward when it is at a forward discount ($F_t < S_t$),

$$x_t = \begin{cases} >0 & \text{if } F_t > S_t, \\ <0 & \text{if } F_t < S_t. \end{cases} \tag{4.3}$$

Here x_t is the number of pounds sold forward. The pound-denominated payoff to this strategy is,

$$\text{Payoff}_2 = x_t \left(\frac{F_t}{S_{t+1}} - 1 \right). \tag{4.4}$$

When (2.2) holds strategy (4.1) yields positive payoffs if and only if strategy (4.3) has positive payoffs because the two payoffs are proportional to one another. In this sense the strategies are equivalent. We focus our analysis on strategy (4.3) for two reasons. First, strategy (4.3) is generally more favorable than (4.1) because it involves lower transactions costs. Second, our sample for forward rates is longer than that for interest rates.

One rationalization of the carry-trade strategy is that an agent believes that $1/S_{t+1}$ follows a martingale,

$$E_t\left(\frac{1}{S_{t+1}}\right) = \frac{1}{S_t}. \tag{4.5}$$

This forecast implies that the expected payoff to the carry trade is:

$$E_t\left(\text{Payoff}_2\right) = x_t\left(\frac{F_t}{S_t} - 1\right).$$

A risk-neutral agent sells the pound forward ($x_t > 0$) when $F_t > S_t$ and buys the pound forward ($x_t < 0$) when $F_t < S_t$.

We consider two versions of the carry trade distinguished by how bid-ask spreads are treated. In both versions we normalize the size of the bet to 1 pound. In the first version we implement (4.3) and calculate payoffs assuming that agents can buy and sell currency at the average of the bid and ask rates. We use $\bar{S}_t$ and $\bar{F}_t$ to denote the average of bid and ask for the spot and forward exchange rate, respectively,

$$\begin{aligned}\bar{S}_t &= \left(S_t^a + S_t^b\right)/2, \\ \bar{F}_t &= \left(F_t^a + F_t^b\right)/2.\end{aligned}$$

The sign of x_t is given by:

$$x_t = \begin{cases} +1 & \text{if } \bar{F}_t \geq \bar{S}_t, \\ -1 & \text{if } \bar{F}_t < \bar{S}_t, \end{cases} \tag{4.6}$$

while the payoff is,

$$\text{Payoff} = x_t\left(\frac{\bar{F}_t}{\bar{S}_{t+1}} - 1\right). \tag{4.7}$$

We refer to this strategy as "carry trade without transactions costs."

In the second version of the carry trade we take bid-ask spreads into account in deciding whether to buy or sell pounds forward and in calculating payoffs. We refer to this strategy as "carry trade with transactions costs." While agents know F_t^a and F_t^b at time t, they must forecast $1/S_{t+1}^a$ and $1/S_{t+1}^b$ to decide whether to buy or sell the pound forward. We assume that agents use (4.5) to compute $E_t\left(1/\bar{S}_{t+1}\right)$. We then use the average of the bid-ask spread over the previous year to compute $E_t\left(1/S_{t+1}^a\right)$ and $E_t(1/S_{t+1}^b)$.[3] Agents adopt the decision rule,

$$x_t = \begin{cases} +1 & \text{if } E_t\left(F_t^b/S_{t+1}^a\right) > 1, \\ -1 & \text{if } E_t\left(F_t^a/S_{t+1}^b\right) < 1, \\ = 0 & \text{otherwise.} \end{cases} \tag{4.8}$$

The payoff to this strategy is:

$$\text{Payoff} = \begin{cases} x_t\left(F_t^b/S_{t+1}^a - 1\right) & \text{if } x_t > 0, \\ x_t\left(F_t^a/S_{t+1}^b - 1\right) & \text{if } x_t < 0, \\ 0 & \text{if } x_t = 0. \end{cases} \tag{4.9}$$

[3] We compute these expectations as follows: $E_t\left(1/S_{t+1}^a\right) = 1/\left(\bar{S}_t + \delta\right)$ and $E_t(1/S_{t+1}^b) = 1/\left(\bar{S}_t - \delta\right)$, where δ is 1/2 of the average bid-ask spread computed over the previous year.

The BGT Strategy Motivated by results in Backus, Gregory, and Telmer (1993) we use the following regression to forecast the payoff to selling pounds forward:

$$\left(\bar{F}_t - \bar{S}_{t+1}\right)/\bar{S}_{t+1} = a + b\left(\bar{F}_t - \bar{S}_t\right)/\bar{S}_t + \xi_{t+1}. \tag{4.10}$$

The BGT strategy involves selling (buying) the pound forward when the payoff predicted by the regression is positive (negative). To avoid "look-ahead" bias, we use recursive estimates of the coefficients in (4.10), where the first estimate is obtained using the first 30 data points.[4]

Table 4 displays estimates of a and b computed using data at 1 and 3-month horizons for the 9 bilateral exchange rates in our sample. For many countries the point estimate of b is well above 1 and is not statistically different from 3. To understand the magnitude of the b estimates it is useful to note the close connection between regressions (4.10) and (3.3) discussed in Fama (1984). Suppose that $1/\bar{S}_t$ is a martingale. Then (4.10) is roughly equivalent to the regression:

$$\left(\bar{F}_t - \bar{S}_{t+1}\right)/\bar{S}_t = a + b\left(\bar{F}_t - \bar{S}_t\right)/\bar{S}_t + \xi_{t+1}.$$

This equation can be re-arranged to show that: $a = -\alpha$ and $b = 1 - \beta$, where α and β are the slope and intercept in (3.3). So our finding that β, the slope coefficient in (3.3), is close to -2 translates into a value of b close to 3.

As with the carry trade we report results for two versions of the BGT strategy, with and without transactions costs. It is convenient to define

$$E_t\left[\left(\bar{F}_t - \bar{S}_{t+1}\right)/\bar{S}_{t+1}\right] = \hat{a} + \hat{b}\left(\bar{F}_t - \bar{S}_t\right)/\bar{S}_t, \tag{4.11}$$

where $\hat{a}$ and $\hat{b}$ are the time t recursive estimates of a and b. We assume that speculators follow the rule:

$$x_t = \begin{cases} +1 & \text{if } E_t\left[\left(\bar{F}_t - \bar{S}_{t+1}\right)/\bar{S}_{t+1}\right] \geq 0, \\ -1 & \text{if } E_t\left[\left(\bar{F}_t - \bar{S}_{t+1}\right)/\bar{S}_{t+1}\right] < 0. \end{cases}$$

The payoff to the strategy is given by (4.7).

In the version of the BGT strategy with transactions costs, we use $E_t\left[\left(\bar{F}_t - \bar{S}_{t+1}\right)/\bar{S}_{t+1}\right]$ and the average of the bid-ask spread over the previous year to compute $E_t\left[\left(F_t^b - S_{t+1}^a\right)/S_{t+1}^a\right]$ and $E_t\left[\left(F_t^a - S_{t+1}^b\right)/S_{t+1}^b\right]$ (see the appendix for details). The decision rule is given by:

$$x_t = \begin{cases} +1 & \text{if } E_t\left[\left(F_t^b - S_{t+1}^a\right)/S_{t+1}^a\right] > 0, \\ -1 & \text{if } E_t\left[\left(F_t^a - S_{t+1}^b\right)/S_{t+1}^b\right] < 0, \\ 0 & \text{otherwise.} \end{cases}$$

The payoff is given by (4.9).

[4] We investigate variants of the BGT strategy that use separate regressions on bid and ask rates. These refinements make little difference to our results.

5. The Returns to Currency Speculation

In this section we study the payoff properties of the carry trade and the BGT trading strategies. We consider these strategies for individual currencies as well as for portfolios of currencies.

Table 5 reports the mean, standard deviation, and Sharpe ratio of the monthly non-annualized payoffs to the two versions of the carry trade discussed in the previous section, with and without transactions costs. We report payoff statistics for the carry trade implemented for individual currencies against the pound and for an equally-weighted portfolio of the currency strategies. Table 6 is the analogue of Table 5 for the BGT strategy. To put our results into perspective note that the monthly, non-annualized Sharpe ratio of the Standard & Poors 500 index (S&P 500) is 0.14 for the period 1976 to 2005.

Even though bid-ask spreads are small, they have a sizable impact on the profitability of currency speculation. For example, without transactions costs the Sharpe ratio associated with the equally-weighted portfolio is roughly 0.18 for the carry trade and 0.20 for the BGT strategy. Incorporating bid-ask spreads reduces the Sharpe ratio to 0.13 for the carry trade and to 0.11 for the BGT strategy. Most of the reduction results from a substantial decline in the expected payoff to the strategies.

It is sometimes argued that since bid-ask spreads are small it is reasonable to ignore them. In one sense bid-ask spreads are small. For example, if an agent buys and sells one pound against the U.S. dollar in the spot market he loses on average $S^a - S^b = 0.0013$ dollars. But in the sense relevant to a currency speculator bid-ask spreads are large. They are of the same order of magnitude as the expected payoff associated with our two currency-speculation strategies. In the remainder of the paper we only consider strategies and payoffs that take bid-ask spreads into account.

Even though Sharpe ratios including transactions costs are high, the average payoffs to currency-speculation strategies are low. A speculator who bets one pound on an equally-weighted portfolio of carry-trade strategies receives a monthly (annual) payoff of 0.0025 (0.03) pounds. So, to generate an average annual payoff of 1 million pounds the speculator must bet of 33.3 million pounds every month. We conclude that to generate substantial profits speculators must wager very large sums of money.

Table 7, which reports statistics for the carry-trade and BGT payoffs computed using a common sample, shows that there are large diversification gains from forming portfolios of currency strategies. For the carry-trade strategy the average Sharpe ratio across-currencies is 0.090, while the Sharpe ratio for an equally weighted portfolio of currencies is 0.125. The analogue estimates for the BGT strategy are 0.062 and 0.110, respectively.

Since there are gains to combining currencies into portfolios, it is natural to construct portfolios that maximize the Sharpe ratio. Accordingly, we compute the portfolio frontier and calculate the portfolio weights that maximize the Sharpe ratio. Specifically at each time t we solve the problem:

$$\begin{aligned} & \min_{w_t} w_t' V_t w_t \\ \text{s.t.} \quad & \sum_{i=1}^{9} w_t^i R_t^i = R_t^p, \\ & \sum_{i=1}^{9} w_t^i = 1, \\ & w_t^i \geq 0, \text{ for all } i. \end{aligned} \tag{5.1}$$

Here w_t^i is the time t portfolio weight of currency i, R_t^i is the expected payoff associated with the trading strategy applied to currency i and R_t^p is the time t expected payoff to the portfolio. The variable w_t represents the vector of portfolio weights. In addition, V_t is the variance-covariance matrix of payoffs to the trading strategy applied to each of the nine currencies. For the carry-trade strategy we estimate the matrix V_t recursively using data up to time t. For the BGT strategy we take the time t estimates of $\hat{a}$ and $\hat{b}$, recreate the historical payoffs, and use these new payoffs to estimate V_t.

Problem (5.1) is completely standard except for the fact that we impose a non-negativity constraint on the portfolio weights (see the appendix for details). This constraint is important because negative weights allow agents to trade at negative bid-ask spreads, thus generating spuriously high payoffs. The solution to (5.1) provides a set of portfolio weights, w_t, for every feasible value R_p. We choose the weights that maximize the Sharpe ratio of the portfolio.

The first row of Figure 1 displays realized returns for the equally-weighted and optimal portfolio carry-trade strategy. The second row presents the analogue results for the BGT strategy. Since realized payoffs are very volatile we display a 12 months moving average of the different series. Interestingly, payoffs to the carry-trade strategy are not concentrated in a small number of periods. In contrast, the BGT strategy seems to do consistently better in the early part of the sample.

We use the realized returns to compute the cumulative realized payoff to committing one U.S. dollar in the beginning of the sample (1977 for the carry trade and 1979 for BGT) to various currency-speculation strategies and reinvesting the proceeds at each point in time. The agent starts with 1 U.S. dollar in his bank account and bets 1 dollar in the currency strategy. From that point on the agent bets the balance of his bank account on the currency strategy (recall that our currency strategies are zero-cost portfolios). The bank account balance never becomes negative in our sample. Currency strategy payoffs are deposited in the agent's account. Balances in the account accumulate interest at the Libor. For comparison we also display the cumulative realized payoff to the S&P 500 index and the 1-month Libor. Figures 2 and 3 display the cumulative nominal returns to various trading strategies. These figures show that all of the strategies, including the S&P 500, dominate the Libor. More interestingly, the total cumulative return to the optimally-weighted carry-trade strategy is very similar to that of the S&P 500. However, the volatility of the returns to this version of the carry trade is much smaller than that of the cumulative return associated with the S&P 500.

The last row of Table 5 reports summary statistics for the payoff to the optimally-weighted portfolio of carry trade strategies. Table 6 presents the analogue statistics for the BGT strategy. Table 7 contrasts the Sharpe ratios of the various strategies analyzed computed over a common sample (1979:10 to 2005:12). These Sharpe ratios are high and are statistically different from zero. The Sharpe ratios of the optimally-weighted portfolio strategies are substantially higher than those of the equally-weighted portfolio strategies.

Figure 4 displays realized Sharpe ratios computed using a three-year rolling window. For both strategies Sharpe ratios are high in the beginning of the 1970s. The optimally weighted carry-trade strategy consistently delivers a positive Sharpe ratio except for a brief period around 1995. In contrast the S&P 500 yields negative returns in the early 1980s and in the 2001 to 2005 period.

So far we have emphasized the mean and the variance of currency payoffs. These statistics are sufficient to characterize the distribution of returns only if that distribution is normal. We now analyze other properties of the distribution of realized payoffs. Figure 5 and 6 show the distribution of payoffs to the carry trade and the BGT strategies implemented for each of our nine currencies. Figure 7 is the analogue to Figures 5 and 6 but pertains to the equally and optimally-weighted BGT and carry-trade strategy payoffs. We exclude from the distribution periods in which the trading strategy dictates no trade. We superimpose on the empirical distribution of payoffs a normal distribution with the same mean and variance as the empirical distribution. It is evident that these distributions are not normal, but are leptokurtic, exhibiting fat tails. This impression is confirmed by Table 8 which reports skewness, excess kurtosis, and the Jarque-Bera normality test. There is very little evidence of skewness in the payoff distributions but there is evidence of excess kurtosis.

One way to assess the economic significance of these deviations from normality is to confront a hypothetical trader with the possibility of investing in the S&P 500 and wagering bets on the optimally-weighted carry trade. The trader's problem is given by,

$$
\begin{aligned}
U &= E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} \right) \\
C_t &= Y_t + X_t^s (1 + r_t^s) + X_t^c r_t^c - X_{t+1}^s, \\
Y_t &= \gamma^t.
\end{aligned}
$$

Here C_t denotes consumption, Y_t is an exogenous income endowment assumed to grow at an annual rate of 1.9 percent, X_t^s and X_t^c are the end-of-period $t-1$ investment in the S&P 500 and in a portfolio of optimally-weighted carry-trade strategies, respectively. The variables r_t^s and r_t^c are the time t realized returns to the S&P 500, and the carry trade, respectively. It is useful to define the ratios $x_t^s = X_t^s / Y_t$ and $x_t^c = X_t^c / Y_t$. We assume that r_t^c and r_t^s are generated by the joint empirical distribution of returns to the S&P 500 and to the optimally-weighted carry trade. We impose that the agent uses a time invariant strategy for these ratios, that is, he sets $x_t^S = x^S$ and $x_t^C = x^C$ for all t. For $\sigma = 5$ we find that the optimal strategy is $x^S = 0.665$, $x^C = 1.935$. These portfolio weights imply that investments in the optimally-weighted carry trade strategy account for 68 percent of the investor's expected return and roughly the same proportion of the variance of his return. So, even though the distribution of payoffs to the carry trade has fatter tails than those of a comparable normal distribution, agents still want to place very large bets on carry-trade strategies.

We can also compare the fat tails associated with currency-speculation payoffs with those present in the returns to the S&P 500 for the same time period. S&P 500 returns display higher excess kurtosis (2.2 with a standard error of 1.3) and skewness (−0.5 with a standard error of 0.35) than the optimally-weighted portfolio of carry-trade strategies. We conclude that fat tails are an unlikely explanation of the Sharpe ratios associated with our currency-speculation strategies.

6. Does Risk Explain the Sharpe Ratio of Currency Strategies?

A natural explanation for the Sharpe ratios of our currency-speculation strategies is that currency returns are risky, in the sense of being correlated with risk factors such as consumption growth. We investigate this possibility by regressing quarterly real payoffs to our currency strategies on a variety of risk factors. These factors include per capita consumption growth, the returns to the S&P 500, the Fama-French (1993) stock-market factors, the slope of the yield curve computed as the yield on 10-year U.S. treasury bills minus the 3-months U.S. treasury-bill rate, the luxury retail sales series constructed by Parker, Ait-Sahalia, and Yogo (2004), U.S. industrial production, the FTSE 100, and per-capita U.K. consumption growth. The first seven factors are denominated in dollars so we convert our pound payoffs into U.S. dollars at the average of bid and ask spot exchange rates to run the relevant regressions. Dollar denominated nominal returns and risk factors are converted to real returns using the U.S. consumption deflator for non-durables and services. Pound returns and risk factors were deflated using the U.K. consumption deflator. See the appendix for a detailed description of the data used in the regressions.

Table 9 reports results for regressions of real payoffs on real risk factors. Our key finding is that, with a single exception, no risk factor is significantly correlated with real payoffs. The exception is the optimally-weighted carry trade, which is correlated with real UK consumption growth. This correlation might explain the high Sharpe ratio associated with the optimally-weighted carry trade as compensation for the riskiness of the associated payoffs to UK investors. But this correlation cannot be used to explain the high Sharpe ratio from the perspective of U.S. investors. We infer that risk-related explanations for the Sharpe ratios of currency-speculation strategies are empirically implausible. This result is consistent with the literature that shows that allowing for different forms of risk aversion does not render risk-adjusted UIP (2.4) consistent with the data.

7. Are Currency Strategy Payoffs Correlated with Monetary Variables?

There is a large literature that emphasizes the role of monetary policy in generating deviations from UIP (e.g. Grilli and Roubini (1992), McCallum (1992), and Alvarez, Atkeson, and Kehoe (2006)). A common theme in this literature is that monetary policy can generate time-varying risk premia. The precise transmission mechanism varies across papers. Motivated by this literature we investigate whether real payoffs to the currency-speculation strategies are correlated with various monetary variables. We begin by converting quarterly nominal payoffs to our currency strategies into U.S. dollars at the average of bid and ask spot exchange rate. We deflate appropriately using the U.S. consumption deflator for non-durables and services. We then regress the dollar payoffs on the Federal Funds rate, the rate of inflation, measured using the consumption deflator, and the growth rate of four different measures of money (M1, M2, M3, and MZM). We also regress pound payoffs, deflated using the U.K. consumption deflator, on the U.K. rate of inflation and the U.K. 3-month treasury-bill rate. Our results are reported in Table 10.

Inflation and the Fed funds rate enter significantly in regressions for three currency-speculation strategies, the equally-weighted carry trade, the equally-weighted BGT, and the optimally-weighted BGT. This correlation is present at low frequencies, reflecting the downward trend in inflation, the Fed funds rate, and the payoffs to the three currency-speculation strategies. The correlation between currency-speculation payoffs and monetary variables offers some support for theories that emphasize the link between monetary policy and the failure of UIP. Still, it is troubling that none of the monetary variables enter the regression significantly. Moreover, it is not clear that existing monetary theories can generate a positive correlation between inflation and currency-speculation payoffs.

8. Price Pressure

Taken at face value, our results pose an enormous challenge for asset pricing theory. In Section 5 we argue that there are currency-speculation strategies that yield much higher Sharpe ratios than the S&P 500. Moreover, the payoffs to these strategies are uncorrelated with standard risk factors. So, investors can significantly increase their expected return, for a given level of the variance of returns, by combining currency speculation with a passive strategy of holding the S&P 500. The obvious question is why don't investors massively exploit this opportunity to the point where either the Sharpe ratio of currency-speculation strategies falls to zero or currency-speculation payoffs become correlated with risk factors.

Here we use evidence from the microstructure literature to argue that, while currency speculators do make profits, there is little, if any, money left on the table. While the average

Sharpe ratio of our currency speculation strategies is positive, the marginal Sharpe ratio is zero.

Our basic argument builds on the literature that emphasizes the potential importance of 'price pressure' in explaining the behavior of asset prices. By price pressure we mean that the price at which investors can buy or sell an asset depends on the quantity they wish to transact. The existence of price pressure can reflect a variety of microstructure frictions such as adverse selection (Kyle (1985) and Easley and O'Hara (1987)) or inventory motives (Garman (1976) and Stoll (1978)). There is an extensive literature documenting the existence of price pressure in the stock market (see Madhavan (2000) for a survey). The literature on price pressure in exchange rate markets is smaller because it is difficult to obtain data on trading volume. In an important paper Evans and Lyons (2002) estimate price pressure for the DM/US dollar and Yen/US dollar markets using daily order flow data collected between May and August 1996. In their empirical model the exchange rate depends on the order flow, x_t, defined as the difference between buyer-initiated and seller-initiated orders over a one-day period. Evans and Lyons (2002) model price pressure as taking the form,

$$S_{t+1} = S_t\ e^{bx_t+u_t}. \tag{8.1}$$

Here u_t is an i.i.d. random variable with zero mean realized at the end of day t. The variable S_t denotes the exchange rate quote at the beginning of day t, before trade starts. During the day the order flow x_t accumulates. The exchange rate at the close of day t is $S_t\ e^{bx_t+u_t}$, reflecting both the order flow and the random shock. This rate is also the value of the exchange rate at the beginning of time $t+1$, S_{t+1}.

To understand the implications of (8.1), imagine that the first transaction of day t is initiated by a trader placing an infinitesimally small order to be executed immediately. Equation (8.1) implies that this order is executed at an exchange rate S_t. In contrast, imagine that the first transaction of day t is initiated by a trader placing a larger order of size z to be executed immediately. This order is executed at an exchange rate $S_t e^{bz}$. Evans and Lyons (2002) estimate $b = 0.0054$, so that a buy order of 1 billion dollars increases the execution spot exchange rate by 0.54 percent. We use Evans and Lyons' estimate of b to study the implications of price pressure for the average and marginal payoffs to our currency-speculation strategies. We assume that their estimate of b applies to both bid, ask, spot, and forward rates.

From the perspective of an individual trader a currency-speculation strategy that appears profitable abstracting from price pressure can be unprofitable once price pressure is taken into account. In addition, (8.1) implies that there is an incentive to break up a large trade into small orders. A trader who places an order for z pounds at the beginning of $t+1$ pays zS_te^{bz}. In contrast, if the trader divides this order into infinitesimal orders and the net order flow is zero while execution occurs, he pays $\int_0^z S_te^{bw}dw = S_t\left(e^{bz}-1\right)/b$, which is lower than zS_te^{bz}.

We focus on the implications of price pressure for the profitability of the carry-trade strategy. Suppose that traders are competitive and risk neutral. To simplify suppose that all trade takes place at the same time at the beginning of the period. If traders bet a total of x_t pounds on the carry trade, the total expected payoff is:

$$\text{Expected Payoff} = \begin{cases} E_t x_t\left(\frac{F_t^b e^{-bx_t}}{S_{t+1}^a e^{bx_t}} - 1\right) & \text{if } x_t > 0, \\ E_t\left(-x_t\right)\left(1 - \frac{F_t^a e^{bx}}{S_{t+1}^b e^{-bx}}\right) & \text{if } x_t < 0. \end{cases} \tag{8.2}$$

In equilibrium traders drive the expected payoff to zero so that x_t satisfies:

$$\begin{aligned} E_t\left(\frac{F_t^b e^{-bx_t}}{S_{t+1}^a e^{bx_t}}\right) &= 1, \text{ if } E_t\left(F_t^b/S_{t+1}^a\right) > 1, \\ E_t\left(\frac{F_t^a e^{bx_t}}{S_{t+1}^b e^{-bx_t}}\right) &= 1, \text{ if } E_t\left(F_t^a/S_{t+1}^b\right) < 1. \end{aligned} \tag{8.3}$$

The value of x_t given by (8.3) is such that the expected marginal payoff to an infinitesimal bet on the carry trade is zero. Equation (8.2) implies that the expected average payoff is also zero.

Now consider the case where traders break up orders into infinitesimally small bets. If traders bet a total of x_t pounds on the carry trade the expected payoff is,

$$\text{Expected Payoff} = \begin{cases} E_t\left[\int_0^{x_t}\left(\frac{F_t^b e^{-bz}}{S_{t+1}^a e^{bz}}\right)dz - x_t\right] & \text{if } x_t > 0, \\ E_t\left[-x_t - \int_0^{-x_t}\left(\frac{F_t^a e^{bz}}{S_{t+1}^b e^{-bz}}\right)dz\right] & \text{if } x_t < 0. \end{cases} \tag{8.4}$$

In equilibrium the marginal expected payoff must be zero. It follows that the value of x_t is given by (8.3). This condition is the same one that x_t satisfies when trades cannot be broken up. Using the fact that the price pressure function (8.1) is convex it is straightforward to show that the equilibrium average expected payoff to the carry trade is positive. So as long as traders break up trades, price pressure can rationalize the observations that currency speculators make profits on average, but that at the margin there is no money to be made from further speculation.

We now investigate the quantitative difference between average and marginal Sharpe ratios when traders can break up trades. We assume that orders arrive uniformly throughout the day. We also assume that our data corresponds to mid-day quotes. These two assumptions imply that our quotes reflect half of the day's net order flow. In our notation we observe,

$$\tilde{F}_t^b = F_t^b e^{-bx/2},$$
$$\tilde{S}_{t+1}^a = S_{t+1}^a e^{bx/2},$$
$$\tilde{F}_t^a = F_t^a e^{bx/2},$$
$$\tilde{S}_{t+1}^b = S_t^b e^{-bx/2}.$$

We suppose that agents implement the carry trade for each of the nine currencies. For each currency and in each period agents compute the optimal x_t and implement the carry-trade strategy by breaking up the trades into infinitesimally small orders. Given our assumptions, the optimal x_t satisfies,

$$\begin{aligned} E_t\left(\frac{\tilde{F}_t^b e^{-bx_t/2}}{\tilde{S}_{t+1}^a e^{bx_t/2}}\right) &= 1, \text{ if } E_t\left(F_t^b/S_{t+1}^a\right) > 1, \\ E_t\left(\frac{\tilde{F}_t^a e^{bx_t/2}}{\tilde{S}_{t+1}^b e^{-bx_t/2}}\right) &= 1, \text{ if } E_t\left(F_t^a/S_{t+1}^b\right) < 1. \end{aligned}$$

We compute $E_t\left(1/\tilde{S}_{t+1}^a\right)$ and $E_t\left(1/\tilde{S}_{t+1}^b\right)$ using the method discussed in section 3.[5] Table 11 reports statistics pertaining to the average payoff corresponding to this strategy. On average speculators place a monthly bet of 2.3 billion pounds. The amounts invested are very volatile with a standard deviation of 1.5 billion pounds. This high standard deviation is consistent with the notion that speculative currency flows are very volatile. By construction the expected marginal payoff and Sharpe ratio associated with this strategy are both zero. However, the expected average payoff and Sharpe ratio are both positive (14 million pounds per month and 0.20 respectively).

While Evans and Lyons' (2002) estimate of $b = 0.0054$ provides a convenient benchmark, it is entirely possible that price pressure has fallen over time. To assess the sensitivity of our results Table 11 reports statistics for values of b that are 1/2, 1/4, and 1/8 of 0.0054. A fall in price pressure induces a proportional rise in the mean and standard deviation of bet

[5]The portfolio constructed in this way does not correspond to either the equally-weighted carry trade or the optimally-weighted carry trade discussed above.

size and in the mean and standard deviation of the payoffs. Once b falls to 1/8 of 0.0054 we obtain a mean monthly bet size of 18 billion pounds and average profits of 110 million pounds per month. Regardless of the value of b, the realized average Sharpe ratio is 0.202, while the expected marginal Sharpe ratio is by construction zero.

In sum, according to our calculations, while currency speculators do make profits, no money is left on the table. Moreover, the profits that speculators do make seem modest relative to the amounts being wagered.

9. A Microstructure Model

In the previous section we argue that the amount of profits that can be made from the failure of UIP is fairly limited. Our analysis so far has not addressed the obvious question of why this failure occurs in the first place. In this section we present a simple microstructure model that can account for the egregious failure of UIP associated with the forward-premium puzzle.

Our model is an application of Glosten and Milgrom (1985) to exchange rate markets. The stochastic process for the spot exchange rate is given by:

$$S_{t+1} = S_t + \phi_t + \varepsilon_{t+1}.$$

The variable ϕ_t represents the change in the exchange rate that is predictable based on public information at time t. To simplify we assume that ϕ_t and ε_{t+1} follow two orthogonal i.i.d. Bernoulli processes:

$$\phi_t = \begin{cases} +\bar{\phi} > 0 & \text{with probability } 1/2, \\ -\bar{\phi} < 0 & \text{with probability } 1/2, \end{cases}$$

$$\varepsilon_{t+1} = \begin{cases} +\bar{\varepsilon} > 0 & \text{with probability } 1/2, \\ -\bar{\varepsilon} < 0 & \text{with probability } 1/2. \end{cases}$$

There is a continuum of traders with measure 1. A fraction α of the traders are informed. By informed we mean that these traders know ε_{t+1} at time t. This simplifying assumption is extreme but none of our qualitative results hinge upon it. We only require that informed traders receive a time t signal that is informative about ε_{t+1}.

A fraction $1-\alpha$ of traders are uninformed. These traders buy pounds forward whenever the pound is expected to appreciate on the basis of public information, that is, $\phi_t > 0$. They sell pounds forward when $\phi_t < 0$. None of our qualitative results depend on the precise form of this trading rule. All that we require is that uninformed traders be more likely to buy than sell pounds forward when $\phi_t > 0$ and be more likely to sell than buy pounds forward when $\phi_t < 0$.

All trade takes place with risk-neutral market makers who have perfect commitment and decide at time zero on price setting rules for bid and ask forward rates. The market maker draws one trader per period from a continuum.[6] The chosen trader can submit an order of fixed size x to buy or sell pounds forward. There is free entry at time zero, so the market maker's expected profit is zero. To simplify we abstract from bid-ask spreads associated with spot rates.

The market maker knows ϕ_t but does not know ε_{t+1} at time t. He forms expectation of ε_{t+1} based on ϕ_t and on whether he receives a buy or a sell order from the trader (i.e. the order flow). There are two states of the world, $\phi_t = \bar{\phi}$, $\phi_t = -\bar{\phi}$ and in each of these states the market maker must quote a bid and an ask forward rate. So we have to compute $F_t^a(\bar{\phi})$, $F_t^b(\bar{\phi})$, $F_t^a(-\bar{\phi})$, and $F_t^b(-\bar{\phi})$. Here $F_t^a(\phi_t)$ and $F_t^b(\phi_t)$ denotes the ask and bid forward rate when the state is ϕ_t.

Consider $F_t^a(\bar{\phi})$. To compute this variable we need to calculate the market maker's expectation, $E(\varepsilon_{t+1}|\text{buy}, \bar{\phi})$. Since $\phi_t = \bar{\phi}$ all uninformed traders buy the pound forward. If $\varepsilon_{t+1} = \bar{\varepsilon}$ informed traders also buy the pound forward. So the probability that the market maker receives a buy order when $\varepsilon_{t+1} = \bar{\varepsilon}$, and $\phi_t = \bar{\phi}$ is given by,

$$\Pr(\text{buy}|\varepsilon_{t+1} = \bar{\varepsilon}, \bar{\phi}) = 1.$$

If $\phi_t = \bar{\phi}$ and $\varepsilon_{t+1} = -\bar{\varepsilon}$, uniformed agents submit a buy order but informed agents submit a sell order. Since there are $1 - \alpha$ uninformed agents, it follows that the probability that the market maker receives a buy order when $\varepsilon_{t+1} = -\bar{\varepsilon}$, $\phi_t = \bar{\phi}$ is,

$$\Pr(\text{buy}|\varepsilon_{t+1} = -\bar{\varepsilon}, \bar{\phi}) = 1 - \alpha.$$

Using Bayes rule,

$$\begin{aligned}
\Pr(\varepsilon_{t+1} = \bar{\varepsilon}|\text{buy}, \bar{\phi}) &= \frac{\Pr(\text{buy}|\varepsilon_{t+1} = \bar{\varepsilon}, \bar{\phi}) \Pr(\varepsilon_{t+1} = \bar{\varepsilon})}{\Pr(\text{buy}|\varepsilon_{t+1} = \bar{\varepsilon}, \bar{\phi}) \Pr(\varepsilon_{t+1} = \bar{\varepsilon}) + \Pr(\text{buy}|\varepsilon_{t+1} = -\bar{\varepsilon}, \bar{\phi}) \Pr(\varepsilon_{t+1} = -\bar{\varepsilon})} \\
&= \frac{1}{2 - \alpha}. \qquad (9.1)
\end{aligned}$$

[6] The probability of a trader trading more than once at time t is zero. This property rules out strategic considerations.

It follows that:

$$\begin{aligned}\Pr(\varepsilon_{t+1} = -\bar{\varepsilon}|\text{buy}, \bar{\phi}) &= 1 - \Pr(\varepsilon_{t+1} = \bar{\varepsilon}|\text{buy}, \bar{\phi}), \\ &= \frac{1-\alpha}{2-\alpha}.\end{aligned} \tag{9.2}$$

Using (9.1) and (9.2) we obtain,

$$\begin{aligned}E(\varepsilon_{t+1}|\text{buy}, \bar{\phi}) &= \Pr(\varepsilon_{t+1} = \bar{\varepsilon}|\text{buy}, \bar{\phi})\bar{\varepsilon} + \Pr(\varepsilon_{t+1} = -\bar{\varepsilon}|\text{buy}, \bar{\phi})(-\bar{\varepsilon}), \\ &= \frac{\alpha\bar{\varepsilon}}{2-\alpha}.\end{aligned}$$

We now compute $F_t^a(\bar{\phi})$. The zero-profit condition implies that when $\phi_t = \bar{\phi}$, the rate at which traders can buy pounds forward from the market maker is equal to the market maker's expectation of the future spot rate,

$$\begin{aligned}F_t^a(\bar{\phi}) &= E(S_{t+1}|\text{buy}, \bar{\phi}) = S_t + \bar{\phi} + E(\varepsilon_{t+1}|\text{buy}, \bar{\phi}), \\ &= S_t + \bar{\phi} + \frac{\alpha\bar{\varepsilon}}{2-\alpha}.\end{aligned}$$

Proceeding as above we can compute the remaining forward rates, $F_t^b(\bar{\phi})$, $F_t^a(-\bar{\phi})$, and $F_t^b(-\bar{\phi})$. In the appendix we show that,

$$\begin{aligned}F_t^a(\bar{\phi}) &= S_t + \bar{\phi} + \frac{\bar{\varepsilon}\alpha}{2-\alpha}, \\ F_t^b(\bar{\phi}) &= S_t + \bar{\phi} - \bar{\varepsilon}, \\ F_t^a(-\bar{\phi}) &= S_t - \bar{\phi} + \bar{\varepsilon}, \\ F_t^b(-\bar{\phi}) &= S_t - \bar{\phi} - \frac{\bar{\varepsilon}\alpha}{2-\alpha}.\end{aligned}$$

Bid-ask spreads are independent of ϕ_t and constant over time, $F^a(\phi_t) - F^b(\phi_t) = 2\bar{\varepsilon}/(2-\alpha)$. In order to be consistent with the high volatility of spot exchange rates, the value of $\bar{\varepsilon}$ must be high, and so the bid-ask spread is also high. However, the model can easily generate lower bid-ask spreads if we introduce a group of uninformed traders that buy and sell with equal probability.

As is standard in this class of models, informed traders make profits on average at the expense of uninformed traders. In the appendix we show that the informed traders' expected profit, $E(\pi^i)$, is,

$$E(\pi^i) = \frac{(1-\alpha)\bar{\varepsilon}}{\alpha + 2(1-\alpha)}. \tag{9.3}$$

The uninformed traders' expected profit, $E(\pi^u)$, is negative and given by,

$$E(\pi^u) = \frac{-\alpha\bar{\varepsilon}}{\alpha + 2(1-\alpha)}. \tag{9.4}$$

Total trader expected profits are zero:

$$\alpha E(\pi^i) + (1-\alpha)E(\pi^u) = 0.$$

In the empirically plausible case where α is close to zero the expected loss to each uninformed trader is vanishingly small.

The following proposition summarizes the key property of our model.

Proposition 9.1. *Suppose that*

$$\bar{\phi} < (1-\alpha)\bar{\varepsilon}/(2-\alpha). \tag{9.5}$$

Then the plim of β in regression (3.3) computed with data generated from our model economy is negative. This results holds regardless of whether the regression is conducted using ask, bid or an average of bid and ask forward rates (see Appendix for proof).

To understand the intuition for this result consider the case in which all traders are informed ($\alpha = 1$). In this case orders are completely revealing about the value of ε_{t+1}. When traders buy (sell) the market maker can infer with certainty that $\varepsilon_{t+1} = \bar{\varepsilon}$ ($\varepsilon_{t+1} = -\bar{\varepsilon}$). So forward rates are given by,

$$F_t^a = S_t + \phi_t + \bar{\varepsilon},$$
$$F_t^b = S_t + \phi_t - \bar{\varepsilon}.$$

The future value of ε_{t+1} is fully reflected in F_t^a and F_t^b. It follows that S_{t+1} is positively related to F_t^a, F_t^b, and the average of these two variables. In the appendix we show that the plim of β in regression (3.3) is one.

Now consider the case where there are informed and uninformed traders. We begin by analyzing the relation between $S_{t+1} - S_t$ and $F_t^a - S_t$. The market maker faces less adverse selection in setting ask rates when $\phi_t = \bar{\phi}$ than when $\phi_t = -\bar{\phi}$. When $\phi_t = -\bar{\phi}$ only informed agents buy the pound forward. Therefore, when the market maker receives a buy order, he can infer with certainty that $\varepsilon_{t+1} = \bar{\varepsilon}$. This information is reflected in the forward rate which is given by, $F_t^a(-\bar{\phi}) = S_t - \bar{\phi} + \bar{\varepsilon}$. When $\phi_t = \bar{\phi}$ both uninformed and informed agents buy the pound forward. In this case a buy order does not necessarily mean that $\varepsilon_{t+1} = \bar{\varepsilon}$. The market maker's expectation of ε_{t+1} is equal to $\bar{\varepsilon}\alpha/(2-\alpha)$ and the forward rate is given by $F_t^a(\bar{\phi}) = S_t + \bar{\phi} + \bar{\varepsilon}\alpha/(2-\alpha)$. Under our regularity conditions $F_t^a(\bar{\phi}) < F_t^a(-\bar{\phi})$. So the ask forward rate is negatively related to ϕ_t. On average the pound appreciates when ϕ_t is positive. Hence, there is a negative relation between $S_{t+1} - S_t$ and $F_t^a - S_t$.

Similar intuition obtains for the relation between $S_{t+1} - S_t$ and $F_t^b - S_t$. The market maker faces less adverse selection in setting bid rates when $\phi_t = -\bar{\phi}$ than when $\phi_t = \bar{\phi}$. When $\phi_t = \bar{\phi}$ only informed agents sell the pound forward. Therefore, when the market maker receives a sell order, he can infer with certainty that $\varepsilon_{t+1} = -\bar{\varepsilon}$. This information is reflected in the forward rate, which is given by, $F_t^b(\bar{\phi}) = S_t + \bar{\phi} - \bar{\varepsilon}$. When $\phi_t = -\bar{\phi}$ both uninformed and informed agents sell the pound forward. In this case a sell order does not necessarily mean that $\varepsilon_{t+1} = -\bar{\varepsilon}$. The market maker's expectation of ε_{t+1} is equal to $-\bar{\varepsilon}\alpha/(2-\alpha)$ and the forward rate is given by $F_t^b(-\bar{\phi}) = S_t - \bar{\phi} - \bar{\varepsilon}\alpha/(2-\alpha)$. Under our regularity conditions $F_t^b(-\bar{\phi}) > F_t^b(\bar{\phi})$. So the bid forward rate is negatively related to ϕ_t. On average the pound appreciates when ϕ is positive. Hence, there is a negative relation between $S_{t+1} - S_t$ and $F_t^b - S_t$.

It is easy to imagine circumstances in which there is an important forecastable component in exchange rate movements that is based on public information. Consider, for example countries with high growth rates of money which lead to predictably high rates of inflation and exchange rate depreciation. Here we would expect movements in ϕ_t to be large relative to movements in ε_{t+1} and our regularity condition (9.5) to fail. This property is a virtue because it predicts that, for such countries, the plim of β in regression (3.3) is one. In fact deviations from UIP are much smaller for high-inflation countries (see Bansal and Dahlquist (2000)).

An important shortcoming of our model is the carry-trade strategy is not profitable. In fact, when $\bar{\phi} < \bar{\varepsilon}$, bid and ask forward rates are such that carry-trader speculators choose not to trade. We conjecture that this shortcoming can be overcome by allowing for risk aversion on the part of market makers along with the assumption that they receive a number of orders that is finite and larger than one. We plan to pursue this conjecture in future work.

Introducing Price Pressure In section 8 we emphasize the importance of price pressure for interpreting the returns to currency speculation. It is straightforward to modify the model to generate price pressure as an equilibrium phenomenon. Proceeding as in Easley and O'Hara (1987), suppose that traders can submit orders of two sizes, high (X) and low (x). Suppose also that uninformed traders choose high or low sizes with probability 1/2, but informed traders are more likely to submit larger orders than small orders. Under these assumptions the bid-ask spread for small orders is smaller than the bid-ask spread for large orders. This result reflects the fact that the adverse selection problem is more severe for larger orders than for small orders. We formally demonstrate these claims in the appendix and discuss the form taken by the regularity condition (9.5).

10. Conclusion

In this paper we document that implementable currency-speculation strategies generate very large Sharpe ratios and that their payoffs are uncorrelated with standard risk factors. We argue that the presence of price pressure limits the size of the bets that agents choose to place on these strategies. Our benchmark calculations, based on the Evans and Lyons (2002) estimates of price pressure, indicate that total profits from the carry trade are 13.8 million pounds per month. Moreover, the marginal payoff to the carry trade is zero so that no money is being left on the table. So, while the statistical failure of UIP is very sharp, the amount of money that can be made from this failure, at least with our currency-speculation strategies, seems relatively small.

We conclude by emphasizing that our finding that payoffs to currency speculation are uncorrelated with risk factors cast doubts on the practice of adding risk-premia shocks to the UIP relation in dynamic general equilibrium models. In these models, risk-premia shocks affect domestic interest rates which in turn affect aggregate quantities such as consumption and output. In the data there is little evidence that disturbances to UIP relationships are correlated with risk factors. Introducing risk-premia shocks amounts to introducing an important source of model mispecification that is very likely to affect policy analyses.

Table 1

Median Bid-Ask Spreads

	Spot	1 month Forward	3 month Forward	Spot	1 month Forward	3 month Forward	Units	
	100 x ln(Ask/Bid)			Foreign currency units				
	Full Sample Period							Dates
Belgium	0.159	0.253	0.291	10.00	15.93	20.00	Centimes	76:01-98:12
Canada	0.053	0.096	0.111	0.10	0.20	0.23	Cents	76:01-05:12
France	0.100	0.151	0.176	1.00	1.50	1.88	Centimes	76:01-98:12
Germany	0.213	0.311	0.319	1.00	1.12	1.13	Pfennig	76:01-98:12
Italy	0.063	0.171	0.208	1.00	4.00	5.00	Lire	76:01-98:12
Japan	0.216	0.272	0.280	1.00	1.08	1.13	Yen	78:06-05:12
Netherlands	0.234	0.344	0.359	1.00	1.25	1.25	Cents	76:01-98:12
Switzerland	0.255	0.412	0.456	1.00	1.13	1.13	Centimes	76:01-05:12
USA	0.055	0.074	0.082	0.10	0.12	0.13	Cents	76:01-05:12
Euro*	0.043	0.060	0.070	0.04	0.06	0.07	Cents	99:01-05:12
	1999-2005							
Canada	0.066	0.071	0.076	0.15	0.16	0.17	Cents	
Japan	0.061	0.066	0.070	0.11	0.12	0.13	Yen	
Switzerland	0.087	0.094	0.103	0.21	0.22	0.24	Centimes	
USA	0.023	0.027	0.027	0.04	0.04	0.05	Cents	
Euro*	0.043	0.060	0.070	0.04	0.06	0.07	Cents	

Results are based on daily data

*Euro quotes are Euro/USD, whereas other quotes are originally in FCU/British pound

Table 2

Covered Interest Arbitrage at 1-Month Horizon

Currency	Median return to borrowing covered in: Pounds	FX	Fraction of periods with positive returns to borrowing covered in: Pounds	FX	Median of positive returns to borrowing covered in: Pounds	FX
	percent		percent		percent	
			Full Sample			
Belgium	-0.21	-0.22	1.92	2.19	0.12	0.14
Canada	-0.11	-0.08	0.37	1.38	0.06	0.02
France	-0.14	-0.12	1.00	1.00	0.26	0.07
Germany	-0.23	-0.22	0.15	0.04	0.09	0.37
Italy	-0.16	-0.13	0.81	0.66	0.10	0.04
Japan	-0.26	-0.27	0.43	0.11	0.09	0.31
Netherlands	-0.30	-0.29	0.06	0.15	0.11	0.10
Switzerland	-0.32	-0.32	0.30	0.18	0.20	0.46
USA	-0.07	-0.07	0.72	0.67	0.01	0.11
Average	-0.20	-0.19	0.64	0.71	0.11	0.18
			1994:1-2005:1			
Belgium	-0.18	-0.19	2.07	2.76	0.05	0.05
Canada	-0.11	-0.09	0.48	1.00	0.12	0.01
France	-0.10	-0.10	0.92	0.61	0.22	0.05
Germany	-0.11	-0.11	0.31	0.08	0.14	0.28
Italy	-0.16	-0.13	0.31	0.23	0.07	0.21
Japan	-0.10	-0.12	0.83	0.24	0.19	0.31
Netherlands	-0.11	-0.11	0.23	0.08	0.11	0.20
Switzerland	-0.12	-0.12	0.42	0.31	0.17	0.17
USA	-0.05	-0.05	1.25	0.62	0.01	0.13
Average	-0.12	-0.12	0.76	0.66	0.12	0.16

Table 3

UIP Regressions, 1976-2005

	1 Month Regression			3 Month Regression		
	α	β	*R2*	α	β	*R2*
Belgium†	-0.002	-1.531	0.028	-0.005	-0.625	0.008
	(0.002)	(0.714)		(0.006)	(0.669)	
Canada	-0.003	-3.487	0.045	-0.007	-2.936	0.072
	(0.002)	(0.803)		(0.005)	(0.858)	
France†	0.000	-0.468	0.004	0.001	-0.061	0.000
	(0.002)	(0.589)		(0.005)	(0.504)	
Germany†	-0.005	-0.732	0.005	-0.012	-0.593	0.007
	(0.003)	(0.704)		(0.008)	(0.650)	
Italy†	0.005	-0.660	0.010	0.008	-0.012	0.000
	(0.002)	(0.415)		(0.006)	(0.392)	
Japan*	-0.019	-3.822	0.030	-0.063	-4.482	0.100
	(0.005)	(0.924)		(0.014)	(1.017)	
Netherlands†	-0.009	-2.187	0.029	-0.018	-1.381	0.026
	(0.004)	(1.040)		(0.009)	(0.816)	
Switzerland	-0.008	-1.211	0.012	-0.020	-1.050	0.022
	(0.003)	(0.533)		(0.008)	(0.536)	
USA	-0.003	-1.681	0.017	-0.008	-1.618	0.037
	(0.002)	(0.880)		(0.006)	(0.865)	

Regression of [S(t+1)/S(t)-1] on [F(t)/S(t)-1]

* Data for Japan begin 7/78

† Data for Euro legacy currencies ends 12/98

Table 4

BGT Regressions, 1976-2005

	1 Month Regression			3 Month Regression		
	a	***b***	***R2***	***a***	***b***	***R2***
Belgium†	0.003	2.617	0.076	0.007	1.676	0.051
	(0.002)	(0.746)		(0.006)	(0.677)	
Canada	0.004	4.392	0.068	0.010	3.914	0.119
	(0.002)	(0.815)		(0.005)	(0.923)	
France†	0.001	1.534	0.040	0.001	1.122	0.047
	(0.002)	(0.590)		(0.005)	(0.508)	
Germany†	0.005	1.689	0.024	0.014	1.542	0.045
	(0.003)	(0.722)		(0.009)	(0.682)	
Italy†	-0.004	1.707	0.060	-0.006	1.041	0.058
	(0.002)	(0.424)		(0.006)	(0.403)	
Japan*	0.020	4.753	0.043	0.065	5.333	0.125
	(0.005)	(0.957)		(0.015)	(1.060)	
Netherlands†	0.009	3.232	0.060	0.020	2.377	0.067
	(0.004)	(1.090)		(0.010)	(0.849)	
Switzerland	0.008	2.130	0.035	0.021	1.954	0.067
	(0.003)	(0.550)		(0.008)	(0.556)	
USA	0.004	2.584	0.038	0.011	2.503	0.079
	(0.002)	(0.920)		(0.006)	(0.940)	

Regression of [F(t)/S(t+1)-1] on [F(t)/S(t)-1]

* Data for Japan begin 7/78

† Data for Euro legacy currencies ends 12/98

Table 5

Returns to the Carry Trade Strategies 76:01-05:12

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
Belgium*	0.0044	0.028	0.157	0.003	0.021	0.129
	(0.0019)	(0.002)	(0.068)	(0.0015)	(0.002)	(0.072)
Canada	0.0053	0.032	0.169	0.004	0.026	0.162
	(0.0018)	(0.002)	(0.059)	(0.0014)	(0.002)	(0.055)
France*	0.0054	0.027	0.201	0.003	0.023	0.142
	(0.0016)	(0.002)	(0.060)	(0.0015)	(0.002)	(0.066)
Germany*	0.0011	0.028	0.038	0.001	0.024	0.038
	(0.0018)	(0.002)	(0.066)	(0.0016)	(0.002)	(0.065)
Italy*	0.0029	0.028	0.105	0.002	0.024	0.090
	(0.0017)	(0.002)	(0.058)	(0.0014)	(0.002)	(0.057)
Japan†	0.0022	0.036	0.061	0.002	0.034	0.048
	(0.0022)	(0.003)	(0.063)	(0.0020)	(0.003)	(0.059)
Netherlands*	0.0024	0.028	0.087	0.002	0.023	0.080
	(0.0018)	(0.002)	(0.068)	(0.0015)	(0.002)	(0.068)
Switzerland	0.0019	0.030	0.063	0.001	0.028	0.017
	(0.0017)	(0.002)	(0.060)	(0.0016)	(0.002)	(0.058)
USA	0.0039	0.031	0.124	0.003	0.029	0.102
	(0.0017)	(0.002)	(0.058)	(0.0016)	(0.002)	(0.059)
Euro‡	0.0014	0.021	0.066	0.002	0.018	0.091
	(0.0017)	(0.002)	(0.083)	(0.0013)	(0.002)	(0.079)
Average	0.0031	0.029	0.107	0.0022	0.025	0.090
Eqall y-weighted portfolio	0.0031	0.017	0.183	0.0025	0.020	0.125
	(0.0009)	(0.001)	(0.061)	(0.0011)	(0.001)	(0.057)
Optimally-weighted portfolio	0.0041	0.018	0.236	0.0042	0.021	0.196
	(0.0009)	(0.001)	(0.059)	(0.0011)	(0.001)	(0.053)

* Euro legacy currencies available 76:1-98:12

† Japanese yen available 78:7-05:12

‡ Euro available 99:1-05:12

Other currencies available 76:1-05:12

16 observations is the minimum number used to compute a covariance matrix in the optimal portfolios, so optimally-weighted returns are generated over period 77:04-05:12

Table 6

Returns to the BGT Strategies 76:01-05:12

	No Transations Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
Belgium*	0.0051	0.027	0.188	0.003	0.026	0.114
	(0.0017)	(0.002)	(0.066)	(0.0017)	(0.002)	(0.065)
Canada	0.0060	0.031	0.194	0.004	0.029	0.133
	(0.0017)	(0.002)	(0.055)	(0.0017)	(0.002)	(0.057)
France*	0.0047	0.027	0.173	0.003	0.023	0.136
	(0.0018)	(0.002)	(0.065)	(0.0016)	(0.002)	(0.073)
Germany*	0.0012	0.028	0.043	0.001	0.022	0.031
	(0.0019)	(0.002)	(0.070)	(0.0015)	(0.002)	(0.067)
Italy*	0.0043	0.026	0.163	0.003	0.024	0.108
	(0.0017)	(0.002)	(0.069)	(0.0016)	(0.002)	(0.069)
Japan†	0.0017	0.036	0.049	0.001	0.029	0.029
	(0.0020)	(0.003)	(0.058)	(0.0017)	(0.003)	(0.058)
Netherlands*	0.0030	0.027	0.115	0.000	0.023	-0.002
	(0.0018)	(0.002)	(0.065)	(0.0015)	(0.002)	(0.067)
Switzerland	0.0018	0.029	0.064	-0.001	0.026	-0.029
	(0.0017)	(0.002)	(0.056)	(0.0015)	(0.002)	(0.059)
USA	0.0057	0.031	0.185	0.005	0.029	0.166
	(0.0018)	(0.002)	(0.064)	(0.0017)	(0.003)	(0.064)
Euro‡	-0.0011	0.021	-0.052	-0.001	0.016	-0.067
	(0.0017)	(0.002)	(0.083)	(0.0015)	(0.002)	(0.095)
Average	0.0032	0.028	0.112	0.0017	0.025	0.062
Eqall y-weighted portfolio	0.0027	0.013	0.202	0.0018	0.017	0.110
	(0.0008)	(0.001)	(0.057)	(0.0010)	(0.001)	(0.060)
Optimally-weighted portfolio	0.0038	0.019	0.197	0.0030	0.022	0.139
	(0.0013)	(0.001)	(0.067)	(0.0013)	(0.001)	(0.062)

* Euro legacy currencies available 76:1-98:12

† Japanese yen available 78:7-05:12

‡ Euro available 99:1-05:12

Other currencies available 76:1-05:12

30 observations is the minimum number used to run the first regression, so returns are generated over period 78:07-05:12

16 observations is the minimum number used to compute a covariance matrix in the optimal portfolios, so optimally-weighted returns are generated over period 79:10-05:12

Table 7

Sharpe Ratios of Portfolio Strategies
Computed over a Common Sample (79:10-05:12)

	Equal Weighted	Optimally Weighted	Difference
Carry trade	0.138	0.210	0.071
	(0.060)	(0.056)	(0.033)
BGT	0.104	0.139	0.035
	(0.062)	(0.062)	(0.032)
Difference	0.034	0.071	
	(0.069)	(0.067)	

Standard errors in parenthesis.

Table 8

Skewness, Kurtosis and Normality Test

	Returns to Carry Trade With Transactions Costs			Returns to BGT Strategy With Transactions Costs		
	Skewness	Excess Kurtosis	Jarque-Bera Test	Skewness	Excess Kurtosis	Jarque-Bera Test
Belgium*	0.413	4.48	238.3	0.397	3.97	167.0
	(0.498)	(1.12)	(0.000)	(0.535)	(2.03)	(0.000)
Canada	-0.047	1.99	59.5	-0.075	0.65	6.1
	(0.238)	(0.59)	(0.000)	(0.170)	(0.34)	(0.047)
France*	-0.006	2.27	59.1	-0.046	2.00	41.1
	(0.324)	(0.69)	(0.000)	(0.352)	(0.64)	(0.000)
Germany*	-0.432	2.89	104.2	1.427	8.29	785.2
	(0.278)	(0.85)	(0.000)	(0.695)	(3.68)	(0.000)
Italy*	0.643	3.73	178.7	-0.270	2.14	49.8
	(0.389)	(1.50)	(0.000)	(0.307)	(0.93)	(0.000)
Japan†	-1.334	7.40	848.7	-0.437	7.89	784.3
	(0.539)	(2.14)	(0.000)	(0.947)	(3.56)	(0.000)
Netherlands*	0.004	3.23	119.4	1.441	6.95	578.0
	(0.341)	(0.98)	(0.000)	(0.610)	(3.39)	(0.000)
Switzerland	-0.833	2.77	156.4	1.306	5.76	547.8
	(0.228)	(0.83)	(0.000)	(0.444)	(2.07)	(0.000)
USA	-0.527	3.62	213.1	-0.556	3.59	193.4
	(0.531)	(1.77)	(0.000)	(0.563)	(1.91)	(0.000)
Euro‡	-0.872	3.17	53.3	0.032	0.72	1.8
	(0.540)	(2.24)	(0.000)	(0.207)	(0.75)	(0.404)
Average	-0.299	3.56	203.1	0.322	4.20	315.5
Equally-weighted portfolio	-0.878	4.10	297.9	0.621	2.22	88.7
	(0.407)	(1.80)	(0.000)	(0.275)	(0.76)	(0.000)
Optimally-weighted portfolio	-0.183	1.00	16.4	-0.004	1.86	45.1
	(0.200)	(0.37)	(0.000)	(0.365)	(1.15)	(0.000)

* Euro legacy currencies available 76:1-98:12

† Japanese yen available 78:7-05:12

‡ Euro available 99:1-05:12

Other currencies available 76:1-05:12

Optimally-weighted Carry Trade: 16 observations is the minimum number used to compute a covariance matrix in the optimal portfolios, so optimally-weighted returns are generated over period 77:04-05:12

BGT: 30 observations is the minimum number used to run the first regression, so returns are generated over period 78:07-05:12

Optimally-weighted BGT: 16 observations is the minimum number used to compute a covariance matrix in the optimal portfolios, so optimally-weighted returns are generated over period 79:10-05:12

Table 9

Real Payoff to Currency Speculation and Risk Factors

	Carry Trade Equally-Weighted Portfolio					Carry Trade Optimally-Weighted Portfolio				
	Intercept	Slope Coefficient(s)			R^2	Intercept	Slope Coefficient(s)			R^2
U.S. Factors*										
S&P500	0.008	0.000			0.000	0.013	0.003			0.000
	(0.003)	(0.039)				(0.004)	(0.042)			
CAPM	0.008	0.000			0.000	0.013	-0.003			0.000
	(0.003)	(0.038)				(0.004)	(0.041)			
Fama-French	0.009	-0.004	-0.017	-0.023	0.002	0.011	0.063	-0.057	0.128	0.038
	(0.003)	(0.051)	(0.075)	(0.068)		(0.004)	(0.051)	(0.086)	(0.069)	
Per-capita consumption growth	0.011	-0.486			0.004	0.015	-0.312			0.001
	(0.004)	(0.663)				(0.005)	(0.720)			
Luxury retail sales growth	0.006	0.021			0.003	0.012	0.000			0.000
	(0.007)	(0.044)				(0.008)	(0.052)			
Industrial production	0.007	0.200			0.006	0.013	0.026			0.000
	(0.003)	(0.200)				(0.004)	(0.225)			
U.K. Factors**										
Per-capita consumption growth	0.004	0.611			0.020	0.006	1.201			0.065
	(0.004)	(0.403)				(0.004)	(0.414)			
FTSE return	0.009	-0.007			0.000	0.013	0.003			0.000
	(0.003)	(0.035)				(0.003)	(0.041)			

	BGT Strategy Equally-Weighted Portfolio					BGT Strategy Optimally-Weighted Portfolio				
	Intercept	Slope Coefficient(s)			R^2	Intercept	Slope Coefficient(s)			R^2
U.S. Factors*										
S&P500	0.005	0.021			0.003	0.010	-0.039			0.006
	(0.003)	(0.041)				(0.004)	(0.055)			
CAPM	0.006	0.010			0.001	0.010	-0.050			0.012
	(0.003)	(0.039)				(0.004)	(0.051)			
Fama-French	0.005	0.024	-0.001	0.034	0.004	0.009	-0.025	-0.030	0.042	0.016
	(0.003)	(0.042)	(0.066)	(0.049)		(0.004)	(0.060)	(0.092)	(0.063)	
Per-capita consumption growth	0.005	0.111			0.000	0.006	0.812			0.008
	(0.004)	(0.742)				(0.006)	(0.949)			
Luxury retail sales growth	0.003	-0.003			0.000	0.007	-0.014			0.001
	(0.005)	(0.037)				(0.006)	(0.047)			
Industrial production	0.006	-0.002			0.000	0.008	0.175			0.003
	(0.003)	(0.223)				(0.004)	(0.309)			
U.K. Factors**										
Per-capita consumption growth	0.003	0.414			0.011	0.006	0.562			0.011
	(0.004)	(0.330)				(0.005)	(0.475)			
FTSE return	0.006	-0.027			0.005	0.011	-0.097			0.040
	(0.003)	(0.032)				(0.004)	(0.046)			

*Nominal payoffs in pounds converted into U.S. dollars at average of bid and ask spot rates and deflated using the U.S.

**Nominal payoffs in pounds deflated using the UK consumption deflator consumption deflator.

Table 10

Real Payoff to Currency Speculation and Monetary Variables

	Carry-Trade Equally-Weighted Portfolio			Carry-Trade Optimally-Weighted Portfolio		
	Intercept	Slope Coefficient	R^2	Intercept	Slope Coefficient	R^2
U.S. Variables*						
Fed funds rate	-0.001	0.140	0.023	0.007	0.089	0.008
	(0.006)	(0.071)		(0.007)	(0.081)	
Inflation	-0.001	0.934	0.028	0.010	0.294	0.002
	(0.006)	(0.421)		(0.007)	(0.500)	
M1 Growth	0.012	-0.238	0.011	0.016	-0.222	0.009
	(0.004)	(0.214)		(0.004)	(0.210)	
M2 Growth	0.009	-0.037	0.000	0.010	0.222	0.003
	(0.007)	(0.398)		(0.008)	(0.432)	
M3 Growth	0.005	0.174	0.003	0.012	0.074	0.000
	(0.007)	(0.351)		(0.009)	(0.451)	
MZM Growth	0.011	-0.112	0.006	0.012	0.076	0.002
	(0.004)	(0.108)		(0.004)	(0.111)	
Term Premium	0.014	-0.297	0.012	0.016	-0.183	0.004
	(0.005)	(0.249)		(0.006)	(0.288)	
U.K. Variables**						
Inflation	0.007	0.062	0.000	0.016	-0.273	0.006
	(0.005)	(0.290)		(0.005)	(0.297)	
UK 3 Mo. T-bill rate	0.000	0.087	0.009	0.007	0.059	0.004
	(0.007)	(0.073)		(0.008)	(0.082)	

	BGT Strategy Equally-Weighted Portfolio			BGT Strategy Optimally-Weighted Portfolio		
	Intercept	Slope Coefficient	R^2	Intercept	Slope Coefficient	R^2
U.S. Variables*						
Fed funds rate	-0.010	0.233	0.084	-0.015	0.378	0.133
	(0.005)	(0.076)		(0.007)	(0.099)	
Inflation	-0.005	1.145	0.052	-0.012	2.356	0.100
	(0.005)	(0.449)		(0.007)	(0.600)	
M1 Growth	0.004	0.132	0.005	0.006	0.302	0.015
	(0.003)	(0.198)		(0.004)	(0.222)	
M2 Growth	0.001	0.330	0.009	0.000	0.643	0.022
	(0.005)	(0.317)		(0.006)	(0.416)	
M3 Growth	0.005	0.068	0.000	0.003	0.382	0.009
	(0.005)	(0.283)		(0.007)	(0.396)	
MZM Growth	0.005	0.061	0.002	0.007	0.113	0.005
	(0.003)	(0.121)		(0.005)	(0.160)	
Term Premium	0.006	-0.031	0.000	0.018	-0.486	0.024
	(0.005)	(0.252)		(0.008)	(0.341)	
U.K. Variables**						
Inflation	0.000	0.422	0.022	-0.004	1.129	0.060
	(0.005)	(0.331)		(0.007)	(0.535)	
UK 3 Mo. T-bill rate	-0.011	0.196	0.060	-0.016	0.297	0.080
	(0.006)	(0.077)		(0.009)	(0.100)	

*Nominal payoffs in pounds converted into U.S. dollars at average of bid and ask spot rates and deflated using the U.S. consumption deflator.

**Nominal payoffs in pounds deflated using the UK consumption deflator.

Table 11

Effects of Price Pressure on Payoffs to Carry-trade Strategy

	Bet Size (millions pounds)		Profits (millions pounds)		
Country results use b=0.0054	Mean	Standard Deviation	Mean	Standard Deviation	Sharpe Ratio
Belgium	149	230	1.28	10.6	0.121
Canada	175	224	1.79	11.9	0.151
France	276	338	1.80	16.6	0.108
Germany	299	282	0.84	13.6	0.061
Italy	389	494	3.19	22.4	0.142
Japan	406	298	2.35	19.3	0.122
Netherlands	199	190	0.68	8.3	0.082
Switzerland	383	356	1.70	18.9	0.090
USA	325	335	2.13	18.5	0.115
Euro	166	170	0.34	5.2	0.066
Portfolio with all currencies					
b=0.0054	2305	1507	13.8	68.5	0.202
	(185)	(156)	(4.1)	(8.6)	(0.050)
b=0.0027	4611	3014	27.7	137.0	0.202
	(370)	(312)	(8.1)	(17.3)	(0.050)
b=0.00135	9222	6027	55.4	274.0	0.202
	(739)	(624)	(16.2)	(34.5)	(0.050)
b=0.000675	18443	12055	110.8	548.1	0.202
	(1478)	(1248)	(32.5)	(69.0)	(0.050)

Figure 1

Realized Returns to Currency Speculation (12 month MA) 1976-2005

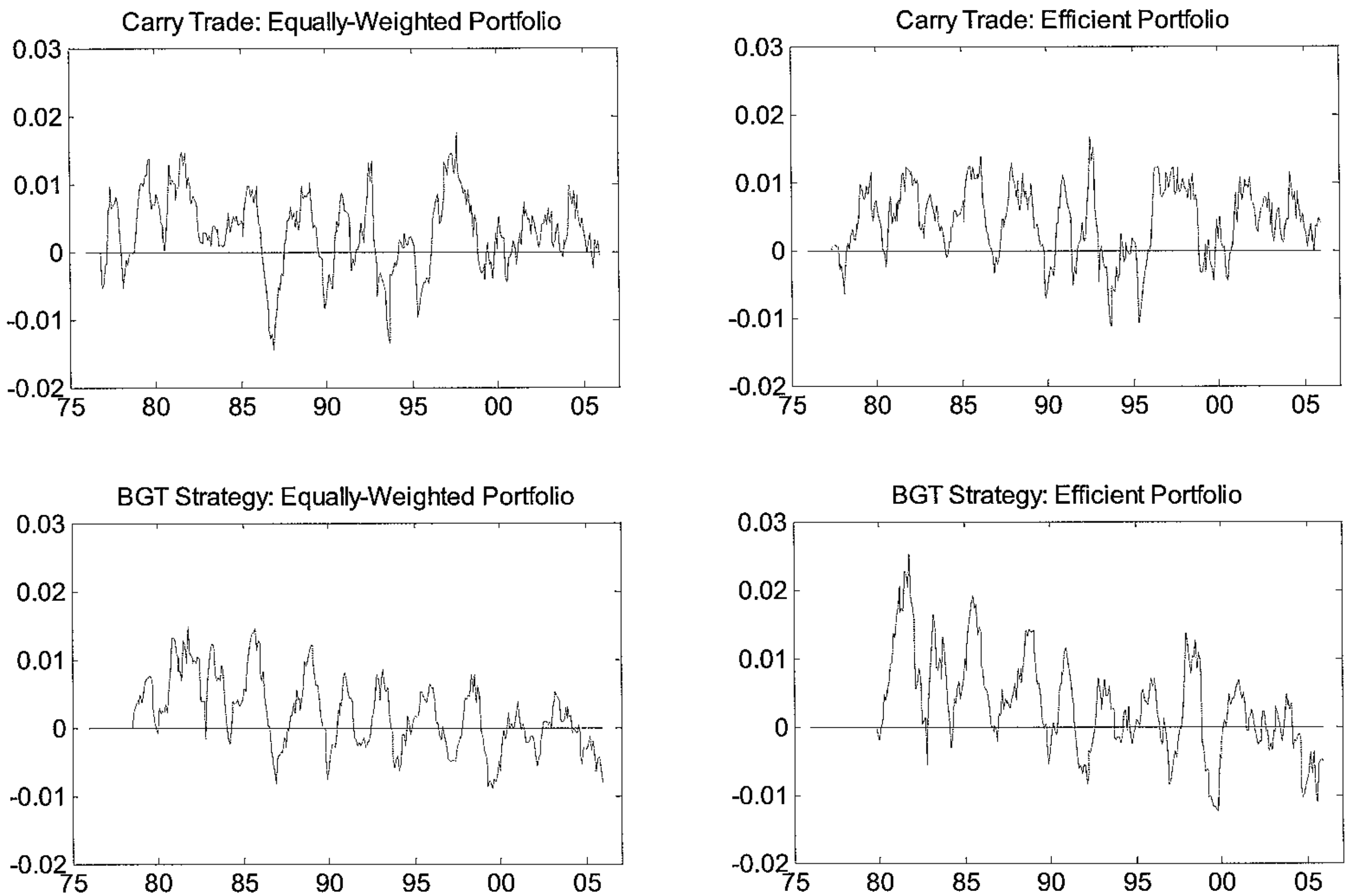


Figure 2

Cumulative Nominal Returns to Trading Strategies, May 1977=1

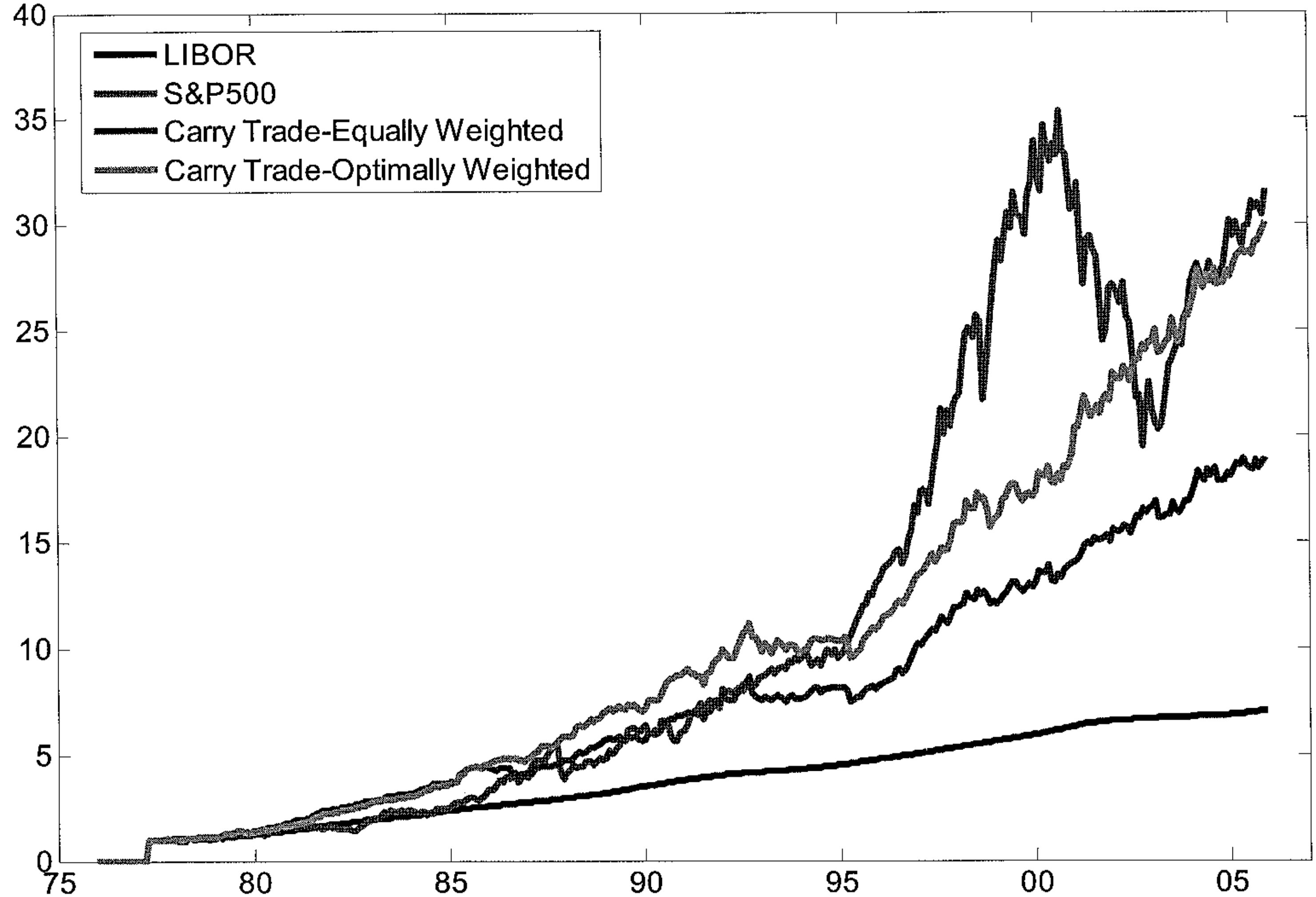


Figure 3

Cumulative Nominal Returns to Trading Strategies, November 1979=1

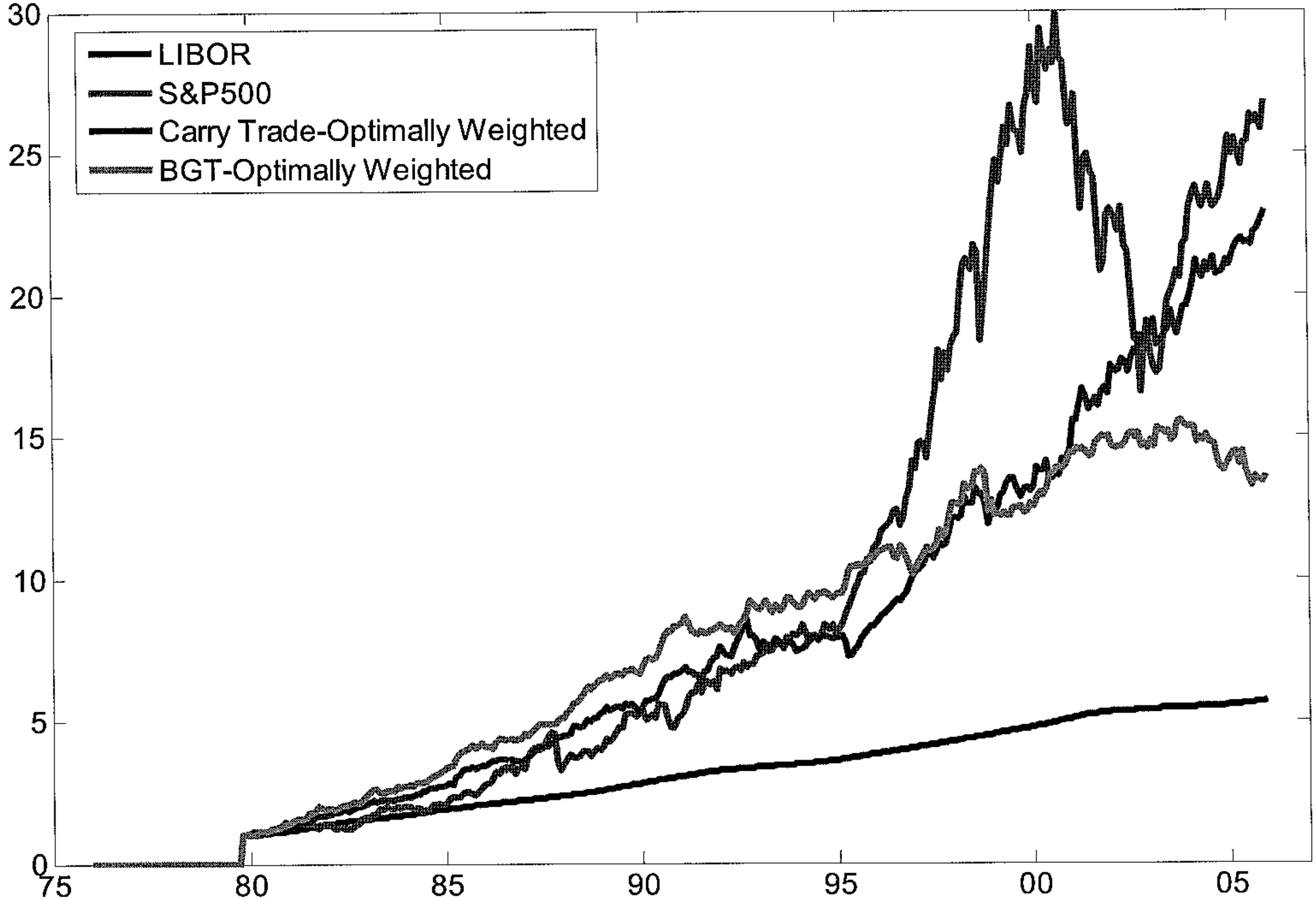


Figure 4

Realized Sharpe Ratio: Three Year Rolling Window

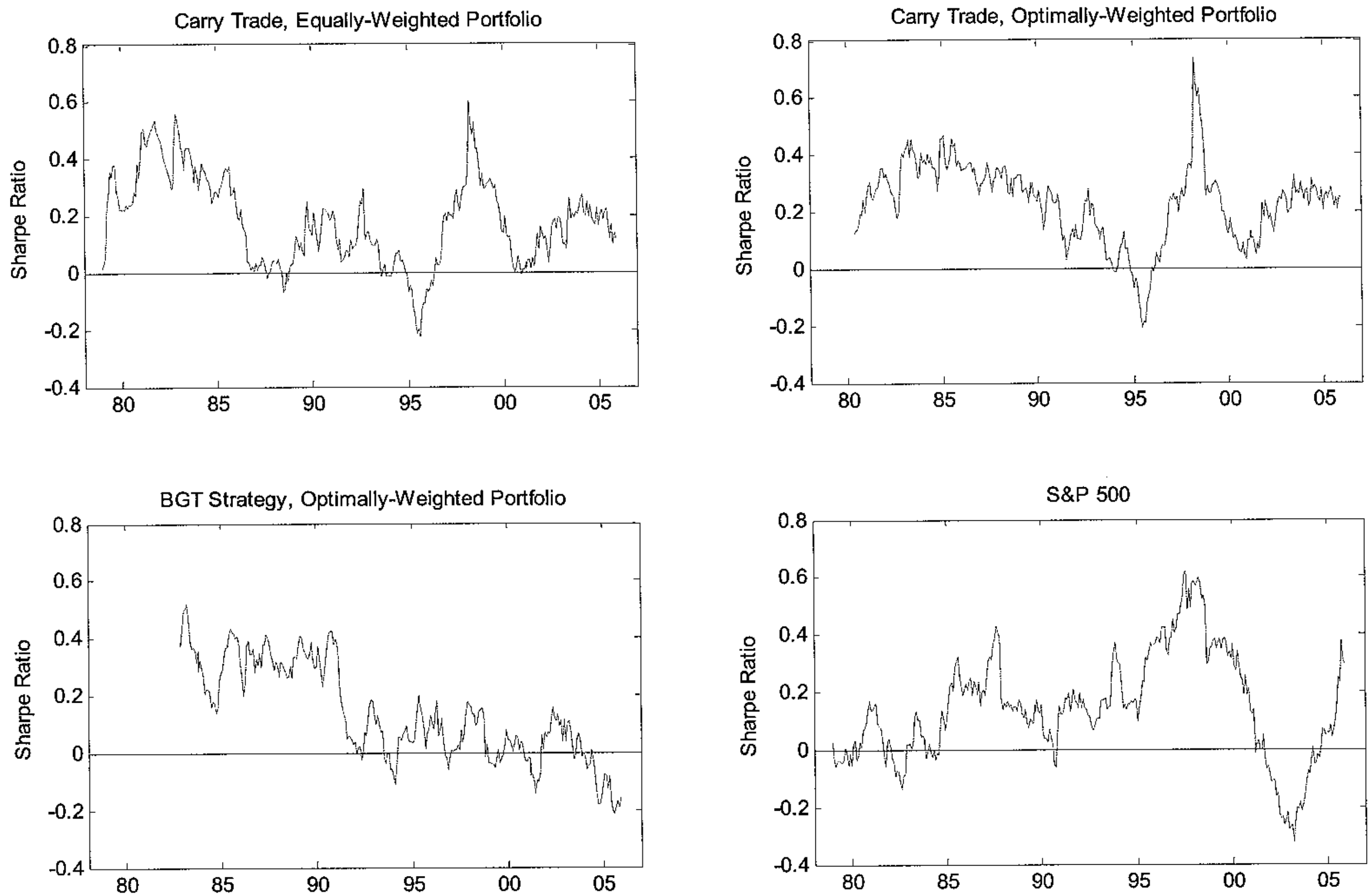


Figure 5

Payoff to Carry Trade

(Percentage of periods with no trade in parenthesis)

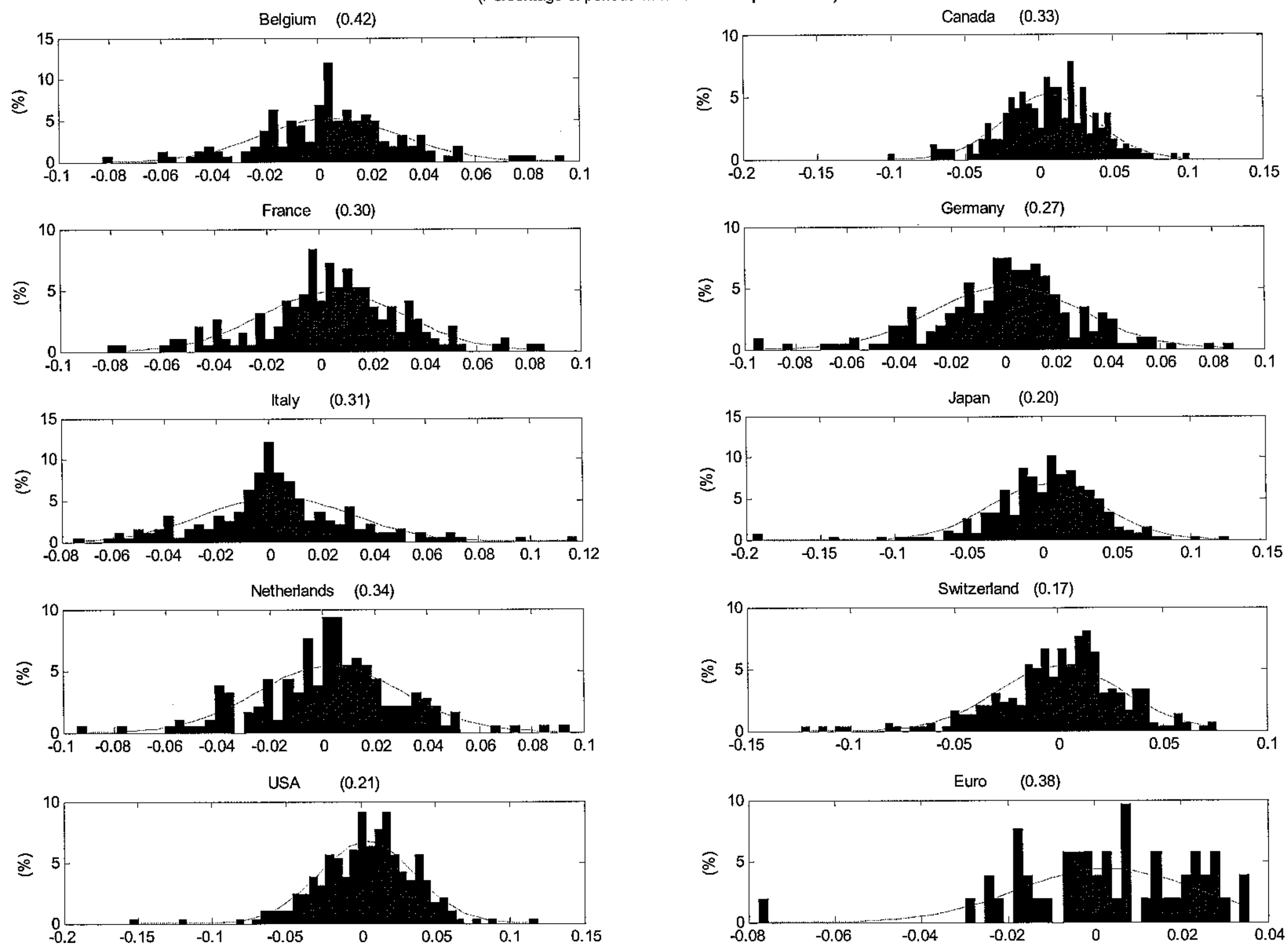


Figure 6

Payoff to BGT Strategy

(Percentage of periods with no trade in parenthesis)

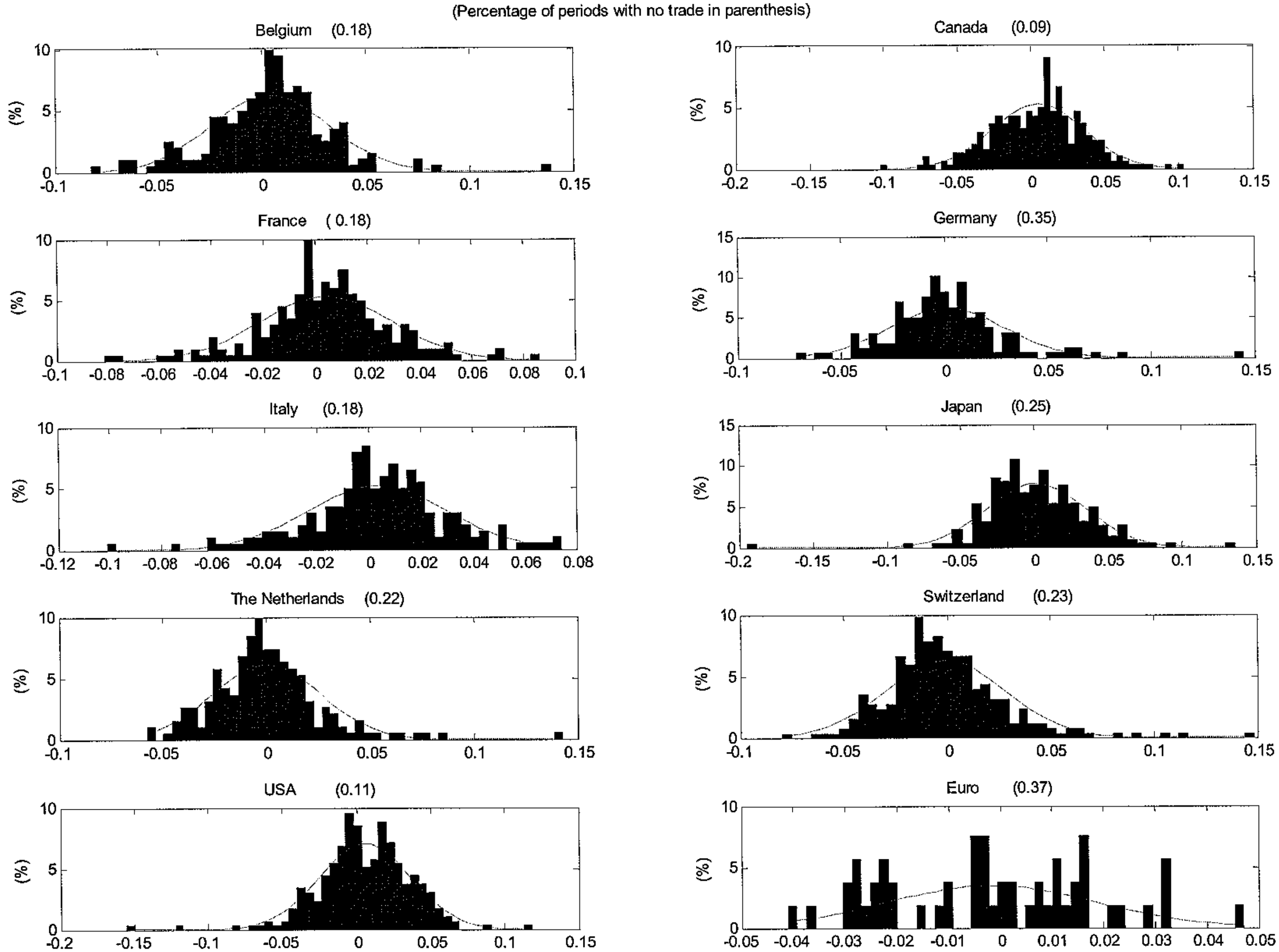
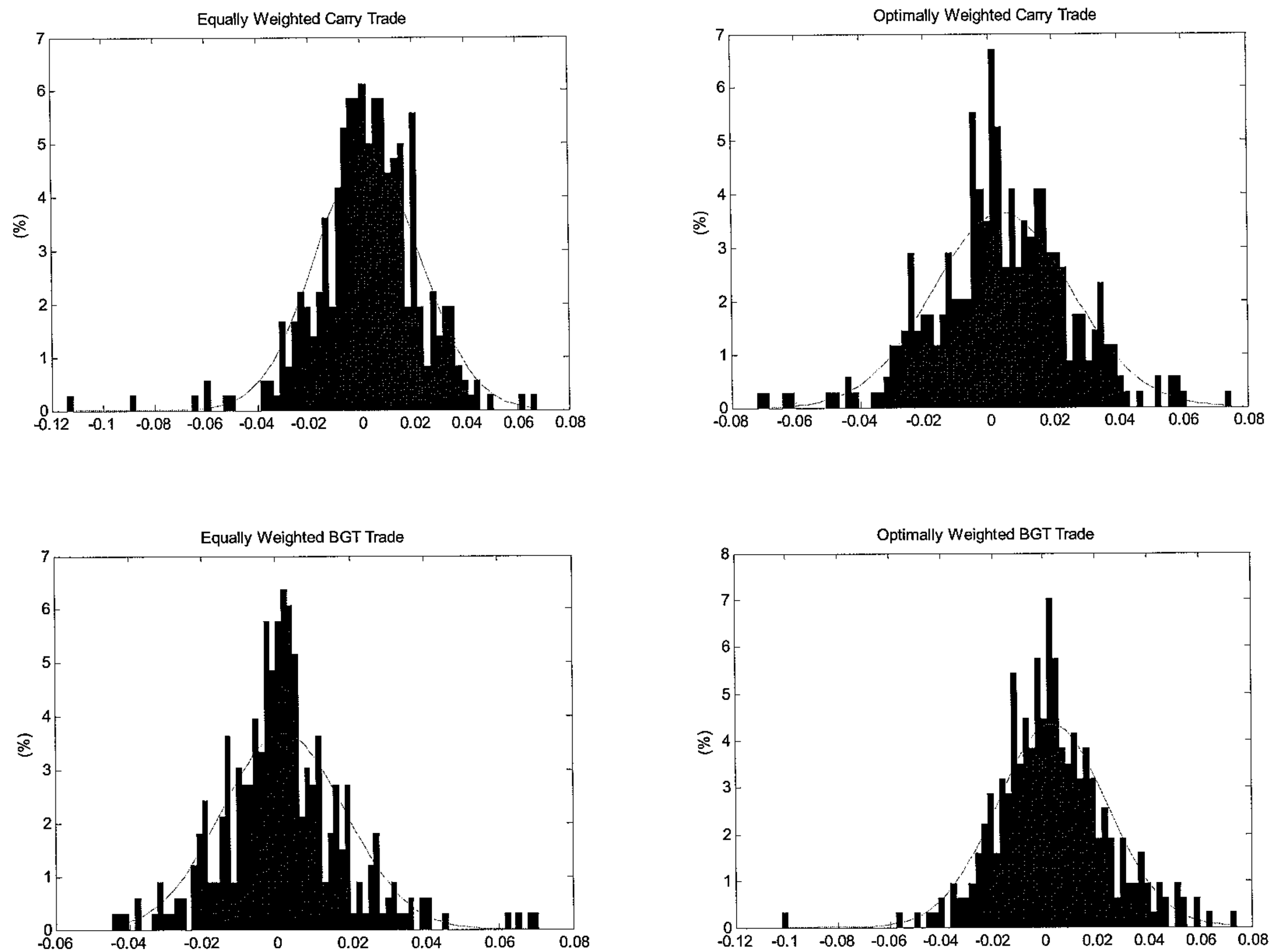


Figure 7


Equally Weighted Carry Trade
Optimally Weighted Carry Trade
Equally Weighted BGT Trade
Optimally Weighted BGT Trade
(%)