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ABSTRACT

Currencies that are at a forward premium tend to depreciate. This 'forward- premium puzzle' is an egregious deviation from uncovered interest parity. We document the properties of the carry trade, a currency speculation strategy that exploits this anomaly. This strategy consists of borrowing low-interest-rate currencies and lending high-interest-rate currencies. We first show that the carry trade yields a high Sharpe ratio that is not a compensation for risk. We then consider a hedged version of the carry trade which protects the investor against large, adverse currency movements. This strategy, implemented with currency options, yields average payoffs that are statistically indistinguishable from the average payoffs to the standard carry trade. We argue that this finding implies that the peso problem cannot be a major determinant of the payoff to the carry trade.

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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). This paper studies the properties of the payoffs to a currency speculation strategy that exploits this anomaly. The strategy, known as the carry trade, involves selling currencies forward that are at a forward premium and buying currencies forward that are at a forward discount. Transaction costs aside, this strategy is equivalent to borrowing low-interest-rate currencies in order to lend high-interest-rate currencies, without hedging the associated currency risk. Consistent with results in the literature, we find that the carry-trade strategy applied to portfolios of currencies yields high average payoffs, as well as Sharpe ratios that are substantially higher than those associated with the U.S. stock market.

The most natural interpretation for the high average payoffs to the carry trade is that they compensate agents for bearing risk. However, we show that linear stochastic discount factors built from conventional measures of risk, such as consumption growth, the returns to the stock market, and the Fama-French (1993) factors, fail to explain the returns to the carry trade. This failure reflects the absence of a statistically significant correlation between the payoffs to the carry trade and traditional risk factors.[1] Our results are consistent with previous work documenting that one can reject consumption-based asset-pricing models using data on forward exchange rates.[2] More generally, it has been difficult to use asset-pricing models such as the CAPM to rationalize the risk-premium movements required to account for the time-series properties of the forward premium.[3]

The most natural alternative explanation for the high average payoffs to the carry trade is that they reflect the presence of a peso problem. A number of authors have recently argued that this problem lies at the root of the failure of UIP.[4] To understand this argument suppose that a foreign currency is at a forward premium, so a carry-trade investor sells this currency forward. Assume that a large appreciation of the foreign currency occurs with a small probability. The investor must be compensated for the negative payoff to the carry trade in this state of the world. From this perspective, the observed returns to the carry

[1] See Villanueva (2007) for additional evidence on this point.

[2] See, for example, Bekaert and Hodrick (1992) and Backus, Foresi, and Telmer (2001).

[3] See, for example, Bekaert (1996) and De Santis and Gérard (1999).

[4] See Farhi and Gabaix (2008). Other authors, such as Rietz (1988), Barro (2006), and Gabaix (2007), argue that peso problems can explain other asset-pricing anomalies such as the equity premium.

trade are positive because the rare event (the large appreciation of the foreign currency) does not occur in sample.

To evaluate this explanation we develop a version of the carry-trade strategy that does not yield high negative returns should a peso event occur. This strategy works as follows. When an investor sells the foreign currency forward he simultaneously buys a call option on that currency. If the foreign currency appreciates beyond the strike price, the investor can buy the foreign currency at the strike price and deliver the currency in fulfilment of the forward contract. Similarly, when an investor buys the foreign currency forward, he can hedge the downside risk by buying a put option on the foreign currency. By construction, this "hedged carry trade" is immune to peso events.

Suppose that the high average payoffs to the carry trade arise because of a peso problem. We argue that, under these circumstances, the average payoff to the hedged carry trade should be significantly lower than the average payoff to the unhedged carry trade. The basic intuition for this result is that, when peso events are associated with very large negative carry-trade payoffs, the price of options used to hedge against these events is very high. In a sample where peso events do not occur, the agent pays a high insurance premium without receiving any payoffs from the insurance policy that are related to the realization of a peso event. So, the average payoff to the hedged carry trade should be low.

To assess the empirical relevance of peso-based explanations for the returns to the carry trade, we compile a new data set on currency-option prices with one-month maturity for six major currencies against the dollar. The key empirical finding of this paper is that the hedged carry trade has average payoffs that are statistically indistinguishable from the average payoffs to the unhedged carry trade. On the basis of these results we conclude that peso-problem considerations cannot account for a large part of the returns to the carry trade.

Our paper is organized as follows. In section 2 we briefly review the basic exchange-rate parity conditions and discuss the carry-trade strategy. We describe our data in Section 3. In Section 4 we characterize the properties of payoffs to the carry trade. In Sections 5 we study whether the payoffs to the carry trade can be explained by risk considerations. In Section 6 we study the properties of the hedged carry trade. Section 7 concludes.

2 Parity Conditions and the Carry Trade

In this section we accomplish three tasks. First, we define notation and state basic asset-pricing conditions that pertain to investments in different currencies. Second, we describe a standard version of the carry trade.

Let S_t denote the spot exchange rate and F_t denote the forward exchange rate for contracts maturing at time $t+1$. Both S_t and F_t are expressed as dollars per foreign currency unit (FCU). Consider the following investment strategy. Borrow one dollar at the domestic interest rate, r_t, convert the dollar at the spot exchange rate into $1/S_t$ FCUs, and invest these FCUs at the foreign interest rate, r_t^*. At time $t+1$ convert the FCU proceeds into dollars at the spot exchange rate S_{t+1}. The payoff to this strategy is:

$$z_{t+1} = (1 + r_t^*) \frac{S_{t+1}}{S_t} - (1 + r_t). \quad (1)$$

Since this strategy involves zero net investment, the payoff must satisfy:

$$E_t(M_{t+1} z_{t+1}) = 0. \quad (2)$$

Here M_{t+1} denotes the stochastic discount factor that prices payoffs denominated in dollars and E_t denotes the time-t conditional expectation operator. Equation (2) implies the following risk-adjusted version of UIP:

$$(1 + r_t) = (1 + r_t^*) \left[E_t \left(\frac{S_{t+1}}{S_t} \right) + \frac{\text{cov}_t \left(S_{t+1}/S_t, M_{t+1} \right)}{E_t M_{t+1}} \right], \quad (3)$$

where $\text{cov}_t(.)$ denotes the time-t conditional covariance.

Covered interest parity implies that:

$$(1 + r_t) = \frac{1}{S_t} (1 + r_t^*) F_t. \quad (4)$$

Together, (3) and (4) imply that the expected change in the exchange rate is equal to the forward premium and a risk-premium correction,

$$E_t \left(\frac{S_{t+1} - S_t}{S_t} \right) = \frac{F_t - S_t}{S_t} - \frac{\text{cov}_t \left[M_{t+1}, \left(S_{t+1} - S_t \right) / S_t \right]}{E_t M_{t+1}}. \quad (5)$$

The literature often focuses on the case in which $\text{cov}_t \left[M_{t+1}, \left(S_{t+1} - S_t \right) / S_t \right] = 0$, so the risk premium is zero.[5] Under this assumption, the forward rate is an unbiased predictor of the future spot rate:

$$E_t \left(\frac{S_{t+1} - S_t}{S_t} \right) = \frac{F_t - S_t}{S_t}. \quad (6)$$

[5]Early contributions to the literature include Bilson (1981) and Fama (1984). See Engel (1996) for a review of the literature.

Tests of relation (6) generally focus on the regression:

$$\left(S_{t+1}-S_t\right)/S_t=\alpha+\beta\left(F_t-S_t\right)/S_t+\xi_{t+1}. \tag{7}$$

Under the null hypothesis that equation (6) holds, $\alpha = 0$, $\beta = 1$, and ξ_{t+1} is orthogonal to time t information. This null hypothesis has been consistently rejected. Estimated values of β are often negative, a result commonly referred to as the 'forward-premium puzzle.' Under the null hypothesis (6), the foreign currency should, on average, appreciate when it is at a forward premium ($F_t > S_t$). The negative point estimates of β imply that the foreign currency actually tends to depreciate when it is at a forward premium. Equivalently, low-interest-rate currencies tend to depreciate.[6]

The Carry Trade The forward premium puzzle motivates a variety of speculation strategies.[7] Here we focus on the carry trade, the strategy most widely used by practitioners (see Galati and Melvin (2004)). Abstracting from bid-ask spreads, the carry trade consists in borrowing a low-interest-rate currency and lending a high-interest-rate currency. The payoff to this strategy, denominated in dollars, is:

$$y_t\left[(1+r_t^*)\frac{S_{t+1}}{S_t}-(1+r_t)\right], \tag{8}$$

where y_t, the amount of dollars borrowed, is given by:

$$y_t=\begin{cases}+1 & \text{if } r_t<r_t^*,\\ -1 & \text{if } r_t^*<r_t.\end{cases} \tag{9}$$

The carry trade is a zero-net-investment strategy. In equation (9) we normalize the amount of dollars we bet on this strategy (the absolute value of y_t) to one.

Suppose the agent believes that S_{t+1} is a martingale:

$$E_tS_{t+1}=S_t. \tag{10}$$

Then the expected payoff to the carry trade is positive and equal to the difference between the higher and the lower interest rates:

$$y_t\left(r_t^*-r_t\right)>0.$$

[6] We report corroborating evidence for these findings using our data set in Table A1 of the Appendix.

[7] A different strategy, proposed by Bilson (1981), Fama (1984), and, Backus, Gregory, and Telmer (1993), uses the following regression to forecast the payoff to selling FCUs forward: $\left(F_t-S_{t+1}\right)/S_{t+1}=a+b\left(F_t-S_t\right)/S_t+\xi_{t+1}$. This strategy involves selling (buying) the FCU forward when the payoff predicted by the regression is positive (negative). Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006) discuss the properties of the payoffs to this strategy.

Since (10) is a reasonable empirical characterization of exchange rates, and interest rate differentials are quite persistent it is not surprising that the carry trade has positive expected profits. Suppose, also, that $\text{cov}_t\left[M_{t+1}, \left(S_{t+1} - S_t\right)/S_t\right] = 0$. In this case there is no risk associated with the carry trade. Since the expected payoff is positive, it is optimal to engage in the carry trade.

The carry-trade strategy can also be implemented by selling the foreign currency forward when it is at a forward premium ($F_t > S_t$) and buying the foreign currency forward when it is at a forward discount ($F_t < S_t$). We consider two versions of this strategy distinguished by how bid-ask spreads are treated. In both versions we normalize the size of the bet to one dollar. In the first version we calculate payoffs assuming that agents can buy and sell currency at the average of the bid and ask rates. From this point on, we denote the average of the bid (S_t^b) and the ask (S_t^a) spot exchange rates by S_t,

$$S_t = \left(S_t^a + S_t^b\right)/2,$$

and the average of the bid (F_t^b) and the ask (F_t^a) forward exchange rates by F_t,

$$F_t = \left(F_t^a + F_t^b\right)/2.$$

The ask (bid) exchange rate is the rate at which a participant in the interdealer market can buy (sell) dollars from (to) a currency dealer.

The value of x_t, the number of FCUs sold forward, is given by:

$$x_t = \begin{cases} +1/F_t & \text{if } F_t \geq S_t, \\ -1/F_t & \text{if } F_t < S_t. \end{cases} \tag{11}$$

This value of x_t is equivalent to buying/selling one dollar forward. The dollar-denominated payoff to this strategy at $t+1$, denoted z_{t+1}, is

$$z_{t+1} = x_t\left(F_t - S_{t+1}\right). \tag{12}$$

We refer to this strategy as the 'carry trade without transaction costs.'

When equation (4) holds, the strategy defined by (11) yields positive payoffs if and only if the strategy defined by (9) has positive payoffs. This result holds because the two payoffs are proportional to each other. In this sense the strategies are equivalent. We focus our analysis on strategy (11) because of data considerations.

In the second version of the carry trade we take bid-ask spreads into account when deciding whether to buy or sell foreign currency forward and in calculating payoffs. We refer to this strategy as the 'carry trade with transaction costs.' Suppose that agents adopt the decision rule,

$$x_t = \begin{cases} +1/F_t^b & \text{if } F_t^b/S_t^a > 1, \\ -1/F_t^a & \text{if } F_t^a/S_t^b < 1, \\ 0 & \text{otherwise.} \end{cases} \tag{13}$$

The payoff to this strategy is:

$$z_{t+1} = \begin{cases} x_t \left(F_t^b - S_{t+1}^a\right) & \text{if } x_t > 0, \\ x_t \left(F_t^a - S_{t+1}^b\right) & \text{if } x_t < 0, \\ 0 & \text{if } x_t = 0. \end{cases} \tag{14}$$

If agents compute forecasts using $E_t S_{t+1}^a = S_t^a$ and $E_t S_{t+1}^b = S_t^b$, then the expected payoff associated with strategy (13) is positive.

3 Data

In this section we describe our data sources for spot and forward exchange rates and interest rates. We also describe the options data that we use to analyze the importance of the peso problem.

Spot and Forward Exchange Rates Our data set on spot and forward exchange rates, obtained from Datastream, covers the Euro and the currencies of 20 countries: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, the UK, and the U.S.

The data consist of daily observations for bid and ask spot exchange rates and one-month forward exchange rates. We convert daily data into non-overlapping monthly observations (see Appendix A for details).

Our data spans the period from January 1976 to January 2008. However, the sample period varies by currency (see Appendix A for details). Exchange rate quotes (bid, ask, and mid, defined as the average of bid and ask) against the British pound (GBP) are available beginning as early as 1976. Bid and ask exchange rate quotes against the U.S. dollar (USD) are only available from January 1997 to January 2008. We obtain mid quotes over the longer sample against the dollar by multiplying GBP/FCU quotes by USD/GBP quotes.

Interbank Interest Rates and Covered Interest Parity We also collected data on interest rates in the London interbank market from Datastream. These data are available for 17 countries/currencies: Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, South Africa, Sweden, Switzerland, the UK, the U.S. and the Euro.

The data consist of daily observations for bid and ask eurocurrency interest rates. We convert daily data into non-overlapping monthly observations. Our data spans the period from January 1976 to January 2008, with the exact sample period varying by currency (see Appendix A for details).

We use the interest rate data, along with the exchange rate data, to assess the quality of our data set and to determine whether we can test UIP using (6). Since (6) follows from the combination of UIP and CIP, we investigate whether CIP holds taking bid-ask spreads into account. We find that deviations from CIP are small and rare. Details of our analysis are provided in Appendix B.

Options Prices Our data on currency option prices are from the Chicago Mercantile Exchange. These data consist of daily observations for the period from January 1987 to January 2008 on the prices of put and call options against the U.S. dollar for the Australian dollar, the Canadian dollar, the Euro, the Japanese yen, the Swiss franc, and the British pound. Appendix C specifies the exact period of availability for each currency.

Since we consider the payoffs to implementing the carry trade at a monthly frequency, we use data on options that are one month from maturity (see Appendix C for details). We work exclusively with options expiring mid-month (on the Friday preceding the third Wednesday). We measure option prices using settlement prices for transactions that take place exactly 30 days prior to the option's expiration date. We measure the time-t forward, spot, and option strike and settlement prices on the same day, and measure the time $t+1$ spot price on the option expiration date. Option prices are measured at time t. The option payoff occurs at time $t+1$. To compute net payoffs we multiply option prices by the 30-day eurodollar interest rate obtained from the Federal Reserve Board. This 30-day interest rate is matched to the maturity of our options data.

Bid-Ask Spreads in Exchange Rates Table 1 displays median bid-ask spreads for spot and forward exchange rates measured in log percentage points ($100 \times \ln(\text{Ask}/\text{Bid})$). The left-hand panel reports spreads over the longest available sample for quotes against the British pound. The center panel reports spreads after the introduction of the Euro for quotes against the pound. The right-hand panel reports spreads over the longest available sample for quotes against the U.S. dollar.

Four observations emerge from Table 1. First, bid-ask spreads are wider in forward markets than in spot markets. Second, there is substantial heterogeneity across currencies in the magnitude of bid-ask spreads. Third, with the exception of South Africa, 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 brokerage systems, such as Reuters' Dealing 2000-2, launched in 1992, and the Electronic Broking System launched in 1993.[8] Fourth, over comparable sample periods, the bid-ask spreads for spot and forward exchange rates against the U.S. dollar are always lower than the analogous spreads against the British pound.

4 Payoffs to the Carry Trade

In this section we study the properties of the payoffs to the carry trade. We consider this strategy for individual currencies as well as for portfolios of currencies. We also discuss the impact of transaction costs on the profitability of the strategy by analyzing the payoffs to the carry trade with and without bid-ask spreads.

For now we focus attention on the returns to an equally-weighted portfolio of carry-trade strategies.[9] This portfolio is constructed by betting $1/n_t$ of one unit of the home currency in each individual currency carry trade. Here n_t denotes the number of currencies in our sample at time t. In the remainder of the paper, unless otherwise noted, we use the term "carry-trade strategy" to refer to the equally-weighted carry trade. Table 2 reports the mean, standard deviation, and Sharpe ratio of the monthly non-annualized payoffs to the carry trade, with and without transaction costs. We consider two alternative home currencies, the British pound and the U.S. dollar. Using the British pound as the home currency allows us to assess the importance of bid-ask spreads using a much longer time series that would be the case if we look only at the U.S. dollar as the home currency.

Consider the results when the British pound is the home currency. Ignoring transaction costs, the Sharpe ratio of the equally-weighted carry-trade portfolio is roughly 0.234. Taking bid-ask spreads into account reduces the Sharpe ratio to 0.167. But the Sharpe ratio is

[8] It took several 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.

[9] In Tables A2 and A3 of the Appendix we report results for individual currencies.

statistically different from zero with and without transaction costs. Next consider the results when the dollar is the home currency. Ignoring transaction costs, the Sharpe ratio of the equally-weighted carry-trade portfolio is roughly 0.306. Taking bid-ask spreads into account reduces the Sharpe ratio to 0.250. But, once again, the Sharpe ratio is statistically different from zero, both with and without transaction costs. The impact of transaction costs is smaller when the dollar is the base currency, because bid-ask spreads are lower for the dollar than for the pound (see Table 1).

The results in Table 2 may overstate the impact of transaction costs on the carry-trade payoff because there are alternative ways to execute the carry trade that can reduce the impact of these costs. We compute the payoffs to the carry trade executed through forward markets. However, when interest-rate differentials are persistent, it can be more cost efficient to execute the carry trade through money markets. To be concrete suppose that the Yen interest rate is lower than the dollar interest rate. We can implement the carry trade by borrowing Yen, converting the proceeds into dollars in the spot market and investing the dollars in the U.S. money market. This dollar investment and Yen loan are rolled over as long as interest rate differentials persist. When the strategy is initially implemented, the investor pays one bid-ask spread to convert the proceeds of the Yen loan into dollars. In the final phase of the strategy the investor pays a second bid-ask spread in the spot exchange market to convert dollar into Yen to pay back the initial Yen loan. In contrast, the strategy that underlies the payoffs in Table 2 incurs transaction costs associated with closing out the investor's position every month.

Taken together, our results indicate that, while transaction costs are quantitatively important, they do not explain the profitability of the carry trade. For the remainder of this paper we abstract from transaction costs and work with spot and forward rates that are the average of bid and ask rates.[10] Given this decision we can work with the longer data set (from January 1976 to January 2008) using the U.S. dollar as the home currency.

Table 3 reports statistics for the payoffs to the equally-weighted carry trade and summary statistics for the individual-currency carry trades. The latter are computed by taking the average of the statistics for the carry trade applied to each of the 20 currencies in our sample. To put our results into perspective, we also report statistics for excess returns to the value-weighted U.S. stock market. Two results emerge from this table. First, there are large gains

[10]In Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006) we present a more comprehensive set of results for the carry trade payoffs taking bid-ask spreads into account.

to diversification. The average Sharpe ratio across currencies is 0.138, while the Sharpe ratio for an equally-weighted portfolio of currencies is 0.280. This large rise in the Sharpe ratio is due to the fact that the standard deviation of the payoffs is much lower for the equally-weighted portfolio.[11] Second, the Sharpe ratio of the carry trade is substantially larger than that of the U.S. stock market (0.280 versus 0.133). While the average excess return to the U.S. stock market is larger than the payoff to the carry trade (7.0 versus 5.1 percent on an annual basis), the returns to the U.S. stock market are much more volatile than the excess returns to the carry trade (14.8 versus 5.1 percent annualized standard deviation).

Figure 1 displays 12-month moving averages of the realized payoffs and Sharpe ratios associated with the carry trade. Negative payoffs are relatively rare and positive payoffs are not concentrated in a small number of periods.

To provide a different perspective on the profitability of the carry trade we use the realized payoffs to compute the cumulative realized return to committing one dollar in 1976 to the carry trade and reinvesting the proceeds at each point in time. The agent starts with one U.S. dollar in his bank account and bets that dollar in the carry trade. From that point on the agent bets the balance of his bank account on the carry trade. Carry-trade strategy payoffs are deposited or withdrawn from the agent's account. Since the currency strategy is a zero-cost investment, the agent's net balances stay in the bank and accumulate interest at the Treasury bill rate. It turns out that the bank account balance never becomes negative in our sample.

Figure 2 displays the cumulative return to the carry-trade strategy. For comparison we also display the cumulative realized return to the U.S. stock market and to the one-month Treasury bill. These figures show that the carry-trade strategy and the U.S. stock market have higher cumulative returns than the Treasury bill. Consistent with the results reported in Table 3, the total cumulative return to the carry trade is somewhat smaller than that of the U.S. stock market but much less volatile.

Fat Tails So far we have emphasized the mean and variance of the payoffs to the carry trade. These statistics are sufficient to characterize the distribution of the payoffs only if this

[11] Since there are gains to combining currencies into portfolios, it is natural to construct portfolios that maximize the Sharpe ratio. See Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006) for details on how to implement this strategy. For the sample considered in this paper the Sharpe ratios associated with the equally-weighted and optimally-weighted portfolios are very similar. For this reason we do not report results for the latter portfolio.

distribution is normal. We now analyze other properties of the payoff distribution. Figure 3 shows the sample distributions of the dollar payoffs to the carry trade and to the U.S. stock market.[12] In addition we display a normal distribution with the same mean and variance as the empirical distribution of the payoffs. It is evident that the distributions of both payoffs are leptokurtic, exhibiting fat tails. This impression is confirmed by Table 3 which reports skewness and excess kurtosis statistics, as well as the results of the Jarque-Bera normality test statistics.[13] While both distributions have fat tails, the bad outcomes associated with the carry trade are small compared to those associated with the U.S. stock market (see Figure 3). We conclude that fat tails are an unlikely explanation of the high average payoffs associated with our currency-speculation strategies.

5 Does Risk Explain the Average Payoff of the Carry Trade?

A natural explanation for the high average payoff to the carry trade is that the carry-trade strategy is risky. Recall that according to equation (5):

$$\frac{F_t - S_t}{S_t} = E_t\left(\frac{S_{t+1} - S_t}{S_t}\right) + \frac{\text{cov}_t\left[M_{t+1}, \left(S_{t+1} - S_t\right)/S_t\right]}{E_t M_{t+1}}.$$

It is always possible to define the time-varying risk premium, p_t, as:

$$p_t = \frac{F_t - S_t}{S_t} - E_t\left(\frac{S_{t+1} - S_t}{S_t}\right).$$

By construction, such risk premia can rationalize the payoffs to the carry trade. For example, if the exchange rate is a martingale, then this procedure labels the forward premium as the risk premium. A more challenging task is to define an economically meaningful stochastic discount factor, M_{t+1}, such that:

$$p_t = \frac{\text{cov}_t\left[M_{t+1}, \left(S_{t+1} - S_t\right)/S_t\right]}{E_t M_{t+1}}.$$

In our empirical work we use the real quarterly dollar-denominated excess returns, R_t^e, to our carry-trade strategies.[14] Accordingly, we focus on finding a stochastic discount factor,

[12] Figure A1 in the Appendix shows the sample distributions of the dollar payoffs to the carry trade implemented for each of our 20 currencies.

[13] In Table A4 of the Appendix we report skewness, excess kurtosis, and the Jarque-Bera normality test for the dollar payoffs to the carry trade implemented for each of our 20 currencies.

[14] In Appendix D we show how we convert monthly payoffs to real quarterly excess returns.

m_{t+1}, that prices real dollar-denominated excess returns. By definition,

$$E_t\left(R^e_{t+1}m_{t+1}\right) = 0. \tag{15}$$

We consider linear stochastic discount factors of the form:

$$m_t = \xi\left[1 - (f_t - \mu)' b\right]. \tag{16}$$

Here ξ is a scalar, f_t is a vector of risk factors, $\mu = E(f_t)$, and b is a conformable vector. Equations (15) and (16) imply that:

$$E(R^e_t) = \beta\lambda$$

where

$$\begin{aligned} \beta &= \operatorname{cov}(R^e_t, f'_t)V_f^{-1}, \\ \lambda &= V_f b. \end{aligned} \tag{17}$$

Here V_f is the covariance matrix of the factors, β is a measure of the systematic risk associated with the payoffs, and λ is a vector of risk premia. Note that β is the population value of the regression coefficient of R^e_t on f_t.

Time-Series Risk-Factor Analysis In our analysis we consider the following risk factors: the excess returns to the value-weighted U.S. stock market, the Fama-French (1993) factors (the excess return to the value weighted U.S. stock market, the size premium (SMB), and the value premium (HML)), real U.S. per capita consumption growth (nondurables and services), the factors proposed by Yogo (2006) (the growth rate of per capita consumption of nondurables and services, the growth rate of the per capita service flow from the stock of consumer durables, and the return to the value-weighted U.S. stock market), luxury sales growth (obtained from Aït-Sahalia, Parker and Yogo (2004)), GDP growth, the Fed Funds Rate, the term premium (the yield spread between the 10 year Treasury bond and the three month Treasury bill), the liquidity premium (the spread between the three month Eurodollar rate and the three month Treasury bill), and two measures of volatility, the VIX and the VXO (the implied volatility of the S&P 500 and S&P 100 index options, respectively, calculated by the Chicago Board Options Exchange).

Table 4 reports the estimated regression coefficients associated with the different risk-factor candidates, along with the corresponding test statistics. Our key finding is that none of the risk factors covaries significantly with the payoffs to the carry trade. As Table 3 shows, the average payoff to the carry trade is statistically different from zero. Factors that have zero βs clearly cannot account for these returns. So the results in Table 4 are consistent with the view that risk-related explanations for the high average payoffs to the carry trade are empirically implausible.

Panel Risk-Factor Analysis We now provide a complementary way of assessing the shortcomings of risk-related explanations for the payoffs to the carry trade. We estimate the parameters of stochastic discount factor models built using the risk factors detailed in Table 4. In addition, we also use the Campbell-Cochrane (1990) stochastic discount factor (see Appendix D for details on how we construct this SDF).[15] We use the estimated stochastic discount factor models to generate the expected excess returns to the carry-trade strategy and the 25 Fama-French portfolios of U.S. stocks sorted on the basis of firm size and the ratio of book-to-market value. We then study how well the model explains the average excess return associated with the carry trade, as well as the cross-sectional variation of the different excess returns used in the estimation procedure.

It follows from equation (15) and the law of iterated expectations that:

$$E\left(R_t^e m_t\right) = 0. \tag{18}$$

Here R_t^e denotes a 26×1 vector of time-t excess returns to the carry-trade strategy and the 25 Fama-French portfolios.

We estimate b and μ by the generalized method of moments (GMM) using equation (18) and the moment condition $\mu = E(f_t)$. The first stage of the GMM procedure, which uses the identity matrix to weight the GMM errors, is equivalent to the Fama-MacBeth (1973) procedure. The second stage uses an optimal weighting matrix.[16]

It is evident from equations (16) and (18) that $\xi = E(m_t)$ is not identified. Fortunately, the point estimate of b and inference about the model's over-identifying restrictions are invariant to the value of ξ, so we set ξ to one for convenience. It follows from equations (16) and (18) that:

$$E\left(R_t^e\right) = -\frac{\mathrm{cov}(R_t^e, m_t)}{E\left(m_t\right)} = E\left[R_t^e \left(f_t - \mu\right)' b\right]. \tag{19}$$

[15] Verdelhan (2007) argues that open-economy models in which agents have Campbell-Cochrane (1999) preferences can generate non-trivial deviations from UIP.

[16] Details of our GMM procedure are provided in Appendix E.

Given an estimate of b, the predicted mean excess return is the sample analogue of the right-hand side of equation (19), which we denote by $\hat{R}^e$. The actual mean excess return is the sample analogue of the left-hand side of equation (19), which we denote by $\bar{R}^e$. We denote by $\tilde{R}^e$ the average across the elements of $\bar{R}^e$. We evaluate the model using the R^2 between the predicted and actual mean excess returns. The R^2 measure is:

$$R^2 = 1 - \frac{(\bar{R}^e - \hat{R}^e)'(\bar{R}^e - \hat{R}^e)}{(\bar{R}^e - \tilde{R}^e)'(\bar{R}^e - \tilde{R}^e)}.$$

This R^2 measure is invariant to the value of ξ.

For each risk factor, or vector of factors, Table 5 reports the first and second-stage estimates of b, the R^2, and the value of Hansen's (1982) J statistic used to test the over-identifying restrictions implied by equation (18). The results fall into two categories, depending on whether the b parameters associated with a particular risk-factor model are estimated with any degree of precision. For the CAPM and the Fama-French model, the b parameters are precisely estimated and are statistically different from zero.[17] But the over-identifying restrictions associated with these models are overwhelmingly rejected. Interestingly, the CAPM explains none of the cross-sectional variation in the excess returns. In contrast the Fama-French model explains a substantial component of the cross-sectional variation in the excess returns.

The second category of results pertains to the remaining risk-factor models. For all these models, the b parameters associated with the corresponding risk factors are estimated with great imprecision. In no case can we reject the null hypothesis that the b parameters are equal to zero or that the model-implied excess return to the carry trade is equal to zero. Moreover the R^2s paint a dismal picture of the ability of these risk factors to explain the cross-sectional variation in expected returns. Indeed, most of the R^2s are actually *negative.* However, because the b parameters are estimated with enormous imprecision, it is difficult to statistically rule out regions of the parameter space for which the model's predictions for excess returns are consistent with the data. Since there is little information in the sample about the b parameters it is hard to statistically reject these factor models.[18]

We now provide an alternative perspective on the performance of four stochastic discount factor models that have received substantial attention in the literature. These models are:

[17] An exception is the coefficient associated with the SMB factor in the Fama-French model.

[18] We also estimated the parameters of these factor models using data beginning in 1948 for the Fama French portfolio returns. This extension has very little impact on the precision with which we estimate the b parameters.

the CAPM model, the C-CAPM model, the Extended C-CAPM model, and the Fama-French model. Figure 4 plots the predictions of these models for $E(R_t^e)$ against the sample average of R_t^e. The circles pertain to the Fama-French portfolios, while the star pertains to the carry trade. It is clear that the first three models do a poor job of explaining the excess returns to the Fama-French portfolios and the excess returns to the carry trade. Not surprisingly, the Fama-French model does a reasonably good job at pricing the excess returns to the Fama-French portfolios. However, the model greatly understates the excess returns associated with the carry trade. The quarterly excess return to the carry trade is 1.30 percent. The Fama-French model predicts that this return should equal -0.04 percent. The solid line through the star is a two-standard-error band for the difference between the data and model excess return, i.e. the pricing error. Clearly, we can reject the hypothesis that the model accounts for the excess returns associated with the carry trade, i.e. from the perspective of the model the carry trade has a positive alpha.

The previous results give rise to the question: can we gain insight into the types of carry trades that generate positive alpha? To address this question we pursue an interesting hypothesis proposed by Brunnermeier, Nagel, and Pedersen (2008). These authors show that currencies that have high forward premia have carry trade payoffs that exhibit high negative skewness. They argue that this conditional "crash risk" discourages speculators from taking large enough positions to enforce UIP. Crash risk cannot explain the returns to the equally-weighted carry trade because the left tail of the distribution of payoffs associated with this strategy is not very large (see Figure 3). But it still could be the case that most of the equally-weighted carry-trade payoff comes from trades executed when the absolute value of the forward premium is large, possibly because the downside risk stemming from a large adverse movement in exchange rates is also large.

To pursue this hypothesis we divide all of the trades in our sample into ten deciles ranked according to the absolute value of the forward premium associated with each trade. We then compute the average, standard deviation, skewness, and kurtosis, for each of the ten groups of trades. Figure 5 summarizes our results. Clearly there is a positive correlation between the mean payoff and the absolute value of the forward premium. There is also a negative correlation between the skewness in returns and the absolute value of the forward premium. Taken together these results offer some support to the Brunnermeier, et al. (2008) hypothesis.

Figure 5 suggests that carry-trade payoffs are particularly large in periods in which the forward premium is large in absolute value. We now investigate the alphas associated with trades executed when the absolute value of the forward premium is high. To this end we rank, in every period, each currency according to the absolute value of the forward premium. On this basis we divide the currencies into five groups.[19] We then calculate the payoff to the carry trade for each of these five groups. We re-estimate the parameters of the stochastic discount factor models using the payoff to the five carry-trade portfolios and the 25 Fama-French portfolios. The results are reported in Table 6. These results are very similar to those obtained with the equally-weighted carry trade and the 25 Fama-French portfolios.

Figure 6 plots the predictions of the estimated CAPM, C-CAPM, Extended C-CAPM, and Fama-French models for the mean of the five carry-trade portfolios and 25 Fama-French portfolios against the sample average of the corresponding excess returns in the data. The Fama-French model does a reasonable job at accounting for the average excess returns of the Fama-French portfolios, but it does a very poor job with respect to the carry-trade portfolios. For the Fama-French model, the portfolios with the highest forward premia (in absolute value) have statistically significant alphas. The other stochastic discount factor models do a poor job with respect to the Fama-French portfolios. Interestingly, the large carry-trade alphas for the CAPM and Extended CAPM model are, again, associated with the large forward premium portfolios.

To summarize, we find very little evidence in either time-series data or panel data to support the view that the payoffs to our carry-trade strategies are a compensation for bearing risk.[20] It is worth emphasizing that in this paper we focus on linear stochastic discount factors. We do not rule out the possibility that some yet to be discovered non-linear stochastic discount factor models can simultaneously rationalize the cross-sectional variation in the carry-trade and Fama-French portfolios. Rather than pursue that possibility we turn our attention to peso problem based explanations of the payoffs to the carry trade.

[19]There is a subtle but important difference between these portfolios and the ones considered in Figure 5. The latter cannot be formed in real time because they are based on deciles constructed using the entire sample.

[20]Lustig and Verdelhan (2007) argue that aggregate consumption growth risk explains the cross-sectional variation in the excess returns to going long on currency portfolios that are sorted by their interest rate differential with respect to the U.S. Burnside (2007) challenges their results based on two findings. First, the time-series covariance between the excess returns to these portfolios and standard risk factors, including aggregate consumption growth, is not significantly different from zero. Second, imposing the constraint that a zero β asset has a zero excess return leads to a substantial deterioration in the ability of their model to explain the cross-sectional variation in excess returns to the portfolios.

6 Peso Problems and the Hedged Carry Trade

In this section we assess the ability of peso problems to account for the statistical properties of the payoffs to the carry trade. First, we describe a version of the carry trade which immunizes a trader from the consequences of peso-like events. Second, we report the empirical properties of the payoff associated with that strategy. Finally, we assess quantitatively the importance of the peso problem.

6.1 The Hedged Carry Trade

In standard versions of the carry trade an agent who trades at time t is exposed to the possibility of large negative returns caused by large adverse movements in the time $t+1$ spot exchange rate. We now describe a version of the carry trade that eliminates the possibility of large, negative payoffs. This version, which we refer to as the "hedged carry trade," uses options to eliminate the lower tail of the payoff distribution. We describe this strategy ignoring bid-ask spreads.

Consider a call option which gives an agent the right, but not the obligation, to buy foreign currency with dollars at a strike price of K_t dollars per FCU. We denote the dollar price of this option by C_t. The payoff of the call option in dollars, net of the option price, is:

$$z_{t+1}^C = \max\{0, S_{t+1} - K_t\} - C_t(1 + r_t).$$

Now consider a put option which gives an agent the right, but not the obligation, to sell foreign currency at a strike price of K_t dollars per FCU. We denote the dollar price of this option by P_t. The payoff of the put in dollars, net of the option price is:

$$z_{t+1}^P = \max\{0, K_t - S_{t+1}\} - P_t(1 + r_t).$$

To understand the motivation for the hedged carry trade suppose that an agent sells one FCU forward. Then, the worst case scenario in the standard carry trade arises when there is a large appreciation of the foreign currency. In this state of the world the agent realizes large losses because he has to buy foreign currency at a high value of S_{t+1} to deliver on the forward contract. However, if the agent buys a call option on the foreign currency, he can buy a FCU at the strike price $K_t < S_{t+1}$. In this case the minimum payoff of the hedged carry trade is:

$$(F_t - S_{t+1}) + (S_{t+1} - K_t) - C_t(1 + r_t) = F_t - K_t - C_t(1 + r_t). \tag{20}$$

Similarly, suppose that an agent buys one FCU forward. Then, the worst case scenario in the standard carry trade is a large depreciation of the foreign currency. In this state of the world the agent sells the foreign currency he receives from the forward contract at a low value of S_{t+1}. However, if the agent bought a put option on the foreign currency he can sell the FCU at the strike price $K_t > S_{t+1}$. In this case the minimum payoff associated with the hedged carry trade is:

$$(S_{t+1} - F_t) + (K_t - S_{t+1}) - P_t(1 + r_t) = K_t - F_t - P_t(1 + r_t). \tag{21}$$

We define the hedged carry-trade strategy as:

$$\begin{aligned} \text{If } F_t &> S_t, \text{ sell } 1/F_t \text{ FCUs forward and buy } 1/F_t \text{ call options} \\ \text{If } F_t &< S_t, \text{ buy } 1/F_t \text{ FCUs forward and buy } 1/F_t \text{ put options.} \end{aligned}$$

In order to normalize the size of the bet to one dollar, we choose the amount of FCUs traded equal to $1/F_t$. The dollar payoff to this strategy is:

$$z^H_{t+1} = \begin{cases} z_{t+1} + z^C_{t+1}/F_t & \text{if } F_t > S_t, \\ z_{t+1} + z^P_{t+1}/F_t & \text{if } F_t < S_t, \end{cases} \tag{22}$$

where z_{t+1} is the carry-trade payoff defined in (12).[21]

We implement the hedged carry trade using strike prices that are close to "at-the-money," that is K_t is as close as possible to the current spot exchange rate, S_t. We choose these strike prices because most of the options traded are actually close to being at-the-money. Options that are way out-of-the-money tend to be sparsely traded and relatively expensive. By choosing the strike price to be close to "at the money" we are being conservative in terms of over-insuring against the losses associated with rare, peso-problem-like events.

To illustrate how trading volume varies with moneyness we use data from the Chicago Mercantile Exchange that contains all transactions on currency puts and calls for a single day (November 14, 2007). This data set contains records for 260 million contract transactions. Figure 7 displays the volume of calls and puts of five currencies (the Canadian dollar, the Euro, the Japanese yen, the Swiss franc, and the British pound) against the U.S. dollar . In all cases the bulk of the transactions are concentrated on strike prices near the spot price.

[21] An alternative way to implement the hedged carry trade is to buy $1/F_t$ put options on the foreign currency when it is at a forward premium and $1/F_t$ call options on the foreign currency when it is at a forward discount. Using the put-call-forward parity condition, $(C_t - P_t)(1 + r_t) = F_t - K_t$, it is easy to show that this strategy for hedging the carry trade is equivalent to the one described in the text.

Interestingly, there is substantial skewness in the volume data. Most call options are traded at strike prices greater than or equal to the spot price. Similarly, most put options are traded at strike prices less than or equal to the spot price.

6.2 The Returns to the Hedged Carry Trade

In this subsection we compare the empirical properties of the returns to the carry trade and to the hedged carry trade. As discussed in Section 3 our option data cover six currencies and a shorter sample period (January 1987 to January 2008) than our data set on forward contracts. To assess the potential importance of the peso problem, we compute the payoffs to the carry trade and hedged carry trade over the same sample period and set of currencies.

Table 7 reports the mean, standard deviation, and Sharpe ratio of the monthly non-annualized payoffs to the carry trade, the hedged carry trade, and the U.S. stock market. Recall that we are abstracting from bid-ask spreads in calculating the payoffs to the hedged carry trade. In Section 4 we find that taking transaction costs into account reduces the average payoff to the unhedged carry trade executed with the U.S. dollar as the home currency by 9 percent. Using the data that underlies Figure 7 we compute average bid-ask spreads for puts and calls against the Canadian dollar, the Euro, the Japanese yen, and the Swiss franc. The average bid-ask spread in this data is 5.2 percent.[22] This estimate is slightly higher than the point estimate of 4.4 percent provided by Chong, Ding, and Tan (2003).[23] We use our estimate of the bid-ask spread to assess the impact of transaction costs on the average payoffs of the hedged carry trade. We find that the average payoff to the hedged carry trade declines by 12 percent as a result of transaction costs.[24] So, as with the unhedged carry trade, transaction costs are significant for the hedged carry trade but do not eliminate the average payoff.

The annualized average payoff to the hedged carry trade is lower than that of the carry trade (2.5 versus 3.3 percent).This fact offers some support to the view proposed by Farhi and Gabaix (2008), that peso problems play a role in accounting for the excess returns to the carry trade. However, the average payoffs of the carry trade and the hedged carry trade

[22] The average bid-ask spreads for individual currencies are: Canadian dollar call 5.33 percent, put 4.39 percent, Euro call 4.26 percent, put 4.78 percent, Japanese yen call 5.26 percent, put 5.61 percent, Swiss franc call 5.33 percent, put 6.35 percent, and British pound call 4.29 percent, and put 4.57 percent.

[23] Chong, Ding and Tan's (2003) estimate is based on data from the Bloomberg Financial Database for the period from December 1995 through March 2000.

[24] To assess the impact of transaction costs we increased the prices of the puts and calls used in our strategy by one half of the average bid-ask spread (2.6 percent).

are not statistically different from each other.

The first panel of Figure 8 displays a 12-month moving average of the realized payoffs for the hedged and unhedged carry-trade strategies. The second panel displays a 12-month moving average of the realized Sharpe ratios for both carry-trade strategies. The payoffs and Sharpe ratios of the two strategies are highly correlated. In this sense, the hedged and unhedged carry trade appear quite similar.

Figure 9 displays the cumulative returns to the carry trade, the hedged carry trade, the U.S. stock market, and the 30-day Treasury-bill rate. Consistent with the results in Table 7, the total cumulative return to the unhedged carry trade is somewhat larger than the cumulative return to the hedged carry trade. However, the volatility of the cumulative payoffs to the unhedged carry trade is larger than that of the hedged carry trade.

There is an important dimension along which the payoffs of the two carry-trade strategies are quite different. As Figure 10 shows, the distribution of payoffs to the unhedged carry trade has a substantial left tail. Hedging eliminates most of the left tail. This property reflects the fact that our version of the hedged carry trade uses options with strike prices that are close to at the money.

Based on the previous results we conclude that the profitability of the carry trade remains intact when we hedge away peso events. It is still possible, however, that hedging changes the nature of the payoffs so as to induce a correlation with traditional risk measures. We now investigate this possibility.

Recall from equation (17) that β is the population value of the regression coefficient of the carry-trade payoff on candidate risk factors. Table 8 reports our estimates of β for the hedged carry trade using the risk factors considered in Section 5. We find that, with the exception of GDP growth and the Fama-French HML factor, the estimated values of β are not significantly different from zero. So, these factors aside, we cannot reject the hypothesis that the payoffs to the hedged carry trade are not compensation for risk. Evidently, hedging away peso events does not change the payoffs in such a way that induces a statistically significant correlation between carry trade payoffs and risk factors. We return to the case of the Fama-French factors and GDP growth below.

We now turn to a panel risk-factor analysis of the hedged carry-trade payoffs. We estimate the parameters of the same stochastic discount factor models considered in Section 5. Our estimation results are generated using a 26×1 vector of time-t excess returns to the hedged carry-trade strategy and the 25 Fama-French portfolios. We report our results in Table 9. The key finding is that the results for the hedged carry trade are very similar in character to those reported in Table 8 for the unhedged carry trade over the longer sample period. These results can be summarized as follows. First, for the CAPM and the Fama-French model, the b parameters are precisely estimated and are statistically different from zero. The over-identifying restrictions associated with these models are overwhelmingly rejected. Second, the b parameters associated with the other risk-factor models are estimated with great imprecision. Not surprisingly, in these cases we cannot reject the over-identifying restrictions associated with the model. For these models we cannot reject either the null hypothesis that the b parameters are equal to zero or the associated implication that the model-implied excess return to the carry trade is equal to zero. Third, the only model for which the cross-section R^2s are not negative is the Fama-French model. Finally, the stochastic discount factor model based on GDP growth does very poorly in the sense that the R^2 is very low and the overidentifying restrictions are rejected.

Figure 11 displays the predictions of the CAPM, the C-CAPM, the Extended C-CAPM models, and the Fama-French model for $E(R_t^e)$ against the sample average of R_t^e. The first three models cannot account for the expected returns to either the hedged carry trade or the Fama-French portfolios. The Fama-French model does a reasonable job of explaining the average excess returns to the Fama-French portfolios, but fails to explain the excess returns to the hedged carry trade. From the perspective of this model the hedged carry trade has a positive alpha that is statistically significant.[25]

6.3 Assessing the Importance of the Peso Problem

Suppose that the peso problem explains the positive returns to the unhedged carry trade. What should the average payoff to the hedged carry trade be? To answer this question we assume that a peso event occurs with probability p, in which case the payoff to the carry trade is $z' \ll 0$.[26] Then, equation (15) can be written as:

$$(1-p)\int MzdF(s) + pM'z' = 0. \tag{23}$$

[25]We do not re-do our analysis with portolios of carry trade strategies sorted by the absolute value of the forward premium because we only have option prices for six currencies.

[26]For simplicitly we assume that p is time invariant. Our results can be easily generalized to the case of time-varying p.

Here $F(s)$ denotes the joint distribution of M and z conditional on being in non-peso states of the world, and M' denotes the value of the stochastic discount factor in the peso state.

Consider a sample period in which the peso event does not occur. For such a sample, the population analogue of the risk-adjusted average payoff to the unhedged carry trade is $\int MzdF(s)$. Since z' is negative, equation (23) implies that $\int MzdF(s) > 0$. This observation is at the crux of the view that peso problems can rationalize positive excess returns to the carry trade. We now discuss the empirical relevance of this argument in light of our results.

The covariance between risk factors and the payoffs to the carry trade is not statistically different from zero, at least in our sample. So, to simplify, we assume that $\text{cov}(M, z) = 0$ in non-peso states of the world. We can then rewrite equation (23) as:

$$(1-p)\tilde{E}\,(M)\,\tilde{E}\,(z) + pM'z' = 0. \tag{24}$$

Here $\tilde{E}\,(.)$ denotes the conditional expectation operator defined over non-peso states, e.g. $\tilde{E}\,(z) = \int zdF(s)$.

It is useful to summarize the realized payoffs to the hedged carry trade as follows:

$$z^H = \begin{cases} h & \text{if } z = z', \\ h & \text{if } z \in S^-, \\ z & \text{if } z \in S^+. \end{cases}$$

Here S^- is the subset of non-peso events for which the option purchased by the agent is in the money. The variable h denotes the gross payoff to the hedged carry trade in states of the world where the option is in the money. We denote by z_n^H the payoff to the hedged carry trade net of the options' cost, $c(1+r)$:

$$z_n^H = z^H - c(1+r).$$

Equation (23) implies that:

$$(1-p)\tilde{E}(z_n^H)\tilde{E}(M) + p\,[h - c(1+r)]\,M' = 0. \tag{25}$$

Using equations (24) and (25) we obtain:

$$\tilde{E}(z_n^H) = [h - c(1+r)]\,\frac{\tilde{E}(z)}{z'}. \tag{26}$$

We use equation (26) to assess what the average returns to the hedged carry trade should be in a sample with no peso events. We perform this calculation under the null hypothesis that the excess returns to the carry trade reflect the possibility of a peso event occurring. We then compare the implied value for $\tilde{E}(z_n^H)$ to the actual excess returns to the hedged carry trade.

Since the hedged carry trade uses at-the-money options, h is equal to the absolute value of $(F_t - S_t)/F_t$.[27] The average value of $(F_t - S_t)/F_t$ for the currencies in the equally-weighted hedged carry trade is 0.0020. The average value of $c(1+r)$ for the options used in the hedged carry-trade strategy is 0.0093. The average payoff to the unhedged carry trade is 0.0027. Given these values we use equation (26) to compute $\tilde{E}(z_n^h)$ for different values of z'. Figure 12 displays our results. The solid horizontal line represents the average payoff to the hedged carry trade. The two dashed lines represent a 95 percent confidence interval around this average payoff. We consider alternative values for the payoff to the unhedged carry trade in the peso event. Specifically, we set $z' = 0.0027 - n \times 0.017$, $n = 1, 2, ..., 10$. Here 0.0027 is the sample analogue of $\tilde{E}(z)$ and 0.017 is the estimated standard deviation of the payoffs to the equally-weighted, unhedged carry trade (see Table 7).

Equation (23) shows that, when z' is a large negative number, it is easy to rationalize large observed average payoffs to the unhedged carry trade. But, the more negative is z', the smaller is the payoff to the hedged carry trade in a sample with no peso events. The basic intuition underlying this result is that when z' is a large negative number, the price of options used to hedge against peso events is very high. In a sample where the peso event does not occur, the agent pays a high insurance premium without receiving any payoffs from the insurance policy. So, the average payoff to the hedged carry trade is low.

From Figure 12 we see that if z' is two standard deviations or more below the average payoff to the unhedged carry trade, then the peso problem cannot rationalize the observed returns to the hedged carry trade. When z' is five standard deviations below the average payoff to the unhedged carry trade then the average payoff to the hedged carry trade should be very close to zero. But, in our sample this payoff is statistically indistinguishable from the payoff to the unhedged carry trade. We infer from these results that the peso problem cannot account for a large fraction of the average payoffs to the carry trade.

[27] Recall that, when the FCU is at a forward premium, we sell the $1/F_t$ FCU forward and hedge this transaction with a call option on the FCU. When we choose $K_t = S_t$, the minimum gross payoff to this strategy is given by $(F_t - S_t)/F_t$ (see equation (20)). A similar argument applies to the case where the FCU is at a forward discount.

7 Conclusion

Equally-weighted portfolios of carry-trade strategies generate large positive payoffs and a Sharpe ratio that is almost twice as large as the Sharpe ratio associated with the U.S. stock market. We find that these payoffs are not correlated with standard risk factors. Moreover, standard stochastic discount factor models do not explain the cross-section variation in various asset returns and carry-trade returns. From the perspective of many of these models there is a statistically significant, positive alpha associated with the carry trade.

A natural explanation for the positive alpha is that it reflects a peso problem. To investigate this possibility we develop a version of the carry trade that uses currency options to protect the investor from the downside risk from large, adverse movements in exchange rates. By construction, this hedged carry trade strategy eliminates the large negative payoffs associated with peso events. We show that the payoffs to the hedged carry trade are very similar to those of the unhedged carry trade. We argue that this finding implies that the peso problem cannot account for a major portion of the large alpha associated with the carry trade.

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TABLE 1

Median Bid-Ask Spreads of Exchange Rates
(percent)

	Quotes in FCU per GBP					Quotes in FCU per USD		
	Full Sample			1999:1-2007:1		Full Sample		
	Spot	1 Month Forward	Sample Period	Spot	1 Month Forward	Spot	1 Month Forward	Sample Period
Austria	0.153	0.222	76:01-98:12			0.042	0.056	97:01-08:01
Belgium	0.158	0.253	76:01-98:12			0.111	0.118	97:01-98:12
Canada	0.054	0.095	76:01-08:01	0.070	0.076	0.043	0.047	97:01-08:01
Denmark	0.084	0.142	76:01-08:01	0.057	0.068	0.031	0.039	97:01-08:01
France	0.100	0.151	76:01-98:12			0.030	0.034	97:01-98:12
Germany	0.213	0.311	76:01-98:12			0.035	0.037	97:01-98:12
Ireland	0.094	0.180	79:04-98:12			0.141	0.150	97:01-98:12
Italy	0.063	0.171	76:01-98:12			0.062	0.068	97:01-98:12
Japan	0.193	0.240	76:01-08:01	0.055	0.063	0.040	0.043	97:01-08:01
Netherlands	0.234	0.344	76:01-98:12			0.032	0.038	97:01-98:12
Norway	0.093	0.147	76:01-08:01	0.099	0.107	0.072	0.079	97:01-08:01
Portugal	0.375	0.689	76:01-98:12			0.056	0.061	97:01-98:12
Spain	0.140	0.242	76:01-98:12			0.037	0.045	97:01-98:12
Sweden	0.097	0.157	76:01-08:01	0.086	0.097	0.067	0.073	97:01-08:01
Switzerland	0.239	0.389	76:01-08:01	0.083	0.088	0.059	0.063	97:01-08:01
USA/UK	0.054	0.072	76:01-08:01	0.025	0.027	0.026	0.028	97:01-08:01
Euro	0.054	0.056	99:01-08:01	0.054	0.056	0.030	0.032	99:01-08:01
Australia	0.090	0.095	97:01-08:01	0.084	0.089	0.065	0.068	97:01-08:01
New Zealand	0.114	0.125	97:01-08:01	0.100	0.108	0.084	0.092	97:01-08:01
South Africa	0.177	0.194	97:01-08:01	0.182	0.195	0.148	0.162	97:01-08:01

Note: Results are based on daily data, and are expressed in log percent.

TABLE 2

Payoffs of the Carry-Trade Strategies

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
British Pound is the Base Currency Jan-1976 to Jan-2008						
Equally-weighted carry trade	0.0027	0.011	0.234	0.0026	0.015	0.167
	(0.0007)	(0.001)	(0.059)	(0.0009)	(0.001)	(0.061)
US Dollar is the Base Currency Jan-1997 to Jan-2008						
Equally-weighted carry trade	0.0040	0.013	0.306	0.0037	0.015	0.250
	(0.0013)	(0.001)	(0.100)	(0.0015)	(0.001)	(0.099)

Note: Payoffs are measured either in British pounds, per pound bet, or in US dollars, per dollar bet. The carry-trade portfolio is formed as the equally-weighted average of up to 20 individual currency carry trades against either the British pound or the US dollar. The twenty currencies are indicated in Appendix Tables 2 and 3.

TABLE 3

PAYOFFS OF INVESTMENT STRATEGIES

February 1976 to January 2008

US Dollar is the Base Currency

	Mean	Standard Deviation	Sharpe Ratio	Skewness	Excess Kurtosis	Jarque-Bera Statistic
U.S. stock market	0.0057	0.043	0.133	-0.758	2.65	149.3
	(0.0021)	(0.003)	(0.052)	(0.344)	(1.54)	(0.000)
Equally-weighted carry trade	0.0041	0.015	0.280	-0.664	6.73	753.8
	(0.0008)	(0.001)	(0.066)	(0.606)	(2.30)	(0.000)
Average of individual-currency carry trade	0.0042	0.031	0.138	-0.259	1.03	31.2
Carry-trade portfolios sorted by absolute value of forward premium						
Portfolio 1	0.0018	0.016	0.111	-0.318	4.03	267.0
	(0.0008)	(0.001)	(0.053)	(0.484)	(1.55)	(0.000)
Portfolio 2	0.0019	0.022	0.086	-0.470	2.94	152.3
	(0.0012)	(0.001)	(0.057)	(0.305)	(0.93)	(0.000)
Portfolio 3	0.0036	0.022	0.163	0.164	2.41	95.0
	(0.0011)	(0.001)	(0.051)	(0.276)	(0.57)	(0.000)
Portfolio 4	0.0063	0.025	0.257	-0.368	1.89	65.6
	(0.0013)	(0.001)	(0.058)	(0.221)	(0.45)	(0.000)
Portfolio 5	0.0082	0.028	0.299	-0.352	1.23	32.1
	(0.0016)	(0.001)	(0.060)	(0.151)	(0.38)	(0.000)

Notes: Payoffs are measured in US dollars, per dollar bet. The payoff at time t to the US stock market is the value-weighted excess return on all US stocks reported in Kenneth French's database, divided by $1 + r_{t-1}$ (this normalizes the excess stock returns to the same size of bet as the carry-trade payoffs). The carry-trade portfolio is formed as the equally-weighted average of up to 20 individual currency carry trades against the US dollar. The individual currencies are indicated in Appendix Table 3. Standard errors are reported in parentheses, except for the Jarque-Bera statistic for which the p-value is reported in parentheses. Portfolios 1–5 are ordered according to the absolute value of the forward premium, portfolio 1 and portfolio 5 having the lowest and largest absolute values of the forward premium, respectively.

TABLE 4

Factor Betas of the Equally-Weighted Carry-Trade Portfolio Excess Return
1976Q2 to 2007Q4

Factors	Intercept	Beta(s)			R^2
CAPM	0.013	-0.017			0.002
	(0.003)	(0.033)			
Fama-French factors	0.013	0.016	-0.104	0.010	0.031
	(0.003)	(0.038)	(0.066)	(0.053)	
C-CAPM	0.015	-0.387			0.003
	(0.006)	(0.931)			
Extended C-CAPM	0.008	-0.691	0.817	-0.014	0.020
	(0.009)	(0.978)	(0.716)	(0.035)	
Luxury sales growth	0.013	-0.031			0.008
	(0.008)	(0.050)			
GDP growth	0.012	0.197			0.003
	(0.003)	(0.347)			
Fed Funds rate	0.011	0.035			0.002
	(0.006)	(0.077)			
Term premium	0.014	-0.052			0.001
	(0.004)	(0.236)			
Liquidity premium	0.014	-0.068			0.000
	(0.004)	(0.348)			
VIX volatility measure	0.009	0.014			0.001
	(0.012)	(0.058)			
VXO volatility measure	0.007	0.025			0.003
	(0.009)	(0.038)			

Notes: The table reports estimates of the equation $R_t^e = a + f_t'\beta + \epsilon_{t+1}$, where R_t^e is the quarterly real excess return of the equally-weighted carry-trade portfolio and f_t is a scalar or vector of risk factors. The CAPM factor is the excess return on the value-weighted US stock market ($Mkt - Rf$), the Fama-French factors are the $Mkt - Rf$, SMB and HML factors (available from Kenneth French's database), the C-CAPM factor is real per capita consumption growth, the extended C-CAPM factors are real per capita consumption growth, real per capita durables growth, and the return on the value-weighted US stock market, the term premium is the 10 year T-bond rate minus the 3 month T-bill rate, and the liquidity premium is the 3 month eurodollar rate minus the 3 month T-bill rate. Details of the risk factors are provided in Appendix D. Heteroskedasticity-robust standard errors are in parentheses.

TABLE 5

GMM Estimates of Linear Factor Models

Test Assets are the Fama-French 25 Portfolios and the Equally-Weighted Carry-Trade Portfolio

	First Stage				Second Stage			
	μ	b	λ (%)	R^2	b	λ (%)	R^2	J
CAPM	0.0179	3.59	2.22	-1.08	3.40	2.10	-1.11	59.52
	(0.0070)	(1.46)	(0.77)		(1.28)	(0.71)		(0.00)
Fama-French Factors								
Mkt-Rf	0.0179	5.40	1.73	0.49	5.55	1.95	0.43	57.65
	(0.0070)	(1.98)	(0.71)		(1.85)	(0.72)		(0.00)
SMB	0.0077	0.81	0.69		0.37	0.66		
	(0.0046)	(2.00)	(0.46)		(1.81)	(0.46)		
HML	0.0110	7.09	1.15		6.24	0.84		
	(0.0066)	(2.18)	(0.56)		(1.91)	(0.53)		
C-CAPM	0.0048	622.80	0.91	-2.78	105.00	0.15	-9.29	27.28
	(0.0005)	(680.45)	(1.06)		(141.24)	(0.20)		(0.34)
Extended C-CAPM								
Consumption growth	0.0048	-183.54	-0.34	-0.98	-59.83	-0.10	-7.98	14.45
	(0.0005)	(231.39)	(0.35)		(86.36)	(0.13)		(0.91)
Durables growth	0.0102	-137.14	-0.40		-28.31	-0.10		
	(0.0019)	(130.01)	(0.32)		(74.20)	(0.16)		
Market return	0.0223	3.88	2.20		0.92	0.47		
	(0.0070)	(2.29)	(0.93)		(1.88)	(0.98)		
Luxury sales growth	0.0989	15.70	14.84	-1.14	-1.01	-0.95	-13.97	16.38
	(0.0262)	(21.59)	(19.71)		(3.30)	(3.18)		(0.90)
GDP growth	0.0049	-560.07	-3.16	-3.43	-6.44	-0.04	-11.99	9.66
	(0.0009)	(755.43)	(4.31)		(118.86)	(0.67)		(1.00)

Table 5 is continued on the next page

TABLE 5 (Continued)

GMM Estimates of Linear Factor Models

Test Assets are the Fama-French 25 Portfolios and the Equally-Weighted Carry-Trade Portfolio

	First Stage				Second Stage			
	μ	b	λ (%)	R^2	b	λ (%)	R^2	J
Fed Funds rate	0.0652	-74.35	-9.26	-0.63	1.08	0.14	-12.53	0.98
	(0.0226)	(155.17)	(20.12)		(13.01)	(1.63)		(1.00)
Term premium	0.0166	199.99	3.24	-0.25	15.85	0.26	-10.37	2.44
	(0.0035)	(193.95)	(3.10)		(36.08)	(0.58)		(1.00)
Liquidity premium	0.0087	-386.25	-2.18	-0.28	12.15	0.07	-12.95	1.41
	(0.0033)	(738.07)	(4.41)		(63.67)	(0.36)		(1.00)
VIX volatility measure	0.1891	-22.08	-7.34	-0.19	-1.40	-0.46	-10.25	11.87
	(0.0228)	(28.57)	(8.43)		(4.01)	(1.32)		(0.99)
VXO volatility measure	0.2034	-12.37	-6.18	-0.33	-4.10	-2.05	-5.07	37.78
	(0.0209)	(14.54)	(6.37)		(3.07)	(1.54)		(0.05)
Campbell-Cochrane				-14.71				56.29
								(0.00)

Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t^e m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t^e is a 26×1 vector containing the excess returns of the Fama-French 25 portfolios of US stocks sorted on size and the book-to-market value ratio as well as the quarterly real excess return of the equally-weighted carry-trade portfolio, and f_t is a scalar or vector of risk factors. The factors are described in more detail in the footnote to Table 4 and in Appendix D. The first stage of GMM is equivalent to the two-pass regression method of Fama and MacBeth (1973). The GMM procedure is described in more detail in Appendix E. Since $\hat{\mu}$ is the same for both GMM stages, the estimate is reported once. Estimates of the factor risk premia $\hat{\lambda} = \hat{V}_f \hat{b}$ are also reported (in percent), where $\hat{V}_f$ is the sample covariance matrix of f_t. GMM-VARHAC standard errors are reported in parentheses for $\hat{\mu}$, $\hat{b}$ and $\hat{\lambda}$. The table reports the R^2 measure of fit between the sample mean of R_t^e and the predicted mean returns, given by $d_T \hat{b}$, where $d_T = T^{-1} \sum_{t=1}^{T} R_t^e (f_t' - \hat{\mu})'$. Tests of the overidentifying restrictions are also reported. The test statistic, J, is asymptotically distributed as a χ^2_{26-k}, where k is the number of risk factors. The p-value is in parentheses. The Campbell-Cochrane model is calibrated, as described in Appendix D, to match the mean equity premium and risk free rate in our sample period. Here we report a direct test of the moment condition $E(R_t^e m_t) = 0$ and the cross-sectional R^2 for the calibrated model. The sample period is 1976Q2 to 2007Q4.

TABLE 6

GMM Estimates of Linear Factor Models

Test Assets are the Fama-French 25 Portfolios and Five Carry-Trade Portfolios Sorted on the Basis of the Absolute Forward Premia of the Underlying Currencies

	First Stage				Second Stage			
	μ	b	λ (%)	R^2	b	λ (%)	R^2	J
CAPM	0.0179	3.58	2.22	-0.90	3.39	2.10	-0.92	64.84
	(0.0070)	(1.46)	(0.77)		(1.25)	(0.71)		(0.00)
Fama-French Factors								
Mkt-Rf	0.0179	5.72	1.79	0.14	5.75	2.01	0.09	60.87
	(0.0070)	(1.99)	(0.71)		(1.79)	(0.74)		(0.00)
SMB	0.0077	0.23	0.58		-0.03	0.59		
	(0.0046)	(2.02)	(0.47)		(1.82)	(0.46)		
HML	0.0110	7.22	1.16		6.22	0.81		
	(0.0066)	(2.20)	(0.56)		(1.84)	(0.53)		
C-CAPM	0.0048	605.20	0.88	-2.12	149.79	0.22	-5.44	29.55
	(0.0005)	(646.29)	(1.01)		(112.51)	(0.16)		(0.44)
Extended C-CAPM								
Consumption growth	0.0048	-33.02	0.06	-0.77	35.70	0.06	-5.83	11.21
	(0.0005)	(127.90)	(0.16)		(62.58)	(0.08)		(1.00)
Durables Growth	0.0102	170.14	0.33		9.48	0.04		
	(0.0019)	(122.41)	(0.22)		(53.72)	(0.10)		
Market return	0.0223	4.62	2.39		0.47	0.36		
	(0.0070)	(2.36)	(1.06)		(1.32)	(0.73)		
Luxury sales growth	0.0989	15.25	14.42	-0.92	-0.59	-0.56	-8.13	18.21
	(0.0262)	(20.87)	(19.04)		(3.12)	(2.98)		(0.94)
GDP growth	0.0049	-537.28	-3.03	-2.66	-42.88	-0.24	-7.17	13.10
	(0.0009)	(709.65)	(4.05)		(104.48)	(0.57)		(1.00)

Table 6 is continued on the next page

TABLE 6 (Continued)

GMM Estimates of Linear Factor Models

Test Assets are the Fama-French 25 Portfolios and Five Carry-Trade Portfolios Sorted on the Basis of the Absolute Forward Premia of the Underlying Currencies

	First Stage				Second Stage			
	μ	b	λ (%)	R^2	b	λ (%)	R^2	J
Fed Funds rate	0.0652	-73.25	-9.12	-0.78	0.79	0.10	-8.14	1.03
	(0.0226)	(151.41)	(18.94)		(12.29)	(1.54)		(1.00)
Term premium	0.0166	199.72	3.24	-0.32	15.44	0.25	-6.84	2.57
	(0.0035)	(192.85)	(3.08)		(35.84)	(0.58)		(1.00)
Liquidity premium	0.0087	-385.51	-2.18	-0.28	6.90	0.04	-8.26	1.62
	(0.0033)	(731.91)	(3.80)		(61.72)	(0.35)		(1.00)
VIX volatility measure	0.1891	-21.57	-7.18	-0.41	0.20	0.07	-7.74	14.62
	(0.0228)	(27.63)	(8.15)		(3.44)	(1.15)		(0.99)
VXO volatility measure	0.2034	-12.09	-6.04	-0.69	-2.72	-1.36	-4.76	44.29
	(0.0209)	(14.21)	(6.22)		(2.71)	(1.33)		(0.03)
Campbell-Cochrane				-9.48				61.00
								(0.00)

Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t^e m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t^e is a 30×1 vector containing the excess returns of the Fama-French 25 portfolios of US stocks sorted on size and the book-to-market value ratio as well as the quarterly real excess returns to five carry-trade portfolios, and f_t is a scalar or vector of risk factors. The five carry-trade portfolios are constructed by sorting, on a period-by-period basis, the available currencies into 5 groups arranged according to the absolute value of their forward premia versus the US dollar. The factors, f_t, are described in more detail in the footnote to Table 4 and in Appendix D. The first stage of GMM is equivalent to the two-pass regression method of Fama and MacBeth (1973). The GMM procedure is described in more detail in Appendix E. Since $\hat{\mu}$ is the same for both GMM stages, the estimate is reported once. Estimates of the factor risk premia $\hat{\lambda} = \hat{V}_f \hat{b}$ are also reported (in percent), where $\hat{V}_f$ is the sample covariance matrix of f_t. GMM-VARHAC standard errors are reported in parentheses for $\hat{\mu}$, $\hat{b}$ and $\hat{\lambda}$. The table reports the R^2 measure of fit between the sample mean of R_t^e and the predicted mean returns, given by $d_T \hat{b}$, where $d_T = T^{-1} \sum_{t=1}^{T} R_t^e (f_t' - \hat{\mu})'$. Tests of the overidentifying restrictions are also reported. The test statistic, J, is asymptotically distributed as a χ^2_{30-k}, where k is the number of risk factors. The p-value is in parentheses. The Campbell-Cochrane model is calibrated, as described in Appendix D, to match the mean equity premium and risk free rate in our sample period. Here we report a direct test of the moment condition $E(R_t^e m_t) = 0$ and the cross-sectional R^2 for the calibrated model. The sample period is 1976Q2 to 2007Q4.

TABLE 7

PAYOFFS OF INVESTMENT STRATEGIES

February 1987 to January 2008

US Dollar is the Base Currency

	Mean	Standard Deviation	Sharpe Ratio	Skewness	Excess Kurtosis	Jarque-Bera Statistic
U.S. stock market	0.0055	0.042	0.130	-1.158	3.84	211.3
	(0.0025)	(0.004)	(0.066)	(0.435)	(2.22)	(0.000)
Equally-weighted carry trade	0.0027	0.017	0.155	-0.672	1.09	31.5
	(0.0010)	(0.001)	(0.063)	(0.155)	(0.44)	(0.000)
Hedged, equally-weighted carry trade	0.0021	0.010	0.204	0.751	0.43	25.6
	(0.0007)	(0.001)	(0.061)	(0.145)	(0.43)	(0.000)

Notes: Payoffs are measured in US dollars, per dollar bet. The payoff at time t to the US stock market is the value-weighted excess return on all US stocks reported in Kenneth French's database, divided by $1 + r_{t-1}$. The carry-trade portfolio is formed as the equally-weighted average of up to six individual currency carry trades against the US dollar. The individual currencies are the Australian dollar, the Canadian dollar, the Japanese yen, the Swiss franc, the British pound, and the euro. The hedged carry-trade portfolio combines the forward market positions with an options contract that insures against losses from the forward position (details are provided in the main text). Standard errors are in parentheses, except for the Jarque-Bera statistic for which the p-value is reported in parentheses.

TABLE 8

Factor Betas of the Hedged Equally-Weighted Carry-Trade Portfolio Excess Return
1987Q2 to 2007Q4

Factor	Intercept	Beta(s)			R^2
CAPM	0.012	0.027			0.013
	(0.002)	(0.030)			
Fama-French factors	0.011	0.065	-0.014	0.088	0.078
	(0.002)	(0.036)	(0.043)	(0.040)	
C-CAPM	0.015	-0.552			0.009
	(0.003)	(0.507)			
Extended C-CAPM	0.017	-0.487	-0.191	0.023	0.021
	(0.007)	(0.569)	(0.644)	(0.030)	
Luxury sales growth	0.015	-0.031			0.024
	(0.004)	(0.026)			
GDP growth	0.017	-0.937			0.065
	(0.003)	(0.358)			
Fed Funds rate	0.021	-0.163			0.034
	(0.005)	(0.100)			
Term premium	0.008	0.268			0.028
	(0.003)	(0.199)			
Liquidity premium	0.020	-1.271			0.068
	(0.004)	(0.539)			
VIX volatility measure	0.012	0.012			0.001
	(0.006)	(0.029)			
VXO volatility measure	0.016	-0.017			0.004
	(0.006)	(0.031)			

Notes: The table reports estimates of the equation $R_t^e = a + f_t'\beta + \epsilon_{t+1}$, where R_t^e is the quarterly real excess return of the hedged equally-weighted carry-trade portfolio and f_t is a scalar or vector of risk factors (see the footnotes to Tables 4 and 7). The CAPM factor is the excess return on the value-weighted US stock market ($Mkt - Rf$), the Fama-French factors are the $Mkt - Rf$, SMB and HML factors (available from Kenneth French's database), the C-CAPM factor is real per capita consumption growth, the extended C-CAPM factors are real per capita consumption growth, real per capita durables growth, and the return on the value-weighted US stock market, the term premium is the 10 year T-bond rate minus the 3 month T-bill rate, and the liquidity premium is the 3 month eurodollar rate minus the 3 month T-bill rate. Details of the risk factors are provided in Appendix D. Heteroskedasticity-robust standard errors are in parentheses.

TABLE 9

GMM Estimates of Linear Factor Models

Test Assets are the Fama-French 25 Portfolios and the Hedged Equally-Weighted Carry-Trade Portfolio

	First Stage				Second Stage			
	μ	b	λ (%)	R^2	b	λ (%)	R^2	J
CAPM	0.0173	3.07	1.91	-1.37	2.77	1.72	-1.45	56.81
	(0.0088)	(1.85)	(0.96)		(1.63)	(0.88)		(0.00)
Fama-French Factors								
Mkt-Rf	0.0173	5.01	1.59	0.26	6.41	1.82	0.11	55.47
	(0.0088)	(2.45)	(0.89)		(2.21)	(0.88)		(0.00)
SMB	0.0026	-0.81	0.31		-2.98	-0.14		
	(0.0060)	(2.40)	(0.61)		(2.14)	(0.59)		
HML	0.0101	5.88	1.10		6.92	1.30		
	(0.0091)	(2.40)	(0.72)		(1.92)	(0.74)		
C-CAPM	0.0045	677.51	0.68	-7.11	184.31	0.19	-8.67	37.55
	(0.0004)	(1118.70)	(1.13)		(158.84)	(0.16)		(0.05)
Extended C-CAPM								
Consumption growth	0.0045	-12.58	-0.11	-1.05	18.76	0.03	-6.71	5.24
	(0.0004)	(217.49)	(0.25)		(95.54)	(0.10)		(1.00)
Durables growth	0.0103	-242.84	-0.39		14.32	0.03		
	(0.0025)	(267.82)	(0.42)		(76.41)	(0.12)		
Market return	0.0208	1.59	2.10		0.73	0.40		
	(0.0088)	(2.84)	(1.65)		(2.11)	(1.30)		
Luxury sales growth	0.0967	17.66	16.48	-1.31	-0.41	-0.38	-10.39	13.35
	(0.0265)	(29.67)	(26.95)		(4.14)	(3.89)		(0.97)
GDP growth	0.0046	-53.42	-0.14	-10.00	-8.20	-0.02	-10.03	54.18
	(0.0010)	(138.83)	(0.36)		(43.54)	(0.11)		(0.00)

Table 9 is continued on the next page.

TABLE 9 (Continued)

GMM Estimates of Linear Factor Models

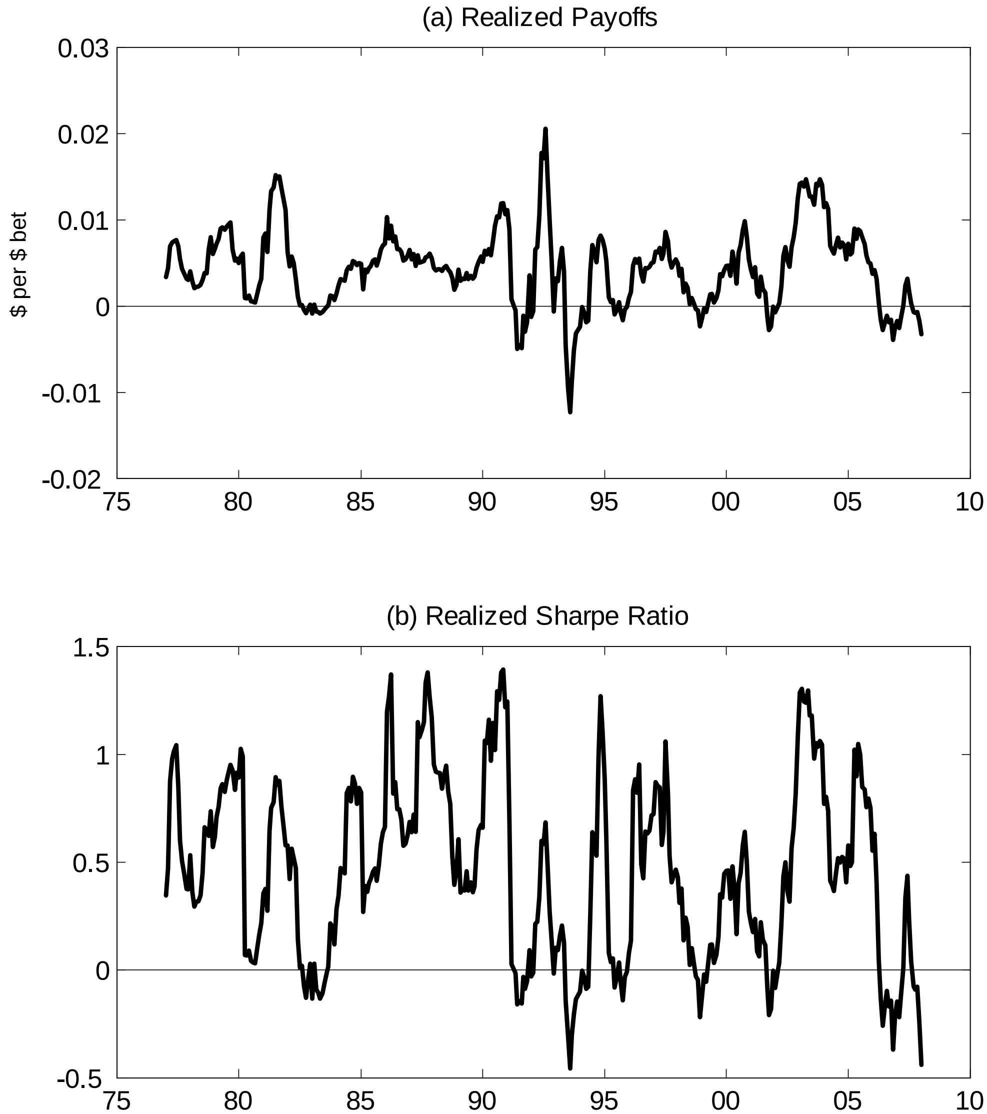
Test Assets are the Fama-French 25 Portfolios and the Hedged Equally-Weighted Carry-Trade Portfolio

	First Stage				Second Stage			
	μ	b	λ (%)	R^2	b	λ (%)	R^2	J
Fed Funds rate	0.0486	-67.34	-3.05	-2.96	-4.67	-0.21	-9.10	3.80
	(0.0082)	(72.12)	(3.10)		(12.53)	(0.56)		(1.00)
Term premium	0.0169	141.89	1.93	-6.11	18.69	0.25	-9.08	4.90
	(0.0038)	(129.75)	(1.79)		(23.41)	(0.32)		(1.00)
Liquidity premium	0.0054	-325.70	-0.48	-1.13	13.82	0.02	-10.82	6.93
	(0.0023)	(489.33)	(0.56)		(56.30)	(0.09)		(1.00)
VIX volatility measure	0.1891	-22.08	-7.34	-0.31	-0.30	-0.10	-12.07	12.63
	(0.0228)	(28.57)	(8.43)		(3.94)	(1.31)		(0.98)
VXO volatility measure	0.2033	-11.31	-5.91	-0.30	-3.68	-1.92	-4.74	38.38
	(0.0220)	(13.35)	(6.14)		(3.05)	(1.60)		(0.04)
Campbell-Cochrane				-11.74				49.65
								(0.00)

Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t^e m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t^e is a 26×1 vector containing the excess returns of the Fama-French 25 portfolios of US stocks sorted on size and the book-to-market value ratio as well as the quarterly real excess return of the hedged equally-weighted carry-trade portfolio (see the note to Table 7), and f_t is a scalar or vector of risk factors. The factors are described in more detail in the footnote to Table 4 and in Appendix D. The first stage of GMM is equivalent to the two-pass regression method of Fama and MacBeth (1973). The GMM procedure is described in more detail in Appendix E. Since $\hat{\mu}$ is the same for both GMM stages, the estimate is reported once. Estimates of the factor risk premia $\hat{\lambda} = \hat{V}_f \hat{b}$ are also reported (in percent), where $\hat{V}_f$ is the sample covariance matrix of f_t. GMM-VARHAC standard errors are reported in parentheses for $\hat{\mu}$, $\hat{b}$ and $\hat{\lambda}$. The table reports the R^2 measure of fit between the sample mean of R_t^e and the predicted mean returns, given by $d_T \hat{b}$, where $d_T = T^{-1} \sum_{t=1}^{T} R_t^e (f_t - \hat{\mu})'$. Tests of the overidentifying restrictions are also reported. The test statistic, J, is asymptotically distributed as a χ^2_{26-k}, where k is the number of risk factors. The p-value is in parentheses. The Campbell-Cochrane model is calibrated, as described in Appendix D, to match the mean equity premium and risk free rate in our sample period. Here we report a direct test of the moment condition $E(R_t^e m_t) = 0$ and the cross-sectional R^2 for the calibrated model. The sample period is 1987Q2 to 2007Q4.

FIGURE 1: Realized Average Payoffs and Sharpe Ratios of the Equally-Weighted Carry-Trade Portfolio

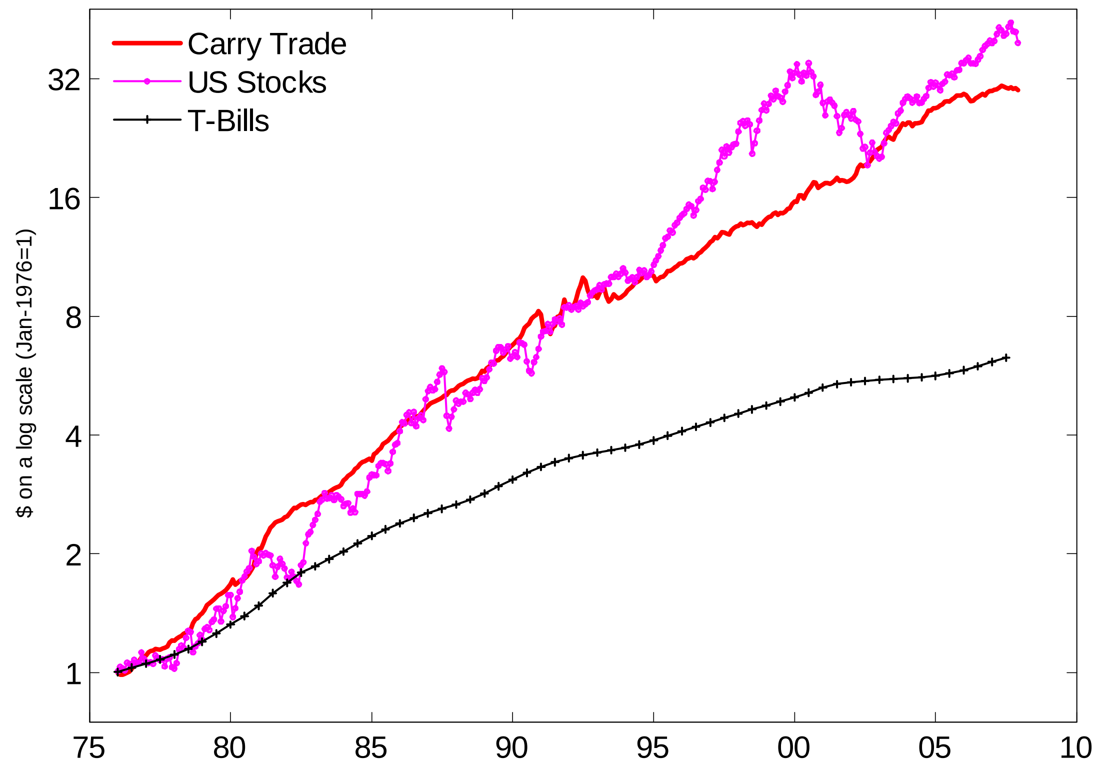
12-Month Rolling Window, February 1977–January 2008



Note: Plot (a) shows the average payoff from month $t-11$ to month t, in US dollars, per dollar bet in the carry trade. Plot (b) shows the ratio of the average payoff, to the standard deviation of the payoff, both being measured from month $t-11$ to month t. The carry-trade portfolio is formed as the equally-weighted average of up to 20 individual currency carry trades against the US dollar.

FIGURE 2: Cumulative Nominal Returns of the Equally-Weighted Carry-Trade Portfolio

February 1976–January 2008



Note: The plots indicate the cumulative value of investing one US dollar at the end of January 1976 in each of the investments indicated.

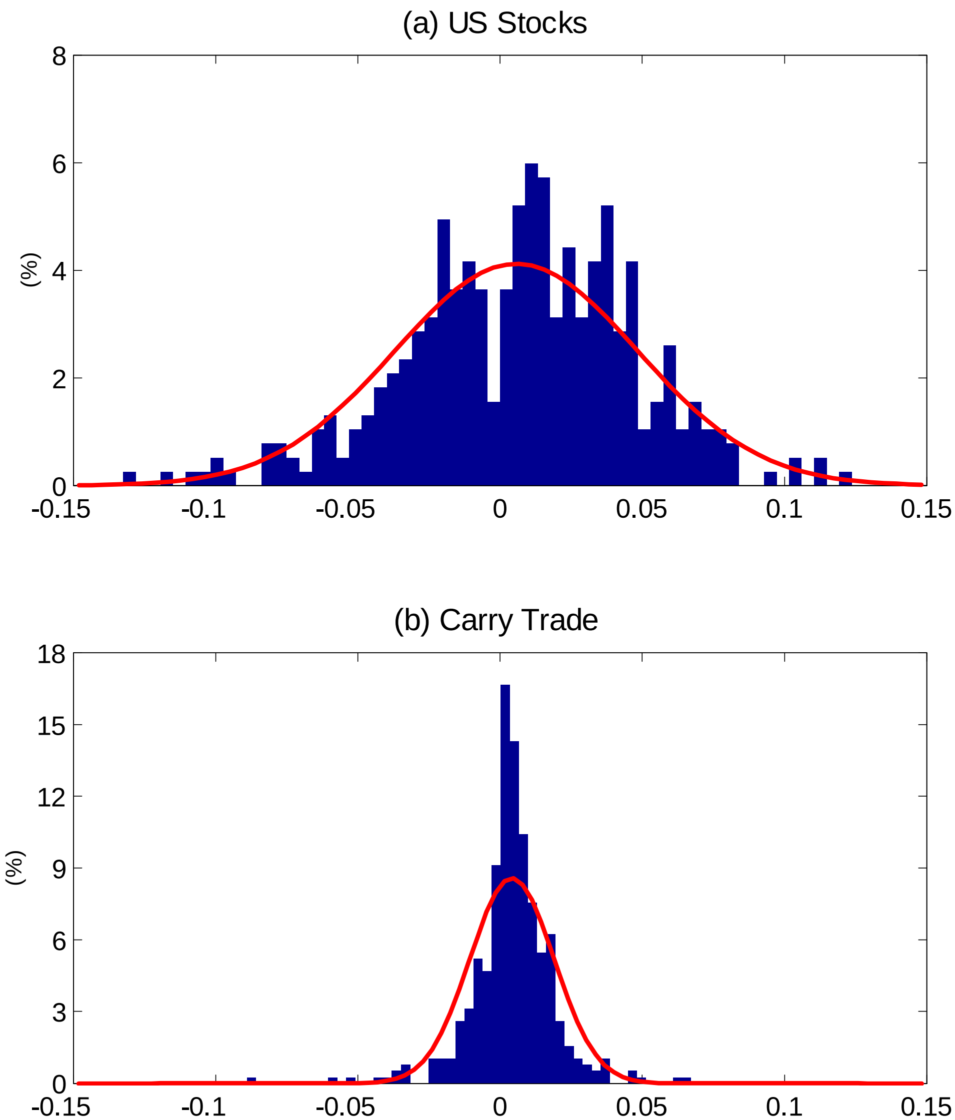
Carry Trade: Since the carry trade is a zero cost investment, the investor continuously invests in T-bills and bets an amount equal to the value of his T-bill portfolio in the equally-weighted carry trade. Profits from the carry trade are continuously re-invested in T-bills. The portfolio is formed as the equally-weighted average of up to 20 individual currency carry trades against the US dollar.

US Stocks: The cumulative nominal return to the value-weighted US stock market from the Fama-French database.

T-Bills: The cumulative nominal return to continuously re-investing in one-month T-bills.

FIGURE 3: Sampling Distributions of the Excess Returns of the Equally-Weighted Carry-Trade Portfolio and the Value-Weighted US Stock Market

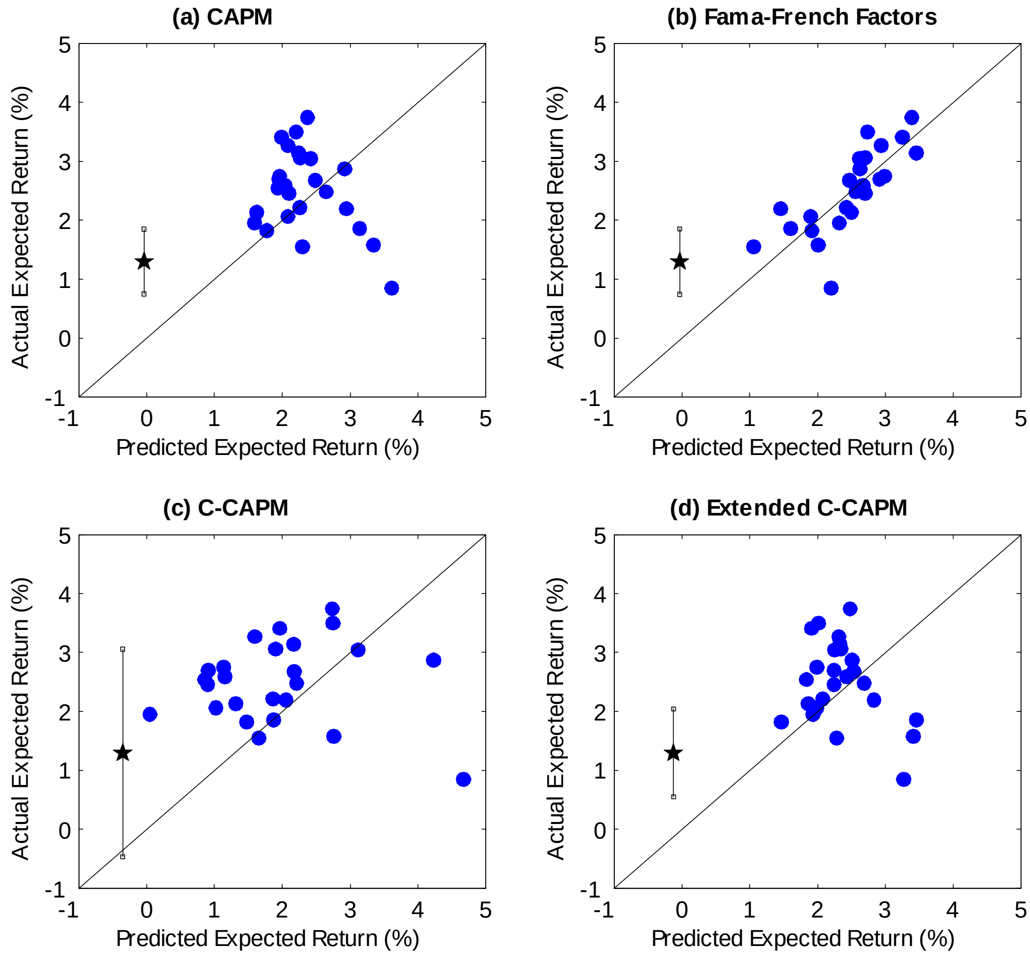
February 1976–January 2008



Note: In each plot the red line indicates the histogram implied by a normal distribution with the same mean and standard deviation as in the sampling distribution. The excess returns are computed at the monthly frequency. US stock excess returns are for the value-weighted US stock market from the Fama-French database. The carry-trade portfolio is formed as the equally-weighted average of up to 20 individual currency carry trades against the US dollar. Excess returns to the carry trade are payoffs scaled by $1 + r_t$.

FIGURE 4: Cross-Sectional Fit of Factor Models Estimated by GMM

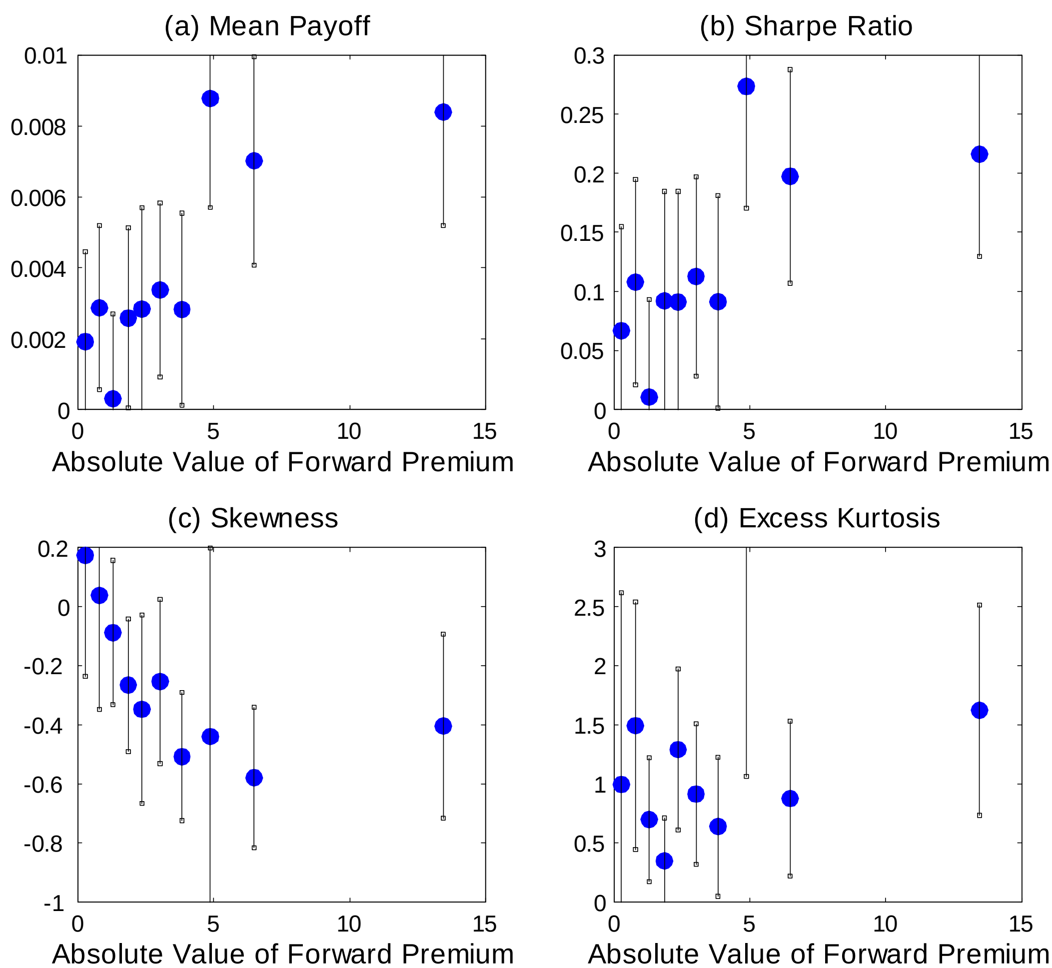
Test Assets are the Fama-French 25 Portfolios & the Equally-Weighted Carry-Trade Portfolio



Note: In each case the parmeters μ and b in the SDF $m_t = 1 - (f_t - \mu)' b$ are estimated by GMM using the method described in the text. The risk factors, f_t, are indicated by the title of each plot with details provided in the main text. The predicted expected return is $(1/T) \sum_{t=1}^{T} R_{it}^e (f_t - \hat{\mu})' \hat{b}$ for each portfolio's excess return, R_{it}^e. The actual expected return is $\bar{R}_i^e = (1/T) \sum_{t=1}^{T} R_{it}^e$. The blue dots correspond to Fama and French's 25 portfolios sorted on the basis of book-to-market value and firm size. The black star represents the carry-trade portfolio formed as the equally-weighted average of up to 20 individual currency carry trades against the US dollar. The black vertical line extending above and below the star is the actual expected return plus a two-standard error band for the pricing error of the carry-trade portfolio. When it does not cross the 45 degree line, the pricing error is statistically significant at the 5 percent level. Sample period is 1976Q2–2007Q4.

FIGURE 5: SUMMARY STATISTICS OF THE PAYOFFS OF THE CARRY TRADE SORTED INTO BINS ACCORDING TO THE SIZE OF THE FORWARD PREMIUM

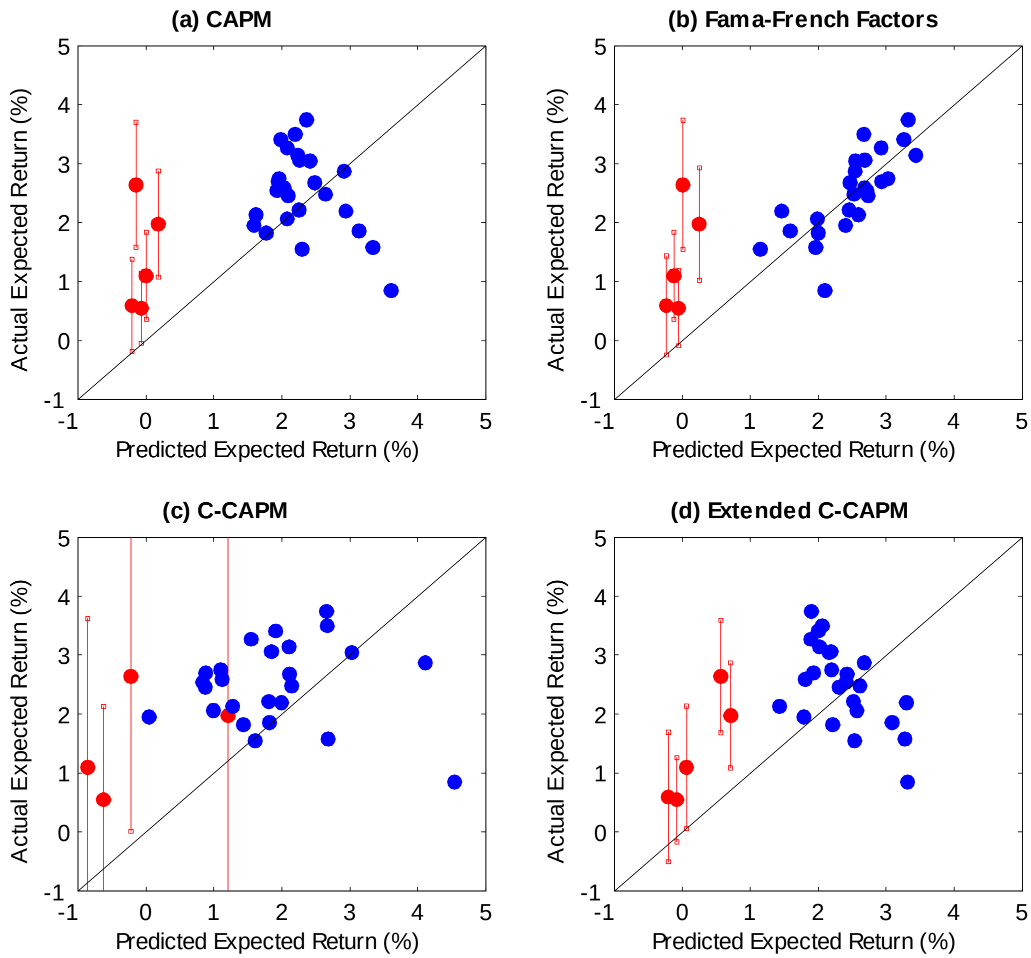
February 1976–January 2008



Note: Each observation on the payoff of the carry trade, denoted z_{it} (where i is the currency index and t is the time index), is sorted into one of 10 bins according to the size of the absolute value of the forward premium on currency i at time $t-1$, $|F_{it-1} - S_{it-1}|/S_{it-1}$. The dividing points between the bins are defined by the 10th–20th-$\cdots$–90th percentiles of the sampling distribution of the forward premium across all observations: 0.53, 1.03, 1.59, 2.11, 2.65, 3.41, 4.28, 5.52, and 7.84 percent on an annualized basis. The summary statistic in each graph is computed for all z_{it} within each bin, and is plotted against the mean value of the annualized forward premium within each bin.

FIGURE 6: Cross-Sectional Fit of Factor Models Estimated by GMM

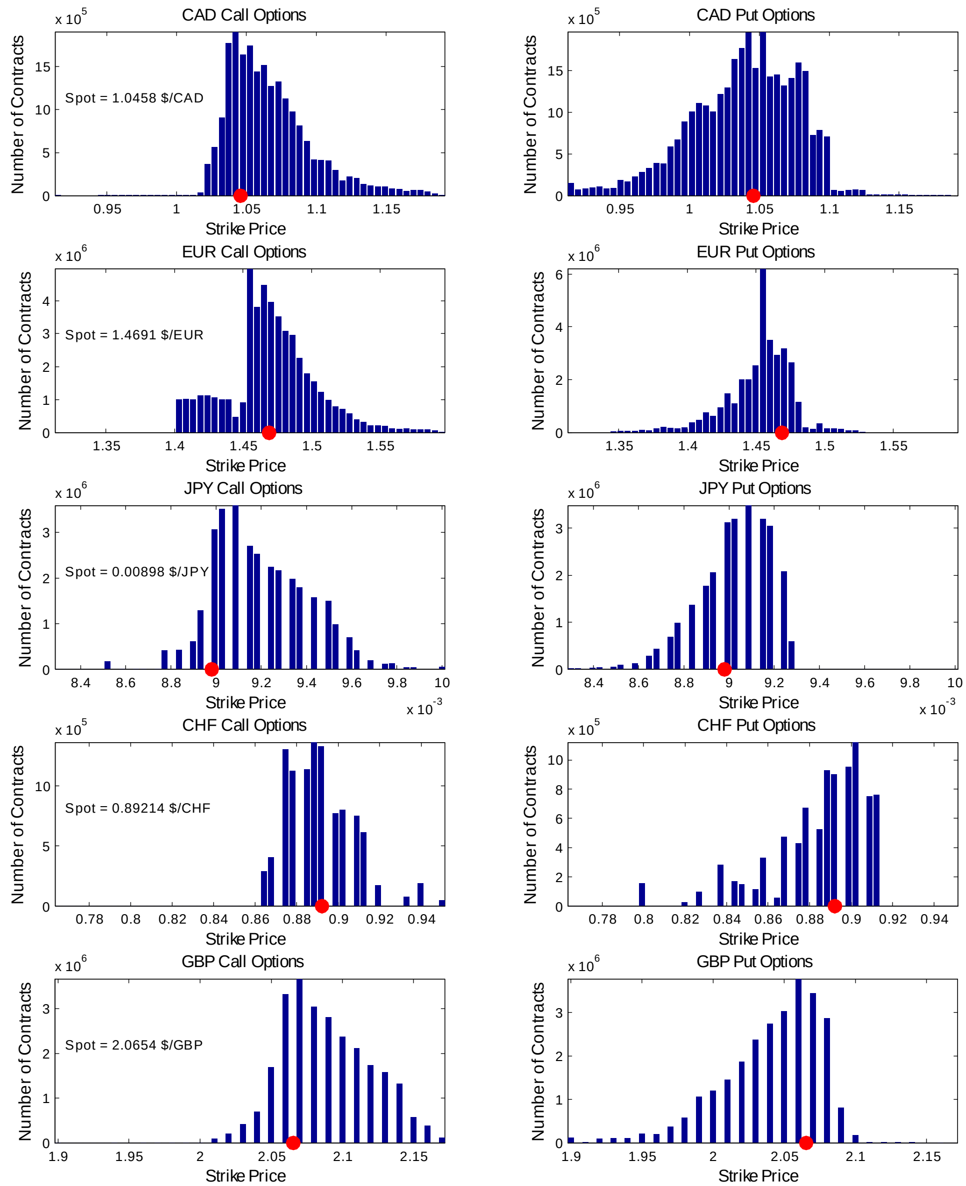
Test Assets are the Fama-French 25 Portfolios & Five Carry-Trade Portfolios Sorted on the Basis of the Absolute Forward Premia on the Underlying Currencies



Note: In each case the parmeters μ and b in the SDF $m_t = 1 - (f_t - \mu)' b$ are estimated by GMM using the method described in the text. The risk factors, f_t, are indicated by the title of each plot with details provided in the main text. The predicted expected return is $(1/T)\sum_{t=1}^{T} R^e_{it}(f_t - \hat{\mu})'\hat{b}$ for each portfolio's excess return, R^e_{it}. The actual expected return is $\bar{R}^e_i = (1/T)\sum_{t=1}^{T} R^e_{it}$. The blue dots correspond to Fama and French's 25 portfolios sorted on the basis of book-to-market value and firm size. The red dots represent carry-trade portfolios formed by, at each date, sorting into 5 bins up to 20 individual currency carry trades against the US dollar on the basis of the absolute forward premium of the dollar against each currency. The red vertical line extending above and below each red dot is the actual expected return plus a two-standard error band for the pricing error of the carry-trade portfolios. When it does not cross the 45 degree line the pricing error is statistically significant at the 5 percent level. Sample period is 1976Q2–2007Q4.

FIGURE 7: THE VOLUME OF CALLS AND PUTS AND MONEYNESS

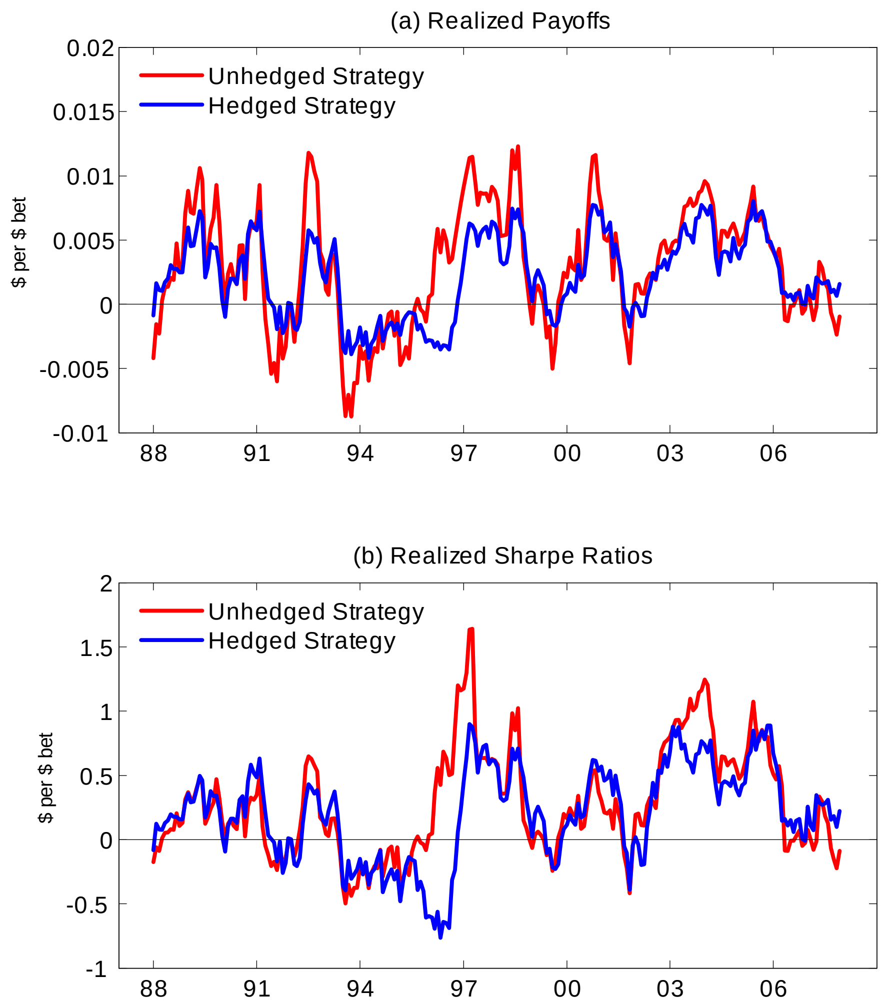
November 14 2007



Note: Each plot indicates the number of contracts traded at different strike prices on Nov. 14 2007 for five currencies: the Canadian dollar (CAD), the Euro (EUR), the Japanese yen (JPY), the Swiss franc (CHF) and the British pound (GBP). The closing spot price of each currency is indicated by the red dot. In this plot currencies are quoted as USD/FCU. Source: the Chicago Mercantile Exchange.

FIGURE 8: Realized Average Payoffs and Sharpe Ratios of the Equally-Weighted Hedged and Unhedged Carry-Trade Portfolios

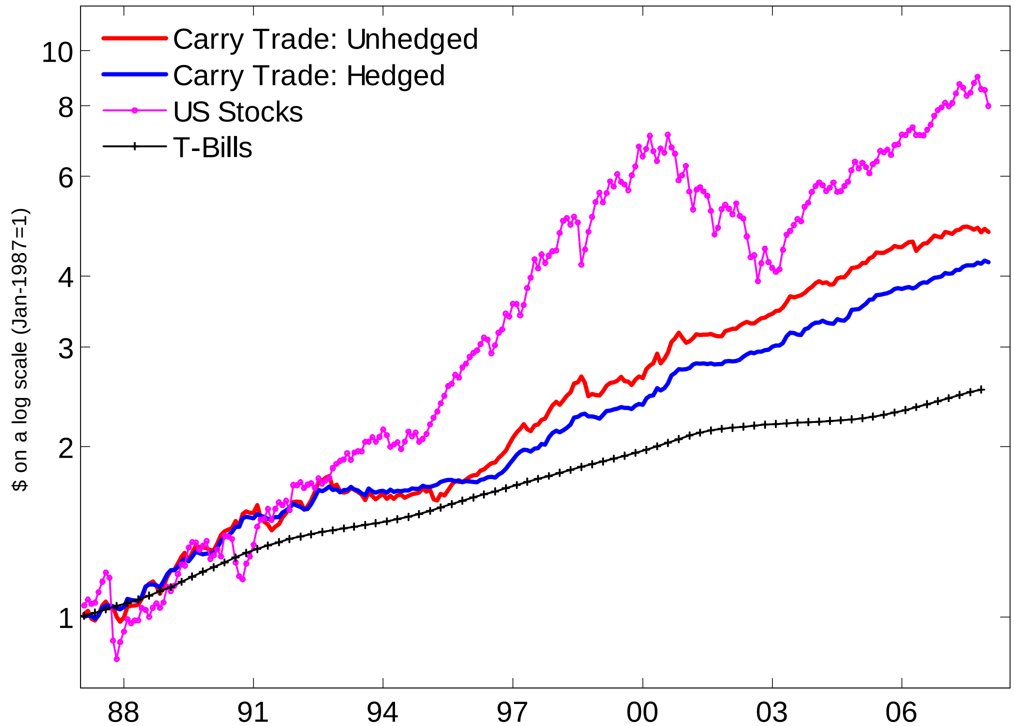
12-Month Rolling Window, February 1987–January 2008



Note: Plot (a) shows the average payoff from month $t-11$ to month t, in US dollars, per dollar bet in the carry trade. Plot (b) shows the ratio of the average payoff, to the standard deviation of the payoff, both being measured from month $t-11$ to month t. The unhedged portfolio is the equally-weighted carry-trade portfolio, described in the main text, formed by taking positions in the forward market currency-by-currency. The hedged position is formed by combining the forward position on each currency in the unhedged portfolio with a near-the-money option that insures against possible losses from the forward position. The carry-trade portfolios are formed as the equally-weighted averages of up to six individual currency carry trades against the US dollar.

FIGURE 9: Cumulative Nominal Returns of the Equally-Weighted Carry-Trade Portfolios

February 1987–January 2008



Note: The plots indicate the cumulative value of investing one US dollar at the end of January 1987 in each of the investments indicated.

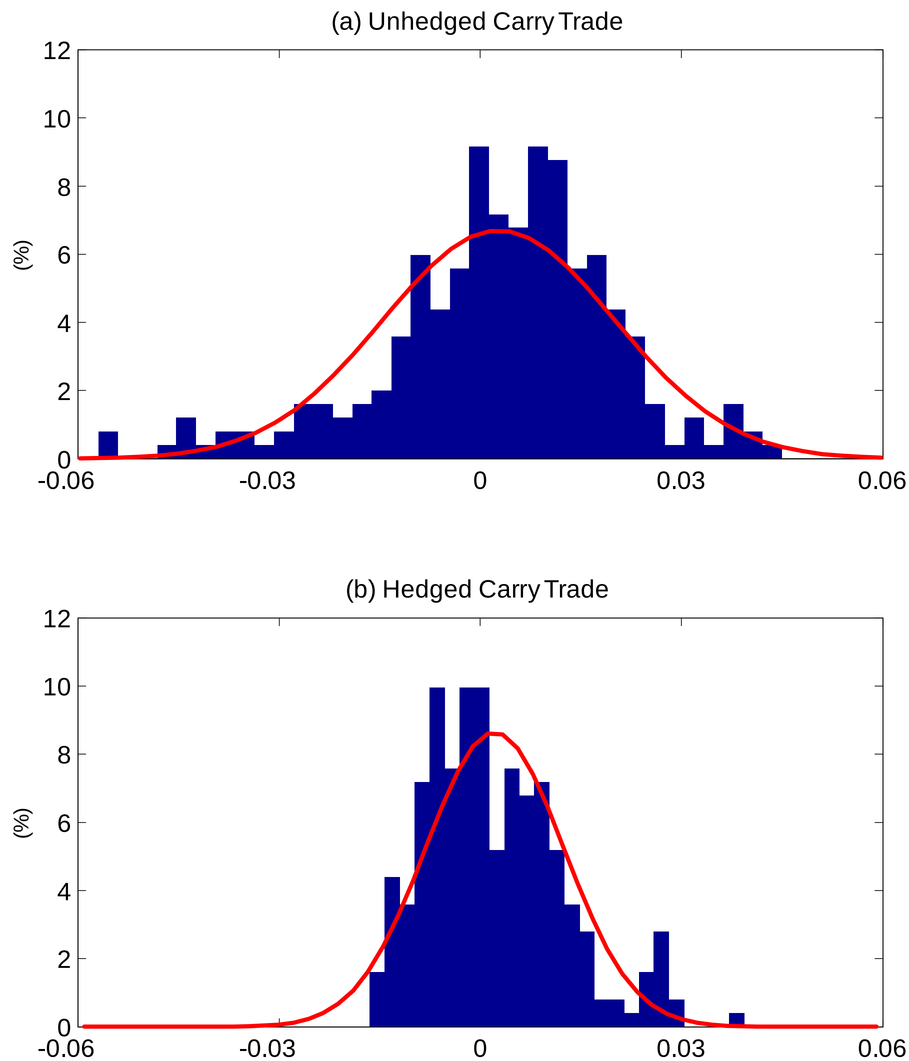
Carry Trade: Since the carry trade is a zero cost investment, the investor continuously invests in T-bills and bets an amount equal to the value of his T-bill portfolio in the equally-weighted carry trade. Profits from the carry trade are continuously re-invested in T-bills. The unhedged portfolio is the equally-weighted carry-trade portfolio, described in the main text, formed by taking positions in the forward market currency-by-currency. The hedged position is formed by combining the forward position on each currency in the unhedged portfolio with a near-the-money option that insures against possible losses from the forward position. The portfolios are formed as the equally-weighted averages of up to six individual currency carry trades against the US dollar.

US Stocks: The cumulative nominal return to the value-weighted US stock market from the Fama-French database.

T-Bills: The cumulative nominal return to continuously re-investing in one-month T-bills.

FIGURE 10: SAMPLING DISTRIBUTIONS OF THE PAYOFFS OF THE EQUALLY-WEIGHTED CARRY-TRADE PORTFOLIOS

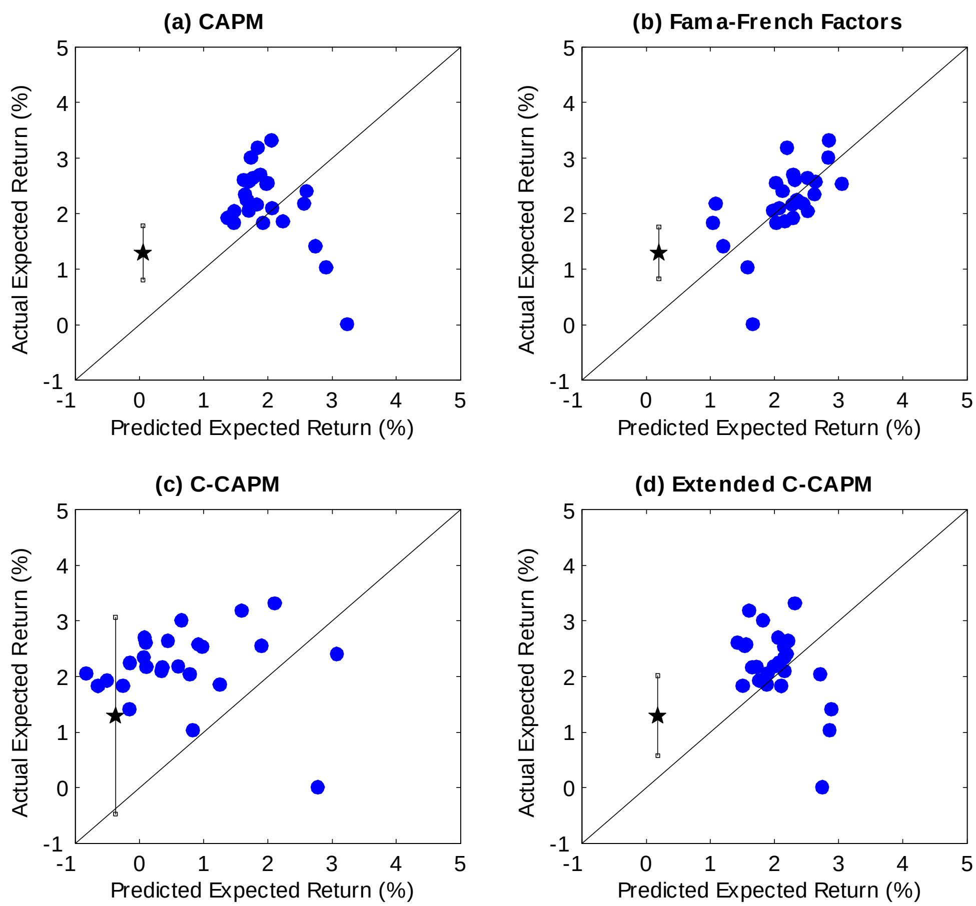
February 1987–January 2008



Note: In each plot the red line indicates the histogram implied by a normal distribution with the same mean and standard deviation as in the sampling distribution. The excess returns are computed at the monthly frequency. The carry-trade portfolios are formed as the equally-weighted average of up to six individual currency carry trades against the US dollar. The unhedged portfolio is formed by taking positions in the forward market currency-by-currency. The hedged position is formed by combining the forward position on each currency in the unhedged portfolio with a near-the-money option that insures against possible losses from the forward position.

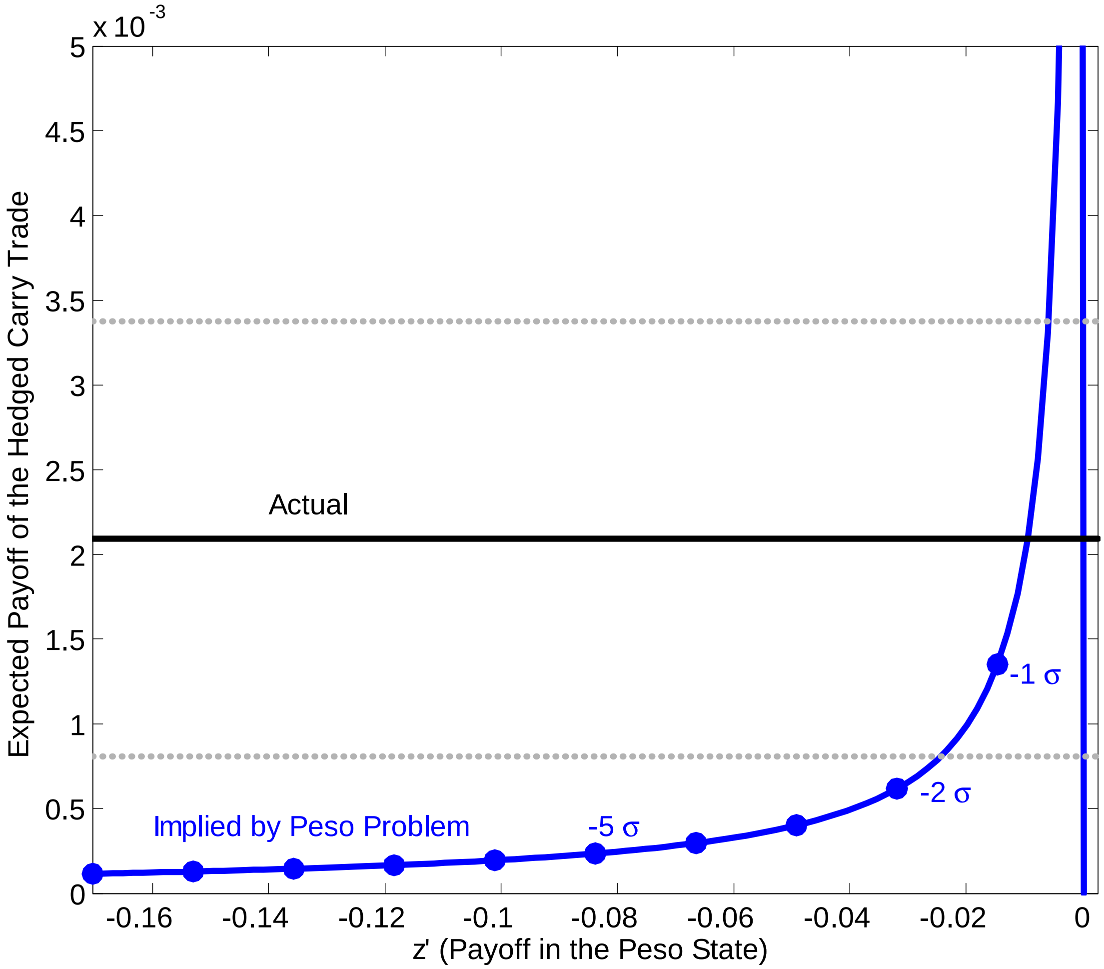
FIGURE 11: Cross-Sectional Fit of Factor Models Estimated by GMM

Test Assets are the Fama-French 25 Portfolios & the Equally-Weighted Hedged Carry-Trade Portfolio



Note: In each case the parmeters μ and b in the SDF $m_t = 1 - (f_t - \mu)'b$ are estimated by GMM using the method described in the text. The predicted expected return is $(1/T)\sum_{t=1}^{T} R_{it}^e(f_t - \hat{\mu})'\hat{b}$ for each portfolio's excess return, R_{it}^e. The actual expected return is $\bar{R}_i^e = (1/T)\sum_{t=1}^{T} R_{it}^e$. The blue dots correspond to Fama and French's 25 portfolios sorted on the basis of book-to-market value and firm size. The black star represents the hedged carry-trade portfolio formed as the equally-weighted average of up to six individual currency carry trades against the US dollar. The hedged position is formed by combining the forward position on each currency in the unhedged portfolio with a near-the-money option that insures against possible losses from the forward position. The black vertical line extending above and below the star is the actual expected return plus a two-standard error band for the pricing error of the carry-trade portfolio. When it does not cross the 45 degree line the pricing error is statistically significant at the 5 percent level. Sample period is 1987Q2-2007Q4.

FIGURE 12: THE PAYOFF IN THE PESO STATE AND THE EXPECTED PROFITS OF THE HEDGED CARRY TRADE



Note: The blue line indicates the value of $\tilde{E}(z_n^H)$ (the observed expected payoff of the hedge carry trade) implied by a model with a peso state, depending on the size of the payoff in the peso state, z'. The points labeled -1σ, -2σ and -5σ are for values of z' that lie one, two and five standard deviations below the mean of the unhedged carry-trade payoff. The black line indicates the point estimate of $\tilde{E}(z_n^H)$ implied by our data. The dotted grey lines represent a two-standard error band around this estimate.

A: Spot and Forward Exchange Rate Data

Our foreign exchange rate data are obtained from Datastream. They are originally sourced by Datastream from the WM Company/Reuters. We use two data sets. The first data set consists of spot exchange rates and one month forward exchange rates for twenty currencies quoted against the British pound. This data set spans the period January 1976 to January 2008. The mnemonics for and availability of each currency are indicated in Table A5. With the exception of euro forward quotes, each exchange rate is quoted as foreign currency units (FCUs) per British pound (GBP). To obtain quotes in GBP/FCU we inverted the original quotes while swapping the bid and ask prices (except for the Euro forward quotes). The original data set includes observations on all weekdays. We sample the data on the last weekday of each month.

The second data set consists of spot exchange rates and one month forward exchange rates for twenty currencies quoted against the U.S. dollar. This data set spans the period December 1996 to January 2008. The mnemonics for and availability of each currency are indicated in Table A6. With the exception of the Irish punt, British pound, Euro (forwards only), Australian dollar, and New Zealand dollar, each exchange rate is quoted as foreign currency units (FCUs) per U.S. dollar (USD). To obtain USD/FCU quotes for the other currencies we inverted the original quotes while swapping the bid and ask prices. We also noticed a problem in the original Datastream data set: the bid and ask spot exchange rates for the Euro are reversed for all data available through 12/29/2006. We reversed the quotes to obtain the correct bid and ask rates. The original data set includes observations on all weekdays. We sample the data on the last weekday of each month.

When we ignore bid-ask spreads we obtain a data set running from January 1976 to January 2008 with all currencies quoted against the U.S. dollar. We convert pound quotes to dollar quotes by multiplying the GBP/FCU quotes by the USD/GBP quotes.

B: Interest Rate Data and CIP

Our eurocurrency interest rate data are obtained from Datastream. They are originally sourced by Datastream from the Financial Times and ICAP. The data set spans the period January 1976 to January 2008. The mnemonics for and availability of each interest rate is indicated in Table A7. The original data set includes observations on all weekdays. We sample the data on the last weekday of each month.

To assess whether CIP holds it is critical to take bid-ask spreads into account. In this appendix the variables r_t^a and r_t^b denote the ask and bid interest rate in the domestic currency. The variables r_t^{*a} and r_t^{*b} denote the ask and bid foreign-currency interest rates.

In the presence of bid-ask spreads equation (4) is replaced with the following two inequalities,

$$\pi_{CIP} = \left(1 + r_t^{*b}\right) \frac{F_t^b}{S_t^a} - (1 + r_t^a) \leq 0, \tag{27}$$

$$\pi_{CIP}^* = \left(1 + r_t^b\right) \frac{S_t^b}{F_t^a} - (1 + r_t^{*a}) \leq 0. \tag{28}$$

Equation (27) implies that there is a non-positive payoff (π_{CIP}) to the "borrowing domestic currency covered strategy." This strategy consists of borrowing one unit of domestic currency, exchanging it for foreign currency at the spot rate, investing the proceeds at the foreign interest rate, and converting the payoff into domestic currency at the forward rate. Equation (28) 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 domestic currency at the spot rate, investing the proceeds at the domestic interest rate, and converting the payoff into foreign currency at the forward rate. Table A8 reports statistics for π_{CIP} and π_{CIP}^* for sixteen currencies.

Table A8 indicates that for all sixteen 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 positive is small. Even in periods where the payoff is positive, the median payoff is very small.

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.

C: Options Data and Options-Based Strategies

Our options data were obtained from the Chicago Mercantile Exchange (CME). We obtained daily quotes for put and call options for six currencies against the U.S. dollar. The currencies are available beginning on the following dates: Australian dollar (January 1994), Canadian dollar (August 1986), Euro (January 1999), Japanese yen (May 1986), Swiss franc (May 1985), British pound (January 1991). The data are available through the end of 2007. Due to sparse coverage in the early part of the sample we begin our analysis no earlier than January 1987.

We use the following notation: the spot exchange rate (S), the one month forward exchange rate (F), the strike price on the closest to in-the-money call option on the dollar (K^C), the strike price on the closest to in-the-money put option on the dollar (K^P), the settlement price of the call option (C), the settlement price of the put option (P), and the one month eurodollar deposit rate, r. We obtained the eurodollar deposit rate from the Federal Reserve Board interest rate database (H.15). Since the CME data pertain to options on foreign currency, in what follows, the variables S, F, K^C and K^P are measured in USD/FCU, while the variables C and P are measured in USD per foreign currency unit transacted.

Since our analysis of the carry trade is done at the monthly frequency using one month forward exchange rates, we restrict attention to options that are one month from maturity. Since we work exclusively with options expiring mid month (on the Friday preceding the third Wednesday) we look for transactions taking place 30 days prior to expiration. To be concrete, take January 2007 as an example of an expiration date. The Friday preceding the third Wednesday is January 12th 2007. We therefore look for transactions involving options expiring on January 12th 2007 that took place on December 13th 2006 as these dates are 30 days apart. For the purpose of calculating payoffs we measure S_t, F_t, K_t^C, K_t^P, C_t, P_t and r_t on December 13th 2006. We measure S_{t+1} as the spot rate observed on January 12 2007.[28]

D: Details of the Risk-Factor Analysis

Defining Quarterly Real Returns The monthly payoffs to the carry trade, denoted generically here as z_t, were defined for trades where $1/F_t$ FCUs were either bought or sold forward. This is equivalent to selling or buying one dollar. It is useful, instead, to normalize the number of dollars sold or bought to $1 + r_{t-1}$, where r_{t-1} is the yield on a one-month Treasury bill at the time when the currency bet is made. That is, we define the monthly excess return

$$R_t^{e,m} = (1 + r_{t-1})z_t.$$

[28]Notice that this means one month's S_{t+1} is not necessarily the next month's S_t. For example, the February 2007 expiration date is February 16th 2007. So the transactions date we look for in January 2007 is January 17th not January 12th. In practice we ignore the fact that this timing creates some slightly overlapping months and some gaps, putting priority on matching maturities of forwards and options.

To see that $R_t^{e,m}$ can be interpreted as an excess return, consider the case where we buy foreign currency forward, so: $z_t = S_t/F_{t-1} - 1$. This value of z_t implies that $R_t^{e,m} = (1+r_{t-1})(S_t/F_{t-1} - 1)$. Assuming that CIP (equation (4)) holds, $R_t^{e,m} = (1+r_{t-1}^*)S_t/S_{t-1} - (1+r_{t-1})$. So, when $(1+r_{t-1})/F_{t-1}$ FCUs are bought forward $R_t^{e,m}$ is the equivalent to the excess return, in dollars, from taking a long position in foreign T-bills.

Let t index months, and let $s = t/3$ be the equivalent index for quarters. To convert the monthly excess return to a quarterly excess return we define:

$$R_s^{e,q} = \Pi_{j=0}^2(1 + r_{t-1-j} + R_{t-j}^{e,m}) - \Pi_{j=0}^2(1 + r_{t-1-j}).$$

This expression corresponds to the appropriate excess return because it implies that the agent continuously re-invests in the carry trade strategy. In month t he bets his accumulated funds from currency speculation times $1 + r_t$. To define the quarterly *real* excess return in quarter s, which we denote R_s^e, notice that this is simply:

$$R_s^e = \frac{R_s^{e,q}}{1+\pi_s}$$

where π_s is the inflation rate between quarter $s-1$ and quarter s.

To generate the returns we use the risk free rate data from Kenneth French's data library: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. These data correspond to the one-month Treasury bill rate from Ibbotson Associates (2006).

We convert nominal returns to real returns using the inflation rate corresponding to the deflator for consumption of nondurables and services found in the U.S. National Income and Product Accounts.

When we work with options data, the returns for the first quarter are the accumulated payoffs (as described above) realized mid-January, mid-February and mid-March. For the second, third and fourth quarters we use the analogous monthly payoffs.

Data Sources for Risk Factors and Other Variables The three Fama-French factors are from Kenneth French's data library. The three factors are Mkt-Rf (the market premium, which we also use to define the CAPM factor), SMB (the size premium) and HML (the book to market premium). Each of these objects is an excess return. Nominal returns are converted to real returns as described above for our currency strategies.

Real per-capita consumption growth is from the U.S. National Income and Product Accounts which can be found at the website of the Bureau of Economic Analysis (BEA):

www.bea.gov. We define real consumption growth as the weighted average of the growth rates of nondurables consumption and services consumption. The weights are the nominal shares of nondurables and services in their sum. We compute the growth rate of the population using the series provided by the BEA in the NIPA accounts. This series displays seasonal variation so we first pass it through the Census X12 filter available from the Bureau of Labor Statistics (www.bls.gov). The inflation series used in all our calculations is the weighted average of the inflation rates for nondurables and services with the weights defined as above.

The risk factors proposed by Yogo (2006) are the market return (Mkt-Rf plus the risk free rate), the real growth rate of per-capita consumption of nondurables and services, and the real growth rate of the per-capita service flow from the stock of consumer durables. To estimate the latter we proceeded as follows. Annual end-of-year real stocks of consumer durables are available from the U.S. National Income and Product Accounts, as are quarterly data on purchases of durables by consumers. Within each year we determine the depreciation rate that makes the quarterly purchases consistent with the annual stocks, and use this rate to interpolate quarterly stocks using the identity: $K_{t+1}^D = C_t^D + (1 - \delta^D)K_t^D$. Here K_t^D is the beginning of period t stock of consumer durables, C_t^D is purchases of durables, and δ^D is the depreciation rate. We assume that the service flow from durables is proportional to the stock of durables.

Real luxury retail sales growth is available from 1987Q1–2001Q4 and is obtained from Aït-Sahalia, Parker and Yogo (2004).

The quarterly index of industrial production is from the Federal Reserve Board of Governors (www.federalreserve.gov), Statistical Release Table G.17. We calculate the growth rate of this series.

The average monthly value of the Fed funds rate is from the Federal Reserve Board of Governors (www.federalreserve.gov), Statistical Release Table H.15 (Selected Interest Rates), Effective Federal Funds Rate (mnemonic FEDFUNDS). We convert this to the quarterly frequency using the average of the three monthly values within each quarter.

The monetary policy shock is from Altig, et.al. (2004). Their estimates of the shock were updated through the end of 2007 by extending the data set. See Altig, et.al. (2004) for details of the underlying data.

Seasonally-adjusted monthly data on the stocks of M1, M2 and MZM are from the Federal

Reserve Board of Governors (www.federalreserve.gov), Statistical Release Table H.6 (Money Stock Measures), (mnemonics M1SL, M2SL and MZMSL). We compute quarterly growth rates by taking the growth rate from the 3rd month of the previous quarter to the 3rd month of the current quarter.

The term premium is defined as the difference between the 10-year T-bond rate and the 3-month Treasury-bill rate. Data are from the Federal Reserve Board of Governors (www.federal reserve.gov), Statistical Release Table H.15 (Selected Interest Rates) for the 3-Month Treasury Bill Secondary Market Rate (mnemonic TB3MS) and the 10-Year Treasury Constant Maturity Rate (mnemonic GS10). We convert this to the quarterly frequency using the average of the three monthly values within each quarter.

The liquidity premium is defined as the difference between the 3-month eurodollar rate and the 3-month Treasury-bill rate. Data are from the Federal Reserve Board of Governors (www.federal reserve.gov), Statistical Release Table H.15 (Selected Interest Rates) for the 3-Month eurodollar rate (mnemonic EDM3). We convert this to the quarterly frequency using the average of the three monthly values within each quarter.

The VIX and VXO volatility measures were obtained at the daily frequency from Datastream (mnemonics CBOEVIX, available from February 1990, and CBOEVXO, available from February 1986). We convert these to the quarterly frequency by averaging across all daily observations within each quarter.

The Campbell-Cochrane SDF is constructed using the same consumption series for nondurables and services described above, and denoted here as C_t. The SDF is

$$m_t = \delta \left[S_t C_t / (S_{t-1} C_{t-1}) \right]^{-\gamma}$$

where $s_t = \ln S_t$ is constructed recursively as follows:

$$\begin{aligned} s_t &= (1-\phi)\bar{s} + \phi s_{t-1} + \lambda_t(\Delta \ln C_t - g) \\ \lambda_t &= \begin{cases} \sqrt{1 - 2(s_{t-1} - \bar{s})}/e^{\bar{s}} - 1 & \text{if } s_{t-1} < s_{\max} \\ 0 & \text{otherwise.} \end{cases} \end{aligned}$$

We calibrate the model parameters to the following values: $g = 0.0049$ (the average quarterly growth rate of real per capita consumption), $\sigma = 0.0052$ (the standard deviation of the quarterly growth rate of real per capita consumption), $\gamma = 2.88$, $\phi = 0.8766$, and $r_f = 0.0044$.

The remaining parameters are determined as

$$\bar{s} = \ln[\sigma\sqrt{\gamma/(1-\phi)}]$$
$$s_{\max} = \bar{s} + (1-e^{2\bar{s}})/2$$
$$\delta = \exp(\gamma g - \gamma(1-\phi)/2 - r_f).$$

With these parameter values the model matches the average quarterly equity premium and real risk free rate in our sample, 1976Q2–2007Q4.

E: GMM Estimation

Generically we use GMM to estimate the linear factor model $m_t = 1 - (f_t - \mu)' b$ using the moment restrictions:

$$E(R_t^e m_t) = 0 \qquad E(f_t) = \mu \tag{29}$$

where R_t^e is an $n \times 1$ vector of excess returns and f_t is a $k \times 1$ vector of risk factors. Define $u_{1t}(b,\mu) = R_t^e m_t = R_t^e[1-(f_t-\mu)'b]$ and let $g_{1T}(b,\mu) = \frac{1}{T}\sum_{t=1}^T u_{1t} = \bar{R}^e - \left(D_T - \bar{R}^e\mu'\right) b$ where $D_T = \frac{1}{T}\sum_{t=1}^T R_t^e f_t'$ and $\bar{R}^e = \frac{1}{T}\sum_{t=1}^T R_t^e$. Define $u_{2t}(\mu) = f_t - \mu$ and let $g_{2T}(\mu) = \frac{1}{T}\sum_{t=1}^T u_{2t} = \bar{f} - \mu$ and $\bar{f} = \frac{1}{T}\sum_{t=1}^T f_t$. Define $u_t = \begin{pmatrix} u_{1t}' & u_{2t}' \end{pmatrix}'$ and $g_T = \begin{pmatrix} g_{1T}' & g_{2T}' \end{pmatrix}'$. We consider GMM estimators that set $a_T g_T = 0$, where a_T is a $2k \times (n+k)$ matrix and takes the form

$$a_T = \begin{pmatrix} d_T' W_T & 0 \\ 0 & I_k \end{pmatrix}, \tag{30}$$

where $d_T = D_T - \bar{R}^e \bar{f}'$, and W_T is an $n \times n$ positive definite weighting matrix. It follows that the GMM estimators of b and μ are

$$\hat{b} = \left(d_T' W_T d_T\right)^{-1} d_T' W_T \bar{R}^e \tag{31}$$
$$\hat{\mu} = \bar{f}. \tag{32}$$

We consider two-stage GMM estimators. In the first stage $W_T = I_n$. In the second stage, $W_T = \left(P_T S_T P_T'\right)^{-1}$ where $P_T = \begin{pmatrix} I_n & \bar{R}^e \hat{b}' \end{pmatrix}$ and S_T is a consistent estimator of $S_0 = \sum_{j=-\infty}^{+\infty} E(u_t u_{t-j}')$. Because u_{2t} may be serially correlated we use a VARHAC estimator, described in Burnside (2007), to compute S_T.

Let

$$\delta_T = \begin{pmatrix} -d_T & \bar{R}^e \hat{b}' \\ 0 & -I_k \end{pmatrix}. \tag{33}$$

A test of the pricing errors is based on

$$J = Tg_T(\hat{b}, \hat{\mu})(\hat{V}_g)^+ g_T(\hat{b}, \hat{\mu}), \tag{34}$$

where the + sign indicates the generalized inverse and

$$\hat{V}_g = A_T S_T A_T' \text{ with } A_T = I_{n+k} - \delta_T \left(a_T \delta_T\right)^{-1} a_T. \tag{35}$$

Equation (29) and the definition of m_t imply that

$$E(R_t^e) = E\left[R_t^e \left(f_t - \mu\right)'\right] b. \tag{36}$$

Corresponding to the right-hand side of (36) is a vector of predicted expected returns, $\hat{R}^e = d_T \hat{b}$. The cross-sectional R^2 measure is:

$$R^2 = 1 - \frac{(\bar{R}^e - d_T \hat{b})'(\bar{R}^e - d_T \hat{b})}{(\bar{R}^e - \tilde{R}^e)'(\bar{R}^e - \tilde{R}^e)}. \tag{37}$$

where $\tilde{R}^e = \frac{1}{n} \sum_{i=1}^{n} \bar{R}_i^e$ is the cross-sectional average of the mean returns in the data.

Equation (36) can be rewritten as

$$E(R_t^e) = \underbrace{E\left[R_t^e \left(f_t - \mu\right)'\right] V_f^{-1}}_{\beta} \underbrace{V_f b}_{\lambda}. \tag{38}$$

The covariance matrix of f_t is estimated by GMM using the moment restriction

$$E\left[(f_t - \mu)(f_t - \mu)' - V_f\right] = 0.$$

An estimate of λ is given by $\hat{\lambda} = \hat{V}_f \hat{b}$ where $\hat{V}_f$ is the sample covariance matrix of the factors. Standard errors for $\hat{\lambda}$ are obtained by the delta method using the joint distribution of $\hat{b}$, $\hat{\mu}$ and $\hat{V}_f$. The details are discussed in Burnside (2007).

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APPENDIX TABLE A1

UIP Regressions

	Against GBP			Against USD			
	α	β	R^2	α	β	R^2	Sample
Austria	0.003	-0.264	0.001	0.003	-1.003	0.007	76:01-98:12
	(0.002)	(0.583)		(0.002)	(0.725)		
Belgium	0.003	-1.049	0.014	0.000	-0.593	0.002	76:01-98:12
	(0.002)	(0.541)		(0.002)	(0.612)		
Canada	0.004	-3.614	0.046	0.000	-0.632	0.004	76:01-08:01
	(0.002)	(0.748)		(0.001)	(0.490)		
Denmark	0.001	-0.879	0.012	0.000	-0.619	0.005	76:01-08:01
	(0.001)	(0.562)		(0.002)	(0.467)		
France	0.000	-0.734	0.011	0.000	0.091	0.000	76:01-98:12
	(0.002)	(0.516)		(0.003)	(0.706)		
Germany	0.005	-0.693	0.004	0.003	-0.657	0.003	76:01-98:12
	(0.003)	(0.711)		(0.002)	(0.832)		
Ireland	0.000	0.967	0.020	0.000	0.367	0.002	79:04-98:12
	(0.002)	(0.429)		(0.003)	(0.978)		
Italy	-0.005	-0.929	0.021	-0.001	0.196	0.001	76:01-98:12
	(0.002)	(0.483)		(0.003)	(0.388)		
Japan	0.018	-3.400	0.024	0.010	-2.400	0.026	78:06-08:01
	(0.005)	(1.025)		(0.003)	(0.667)		
Netherlands	0.010	-2.381	0.037	0.003	-1.691	0.020	76:01-98:12
	(0.004)	(1.110)		(0.002)	(0.809)		
Norway	0.000	-0.598	0.005	-0.001	-0.512	0.003	76:01-08:01
	(0.001)	(0.548)		(0.002)	(0.507)		
Portugal	-0.002	0.546	0.038	-0.002	0.478	0.019	76:01-98:12
	(0.002)	(0.226)		(0.003)	(0.242)		
Spain	0.001	0.727	0.021	0.002	0.848	0.026	76:01-98:12
	(0.002)	(0.744)		(0.003)	(0.534)		
Sweden	-0.001	0.030	0.000	0.000	0.357	0.003	76:01-08:01
	(0.001)	(0.598)		(0.002)	(0.695)		
Switzerland	0.008	-1.099	0.011	0.007	-1.408	0.014	76:01-08:01
	(0.003)	(0.565)		(0.003)	(0.689)		
USA/UK	0.003	-1.427	0.012	-0.002	-1.533	0.014	76:01-08:01
	(0.002)	(0.884)		(0.002)	(0.860)		
Euro	0.006	-3.701	0.017	0.005	-4.334	0.048	98:12-08:01
	(0.004)	(2.430)		(0.002)	(1.655)		
Australia	0.000	-2.996	0.010	-0.003	-4.383	0.042	96:12-08:01
	(0.002)	(2.643)		(0.003)	(1.820)		
New Zealand	0.000	-0.372	0.000	-0.006	-3.687	0.031	96:12-08:01
	(0.004)	(2.520)		(0.004)	(1.695)		
South Africa	-0.012	-1.562	0.008	-0.014	-1.839	0.015	96:12-08:01
	(0.008)	(1.594)		(0.008)	(1.394)		

Notes: The table reports estimates of the equation $S_{t+1}/S_t - 1 = \alpha + \beta(F_t/S_t - 1) + \epsilon_{t+1}$ using monthly data. F and S are measured either in British pound per FCU, or US dollar per FCU. Heteroskedasticity-robust standard errors are in parentheses.

APPENDIX TABLE A2

Payoffs to the Carry-Trade Strategies

February 1976 to January 2008, British Pound is the Base Currency

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
Austria	0.0009	0.027	0.033	0.0015	0.021	0.075
	(0.0018)	(0.002)	(0.067)	(0.0013)	(0.002)	(0.066)
Belgium	0.0036	0.027	0.136	0.0017	0.019	0.089
	(0.0018)	(0.002)	(0.066)	(0.0014)	(0.002)	(0.070)
Canada	0.0047	0.032	0.148	0.0041	0.025	0.159
	(0.0017)	(0.002)	(0.054)	(0.0014)	(0.001)	(0.053)
Denmark	0.0034	0.025	0.135	0.0026	0.020	0.129
	(0.0014)	(0.002)	(0.056)	(0.0011)	(0.001)	(0.054)
France	0.0048	0.026	0.182	0.0035	0.023	0.149
	(0.0016)	(0.002)	(0.059)	(0.0014)	(0.002)	(0.061)
Germany	0.0018	0.027	0.065	0.0011	0.024	0.048
	(0.0017)	(0.002)	(0.064)	(0.0015)	(0.002)	(0.066)
Ireland	0.0002	0.023	0.007	-0.0002	0.016	-0.013
	(0.0014)	(0.002)	(0.061)	(0.0010)	(0.002)	(0.065)
Italy	0.0019	0.027	0.071	0.0010	0.024	0.040
	(0.0017)	(0.002)	(0.062)	(0.0014)	(0.002)	(0.058)
Japan	0.0024	0.034	0.069	0.0023	0.031	0.074
	(0.0021)	(0.002)	(0.064)	(0.0018)	(0.002)	(0.059)
Netherlands	0.0026	0.027	0.098	0.0017	0.022	0.077
	(0.0017)	(0.002)	(0.063)	(0.0015)	(0.002)	(0.067)
Norway	0.0028	0.025	0.114	0.0025	0.019	0.131
	(0.0012)	(0.001)	(0.047)	(0.0010)	(0.001)	(0.051)
Portugal	0.0037	0.026	0.140	-0.0009	0.017	-0.057
	(0.0019)	(0.002)	(0.070)	(0.0010)	(0.002)	(0.057)
Spain	0.0020	0.027	0.072	0.0007	0.023	0.029
	(0.0019)	(0.002)	(0.072)	(0.0017)	(0.003)	(0.073)
Sweden	0.0031	0.026	0.120	0.0015	0.020	0.073
	(0.0012)	(0.002)	(0.048)	(0.0009)	(0.002)	(0.049)
Switzerland	0.0018	0.028	0.063	0.0008	0.025	0.033
	(0.0017)	(0.002)	(0.060)	(0.0014)	(0.002)	(0.056)
USA	0.0046	0.030	0.154	0.0032	0.027	0.118
	(0.0015)	(0.002)	(0.054)	(0.0015)	(0.002)	(0.058)
Euro	0.0008	0.018	0.043	-0.0007	0.017	-0.039
	(0.0017)	(0.002)	(0.095)	(0.0018)	(0.002)	(0.107)
Australia	0.0032	0.029	0.111	0.0011	0.019	0.057
	(0.0023)	(0.002)	(0.081)	(0.0017)	(0.003)	(0.087)
New Zealand	0.0019	0.030	0.065	0.0029	0.019	0.153
	(0.0024)	(0.002)	(0.083)	(0.0018)	(0.003)	(0.096)
South Africa	0.0017	0.046	0.036	-0.0010	0.045	-0.021
	(0.0040)	(0.004)	(0.087)	(0.0039)	(0.004)	(0.087)
Average	0.0026	0.028	0.093	0.0015	0.023	0.065

Notes: Payoffs are measured as British pounds, per pound bet. Euro legacy currencies (Austria, Belgium, France, Germany, Italy, Netherlands, Portugal and Spain) are available 76:01-98:12, except Ireland, which is available 79:04-98:12. The Japanese yen is available 78:7-08:01. The Euro is available 98:12-08:01. The Australian dollar, New Zealand dollar and South African rand are available 96:12-08:01. Other currencies are available for 76:01-08:01. Standard errors are in parentheses.

APPENDIX TABLE A3

Payoffs to the Carry-Trade Strategies

Jan-1997 to Jan-2008, US Dollar is the Base Currency

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
Austria	0.0058	0.027	0.218	0.0054	0.027	0.200
	(0.0056)	(0.003)	(0.200)	(0.0056)	(0.003)	(0.200)
Belgium	0.0059	0.027	0.219	0.0049	0.027	0.181
	(0.0056)	(0.003)	(0.202)	(0.0056)	(0.003)	(0.203)
Canada	0.0020	0.020	0.098	0.0012	0.017	0.070
	(0.0020)	(0.002)	(0.100)	(0.0018)	(0.002)	(0.107)
Denmark	0.0062	0.025	0.245	0.0047	0.024	0.192
	(0.0023)	(0.001)	(0.091)	(0.0023)	(0.002)	(0.092)
France	0.0057	0.027	0.210	0.0053	0.027	0.198
	(0.0055)	(0.003)	(0.197)	(0.0055)	(0.003)	(0.197)
Germany	0.0059	0.027	0.220	0.0055	0.027	0.206
	(0.0056)	(0.003)	(0.200)	(0.0056)	(0.003)	(0.200)
Ireland	0.0022	0.028	0.078	0.0008	0.007	0.108
	(0.0053)	(0.003)	(0.194)	(0.0008)	(0.003)	(0.074)
Italy	-0.0090	0.025	-0.360	-0.0055	0.024	-0.230
	(0.0040)	(0.003)	(0.162)	(0.0042)	(0.004)	(0.157)
Japan	0.0022	0.032	0.068	0.0017	0.032	0.054
	(0.0027)	(0.004)	(0.088)	(0.0027)	(0.004)	(0.087)
Netherlands	0.0061	0.027	0.227	0.0057	0.027	0.212
	(0.0056)	(0.003)	(0.200)	(0.0056)	(0.003)	(0.200)
Norway	0.0050	0.029	0.175	0.0037	0.025	0.147
	(0.0023)	(0.002)	(0.079)	(0.0023)	(0.002)	(0.087)
Portugal	-0.0084	0.025	-0.340	-0.0042	0.021	-0.203
	(0.0051)	(0.002)	(0.199)	(0.0038)	(0.004)	(0.161)
Spain	-0.0039	0.027	-0.148	-0.0037	0.020	-0.181
	(0.0046)	(0.003)	(0.167)	(0.0034)	(0.004)	(0.147)
Sweden	0.0080	0.027	0.290	0.0050	0.025	0.198
	(0.0023)	(0.001)	(0.085)	(0.0021)	(0.002)	(0.083)
Switzerland	0.0001	0.027	0.005	0.0012	0.025	0.049
	(0.0024)	(0.001)	(0.088)	(0.0022)	(0.002)	(0.085)
UK	0.0018	0.021	0.086	0.0012	0.019	0.062
	(0.0018)	(0.001)	(0.084)	(0.0017)	(0.001)	(0.088)
Euro	0.0065	0.025	0.260	0.0052	0.024	0.219
	(0.0026)	(0.002)	(0.102)	(0.0025)	(0.002)	(0.104)
Australia	0.0073	0.030	0.245	0.0051	0.021	0.239
	(0.0024)	(0.002)	(0.085)	(0.0020)	(0.003)	(0.084)
New Zealand	0.0042	0.032	0.129	0.0052	0.026	0.202
	(0.0033)	(0.002)	(0.104)	(0.0027)	(0.003)	(0.106)
South Africa	0.0037	0.045	0.082	0.0013	0.044	0.030
	(0.0044)	(0.004)	(0.098)	(0.0043)	(0.004)	(0.097)
Average	0.0029	0.028	0.100	0.0025	0.025	0.098

Notes: Payoffs are measured as US dollar, per dollar bet. Euro legacy currencies (Austria, Belgium, France, Germany, Ireland, Italy, Netherlands, Portugal and Spain) are available 96:12-98:12. The Euro is available 98:12-08:01. Other currencies are available 96:12-08:01. Standard errors are in parentheses.

APPENDIX TABLE A4

Payoffs to the Carry-Trade Strategy

Jan-1976 to Jan-2008, US Dollar is the Base Currency

	Mean	Standard Deviation	Sharpe Ratio	Skewness	Kurtosis	Jarque-Bera Statistic
Austria	0.0022	0.034	0.066	-0.149	0.83	9.0
	(0.0022)	(0.002)	(0.066)	(0.177)	(0.41)	(0.011)
Belgium	0.0068	0.033	0.207	0.005	0.94	10.2
	(0.0020)	(0.002)	(0.061)	(0.231)	(0.44)	(0.006)
Canada	0.0020	0.016	0.126	-0.500	1.38	46.5
	(0.0009)	(0.001)	(0.056)	(0.169)	(0.50)	(0.000)
Denmark	0.0082	0.030	0.274	-0.127	0.86	12.8
	(0.0017)	(0.001)	(0.059)	(0.142)	(0.41)	(0.002)
France	0.0051	0.032	0.161	-0.033	0.45	2.4
	(0.0019)	(0.002)	(0.062)	(0.155)	(0.31)	(0.308)
Germany	0.0012	0.033	0.035	-0.184	0.51	4.6
	(0.0022)	(0.002)	(0.065)	(0.128)	(0.32)	(0.101)
Ireland	0.0054	0.032	0.170	-0.025	0.36	1.3
	(0.0023)	(0.002)	(0.071)	(0.178)	(0.37)	(0.517)
Italy	0.0025	0.031	0.082	-0.297	1.08	17.4
	(0.0021)	(0.002)	(0.068)	(0.223)	(0.50)	(0.000)
Japan	0.0024	0.035	0.069	-0.669	1.64	66.2
	(0.0020)	(0.002)	(0.058)	(0.246)	(0.87)	(0.000)
Netherlands	0.0034	0.033	0.101	-0.122	0.64	5.4
	(0.0022)	(0.002)	(0.067)	(0.210)	(0.39)	(0.067)
Norway	0.0050	0.029	0.175	-0.179	1.13	22.4
	(0.0014)	(0.001)	(0.050)	(0.173)	(0.43)	(0.000)
Portugal	0.0039	0.032	0.122	-0.053	2.38	65.0
	(0.0021)	(0.002)	(0.065)	(0.378)	(0.98)	(0.000)
Spain	0.0029	0.032	0.089	-0.743	2.05	73.9
	(0.0023)	(0.002)	(0.075)	(0.335)	(1.35)	(0.000)
Sweden	0.0057	0.030	0.193	-0.778	3.25	208.2
	(0.0015)	(0.002)	(0.058)	(0.352)	(1.48)	(0.000)
Switzerland	0.0009	0.035	0.025	-0.228	0.74	12.0
	(0.0020)	(0.002)	(0.056)	(0.209)	(0.46)	(0.002)
UK	0.0053	0.030	0.178	-0.029	1.91	58.2
	(0.0015)	(0.002)	(0.051)	(0.362)	(0.96)	(0.000)
Euro	0.0065	0.025	0.260	-0.138	0.19	0.5
	(0.0026)	(0.002)	(0.102)	(0.294)	(0.51)	(0.773)
Australia	0.0066	0.030	0.221	-0.277	-0.22	2.0
	(0.0027)	(0.002)	(0.096)	(0.177)	(0.22)	(0.375)
New Zealand	0.0042	0.032	0.129	-0.393	0.09	3.5
	(0.0033)	(0.002)	(0.104)	(0.142)	(0.31)	(0.176)
South Africa	0.0037	0.045	0.082	-0.259	0.43	2.5
	(0.0044)	(0.004)	(0.098)	(0.174)	(0.51)	(0.287)
Average	0.0042	0.031	0.138	-0.259	1.03	31.2

Notes: Payoffs are measured as US dollars, per dollar bet. Euro legacy currencies (Austria, Belgium, France, Germany, Italy, Netherlands, Portugal and Spain) are available 76:01-98:12, except Ireland, which is available 79:04-98:12. The Japanese yen is available 78:7-08:01. The Euro is available 98:12-08:01. The Australian dollar, New Zealand dollar and South African rand are available 96:12-08:01. Other currencies are available for 76:01-08:01. Standard errors are in parentheses.

APPENDIX TABLE A5

Datastream Mnemonics for Currency Quotes Against the British Pound

Currency	Spot Rate	Forward Rate	Availability	Quote
Austrian schilling	AUSTSCH	AUSTS1F	76:01–98:12	FCU/GBP
Belgian franc	BELGLUX	BELXF1F	76:01–98:12	FCU/GBP
Canadian dollar	CNDOLLR	CNDOL1F	76:01–08:01	FCU/GBP
Danish krone	DANISHK	DANIS1F	76:01–08:01	FCU/GBP
French franc	FRENFRA	FRENF1F	76:01–98:12	FCU/GBP
German mark	DMARKER	DMARK1F	76:01–98:12	FCU/GBP
Irish punt	IPUNTER	IPUNT1F	79:04–98:12	FCU/GBP
Italian lira	ITALIRE	ITALY1F	76:01–98:12	FCU/GBP
Japanese yen	JAPAYEN	JAPYN1F	78:06–08:01	FCU/GBP
Netherlands guilder	GUILDER	GUILD1F	76:01–98:12	FCU/GBP
Norwegian krone	NORKRON	NORKN1F	76:01–08:01	FCU/GBP
Portuguese escudo	PORTESC	PORTS1F	76:01–98:12	FCU/GBP
Spanish peseta	SPANPES	SPANP1F	76:01–98:12	FCU/GBP
Swedish krona	SWEKRON	SWEDK1F	76:01–08:01	FCU/GBP
Swiss franc	SWISSFR	SWISF1F	76:01–08:01	FCU/GBP
U.S. dollar	USDOLLR	USDOL1F	76:01–08:01	FCU/GBP
Euro	ECURRSP	UKEUR1F	98:12–08:01	FCU/GBP
Australia	AUSTDOL	UKAUD1F	96:12–08:01	FCU/GBP
New Zealand	NZDOLLR	UKNZD1F	96:12–08:01	FCU/GBP
South Africa	COMRAND	UKZAR1F	96:12–08:01	FCU/GBP

Notes: To obtain bid, ask (offer), and mid quotes for the exchange rates the suffixes (EB), (EO) and (ER) are added to the mnemonics indicated. Datastream stopped publishing forward exchange rate data under the original mnemonics at the end of January 2007. So, from the end of January 2007 until the end of the sample, the mnemonics for the Canadian dollar, Danish krone, Japanese yen, Norwegian krone, Swedish krona, Swiss franc and U.S. dollar forward exchange rates changed to UKCAD1M, UKDKK1M, UKJPY1M, UKNOK1M, UKSEK1M, UKCHF1M, USGBP1M.

APPENDIX TABLE A6

Datastream Mnemonics for Currency Quotes Against the U.S. Dollar

Currency	Spot Rate	Forward Rate	Availability	Quote
Austrian schilling	AUSTSC$	USATS1F	96:12–98:12	FCU/USD
Belgian franc	BELGLU$	USBEF1F	96:12–98:12	FCU/USD
Canadian dollar	CNDOLL$	USCAD1F	96:12–08:01	FCU/USD
Danish krone	DANISH$	USDKK1F	96:12–08:01	FCU/USD
French franc	FRENFR$	USFRF1F	96:12–98:12	FCU/USD
German mark	DMARKE$	USDEM1F	96:12–98:12	FCU/USD
Irish punt	IPUNTE$	USIEP1F	96:12–98:12	USD/FCU
Italian lira	ITALIR$	USITL1F	96:12–98:12	FCU/USD
Japanese yen	JAPAYE$	USJPY1F	96:12–08:01	FCU/USD
Netherlands guilder	GUILDE$	USNLG1F	96:12–98:12	FCU/USD
Norwegian krone	NORKRO$	USNOK1F	96:12–08:01	FCU/USD
Portuguese escudo	PORTES$	USPTE1F	96:12–98:12	FCU/USD
Spanish peseta	SPANPE$	USESP1F	96:12–98:12	FCU/USD
Swedish krona	SWEKRO$	USSEK1F	96:12–08:01	FCU/USD
Swiss franc	SWISSF$	USCHF1F	96:12–08:01	FCU/USD
British pound	USDOLLR	USGBP1F	96:12–08:01	USD/FCU
Euro	EUDOLLR	USEUR1F	98:12–08:01	FCU/USD
Australian dollar	AUSTDO$	USAUD1F	96:12–08:01	USD/FCU
New Zealand dollar	NZDOLL$	USNZD1F	96:12–08:01	USD/FCU
South African rand	COMRAN$	USZAR1F	96:12–08:01	FCU/USD

Notes: To obtain bid, ask (offer), and mid quotes for the exchange rates the suffixes (EB), (EO) and (ER) are added to the mnemonics indicated. Euro forward quotes are quoted in USD/FCU.

APPENDIX TABLE A7

DATASTREAM MNEMONICS FOR EURODOLLAR INTEREST RATES

Currency	Mnemomic	Availability
Belgium	ECBFR1M	78:06–98:12
Canada	ECCAD1M	76:01–08:01
Denmark	ECDKN1M	85:06–08:01
France	ECFFR1M	76:01–98:12
Germany	ECWGM1M	76:01–98:12
Italy	ECITL1M	78:06–98:12
Japan	ECJAP1M	78:08–08:01
Netherlands	ECNLG1M	76:01–98:12
Norway	ECNOR1M	97:04–08:01
Sweden	ECSWE1M	97:04–08:01
Switzerland	ECSWF1M	76:01–07:11
United Kingdom	ECUKP1M	76:01–08:01
United States	ECUSD1M	76:01–08:01
Euro	ECEUR1M	99:01–08:01
Australia	ECAUD1M	97:04–08:01
New Zealand	ECNZD1M	97:04–08:01
South Africa	ECSAR1M	97:04–08:01

Notes: To obtain bid, ask (offer), and mid quotes for the exchange rates the suffixes (EB), (EO) and (ER) are added to the mnemonics indicated.

APPENDIX TABLE A8 (Part 1)

Covered Interest Arbitrage at the One-Month Horizon

Currency	Median return to borrowing covered in GBP (percent)	Median return to borrowing covered in FX (percent)	Number of months with positive returns to borrowing covered in GBP	Number of months with positive returns to borrowing covered in FX	Median of positive returns to borrowing covered in GBP (percent)	Median of positive returns to borrowing covered in FX (percent)
			Full Sample, 1976:1-2008:1			
Belgium	-0.21	-0.21	3	6	0.00	0.27
Canada	-0.11	-0.08	4	8	0.04	0.02
Denmark	-0.11	-0.11	4	2	0.02	0.43
France	-0.15	-0.12	3	5	0.01	0.05
Germany	-0.27	-0.27	0	0		
Italy	-0.17	-0.13	4	6	0.08	0.03
Japan	-0.22	-0.24	0	0		
Netherlands	-0.33	-0.30	0	1		0.11
Norway	-0.12	-0.12	0	6		0.03
Sweden	-0.11	-0.11	0	0		
Switzerland	-0.32	-0.32	0	1		0.17
USA	-0.07	-0.07	3	2	0.02	0.01
Euro	-0.06	-0.06	1	0	0.01	
Australia	-0.11	-0.09	0	0		
New Zealand	-0.14	-0.12	0	0		
South Africa	-0.22	-0.20	1	1	0.04	0.18
Average	-0.17	-0.16	1.4	2.4	0.01	0.08
			1999:1-2008:1			
Canada	-0.08	-0.08	0	0		
Denmark	-0.07	-0.08	1	1	0.01	0.45
Japan	-0.05	-0.08	0	0		
Norway	-0.12	-0.12	0	6		0.03
Sweden	-0.10	-0.11	0	0		
Switzerland	-0.09	-0.10	0	1		0.17
USA	-0.04	-0.03	2	0	0.01	
Euro	-0.06	-0.06	1	0	0.01	
Australia	-0.10	-0.09	0	0		
New Zealand	-0.13	-0.11	0	0		
South Africa	-0.22	-0.20	0	0		
Average	-0.10	-0.10	0.3	0.5	0.00	0.06

Table A8 is continued on the next page.

APPENDIX TABLE A8 (Part 2)

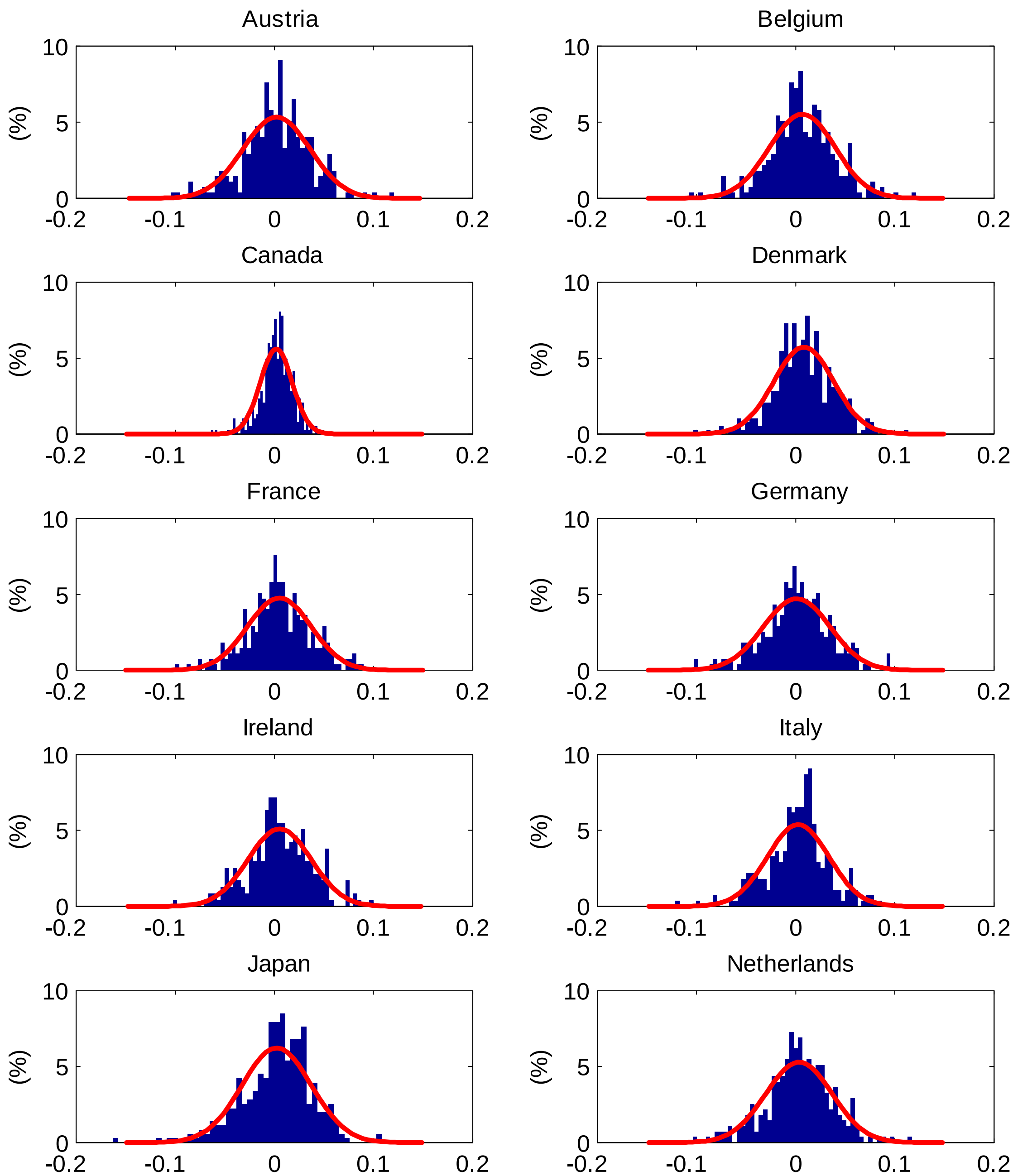
Covered Interest Arbitrage at the One-Month Horizon

Currency	Median return to borrowing covered in USD (percent)	Median return to borrowing covered in FX (percent)	Number of months with positive returns to borrowing covered in USD	Number of months with positive returns to borrowing covered in FX	Median of positive returns to borrowing covered in USD (percent)	Median of positive returns to borrowing covered in FX (percent)
			Full Sample, 1996:12-2008:1			
Belgium	-0.11	-0.13	0	0		
Canada	-0.05	-0.05	0	0		
Denmark	-0.04	-0.05	2	0	0.01	
France	-0.03	-0.05	3	1	0.01	0.00
Germany	-0.04	-0.05	0	0		
Italy	-0.07	-0.07	0	0		
Japan	-0.03	-0.06	16	0	0.01	
Netherlands	-0.04	-0.06	0	0		
Norway	-0.09	-0.09	0	0		
Sweden	-0.08	-0.08	0	0		
Switzerland	-0.06	-0.07	0	0		
USA	-0.04	-0.04	0	1		0.00
Euro	-0.03	-0.04	3	0	0.00	
Australia	-0.08	-0.07	1	2	0.00	0.01
New Zealand	-0.12	-0.09	0	1		0.00
South Africa	-0.18	-0.16	1	1	0.11	0.24
Average	-0.07	-0.07	1.6	0.4	0.02	0.05

Notes: Part 1 of the table indicates the returns to borrowing British pounds to lend (covered) in foreign currency and the returns to borrowing foreign foreign currency to lend (covered) in British pounds. Part 2 of the table indicates the returns to borrowing US dollars to lend (covered) in foreign currency and the returns to borrowing foreign foreign currency to lend (covered) in US dollars. The sample period for individual currencies varies, as detailed in Appendix B.

APPENDIX FIGURE A1 (Part 1): Sampling Distributions of the Payoffs of the Carry Trade by Currency

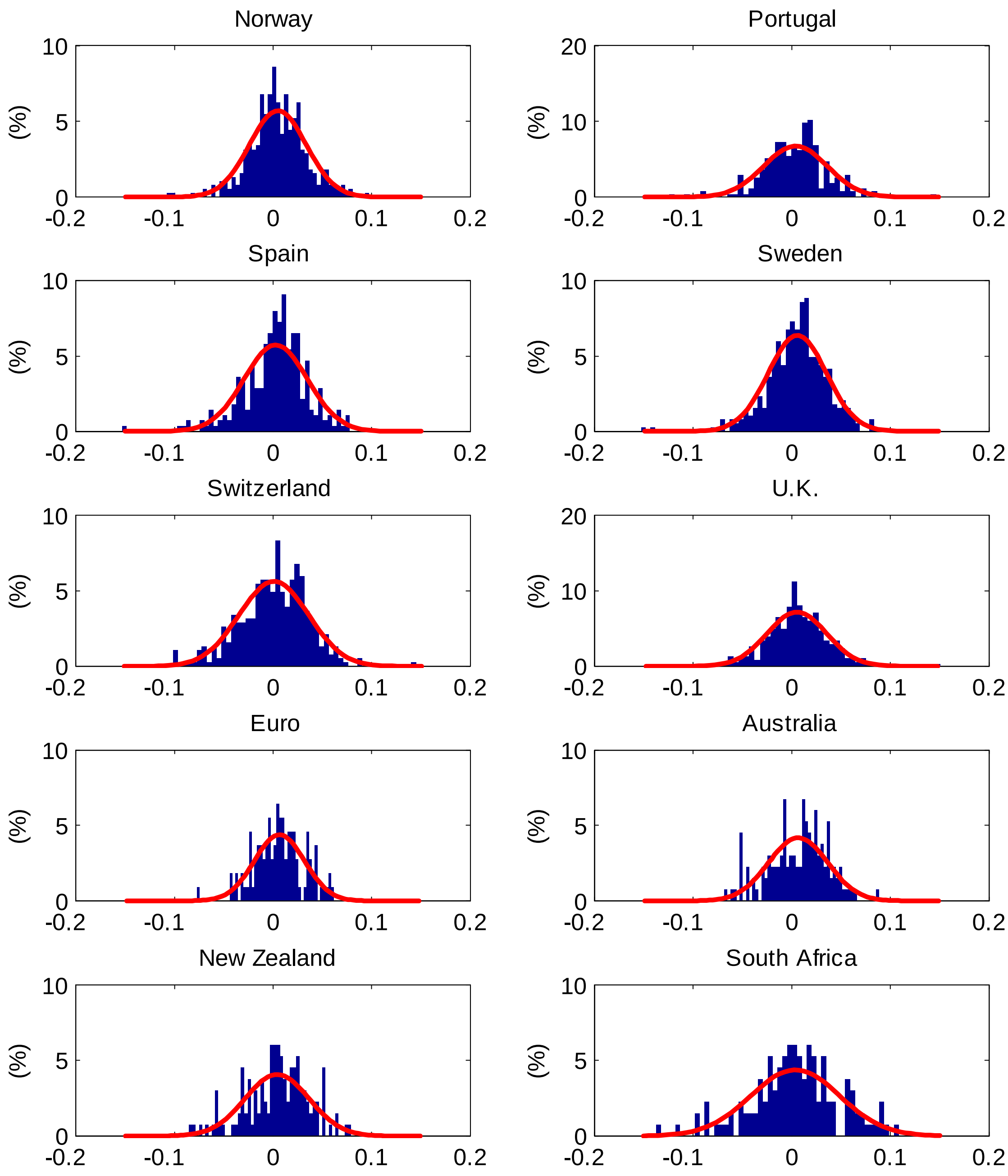
February 1976–January 2008



Note: In each plot the red line indicates the histogram implied by a normal distribution with the same mean and standard deviation as in the sampling distribution. The payoffs are computed at the monthly frequency.

APPENDIX FIGURE A1 (Part 2): Sampling Distributions of the Payoffs of the Carry Trade by Currency

February 1976–January 2008



Note: In each plot the red line indicates the histogram implied by a normal distribution with the same mean and standard deviation as in the sampling distribution. The payoffs are computed at the monthly frequency.