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ABSTRACT

We study the properties of the carry trade, a currency speculation strategy in which an investor borrows low-interest-rate currencies and lends high-interest-rate currencies. This strategy generates payoffs which are on average large and uncorrelated with traditional risk factors. We investigate whether these payoffs reflect a peso problem. We argue that they do. We reach this conclusion by analyzing the payoffs to the hedged carry trade, in which an investor uses currency options to protect himself from the downside risk from large, adverse movements in exchange rates.

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1 Introduction

The forward exchange rate is a biased forecaster of the future spot exchange rate. This fact is often referred to as the 'forward-premium puzzle.' In this paper we study the properties of a widely-used currency speculation strategy that exploits this puzzle. 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 payoff to the carry trade is that it compensates 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. Our results are consistent with previous work documenting that one can reject consumption-based asset-pricing models using data on forward exchange rates.[1] More generally, it has been difficult to use structural asset-pricing models to rationalize the risk-premium movements required to account for the time-series properties of the forward premium (see Bekaert (1996)).

The most natural alternative explanation for the high average payoff to the carry trade is that it reflects the presence of a peso problem. We use the term "peso problem" as defined by Cochrane (2001), i.e. "a generic term for the effects of small probabilities of large events on empirical work." This definition of a peso problem is consistent with agents being risk averse and is equivalent to the "rare event" problem that has received substantial attention in the literature. In what follows, we use the term "peso event" to refer to a rare event in which there are either large negative payoffs to the carry trade or unusually high values of the stochastic discount factor (SDF).

A number of authors have recently argued that the peso problem or rare event problem lies

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

at the root of the failure of uncovered interest parity (UIP).[2] Not surprisingly, peso problems can in principle also explain the positive average payoff to the carry trade. To understand the basic argument, suppose that a foreign currency is at a forward premium, so that a carry-trade investor sells this currency forward. Assume that a substantial appreciation of the foreign currency occurs with small probability. The investor must be compensated for the negative payoff to the carry trade in this state of the world. The degree of compensation depends on the value of the SDF in the peso state and the magnitude of the negative payoff.

In this paper we ask the following question: is the large average payoff to the unhedged carry trade a compensation for peso-event risk? Our basic approach to answering this question relies on analyzing the payoffs to a version of the carry-trade strategy that does not yield high negative returns in a peso state. 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. We use data on currency options to estimate the average payoff to the hedged carry trade.

Using information on the average payoffs to the hedged and unhedged carry trade, we obtain estimates of the payoff to the unhedged carry trade and the SDF in the peso event. Our main findings can be summarized as follows. First, the average payoff to the unhedged-carry-trade strategy is statistically significant. Second, the payoffs to this strategy are uncorrelated with conventional risk-factor measures. Third, the average payoff to the hedged carry trade is statistically significant. Fourth, the payoffs to this strategy are correlated with some risk-factor measures such as the Fama-French (1993) factors. Fifth, the average risk-adjusted payoff to the hedged carry trade strategy is not statistically different from zero.

We interpret these findings as supportive of the view that the average payoff to the unhedged carry trade reflects the possibility of a peso event that does not occur in sample, at least as far as we can measure. We reach this conclusion as follows. Our first two findings imply that the peso event did not occur in sample. If it did, the average risk-adjusted payoff

[2] See Farhi and Gabaix (2008). In related work Brunnermeier, Nagel, and Pedersen (2008) emphasize the importance of crash-related risk. 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.

to the unhedged carry trade would be zero. Our last three findings imply that the positive risk-adjusted average payoff to the unhedged carry trade disappears once we hedge the peso event.

Given our results an obvious question is: what is the nature of the peso event that agents are being compensated for? Conceptually it is useful to distinguish between two extreme possibilities. The first possibility is that the salient feature of a peso state is large carry-trade losses.[3] The second possibility is that the salient feature of a peso state is a large value of the SDF. A key contribution of this paper is to assess the relative importance of these two possibilities. We do so by estimating the size of carry-trade losses and the level of the SDF in the peso state. We find that a peso event reflects high values of the SDF in the peso state rather than very large negative payoffs to the unhedged carry trade in that state. The intuition for why the losses to the unhedged carry trade are small in the peso state is as follows. Any gains to the carry trade in the non-peso state must on average be compensated, on a risk-adjusted basis, by losses in the peso state. Since the average gains to the hedged and unhedged carry trade in the non-peso state are similar, the risk-adjusted losses of these two strategies in the peso state must also be similar. Given that the value of the SDF in the peso state is the same for both strategies, the actual losses of the two strategies in the peso state must be similar. The options that we use in the hedged carry trade are always in the money in the peso state. So we know how much an agent loses in the peso state if he is pursuing the hedged carry trade. Since these losses turn out to be small, the losses to the unhedged carry trade in the peso state must also be small.

The rationale for why the SDF is much larger in the peso state than in the non-peso state is as follows. We just argued that the unhedged carry trade makes relatively small losses in the peso state. At the same time, the average payoff to the unhedged carry trade in the non-peso state is large. The only way to rationalize these observations is for the SDF to be very high in the peso state. So, even though the losses in the peso state are moderate, the investor attaches great importance to those losses.

A possible shortcoming of our methodology is that we can always produce values of the SDF and the carry-trade payoff in the peso state that rationalize the observed average payoffs to the carry trade. The skeptical reader may conclude that we have documented an interesting puzzle without providing a credible resolution of that puzzle. So, it is of interest

[3] See Bates (1996a) for a related argument that exchange rate jumps can explain the volatility smile present in currency options.

to bring additional data to bear on the plausibility of our estimates. To this end, we consider two versions of an equity strategy that involves borrowing one dollar at the Treasury-bill rate and investing it in the stock market. In the first version the agent does not hedge against adverse movements in the stock market. In the second version the agent buys at-the-money put options which exactly compensate him for a fall in the stock market. We find that, in sharp contrast to the carry trade, the hedged stock market strategy yields large, negative average payoffs. Using the average payoffs to the two stock market strategies we generate an independent estimate of the value of the SDF in the peso state. Remarkably, the same estimate of the peso state SDF that rationalizes the average payoffs to the carry trade also rationalizes the equity premium.

Our paper is organized as follows. In section 2 we describe the carry-trade strategy and discuss our method for estimating carry trade losses and the value of the SDF in the peso state. We describe our data in Section 3. In Section 4 we study the covariance between the payoffs to the carry trade and traditional risk factors, using both time series and panel data. In Section 5 we study the properties of the hedged carry trade. Together, Sections 4 and 5 provide the inputs for quantifying the ability of peso events to account for the observed returns to the carry trade. In Section 6 we report our results and generalize the analysis to multiple peso states. Section 7 concludes.

2 Peso problems and the carry trade

The failure of UIP motivates a variety of speculation strategies. In this paper we focus on the carry trade, the strategy most widely used by practitioners (see Galati and Melvin (2004)). In this section we describe a procedure for analyzing peso-event explanations for carry-trade payoffs.

The carry trade consists of borrowing a low-interest-rate currency and lending a high-interest-rate currency. Abstracting from transactions costs, the payoff to the carry trade, denominated in dollars, is:[4]

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

The variable S_t denotes the spot exchange rate expressed as dollars per foreign currency unit (FCU). The variables r_t and r_t^* represent the domestic and foreign interest rate, respectively.

[4] We study the impact of transactions costs in Section 4.

The amount of dollars borrowed, y_t, is given by:

$$y_t = \begin{cases} +1 & \text{if } r_t < r_t^*, \\ -1 & \text{if } r_t^* \leq r_t. \end{cases} \tag{2}$$

We normalize the amount of dollars we bet on this strategy (the absolute value of y_t) to one.

If S_{t+1} is a martingale:

$$E_t S_{t+1} = S_t, \tag{3}$$

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

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

The carry-trade strategy can also be implemented by selling the foreign currency forward when it is at a forward premium ($F_t \geq S_t$) and buying the foreign currency forward when it is at a forward discount ($F_t < S_t$). The value of w_t, the number of FCUs sold forward, is given by:

$$w_t = \begin{cases} +1/F_t & \text{if } F_t \geq S_t, \\ -1/F_t & \text{if } F_t < S_t. \end{cases} \tag{4}$$

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

$$z_{t+1} = w_t \left(F_t - S_{t+1}\right). \tag{5}$$

Covered interest rate parity implies that:

$$\left(1 + r_t\right) = \frac{F_t}{S_t} \left(1 + r_t^*\right). \tag{6}$$

When equation (6) holds, the strategy defined by (4) yields positive payoffs if and only if the strategy defined by (2) 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 (4) because of data considerations.

The impact of peso problems In this subsection we discuss our strategy to analyze peso-event explanations of carry-trade payoffs. Since the carry trade is a zero net-investment strategy, the payoff, z_t, must satisfy:

$$E_t \left(M_{t+1} z_{t+1}\right) = 0. \tag{7}$$

Here M_{t+1} denotes the SDF that prices payoffs denominated in dollars and E_t denotes the time-t conditional expectations operator. Equation (7) implies that:

$$E(z_{t+1}) = -\frac{\text{cov}(M_{t+1}, z_{t+1})}{E(M_{t+1})}. \tag{8}$$

In light of equation (8) a natural explanation for the positive average payoffs to the carry trade is that these payoffs compensate agents for the risk resulting from negative covariance between M and z. In our empirical work (see Section 4) we document that the covariance between the payoffs to the carry trade and a host of traditional risk factors is not statistically different from zero.[5] This finding implies that traditional risk-based explanations are not a plausible rationale for the positive average payoffs to the carry trade.

An alternative explanation relies on the existence of peso events. To pursue this explanation we partition Ω, the set of possible states, s_t, into two sets. The first set, Ω^N, consists of those values of s_t corresponding to non-peso events. The second set, Ω^P, consists of those values of s_t corresponding to a peso event. For simplicity, we assume that for all $s_t \in \Omega^P$, $z(s_t) = z' < 0$ and $M(s_t) = M'$.

We denote by $\mathcal{F}^N(s_{t+1})$ the unconditional distribution of s_{t+1} in non-peso states. For future reference we define $\mathcal{F}^N(s_{t+1}|s_t)$ as the conditional distribution of s_{t+1} given s_t, where both s_{t+1} and s_t are in Ω^N. To simplify, we assume that the conditional and unconditional probability of the peso state is p. The unconditional version of equation (7) is:

$$(1-p)\int_{\Omega^N} M(s_{t+1})z(s_{t+1})d\mathcal{F}^N(s_{t+1}) + pM'z' = 0. \tag{9}$$

Letting $E^N(\cdot)$ denote the expectation over non-peso states, e.g. $E^N(z) = \int_{\Omega^N} z(s_{t+1})d\mathcal{F}^N(s_{t+1})$, we can rewrite (9) as

$$(1-p)E^N(Mz) + pM'z' = 0. \tag{10}$$

In our empirical results, we find that there are no peso events in our sample and that the covariance between M and z is zero in non-peso states. If we impose this result in equation

[5] See Villanueva (2007) for additional evidence on this point. 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 the Lustig-Verdelhan portfolios and standard risk factors, including aggregate consumption growth, is not significantly different from zero. Second, imposing the constraint that a zero beta 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.

(10) we can rewrite it as:[6]

$$(1-p)E^{N}(M)\,E^{N}(z)+pM'z'=0. \quad (11)$$

While there is no covariance between M and z in non-peso states, the unconditional covariance between M and z, $\text{cov}(M,z)$, can still be negative if $M' > E^N(M)$ or $z' < E^N(z)$. Under these circumstances the unconditional mean return over peso and non-peso states, $(1-p)E^N(z)+pz'$, can be positive. So, the existence of risk associated with peso events can rationalize positive returns to the carry trade, even in population.[7] This result is not useful in our context because we assume that there are no peso events in our sample. Explanations of the carry trade payoffs based on in-sample peso events run into the obvious problem that there is no covariance between standard risk factors and those payoffs.

Since z' is negative, equation (11) implies that the average return over non-peso states, $E^N(z)$, is positive. This observation captures the conventional view that a peso problem can rationalize positive excess returns to the carry trade. The question we focus on is: can the existence of peso events provide a plausible rationale for our estimate of the average payoff to the carry trade in non-peso states? To study this question we develop a version of the carry-trade strategy that does not yield high negative returns when a peso event occurs. We call this strategy the "hedged carry trade." We now describe this strategy in detail.

The hedged carry trade We begin by defining the notation we use to describe options contracts. A call option 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:

$$z_{t+1}^{C}=\max\left(0,S_{t+1}-K_{t}\right)-C_{t}\left(1+r_{t}\right).$$

A put option 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:

$$z_{t+1}^{P}=\max\left(0,K_{t}-S_{t+1}\right)-P_{t}\left(1+r_{t}\right).$$

[6] This assumption is consistent with Farhi and Gabaix's (2008) assumption that the stochastic discount factor for returns denominated in the world currency is constant in non-disaster states.

[7] See Farhi and Gabaix (2008) for a related discussion.

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. Suppose that the agent buys, at time t, a call option on the foreign currency with a strike price K_t. Then, whenever $S_{t+1} > K_t$, the agent buys FCUs at the price K_t. In this case the minimum payoff of the hedged carry trade is:

$$(F_t - S_{t+1}) + (S_{t+1} - K_t) - C_t (1 + r_t) = F_t - K_t - C_t (1 + r_t) . \tag{12}$$

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}. Suppose that the agent buys, at time t, a put option on the foreign currency with a strike price K_t. Then, whenever $S_{t+1} < K_t$, the agent sells FCUs at a price K_t. In this case the minimum payoff of the hedged carry trade is:

$$(S_{t+1} - F_t) + (K_t - S_{t+1}) - P_t (1 + r_t) = K_t - F_t - P_t (1 + r_t) . \tag{13}$$

We define the hedged carry-trade strategy as:

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

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

$$z^H_{t+1} = \begin{cases} z_{t+1} + z^C_{t+1}/F_t & \text{if } F_t \geq S_t, \\ z_{t+1} + z^P_{t+1}/F_t & \text{if } F_t < S_t, \end{cases} \tag{14}$$

where z_{t+1} is the carry-trade payoff defined in (5).

An alternative way to implement the hedged carry trade is to use options only, instead of using a combination of forwards and options. Under this alternative implementation we buy $1/F_t$ call options on the foreign currency when it is at a forward discount and $1/F_t$ put options on the foreign currency when it is at a forward premium. Using the put-call-forward parity condition,

$$(C_t - P_t) (1 + r_t) = F_t - K_t, \tag{15}$$

it is easy to show that this strategy for hedging the carry trade is equivalent to the one described above.[8]

The minimum payoff to the hedged carry trade, h_{t+1}, is negative. To see this we can use the put-call-forward parity condition, (15) and equations (12) and (13) to write the minimum payoffs as follows:

$$h_{t+1} = \begin{cases} -P_t(1+r_t)/F_t & \text{if } F_t \geq S_t, \\ -C_t\,(1+r_t)\,/F_t & \text{if } F_t < S_t. \end{cases} \tag{16}$$

Since option prices are positive, h_{t+1} is negative.

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

$$z_{t+1}^H = \begin{cases} h_{t+1} & \text{if option is in the money,} \\ z_{t+1} - c_t(1+r_t)/F_t & \text{if option is out of the money.} \end{cases}$$

The variable c_t denotes the cost of the put or call option. Note that the option is in the money in the peso states as well as in some non-peso states.

Using options to assess the effect of peso problems Since the hedged carry trade is a zero net-investment strategy, the payoff, z_t^H, must satisfy:

$$(1-p)\int_{\Omega^N}\left[M(s_{t+1})z^H\,(s_{t+1})\right]d\mathcal{F}^N(s_{t+1}|s_t) + ph(s_t)M' = 0. \tag{17}$$

Taking expectations over all non-peso states we obtain:

$$(1-p)E^N(Mz^H) + pE^N(h)M' = 0. \tag{18}$$

Using equation (18) to solve for pM' and replacing this term in equation (11), we obtain:

$$z' = E^N(h)\frac{E^N\,(M)\,E^N\,(z)}{E^N(Mz^H)}. \tag{19}$$

We can estimate the variables on the right-hand side of equation (19) and compute an estimate of z'. In estimating z' we do not have to take a stand on the values of p or M'. We can normalize $E^N(M)$ to one since its value is not identified by the pricing equations for zero net-investment strategies. Given our estimate of z' and a value of p we can use equation (11) to estimate $M'/E^N(M)$,

$$\frac{M'}{E^N(M)} = \frac{(1-p)E^N(z)}{p\,(-z')}. \tag{20}$$

[8] This equivalence requires that the strike price of the options be the same in the two strategies.

There are two possible outcomes of these calculations. The first possible outcome is that our estimate of z' is a large negative value, consistent with the conventional view about the payoffs to the carry trade in the peso state. The second possible outcome is that our estimate of z' is a small negative value. In this case a peso event can still explain the average returns to the carry trade but only if M' is large relative to $E^N(M)$. So, in this case, the carry trade makes relatively small losses in the peso event, but traders value those losses very highly.

A natural question is whether the implied value of M' is empirically plausible. To answer this question we consider an equity strategy whose payoff is also potentially affected by the peso event, s'. Using hedged and unhedged versions of this strategy we obtain an alternative estimate of M'. We then assess whether this estimate of M' is consistent with the one implied by equation (20). The equity strategy involves borrowing one dollar at the Treasury-bill rate, r_t, and investing it in the S&P 100 index.[9] We denote the ex-dividend price of the index and the associated dividend yield by V_t and d_t, respectively. The payoff to this strategy in non-peso states is given by:

$$x_{t+1} = V_{t+1}/V_t + d_t - (1 + r_t).$$

Now consider the following hedged version of the equity strategy: borrow at the Treasury-bill rate to invest in the S&P 100 index and buy at-the-money put options on the S&P 100 index. These put options exactly compensate an investor for a fall in the S&P 100. It follows that, any time the S&P 100 index falls, the payoff to the hedged equity strategy is the dividend yield of the index minus the dollar interest rate, and the price of the option $(c_t^x (1 + r_t))$. By assumption the stock index falls in the peso state as well as in some non-peso states. In these states the payoff to the hedged stock strategy is $d_t - c_t^x (1 + r_t)$. In summary, the payoff to the hedged equity strategy net of the options cost is given by:

$$x_{t+1}^H = \begin{cases} x_{t+1} - c_t^x (1 + r_t) & \text{if } V_{t+1} \geq V_t \\ d_t - r_t - c_t^x (1 + r_t) & \text{if } V_{t+1} < V_t. \end{cases}$$

The payoff of the unhedged equity strategy in the peso state is x'. The payoffs to the unhedged equity strategy must satisfy:

$$(1 - p) \int_{\Omega^N} M(s_{t+1}) x(s_{t+1}) d\mathcal{F}^N(s_{t+1}|s_t) + pM'x' = 0. \quad (21)$$

Taking expectations with respect to non-peso states:

$$(1 - p)E^N(Mx) + pM'x' = 0. \quad (22)$$

[9]The choice of this index is driven by data considerations.

The payoffs to the hedged-stock strategy must satisfy:

$$(1-p)\int_{\Omega^N} M(s_{t+1})x^H(s_{t+1})d\mathcal{F}^N(s_{t+1}|s_t)+pM'\left\{d(s_t)-r(s_t)-c^x(s_t)\left[1+r(s_t)\right]\right\}=0. \quad (23)$$

Taking expectations with respect to non-peso states:

$$(1-p)E^N(Mx^H)+pM'E^N\left[d-r-c^x(1+r)\right]=0. \quad (24)$$

We can use the payoffs from the hedged and unhedged equity strategy to generate estimates of M' and x'. We solve equation (22) for x':

$$x'=E^N\left[d-r-c^x(1+r)\right]\frac{E^N(Mx)}{E^N(Mx^H)}. \quad (25)$$

Equation (24) implies:

$$M'=\frac{(1-p)E^N(Mx)}{p(-x')}. \quad (26)$$

We use the Fama-French (1993) model to compute a time series for $M(s_t)$ and estimate $E^N(Mx)$ and $E^N(Mx^H)$. Given a value of p we then estimate x' and M'. The key test of the second interpretation of the peso event is whether the value of M' that emerges from this procedure is consistent with the value of M' implied by equation (20).

The next three sections of this paper provides the inputs necessary to implement the procedures just described. In Section 6 we report our results.

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 July 2009. 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 July 2009. 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 July 2009, with the exact sample period varying by currency (see Appendix A for details).

To assess the quality of our data set we investigate whether covered-interest parity (CIP) holds taking bid-ask spreads into account. We find that deviations from CIP are small and rare. We provide details of our analysis in Appendix B.

Option prices We use two options data sets. Our first data set is from the Chicago Mercantile Exchange (CME). These data consist of daily observations for the period from January 1987 to April 2009 on the prices of put and call options against U.S. dollar futures 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. When a futures contract and an option contract expire on the same date, an option on currency futures is equivalent to an option on the spot exchange rate. This equivalence results from the fact that the price of a futures contract coincides with the spot exchange rate at maturity. In practice the expiration dates of the two contracts do not generally coincide in our data set. In Appendix C we describe how to modify our hedging strategy to take this fact into account. This modification involves adjusting both the number of options purchased and their strike price. Our modified hedging strategy is exactly equivalent to the hedging strategy described in Section 2 whenever interest rates are constant over the period between the expiration of the option and the expiration of the futures contract.

Since we compute carry-trade payoffs 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 near the beginning of each month (two Fridays prior to 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 $t+1$ futures price on the option expiration date. 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 set.

Our second set of options data is from J.P. Morgan. These data consist of daily observations of one-month at-the-money-forward implied volatility quotes, and spot exchange rates for the following currencies: the Australian dollar, the Canadian dollar, the Danish krone, the Euro, the Japanese yen, the Swiss franc, the British pound, the New Zealand dollar, the Norwegian krone, the Swedish krone, and the South African rand. Our sample period is from February 1995 to July 2009. We convert the implied volatility quotes to option prices using the Black-Scholes formula in combination with forward premia calculated using the data described in Appendix A. We use the same transactions dates as for the CME data. The implied volatilities in the two data sets are very similar.

Bid-ask spreads in exchange rates Table 1 displays median bid-ask spreads for spot and forward exchange rates measured in log-percentage points ($100 \times \ln(\text{Ask/Bid})$). 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, bid-ask spreads have generally declined 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 Service launched in 1993.[10] Fourth, over comparable sample

[10] It took several years for these electronic trading systems to capture large transactions volumes. We break

periods, the bid-ask spreads for spot and forward exchange rates against the U.S. dollar are, with the exception of Ireland, 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. First, we compute the mean and variance of the payoff to the carry trade with and without transactions costs. Second, we investigate whether there are large, negative payoffs in our sample that could plausibly be referred to as peso events.[11] Third, we study the covariance between the payoffs to the carry trade and various risk factors using both time series and panel data.

We consider two versions of the carry trade. In the 'carry trade without transaction costs' we assume that agents can buy and sell currency at the average of the bid and ask rates. We compute S_t as the average of the bid (S_t^b) and the ask (S_t^a) spot exchange rates,

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

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

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

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.

In the 'carry trade with transaction costs' we take bid-ask spreads into account when deciding whether to buy or sell foreign currency forward and in calculating payoffs. In this case the number of FCUs sold forward, w_t, is given by:

$$w_t = \begin{cases} +1/F_t^b & \text{if } F_t^b/S_t^a > 1, \\ -1/F_t^a & \text{if } F_t^a/S_t^b < 1, \\ 0 & \text{otherwise.} \end{cases} \tag{27}$$

The payoff to this strategy is:

$$z_{t+1} = \begin{cases} w_t\left(F_t^b - S_{t+1}^a\right) & \text{if } x_t > 0, \\ w_t\left(F_t^a - S_{t+1}^b\right) & \text{if } x_t < 0, \\ 0 & \text{if } x_t = 0. \end{cases} \tag{28}$$

the sample in 1999, as opposed to in 1992 or 1993, to fully capture the impact of these trading platforms.

[11] Recall that we are using Cochrane's definition of a peso event as a rare event that might or might not be realized in sample.

4.1 Mean and variance of carry-trade payoffs

We consider the carry-trade strategy for individual currencies as well as for portfolios of currencies. For now we focus attention on the returns to an equally-weighted portfolio of carry-trade strategies.[12] 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. Also, we report all statistics on an annualized basis. Table 2 reports the mean, standard deviation, and Sharpe ratio of the monthly 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 than would be the case if we looked 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 0.748. Taking bid-ask spreads into account reduces the Sharpe ratio to 0.507. But the Sharpe ratio is 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 0.865. Taking bid-ask spreads into account reduces the Sharpe ratio to 0.694. 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 effect of transaction costs on the carry-trade payoff because there are alternative ways to execute the carry trade that can reduce 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 the interest rate differential persists. 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

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

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.[13] Given this decision we can work with the longer data set (from January 1976 to July 2009) 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. We compute the latter 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 to diversification. The average Sharpe ratio across currencies is 0.442, while the Sharpe ratio for an equally-weighted portfolio of currencies is 0.911. 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.[14] Second, the Sharpe ratio of the carry trade is substantially larger than that of the U.S. stock market (0.911 versus 0.373). While the average excess return to the U.S. stock market is larger than the payoff to the carry trade (0.058 versus 0.048), the returns to the U.S. stock market are much more volatile than the excess returns to the carry trade (0.156 versus 0.053).

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. In addition there is no pronounced time trend in either the payoffs or the Sharpe ratios. It is worth noting that during the recent period encompassing the financial crisis the payoffs are negative. We discuss the impact of the crisis on carry trade payoffs at the end of this section.

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[13] In an earlier version of this paper (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.

[14] 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.

4.2 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 distribution is normal. We now analyze other properties of the payoff distribution. Figure 2 shows the sample distributions of the dollar payoffs to the carry trade and to the U.S. stock market.[15] 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 tests.[16] 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 2).

4.3 The impact of the financial crisis on carry-trade payoffs

Figure 3 shows the cumulative payoffs to investing one dollar in January 1976 in three different strategies. The first strategy involves investing in one-month Treasury bills. The second strategy involves investing in a value-weighted index of the universe of U.S. stocks from the CRSP database. In both of these strategies the proceeds are always reinvested. The third strategy is the carry trade. Since this strategy involves zero net investment we compute the cumulative payoffs as follows. We initially deposit one U.S. dollar in a bank account that yields the same rate of return as the Treasury bill rate. In the beginning of every period we bet the balance of the bank account on the carry trade strategy. At the end of the period payoffs to the carry trade are deposited into the bank account.

Three features of Figure 4 are worth noting. First, the cumulative payoff to the carry trade and stock market strategies are very similar. Second, the payoffs to the carry trade are much less volatile than those of the U.S. stock market. These two features account for why the Sharpe ratio of the carry-trade strategy is roughly 2.5 times higher than that of the U.S. stock market. Third, in the recent financial crisis the carry trade strategy lost money, but these losses are much smaller than those associated with the U.S. stock market. The U.S. stock market cumulative return peaked at $44.32 in October 2007 and fell to a trough

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

[16] 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.

of \$21.47 in February 2009, a decline of 51.6 percent. The carry trade portfolio cumulative return peaked at \$31.22 in July 2008 and fell to a trough of \$27.87 in February 2009, a decline of 10.7 percent. Both the cumulative payoffs to the carry trade and the U.S. stock market strategies have partially recovered from their trough values.

The worst monthly payoffs (i.e. the largest drawdowns) to the carry trade from February 1976 to July 2009 are: −8.9 percent (March 1991), −5.8 percent (October 1992), and −5.1 percent (June 1993). The three worst monthly payoffs to the carry trade from July 2008 to July 2009 are: −4.2 percent (September 2008), −3.9 percent (August 2008), and −3.7 percent (January 2009).[17] The three worst monthly payoffs to the stock market strategy in our sample are −23.0 (October 1987), −18.5 percent (October 2008), and −16.1 (August 1998). It is worth emphasizing that the largest drawdowns associated with the carry trade strategy did not occur during the recent financial crisis. In contrast, one of the three worst payoffs to the stock market strategy did occur during the recent financial crisis.

4.4 Risk factor analysis of carry-trade payoffs

In this subsection we show that the covariance of the payoffs to the carry trade and traditional risk factors is not statistically different from zero. We do so using both time-series and panel-data analysis. We consider data at both the monthly and quarterly frequencies. When data on the risk factors are available at the monthly frequency, we define a 26×1 vector R_t containing the time-t nominal payoffs to the carry-trade strategy and the nominal excess returns of the 25 Fama-French (1993) portfolios of equities sorted by firm size and the ratio of book value to market value. When data on the risk factors are available at the quarterly frequency, we define a 26×1 vector R_t containing the time-t real excess returns to the carry-trade strategy and the 25 Fama-French (1993) portfolios.[18] These payoffs must satisfy:

$$E_t \left(R_{t+1} m_{t+1} \right) = 0, \tag{29}$$

where, when the data are monthly, m_{t+1} is the SDF that prices nominal USD-denominated excess returns and, when the data are quarterly, m_{t+1} is the SDF that prices real USD-denominated excess returns. We consider linear SDFs of the form:

$$m_t = \xi \left[1 - \left(f_t - \mu \right)' b \right]. \tag{30}$$

[17] Because of data limitations we cannot compute the drawdowns on the carry trade strategy at a daily frequency.

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

Here ξ is a scalar, f_t is a vector of risk factors, $\mu = E(f_t)$, and b is a conformable vector.[19] To simplify our analysis we abstract from non-negativity constraints on m_t (see Li, Xu and Zhang (2010) for a discussion of the potential importance of this issue).

It follows from equation (29) and the law of iterated expectations that:

$$E\left(R_t m_t\right) = 0. \tag{31}$$

Equations (31) and (30) imply that:

$$E(R_t) = \beta\lambda$$

where

$$\begin{aligned} \beta &= \mathrm{cov}(R_t, f_t')V_f^{-1}, \\ \lambda &= V_f b. \end{aligned} \tag{32}$$

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_t on f_t. Our time-series analysis focuses on estimating the betas of the carry trade returns for different candidate risk factors. Our panel analysis provides complementary evidence on the importance of different risk factors by estimating alternative SDF models using the moment condition (31). One of these models is the Fama-French (1993) model that we later use to estimate M'.

Time-series risk-factor analysis We consider the following risk factors: 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 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)), industrial production 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

[19] We abstract from the possibility that the factor loading b is a time-varying function of the state of the economy (see DeSantis and Gerard (1998)).

Eurodollar rate and the three month Treasury bill), the Pastor-Stambaugh (2003) liquidity measures, and three measures of volatility: the VIX, the VXO (the implied volatility of the S&P 500 and S&P 100 index options, respectively, calculated by the Chicago Board Options Exchange) and the innovation to the VXO.[20] The first four factors are available only on a quarterly basis.

Table 4 reports the estimated regression coefficients associated with the different risk-factor candidates that are available at a monthly frequency, along with the corresponding test statistics. Table 5 is the analogue of Table 4 for the risk factors that are available at a quarterly frequency. 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.

Our procedure for assessing the importance of peso events assumes that the covariance between the payoffs to the carry trade and the SDF is zero in non-peso event states. Recall that there are no large, negative payoffs to the carry trade in our sample. The results of this subsection provide evidence for the zero-covariance assumption used in our procedure.

Panel risk-factor analysis We now discuss the results of estimating the parameters of SDF models built using the monthly and quarterly risk factors detailed in Tables 4 and 5, respectively. In addition, we also test a quarterly version of the Campbell-Cochrane (1999) SDF (see Appendix D for details on how we construct this SDF).[21] We use the estimated SDF models to generate the expected excess returns to the carry-trade strategy and the 25 Fama-French portfolios. 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.

We estimate b and μ by the generalized method of moments (GMM) using equation (31) 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. We provide details of our

[20] To construct the innovation in the VXO we estimated ARMA models of order up to ARMA(12,12) and selected an AR(3) model on the basis of the Bayesian information criterion. The VXO innovation is the residual from the AR(3) model. We experimented with a variety of ARIMA models for the VXO, including the random walk, and obtained similar results.

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

GMM procedure in Appendix E.

It is evident from equations (30) and (31) that $\xi = E(m_t)$ is not identified. Fortunately, the point estimate of b and inference about the model's overidentifying restrictions are invariant to the value of ξ, so we set ξ to one for convenience. It follows from equations (30) and (31) that:

$$E\left(R_t\right) = -\frac{\operatorname{cov}\left(R_t, m_t\right)}{E\left(m_t\right)} = E\left[R_t\left(f_t - \mu\right)' b\right]. \tag{33}$$

Given an estimate of b, the predicted mean excess return is the sample analogue of the right-hand side of equation (33), which we denote by $\hat{R}$. The actual mean excess return is the sample analogue of the left-hand side of equation (33), which we denote by $\bar{R}$. We denote by $\tilde{R}$ the average across the elements of $\bar{R}$. We evaluate the model using the R^2 between the predicted and actual mean excess returns. The R^2 measure is

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

and is invariant to the value of ξ.

For each monthly risk factor, or vector of factors, Table 6 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 overidentifying restrictions implied by equation (31). In addition, we report the alpha of the carry trade portfolio, i.e. the average payoff that is not priced by the risk factor. Table 7 is the analogue of Table 6 for quarterly factors. The results for the monthly factors fall into two categories, depending on whether the model is rejected based on the test of the overidentifying restrictions. For the CAPM, the Fama-French model, the liquidity premium, the Pastor-Stambaugh level and innovation, and the three stock market volatility measures, the model is rejected at the one percent level. In addition, the pricing error of the carry trade portfolio is statistically significant for each of these models.

The second category of results pertains to the remaining risk-factor models, which are not rejected according to the test of the overidentifying restrictions. These models use industrial production growth, the Fed Funds rate and the term premium as risk factors. 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, and in no case can we reject that the model-implied excess return to the carry trade is equal to zero. Moreover, the R^2 statistics paint a dismal picture of the ability of these risk factors to explain the cross-sectional variation in expected returns. Indeed, the R^2 statistics associated with these models 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.[22]

Consider, next, the results for quarterly risk factors. The b parameters associated with the extended C-CAPM, GDP growth, and luxury sales growth are very imprecisely estimated and the overidentifying restrictions associated with the models are not rejected. The parameter associated with the C-CAPM is somewhat more precisely estimated and there is only marginal evidence against this model. But again, in all cases, the R^2 statistics imply that that these quarterly risk factors explain virtually none of the cross-sectional variation in expected returns. Finally, the overidentifying restrictions associated with our version of the Campbell-Cochrane model are overwhelmingly rejected.

We now provide an alternative perspective on the performance of four SDF models that have received substantial attention in the literature. These models are: 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 $E(R_t)$ against the sample average of R_t. 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 annualized average excess return to the carry trade is 4.82 percent. The Fama-French model predicts that this average return should equal 0.15 percent. The solid line through the star is a two-standard-error band for the difference between the data and model average excess returns, i.e. the pricing error. Clearly, we can reject the hypothesis that the model accounts for the average excess returns associated with the carry trade, i.e. from the perspective of the model the carry trade has a positive alpha.

Had there been a peso event in the sample the estimated alpha of the unhedged carry trade should not be statistically different from zero. So, as best as we can measure, there is

[22] 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.

no peso event in our sample.

Recall that our procedure for evaluating the importance of peso events assumes that the covariance between the payoffs to the carry trade and the SDF is zero in non-peso states. So, the results of this section provide supporting evidence for our maintained assumption that the covariance between payoffs to the carry trade and the SDF is zero in non-peso states of the world.[23]

5 Payoffs to the hedged carry trade

In this section we discuss the empirical properties of the hedged carry trade. As discussed in Section 3 our primary option data set from the CME covers six currencies and a shorter sample period (February 1987 to April 2009) than our data set on forward contracts. We compute the payoffs to the carry trade and hedged carry trade over the same sample period and set of currencies.

We implement the hedged carry trade using strike prices that are close to "at the money" (see Appendix C for details). 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.[24]

To illustrate how trading volume varies with moneyness we use data from the CME 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 5 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. 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

[23] We only consider 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.

[24] See Jurek (2008) for a detailed analysis of the impact of hedging using out-of-the-money options. Jurek finds that the payoffs to the carry trade hedged with these options is positive and highly statistically significant. See also Bhansali (2007) who considers hedging strategies in the course of investigating the relation between implied exchange-rate volatility and the payoffs to the carry trade.

than or equal to the spot price.

Table 8 reports the mean, standard deviation, and Sharpe ratio of the monthly 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 2.0 percent. Using the data that underlies Figure 5 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.[25] This estimate is slightly higher than the point estimate of 4.4 percent provided by Chong, Ding, and Tan (2003).[26] 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 from 0.0158 to 0.0121 as a result of transaction costs.[27]

The average payoff to the hedged carry trade is lower than that of the carry trade (1.6 versus 3.0 percent). However, the average payoffs of the carry trade and the hedged carry trade are not statistically different from each other. Table 8 shows that these results are robust to including the financial crisis period. While the Sharpe ratios of the two carry-trade strategies are reduced when we include the crisis period, the Sharpe ratios continue to be statistically different from zero.

The first panel of Figure 6 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.

There is an important dimension along which the payoffs of the two carry-trade strategies are quite different. As Figure 7 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

[25] The average bid-ask spreads for individual currencies are: Canadian dollar call 5.3 percent, put 4.4 percent, Euro call 4.3 percent, put 4.8 percent, Japanese yen call 5.3 percent, put 5.6 percent, Swiss franc call 5.3 percent, put 6.4 percent, and British pound call 4.3 percent, and put 4.6 percent.

[26] 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.

[27] 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).

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 substantial losses. 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.

Figure 8 shows the cumulative payoffs to the three strategies included in Figure 3 as well as the cumulative payoff to the hedged carry trade, beginning from a common initial date, December 1986. Two key features are worth noting. First, the cumulative payoff to the hedged carry trade is somewhat lower than that of the unhedged carry trade. This result reflects the cost of the options used in the hedged strategy and the fact that there are no large negative payoffs to the unhedged carry trade in sample. Second, the payoffs associated with the hedged carry trade are less volatile than those of the unhedged carry trade. This result reflects the fact that the hedging strategy truncates the negative payoffs to the unhedged carry trade that actually do occur in the sample.

Recall from equation (32) that β is the population value of the regression coefficient of the carry-trade payoff on candidate risk factors. Table 9 reports our estimates of β for the hedged carry trade using the risk factors that are available at a monthly frequency. Table 10 is the analogue of Table 9 for the risk factors that are available at a quarterly frequency. We find that, with the exception of two Fama-French factors (the excess return to the value-weighted U.S. stock market and the value premium) 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 it induces a statistically significant correlation between carry-trade payoffs and risk factors. We return to the case of the Fama-French factors below.

We now turn to a panel risk-factor analysis of the hedged carry-trade payoffs. We estimate the parameters of the same SDF 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 11 for the monthly risk factors and in Table 12 for the quarterly risk factors. As before, our results fall into two categories, depending on whether the model is rejected based on the test of the overidentifying restrictions. For the CAPM, the Fama-French model, industrial production growth, the liquidity premium, the Pastor-Stambaugh level and innovation, and the three stock market volatility measures, the C-CAPM, and the Campbell-Cochrane SDF, the model is rejected at the one percent level. Additionally, with the exception of the Fama-French model, the cross-sectional R^2 is negative. For those models that are not rejected on the basis of the test of the overidentifying restrictions, the b parameters are estimated with great imprecision and the cross-sectional R^2s are negative. 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 hedged carry trade is equal to zero.

Comparing Tables 6 and 7 with Tables 11 and 12 we can assess the impact of hedging on the pricing errors, i.e. the alpha of the strategy. In Tables 6 and 7 we see that many of the alphas associated with the carry trade are positive and statistically significant. This result is particularly interesting in the case of the Fama-French model because the b parameters are estimated with reasonable precision and the R^2 is positive and large (0.40). Table 11 shows that the α of the hedged carry trade implied by the Fama-French model is not statistically significant.[28]

Figure 9 displays the predictions of the CAPM, the C-CAPM, the extended C-CAPM models, and the Fama-French model for $E(R_t)$ against the sample average of R_t. The first three models cannot account for the expected returns to the Fama-French portfolios. The Fama-French model does a reasonable job of explaining the average excess returns to the Fama-French portfolios and the excess returns to the hedged carry trade.[29] In contrast, the Fama-French model does not explain the payoffs to the unhedged carry trade (see Figure 4).

Taken together our results are consistent with the view that the positive average payoff to the unhedged carry trade reflects a peso problem. This conclusion stems from the observation that once we hedge against the peso problem the evidence for a positive alpha becomes much weaker.

[28] The alpha of the hedged carry trade implied by the Pastor-Stambaugh risk factor is significantly different from zero, but the R^2 associated with the Pastor-Stambaugh model is negative.

[29] The use of options in the construction of the hedged carry-trade strategies can introduce non-linearities in the portfolio payoffs (see Grinblatt and Titman (1989), Glosten and Jagannathan (1994), Guasoni, Huberman, and Wang (2008), and Broadie, Chernov and Johannes (2010)). Following Glosten and Jaganathan (1994), we re-do the cross-sectional analysis allowing for quadratic terms in the factors. Our results regarding alpha are unaffected by this extension.

6 Characterizing the nature of peso events

In this section we implement the strategy for assessing the importance of peso events discussed in Section 2. This section is organized as follows. In Subsection 6.1 we report estimates of z' and M' based on the average payoffs to the unhedged and hedged carry trade. We compute these estimates using our benchmark CME data set. In Subsection 6.2 we incorporate stock returns into our empirical analysis. We assess the robustness of our results in Subsection 6.3 using data from J.P. Morgan. Finally, in Subsection 6.4 we extend our analysis to allow for multiple peso events. Up to this point we reported all statistics on an annualized basis. In this section we report monthly statistics so that our calculations are easier to follow.

6.1 Benchmark estimates

We first assume that there is zero covariance between the z^H and M in non-peso states. In this case, we can rewrite equation (19) as:

$$z' = E^N(h)\frac{E^N(z)}{E^N(z^H)}. \tag{34}$$

The empirical analysis summarized in the previous two sections provided us with the inputs necessary to estimate z'. We summarize our estimates of these inputs in Table 13.

The mean minimum net payoff to the hedged carry trade, $E^N(h)$, is equal to -0.0105. We estimate $E^N(z)$ and $E^N(z^H)$ by their sample averages, 0.0025 and 0.0013, respectively.

Substituting these estimates into equation (34) we obtain a point estimate of z' equal to -0.0198 with a standard error of 0.0055. The implied two-standard-error band for z' is $(-0.009, -0.031)$. The standard deviation of z in our sample is 0.0179 on a monthly basis. So, our point estimate for z' is roughly 1.25 standard deviations below the estimated value of $E^N(z)$. The lower bound of the two-standard-error band for z' (-0.031) is only two standard deviations below the average payoff to the unhedged carry trade. Thus, there is little evidence to support the view that z' is a very large negative value relative to the empirical distribution of payoffs to the carry trade.[30]

[30] These results are consistent with the findings in Bates (1996b). Bates studies high-frequency data on options prices for the Deutsche Mark and the Yen against the U.S. dollar over the period 1984 to 1992. He investigates whether peso problems can account for deviations from uncovered interest rate parity. Bates finds no evidence of a peso event defined as a large, negative, value of z'.

Given an estimate of z' we can estimate $M'/E^N(M)$ using equation (20), repeated here for convenience:

$$\frac{M'}{E^N(M)} = \frac{(1-p)E^N(z)}{p(-z')}. \tag{35}$$

Barro, Nakamura, Steinsson, and Ursúa (2009) estimate a value of p equal to 0.014 at the annual frequency. Motivated by the estimate in Barro, Nakamura, Steinsson, and Ursúa (2009), we use a value of p at the monthly frequency which implies that with probability 0.986 no peso event will occur over a 12 month period. In conjunction with equation (35), this value of p yields an estimate of $M'/E^N(M)$ equal to 106, with a standard error 38. This result supports interpreting the peso event as primarily reflecting a high value of the stochastic discount factor. That is, traders value losses very highly in a peso state.

The analysis so far is based on the assumption that the payoffs to the hedged carry trade are uncorrelated with risk factors. In fact Table 9 provides some evidence that these payoffs are correlated with the Fama-French factors. To allow for this possibility we re-estimate z' using the Fama-French (1993) model fit to the 25 Fama-French portfolios over the period 1986–2009 to compute a time series for M_t. We then use equation (19) to estimate z'. The resulting value of z' is -0.0224. We conclude that the estimate of z' is not very sensitive to allowing the hedged-carry-trade payoffs to be correlated with risk factors.

6.2 Incorporating stock-market data into our analysis

We begin by contrasting the effect of hedging in stock markets and in currency markets. Hedging substantially reduces the excess return from investing in the stock market. As Table 8 indicates, over the period February 1987–April 2009, the annualized rate of return drops from 6.9 percent to -4.8 percent as we go from the unhedged to the hedged stock-market strategy. In sharp contrast, over the same sample period, the annualized payoff to the carry trade only drops from 3.0 percent to 1.6 percent as we go from the unhedged to the hedged carry trade.

In section 2 we develop estimators of M' and x', the payoff to the stock market strategy in a peso state. Our estimators are based on the average payoffs in non-peso states to a hedged and unhedged stock market investment strategy. We repeat the two key equations underlying these estimators for convenience:

$$x' = E^N\left[d - r - c^x(1+r)\right]\frac{E^N(Mx)}{E^N\left(Mx^H\right)}. \tag{36}$$

$$\frac{M'}{E^N(M)} = \frac{(1-p)E^N(Mx)}{p(-x')E^N(M)}. \quad (37)$$

We use estimates of the Fama-French (1993) model fit to the 25 Fama-French portfolios over the period February 1986–July 2009 to compute a time series for M_t. The options data we use to construct the hedged equity strategy are available over this same time period. We use sample averages of $M_t x_t$ and $M_t x_t^H$ to estimate $E^N(Mx)$ and $E^N(Mx^H)$, respectively.[31]

We summarize our results in Table 13. We estimate x' to equal -0.188. This value of x' is roughly ten times larger in absolute value than z'. By this metric the peso event has a larger impact on stock market payoffs than on carry trade payoffs. Using the same value of p discussed above, our point estimate of $M'/E^N(M)$ based on stock returns is equal to 82.2. Recall that our estimate of $M'/E^N(M)$ based on carry-trade returns is 106. These two estimates are not statistically significantly different from each other. In this sense, the same value of $M'/E^N(M)$ can account for the equity premium and the observed average payoffs to the carry trade.

Taken together, the results of this subsection provide corroborating evidence for the view that the hallmark of a peso event is a large rise in the value of the SDF. Sampling uncertainty aside, this large rise is associated with large, negative stock market payoffs and relatively modest, negative carry-trade payoffs.

6.3 Robustness analysis: J.P. Morgan data

To assess the robustness of our inference we begin by redoing our analysis using the six-currency version of the J.P. Morgan data set. We report our results in Table 13. Our estimates of $E^N(h)$, $E^N(z)$ and $E^N(z^H)$ imply an estimate of z' equal to -0.0328 with a standard error of 0.0113. Table 13 also reports results based on the ten currency version of the J.P. Morgan data set. These estimates imply an estimate for z' equal to -0.0375 with a standard error of 0.0146. So, for both J.P. Morgan data sets, our estimate of z' is reasonably close to the estimate that we obtained with the CME data set (-0.0198).

[31] The results reported in the text are based on a linear SDF. We find that the same implied values of x' and $M'/E^N(M)$ cannot be rejected when we use an SDF that includes quadratic terms in some or all of the Fama-French factors.

6.4 Robustness analysis: allowing for multiple-peso states

Under the assumption that there is a single peso state we find that the payoff to the unhedged carry trade is moderately negative (-0.0198). However, there is trade in options that protect investors against much larger movements in exchange rates than those implied by our estimate of z'. At first glance, the fact that these way-out-of-the-money options are traded is a challenge for our interpretation of a peso event. We now show that this observation is not a problem for our interpretation by modifying our analysis to incorporate multiple pesos states. In this setting there can be many options with different strike prices.

We assume that there is a continuum of peso states. As above, we denote the set of peso states by Ω^P and assume that the probability of a peso state, both conditional and unconditional, is p. We denote by $\mathcal{F}^P(s_{t+1})$ the cumulative distribution of s_{t+1} given that $s_{t+1} \in \Omega^P$. We let the functions $M'(s_{t+1})$ and $z'(s_{t+1})$ denote the values of the SDF and payoff to the carry trade for each $s_{t+1} \in \Omega^P$. The payoffs to the unhedged carry trade must satisfy:

$$(1-p)E^N(M)E^N(z) + p\int_{\Omega^P} M'(s_{t+1})z'(s_{t+1})d\mathcal{F}^P(s_{t+1}) = 0. \quad (38)$$

Consider now the hedged carry trade strategy, where the hedging relies on at-the-money options. Since these options are in the money in all peso states, it follows that:

$$(1-p)E^N(M)E^N(z^H) + pE^N(h)\int_{\Omega^P} M'(s_{t+1})d\mathcal{F}^P(s_{t+1}) = 0. \quad (39)$$

Solving equation (39) for $(1-p)E^N(M)$ and substituting the result into equation (38) we obtain

$$\int_{\Omega^P} M'(s_{t+1})z'(s_{t+1})d\mathcal{F}^P(s_{t+1}) = \left[\int_{\Omega^P} M'(s_{t+1})d\mathcal{F}^P(s_{t+1})\right] E^N(h)\frac{E^N(z)}{E^N(z^H)}. \quad (40)$$

Letting $E^P(M') = \int_{\Omega^P} M'(s_{t+1})d\mathcal{F}^P(s_{t+1})$ and $E^P(z') = \int_{\Omega^P} z'(s_{t+1})d\mathcal{F}^P(s_{t+1})$ we can rewrite equation (40) as

$$E^P(M')E^P(z') + \text{cov}^P(M', z') = E^P(M')E^N(h)\frac{E^N(z)}{E^N(z^H)}. \quad (41)$$

We assume that that there is a tendency for worse peso states (large values of M') to be associated with worse payoffs (more negative values of z'), so that $\text{cov}^P(M', z') \leq 0$. In this case equation (41) implies that

$$E^P(z') \geq E^N(h)\frac{E^N(z)}{E^N(z^H)}. \quad (42)$$

Recall that our estimate of the right-hand side of equation (42) is: -0.0198. So, equation (42) implies that the expected value of z' across all peso states is greater or equal to -0.0198. While there can be some large negative values of z', these values must have low probabilities. If we assume that $\text{cov}^P(M', z') = 0$, then equation (42) implies that the average value of z' is equal to -0.0198.

We now consider the implications of this extension for the average value of the SDF across peso states. Solving equation (39) for the average value of the SDF in the peso state we obtain

$$\frac{E^P(M')}{E^N(M)} = -\frac{(1-p)}{p}\frac{E^N\left(z^H\right)}{E^N(h)}. \tag{43}$$

This equation is the analogue of equation (35) and is equivalent to it when (42) holds with equality. Using the estimate of p provided by Barro, Nakamura, Steinsson, and Ursúa (2009), and our estimates of $E^N\left(z^H\right)$ and $E^N(h)$ we obtain the same estimate as before for the ratio of the average values of the SDF in the peso and non-peso states (the left-hand side of equation (43)). It is equal to 106 with a standard error of 38.

In sum, the presence of multiple peso states renders our analysis consistent with the existence of currency options that have a wide array of strike prices.

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 SDF models do not explain the expected returns to the carry trade.

A natural explanation for the positive average payoffs to the carry trade is that they reflect 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 average risk-adjusted payoff to the hedged carry trade is not statistically different from zero. We argue that the positive average payoff to the unhedged carry trade reflects peso event risk that is not realized in our sample.

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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	97:01-98:12
Belgium	0.158	0.253	76:01-98:12			0.111	0.118	97:01-98:12
Canada	0.055	0.095	76:01-09:07	0.071	0.079	0.044	0.049	97:01-09:07
Denmark	0.083	0.140	76:01-09:07	0.056	0.068	0.031	0.039	97:01-09:07
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	0.164	0.186	78:06-09:07	0.055	0.064	0.038	0.042	97:01-09:07
Netherlands	0.234	0.344	76:01-98:12			0.032	0.038	97:01-98:12
Norway	0.093	0.145	76:01-09:07	0.099	0.108	0.072	0.080	97:01-09:07
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	0.154	76:01-09:07	0.086	0.096	0.065	0.071	97:01-09:07
Switzerland	0.231	0.357	76:01-09:07	0.082	0.088	0.058	0.062	97:01-09:07
USA/UK	0.053	0.070	76:01-09:07	0.025	0.027	0.026	0.029	97:01-09:07
Euro	0.053	0.056	99:01-09:07	0.053	0.056	0.026	0.030	99:01-09:07
Australia	0.089	0.095	97:01-09:07	0.084	0.091	0.064	0.068	97:01-09:07
New Zealand	0.108	0.126	97:01-09:07	0.100	0.110	0.080	0.093	97:01-09:07
South Africa	0.172	0.192	97:01-09:07	0.177	0.192	0.144	0.159	97:01-09:07

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

TABLE 2: Annualized Payoffs of the Equally-Weighted Carry-Trade Strategy

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
British Pound is the Base Currency						
February 1976 to July 2008	0.0317	0.040	0.800	0.0302	0.053	0.569
	(0.0079)	(0.002)	(0.204)	(0.0109)	(0.003)	(0.211)
February 1976 to July 2009	0.0319	0.043	0.748	0.0288	0.057	0.507
	(0.0080)	(0.003)	(0.194)	(0.0111)	(0.004)	(0.203)
US Dollar is the Base Currency						
January 1997 to July 2008	0.0486	0.044	1.094	0.0462	0.050	0.920
	(0.0152)	(0.003)	(0.333)	(0.0165)	(0.003)	(0.329)
January 1997 to July 2009	0.0440	0.051	0.865	0.0431	0.062	0.694
	(0.0171)	(0.005)	(0.358)	(0.0213)	(0.007)	(0.356)

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. Heteroskedasticity consistent GMM standard errors are in parentheses.

TABLE 3: ANNUALIZED 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
	February-1976 to July-2008					
U.S. stock market	0.0655	0.148	0.443	-0.751	2.61	147.7
	(0.0248)	(0.009)	(0.179)	(0.340)	(1.52)	(0.000)
Equally-weighted carry trade	0.0500	0.051	0.982	-0.667	6.80	779.2
	(0.0097)	(0.005)	(0.226)	(0.608)	(2.32)	(0.000)
Average of individual-currency carry trades	0.0504	0.109	0.479	-0.254	1.03	31.6
	February-1976 to July-2009					
U.S. stock market	0.0582	0.156	0.373	-0.808	2.53	150.9
	(0.0281)	(0.010)	(0.192)	(0.288)	(1.17)	(0.000)
Equally-weighted carry trade	0.0482	0.053	0.911	-0.648	5.81	592.6
	(0.0101)	(0.005)	(0.222)	(0.520)	(2.02)	(0.000)
Average of individual-currency carry trades	0.0492	0.114	0.442	-0.229	1.57	67.4

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. Heteroskedasticity consistent GMM standard errors are in parentheses, except for the Jarque-Bera statistic for which the p-value is reported in parentheses.

TABLE 4: Factor Betas of the Equally-Weighted Carry-Trade Portfolio Monthly Payoff (February 1976 to July 2009)

Factors	Intercept	Beta(s)			R^2
CAPM	0.004	0.018			0.003
	(0.001)	(0.018)			
Fama-French factors	0.004	0.033	-0.045	0.028	0.016
	(0.001)	(0.019)	(0.031)	(0.033)	
Industrial production growth	0.004	0.140			0.004
	(0.001)	(0.152)			
Fed Funds rate	0.003	0.014			0.001
	(0.002)	(0.025)			
Term premium	0.004	-0.022			0.000
	(0.001)	(0.072)			
Liquidity premium	0.005	-0.333			0.011
	(0.001)	(0.184)			
Pastor-Stambaugh liquidity measures					
Level variable	0.004	0.005			0.000
	(0.001)	(0.012)			
Innovation variable	0.004	0.004			0.000
	(0.001)	(0.015)			
Measures of implied volatility in the stock market					
VIX	0.004	-0.001			0.000
	(0.003)	(0.016)			
VXO	0.004	0.000			0.000
	(0.003)	(0.012)			
VXO innovation	0.004	-0.029			0.005
	(0.001)	(0.019)			

Notes: The table reports estimates of the equation $z_t = a + f_t'\beta + \epsilon_{t+1}$, where z_t is the monthly nominal payoff 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 term premium is the 10 year T-bond rate minus the 3 month T-bill rate, the liquidity premium is the 3 month eurodollar rate minus the 3 month T-bill rate, and the VXO innovation is the residual from fitting an AR(3) process to the VXO volatility measure. For the Pastor-Stambaugh liquidity measures the sample period is February 1976 to December 2008. Other details of the risk factors are provided in Appendix D. Heteroskedasticity-robust standard errors are in parentheses.

TABLE 5: FACTOR BETAS OF THE EQUALLY-WEIGHTED CARRY-TRADE PORTFOLIO QUARTERLY REAL EXCESS RETURN (1976Q2 to 2009Q2)

Factors	Intercept	Beta(s)			R^2
C-CAPM	0.012	0.058			0.000
	(0.005)	(0.840)			
Extended C-CAPM	0.007	-0.210	0.607	0.011	0.009
	(0.008)	(0.921)	(0.663)	(0.034)	
Luxury sales growth	0.013	-0.031			0.008
	(0.008)	(0.050)			
GDP growth	0.011	0.314			0.007
	(0.003)	(0.314)			

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 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. Luxury sales growth is from Aït-Sahalia, Parker and Yogo (2004), and is available over the period 1987Q1–2001Q4. GDP growth is real per capita GDP growth. Details of the risk factors are provided in Appendix D. Heteroskedasticity-robust standard errors are in parentheses.

TABLE 6: GMM Estimates of Linear Factor Models (Monthly Data)
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	α
CAPM	0.0049	3.31	0.68	-0.62	2.01	0.41	-1.97	102	0.047
	(0.0023)	(1.38)	(0.24)		(1.25)	(0.24)		(0.00)	(0.010)
Fama-French Factors									
Mkt-Rf	0.0049	3.73	0.48	0.46	3.45	0.44	0.40	89.4	0.046
	(0.0023)	(1.57)	(0.24)		(1.50)	(0.24)		(0.00)	(0.010)
SMB	0.0027	3.53	0.24		3.21	0.22			
	(0.0016)	(1.87)	(0.15)		(1.80)	(0.15)			
HML	0.0036	7.90	0.43		7.25	0.40			
	(0.0018)	(2.14)	(0.17)		(2.02)	(0.17)			
I.P. growth	0.0017	-239	-1.17	-1.02	10.4	0.05	-10.2	30.0	0.047
	(0.0006)	(219)	(1.13)		(51.7)	(0.26)		(0.22)	(0.020)
Fed Funds rate	0.0627	-81.5	-9.26	-1.51	-2.17	-0.29	-9.05	0.70	0.049
	(0.0211)	(172)	(23.4)		(14.4)	(1.97)		(1.00)	(0.035)
Term premium	0.0171	216	3.66	-0.20	9.79	0.17	-8.64	2.38	0.049
	(0.0030)	(273)	(4.35)		(44.3)	(0.75)		(1.00)	(0.033)
Liquidity premium	0.0033	-179	-0.42	0.24	-157	-0.37	0.10	46.9	0.033
	(0.0006)	(148)	(0.30)		(48.5)	(0.13)		(0.01)	(0.013)
Pastor-Stambaugh liquidity measures									
Level	-0.0278	7.37	3.04	-0.15	9.82	4.05	-1.03	75.6	0.045
	(0.0039)	(4.54)	(1.65)		(2.93)	(1.04)		(0.00)	(0.011)
Innovation	0.0025	7.35	2.46	-0.19	5.14	1.72	-0.91	88.2	0.046
	(0.0029)	(4.19)	(1.23)		(2.87)	(0.83)		(0.00)	(0.011)
Measures of implied volatility in the stock market									
VIX	0.202	-5.90	-3.91	0.01	1.75	1.16	-13.3	43.4	0.042
	(0.019)	(5.37)	(2.76)		(2.68)	(2.01)		(0.01)	(0.017)
VXO	0.214	-4.64	-3.64	-0.20	2.34	1.83	-18.4	50.9	0.045
	(0.021)	(4.12)	(2.55)		(2.24)	(2.08)		(0.00)	(0.013)
VXO innovation	0.0001	-4.49	-0.76	-0.53	-0.85	-0.14	-5.2	84.9	0.044
	(0.0025)	(3.36)	(0.41)		(3.03)	(0.48)		(0.00)	(0.012)

Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t is a 26×1 vector containing the nominal excess returns of the Fama-French 25 value-weighted portfolios of US stocks sorted on size and the book-to-market value ratio as well as the monthly nominal payoff of the equally-weighted carry-trade portfolio, and f_t is a scalar or vector of risk factors (described in more detail in the footnote to Table 4). 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 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 R^2 is a measure of fit between the sample mean of R_t and the predicted mean returns, given by $T^{-1}\sum_{t=1}^{T} R_t(f_t' - \hat{\mu})'\hat{b}$. 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 pricing error of the equally-weighted carry-trade portfolio (α) is reported annualized. It's standard error is in parentheses. The sample period is February 1976 to July 2009, except for the Pastor-Stambaugh liquidity measures (available through December 2008).

TABLE 7: GMM Estimates of Linear Factor Models (Quarterly Data)
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	α
C-CAPM	0.0044	348	0.60	-0.61	196	0.34	-2.33	35.8	0.049
	(0.0006)	(307)	(0.55)		(83.7)	(0.13)		(0.07)	(0.026)
Extended C-CAPM									
Consumption	0.0044	245	0.57	-0.36	11.2	0.02	-7.77	2.83	0.050
	(0.0006)	(323)	(0.61)		(114)	(0.20)		(1.00)	(0.031)
Durables	0.0100	213	0.67		0.96	0.01			
	(0.0028)	(265)	(0.70)		(61.5)	(0.17)			
Market return	0.0184	1.50	1.94		0.23	0.22			
	(0.0073)	(3.52)	(1.50)		(2.14)	(1.22)			
Luxury sales	0.0989	15.7	14.8	-1.14	0.25	0.24	-12.3	17.1	0.041
	(0.0262)	(21.6)	(19.7)		(3.13)	(2.95)		(0.88)	(0.045)
GDP growth	0.0044	423	2.73	-1.12	122	0.79	-5.47	12.6	0.040
	(0.0010)	(753)	(4.76)		(94.0)	(0.55)		(0.98)	(0.039)
Campbell-Cochrane SDF				-4.45				58.8	0.034
								(0.00)	(0.022)

Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t is a 26×1 vector containing the real quarterly excess returns of the Fama-French 25 value-weighted portfolios of US stocks sorted on size and the book-to-market value ratio and the equally-weighted carry-trade portfolio, and f_t is a scalar or vector of risk factors (described in more detail in the footnote to Table 5). 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 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 R^2 is a measure of fit between the sample mean of R_t and the predicted mean returns, given by $T^{-1} \sum_{t=1}^{T} R_t (f_t' - \hat{\mu})' \hat{b}$. 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 pricing error of the equally-weighted carry-trade portfolio (α) is reported annualized. It's standard error is in parentheses. The sample period is 1976Q2 to 2009Q2, except for luxury sales growth (available 1987Q1–2001Q4).

TABLE 8: Annualized Payoffs of Investment Strategies
February 1987 to April 2009, US Dollar is the Base Currency

	Mean	Standard Deviation	Sharpe Ratio	Skewness	Excess Kurtosis	Jarque-Bera Statistic
	February 1987 to July 2008					
U.S. stock market	0.0616	0.147	0.420	-1.135	3.71	204
	(0.0295)	(0.013)	(0.223)	(0.427)	(2.17)	(0.000)
S&P 100 stock index						
Unhedged	0.0819	0.060	0.538	-0.534	2.25	66.5
	(0.0328)	(0.004)	(0.218)	(0.293)	(0.69)	(0.000)
Hedged	-0.0370	0.095	-0.389	1.130	2.47	121
	(0.0195)	(0.007)	(0.214)	(0.339)	(1.60)	(0.000)
Equally-weighted carry trade						
Unhedged	0.0348	0.059	0.586	-0.679	1.58	46.6
	(0.0131)	(0.005)	(0.238)	(0.189)	(0.49)	(0.000)
Hedged	0.0180	0.034	0.530	0.957	1.09	52.2
	(0.0077)	(0.002)	(0.210)	(0.177)	(0.72)	(0.000)
	February 1987 to April 2009					
U.S. stock market	0.0452	0.158	0.286	-1.141	3.31	180
	(0.0349)	(0.014)	(0.239)	(0.333)	(1.53)	(0.000)
S&P 100 stock index						
Unhedged	0.0687	0.163	0.422	-0.593	2.00	60.0
	(0.0347)	(0.013)	(0.233)	(0.246)	(0.63)	(0.000)
Hedged	-0.0479	0.098	-0.491	0.955	2.24	96.3
	(0.0214)	(0.007)	(0.225)	(0.339)	(1.44)	(0.000)
Equally-weighted carry trade						
Unhedged	0.0296	0.062	0.476	-0.708	1.47	46.3
	(0.0136)	(0.005)	(0.234)	(0.154)	(0.44)	(0.000)
Hedged	0.0158	0.035	0.449	0.722	1.14	37.6
	(0.0078)	(0.002)	(0.212)	(0.248)	(0.63)	(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 9: FACTOR BETAS OF THE HEDGED EQUALLY-WEIGHTED CARRY-TRADE PORTFOLIO MONTHLY PAYOFF
(February 1987 to April 2009)

Factors	Intercept	Beta(s)			R^2
CAPM	0.001	0.021			0.009
	(0.001)	(0.015)			
Fama-French factors	0.001	0.037	-0.003	0.060	0.042
	(0.001)	(0.018)	(0.020)	(0.025)	
Industrial production growth	0.001	0.184			0.014
	(0.001)	(0.108)			
Fed Funds rate	0.001	0.008			0.000
	(0.002)	(0.034)			
Term premium	0.002	-0.242			0.011
	(0.001)	(0.263)			
Liquidity premium	0.001	-0.003			0.001
	(0.001)	(0.009)			
Pastor-Stambaugh liquidity measures					
Level variable	0.001	-0.003			0.001
	(0.001)	(0.009)			
Innovation variable	0.001	-0.004			0.001
	(0.001)	(0.010)			
Measures of implied volatility in the stock market					
VIX	0.002	-0.006			0.003
	(0.002)	(0.012)			
VXO	0.003	-0.007			0.004
	(0.002)	(0.009)			
VXO innovation	0.001	0.004			0.000
	(0.001)	(0.016)			

Notes: The table reports estimates of the equation $z_t^H = a + f_t'\beta + \epsilon_{t+1}$, where z_t^H is the monthly nominal payoff of the hedged equally-weighted carry-trade portfolio and f_t is a scalar or vector of risk factors. The risk factors are described in the footnote to Table 4. For the Pastor-Stambaugh liquidity measures the sample period is February 1987 to December 2008. Heteroskedasticity-robust standard errors are in parentheses.

TABLE 10: Factor Betas of the Hedged Equally-Weighted Carry-Trade Portfolio Quarterly Real Excess Return (1987Q1 to 2009Q1)

Factors	Intercept	Beta(s)			R^2
C-CAPM	0.004	-0.041			0.005
	(0.002)	(0.059)			
Extended C-CAPM	0.004	-0.038	-0.008	0.007	0.005
	(0.002)	(0.067)	(0.078)	(0.095)	
Luxury sales growth	0.002	0.641			0.025
	(0.003)	(0.551)			
GDP growth	-0.001	0.104			0.005
	(0.008)	(0.147)			

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. The risk factors are described in the footnote to Table 5. For luxury sales growth, the sample period is 1987Q1 to 2001Q4. Heteroskedasticity-robust standard errors are in parentheses.

TABLE 11: GMM Estimates of Linear Factor Models (Monthly Data)
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	α
CAPM	0.0038	2.30	0.48	-0.41	2.00	0.42	-0.49	83.4	0.015
	(0.0028)	(1.64)	(0.30)		(1.49)	(0.28)		(0.00)	(0.008)
Fama-French Factors									
Mkt-Rf	0.0038	2.86	0.37	0.32	3.18	0.41	0.29	78.8	0.011
	(0.0028)	(1.79)	(0.28)		(1.73)	(0.28)		(0.00)	(0.008)
SMB	0.0009	1.68	0.07		1.32	0.03			
	(0.0021)	(2.13)	(0.20)		(2.02)	(0.20)			
HML	0.0025	5.47	0.34		5.71	0.36			
	(0.0020)	(2.45)	(0.21)		(2.31)	(0.22)			
I.P. growth	0.0017	-197	-0.81	-1.55	1.14	0.00	-5.13	43.7	0.016
	(0.0006)	(308)	(1.32)		(48.1)	(0.20)		(0.01)	(0.012)
Fed Funds rate	0.0469	32.9	1.62	-4.40	0.30	0.01	-5.08	1.66	0.016
	(0.0244)	(41.1)	(2.22)		(8.29)	(0.41)		(1.00)	(0.010)
Term premium	0.0173	-85.6	-1.14	-3.79	3.19	0.04	-5.19	5.93	0.016
	(0.0048)	(107)	(1.42)		(19.0)	(0.25)		(1.00)	(0.012)
Liquidity premium	0.0023	-87.2	-0.17	0.03	38.0	0.07	-10.5	71.8	0.018
	(0.0008)	(85.5)	(0.15)		(44.6)	(0.12)		(0.00)	(0.009)
Pastor-Stambaugh liquidity measures									
Level	-0.0281	5.25	2.89	-0.09	4.98	2.73	-0.10	75.4	0.018
	(0.0055)	(4.47)	(2.22)		(2.49)	(1.21)		(0.00)	(0.008)
Innovation	0.0011	5.57	2.42	-0.11	2.13	0.92	-2.15	81.5	0.017
	(0.0041)	(4.51)	(1.75)		(2.55)	(1.03)		(0.00)	(0.008)
Measures of implied volatility in the stock market									
VIX	0.200	-4.15	-2.70	0.09	2.47	1.60	-12.4	50.9	0.014
	(0.021)	(3.86)	(1.97)		(2.23)	(1.86)		(0.01)	(0.010)
VXO	0.213	-3.37	-2.73	-0.02	2.49	2.02	-15.4	56.3	0.017
	(0.025)	(3.16)	(2.04)		(1.90)	(1.95)		(0.00)	(0.009)
VXO innovation	0.0006	-3.83	-0.67	-0.25	-0.85	-0.15	-3.2	82.4	0.016
	(0.0026)	(3.22)	(0.42)		(2.90)	(0.47)		(0.00)	(0.008)

Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t is a 26×1 vector containing the nominal excess returns of the Fama-French 25 value-weighted portfolios of US stocks sorted on size and the book-to-market value ratio as well as the monthly nominal payoff of the hedged equally-weighted carry-trade portfolio, and f_t is a scalar or vector of risk factors (described in more detail in the footnote to Table 4). Details of the procedure are provided in the footnote to Table 6. GMM-VARHAC standard errors are reported in parentheses for $\hat{\mu}$, $\hat{b}$, $\hat{\lambda}$ and the pricing error, α. For the J statistic the p-value is in parentheses. The sample period is February 1987 to April 2009, except for the Pastor-Stambaugh liquidity measures (available through December 2008).

TABLE 12: GMM ESTIMATES OF LINEAR FACTOR MODELS (QUARTERLY DATA)
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	α
C-CAPM	0.0041	211	0.29	-0.44	153	0.21	-0.83	54.6	0.013
	(0.0006)	(203)	(0.28)		(57.8)	(0.09)		(0.00)	(0.011)
Extended C-CAPM									
Consumption	0.0041	35.5	0.14	-0.28	-8.16	-0.01	-6.11	2.67	0.016
	(0.0008)	(149)	(0.23)		(76.0)	(0.09)		(1.00)	(0.011)
Durables	0.0104	156	0.34		-0.15	0.00			
	(0.0048)	(145)	(0.35)		(42.1)	(0.07)			
Market return	0.0152	1.46	1.20		-0.02	-0.07			
	(0.0090)	(2.05)	(1.35)		(1.07)	(0.77)			
Luxury sales	0.0989	15.8	14.9	-0.67	0.34	0.32	-10.0	16.7	0.015
	(0.0262)	(21.7)	(19.8)		(3.13)	(2.94)		(0.89)	(0.019)
GDP growth	0.0040	125	0.48	-0.22	60.9	0.23	-1.64	27.0	0.011
	(0.0020)	(143)	(0.47)		(54.1)	(0.18)		(0.36)	(0.010)
Campbell-Cochrane SDF				-4.45				58.8	0.034
								(0.00)	(0.022)

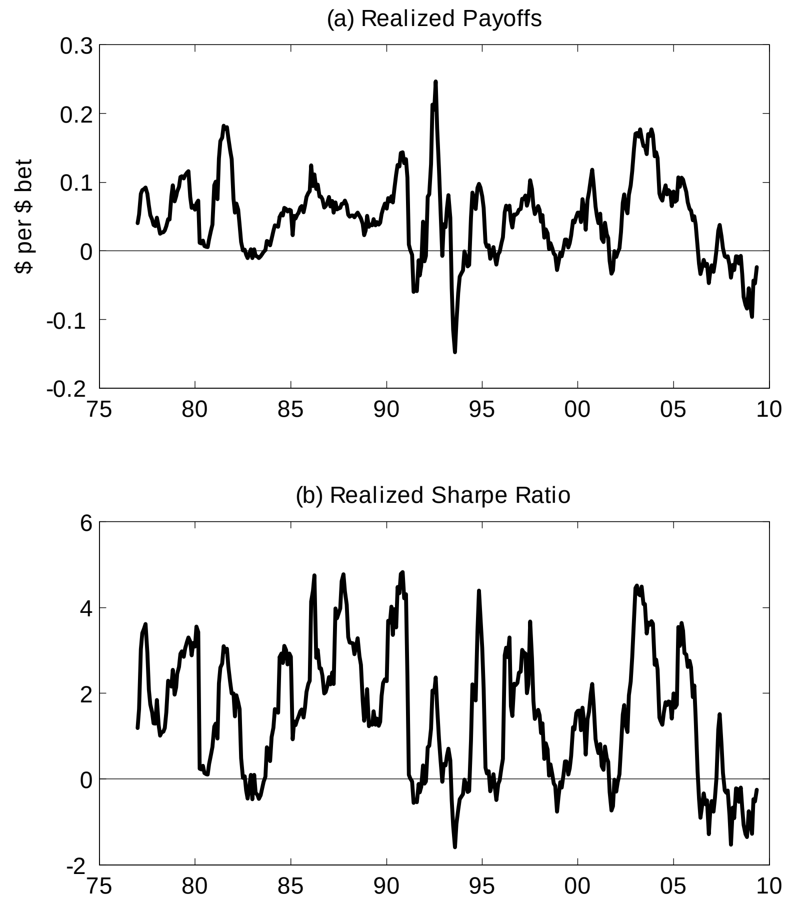
Notes: The table reports GMM estimates of the SDF $m_t = 1 - (f_t - \mu)'b$ using the moment conditions $E(R_t m_t) = 0$ and $E(f_t - \mu) = 0$, where R_t is a 26×1 vector containing the real quarterly excess returns of the Fama-French 25 value-weighted portfolios of US stocks sorted on size and the book-to-market value ratio and the hedged equally-weighted carry-trade portfolio, and f_t is a scalar or vector of risk factors (described in more detail in the footnote to Table 5). Details of the procedure are provided in the footnote to Table 7. GMM-VARHAC standard errors are reported in parentheses for $\hat{\mu}$, $\hat{b}$, $\hat{\lambda}$ and the pricing error, α. For the J statistic the p-value is in parentheses. The sample period is 1987Q1 to 2009Q1, except for luxury sales growth (available 1987Q1–2001Q4).

TABLE 13: Estimates of Moments Used as Inputs in Peso Event Calculations

	Equally-Weighted Carry Trade Portfolio			S&P 100 Index
	CME Data (1987M2–2009M4)	J.P. Morgan Data (1996M2-2009M7)		(1986M2–2009M7)
		6 currencies	10 currencies	
E^N(Unhedged payoff)	0.0025 (0.0011)	0.0036 (0.0011)	0.0047 (0.0013)	0.0068 (0.0029)
E^N(Hedged payoff)	0.0013 (0.0007)	0.0020 (0.0007)	0.0029 (0.0015)	-0.0032 (0.0018)
$E^N(M\times$ unhedged payoff)	0.0020 (0.0012)			0.0182 (0.0026)
$E^N(M\times$ hedged payoff)	0.0009 (0.0007)			0.0025 (0.0020)
E^N (minimum hedged payoff)	-0.0105 (0.0004)	-0.0108 (0.0006)	-0.0114 (0.0006)	-0.0257 (0.0015)
Payoff in the peso event				
Not risk corrected	-0.0198 (0.0055)	-0.0328 (0.0113)	-0.0375 (0.0146)	
Risk corrected	-0.0224 (0.0096)			-0.188 (0.130)
$M'/E^N(M)$				
Peso payoff not risk corrected	106.0 (38.0)	80.3 (44.0)	78.9 (50.0)	
Peso payoff is risk corrected	76.3 (55.6)			82.2 (66.6)

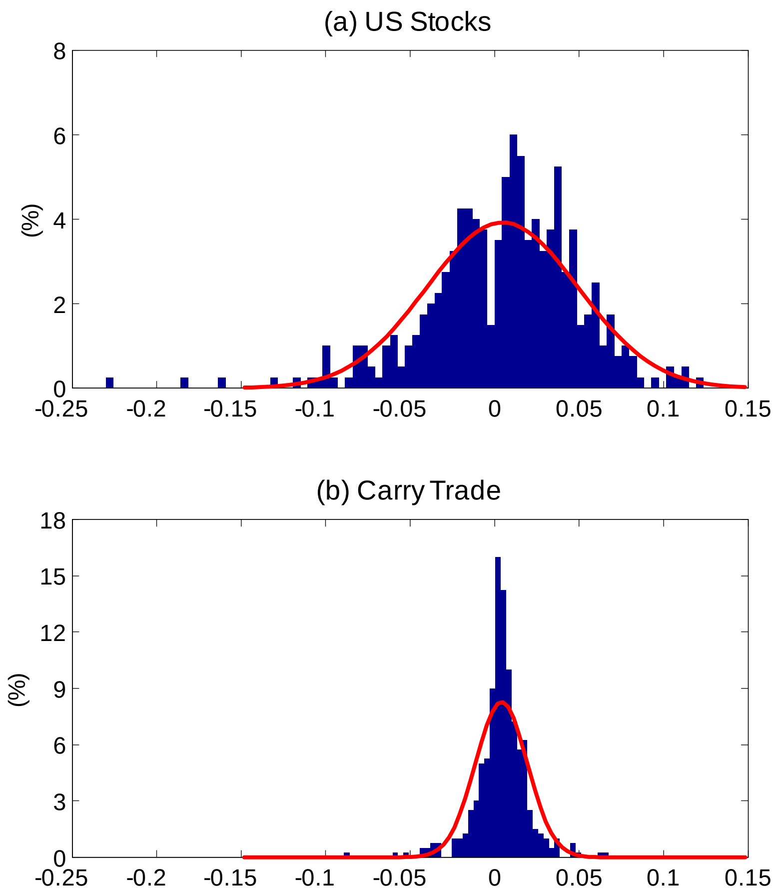
Notes: The unhedged payoff to the carry trade and S&P 100 index portfolios are denoted z and x, respectively, in the text, while the hedged payoffs are denoted z^H and x^H, respectively. The payoffs to these two strategies in the peso state are denoted z' and x', respectively, in the text. The variables M and M' are, respectively, the stochastic discount factor in non-peso and peso states. The operator E^N is the unconditional expectations operator that applies to non-peso states of the world. The CME, J.P. Morgan, and S&P 100 stock market data are described in Appendix C. Heteroskedasticity consistent GMM standard errors are in parentheses.

FIGURE 1: Annualized Realized Average Payoffs and Sharpe Ratios of the Equally-Weighted Carry-Trade Portfolio
12-Month Rolling Window, February 1977–May 2009



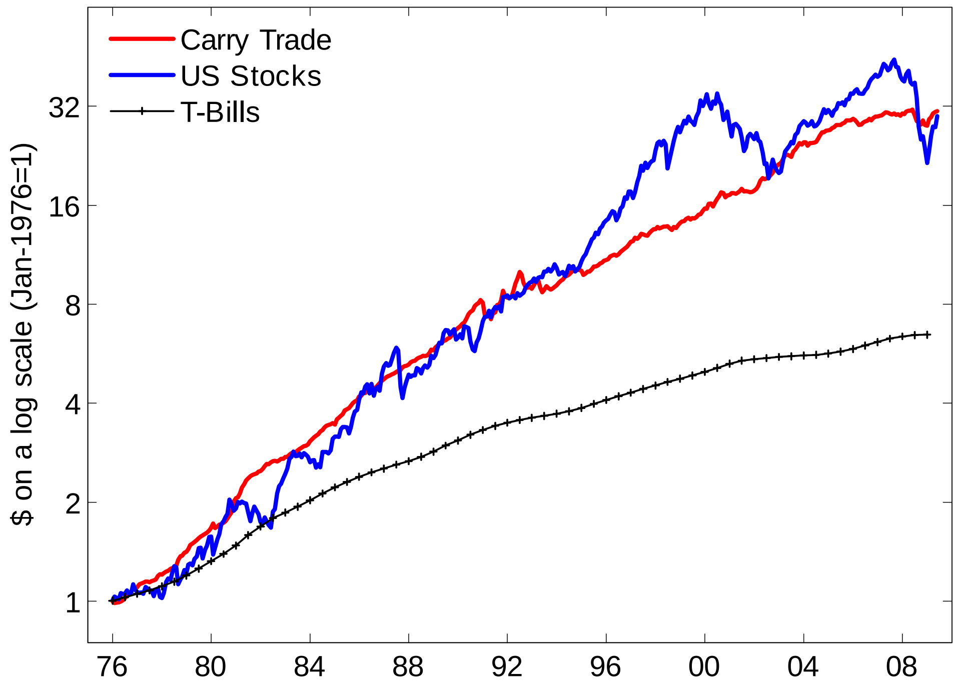
Note: Plot (a) shows the annualized average payoff from month $t-11$ to month t, in US dollars, per dollar bet in the carry trade. Plot (b) shows the ratio of the annualized average payoff, to the annualized standard deviation of the payoff, both being measured from month $t-11$ to month t. The carry-trade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

FIGURE 2: Sampling Distributions of the Excess Returns of the Equally-Weighted Carry-Trade Portfolio and the Value-Weighted US Stock Market (February 1976–May 2009)



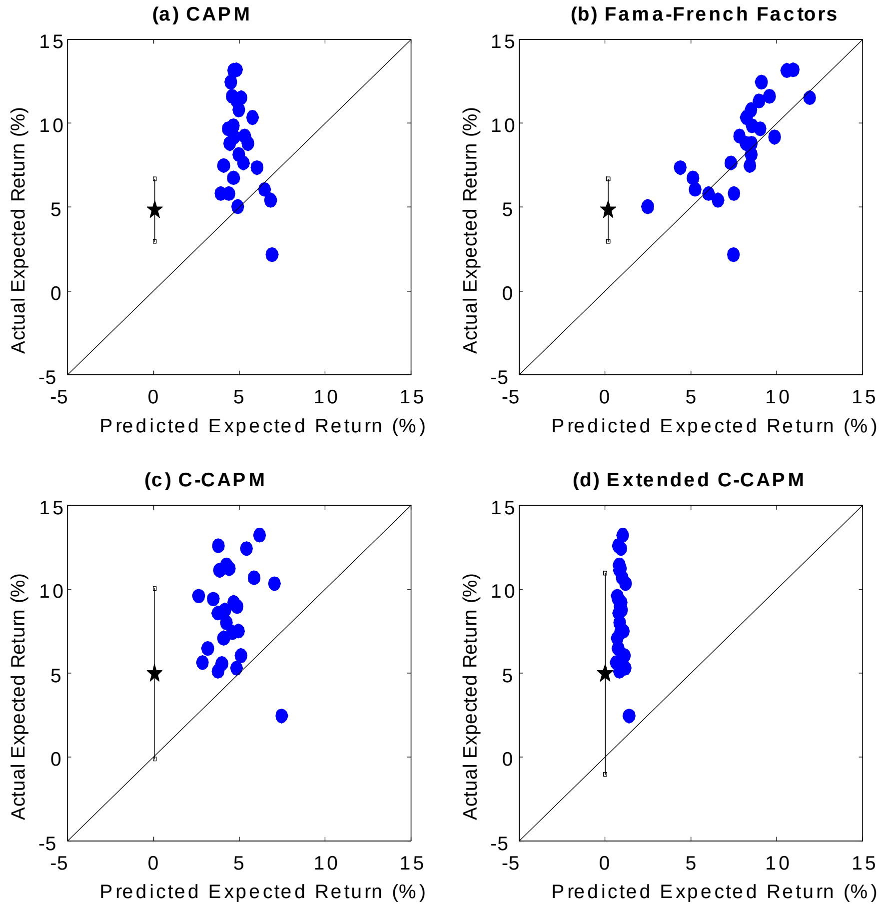
Note: In each plot the red line indicates the histogram implied by a normal distribution with the same mean and standard deviation as in the sampling distribution. The excess returns are computed at the monthly frequency. US stock excess returns are for the value-weighted US stock market from the Fama-French 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 3: Cumulative Returns of Various Strategies (February 1976–July 2009)



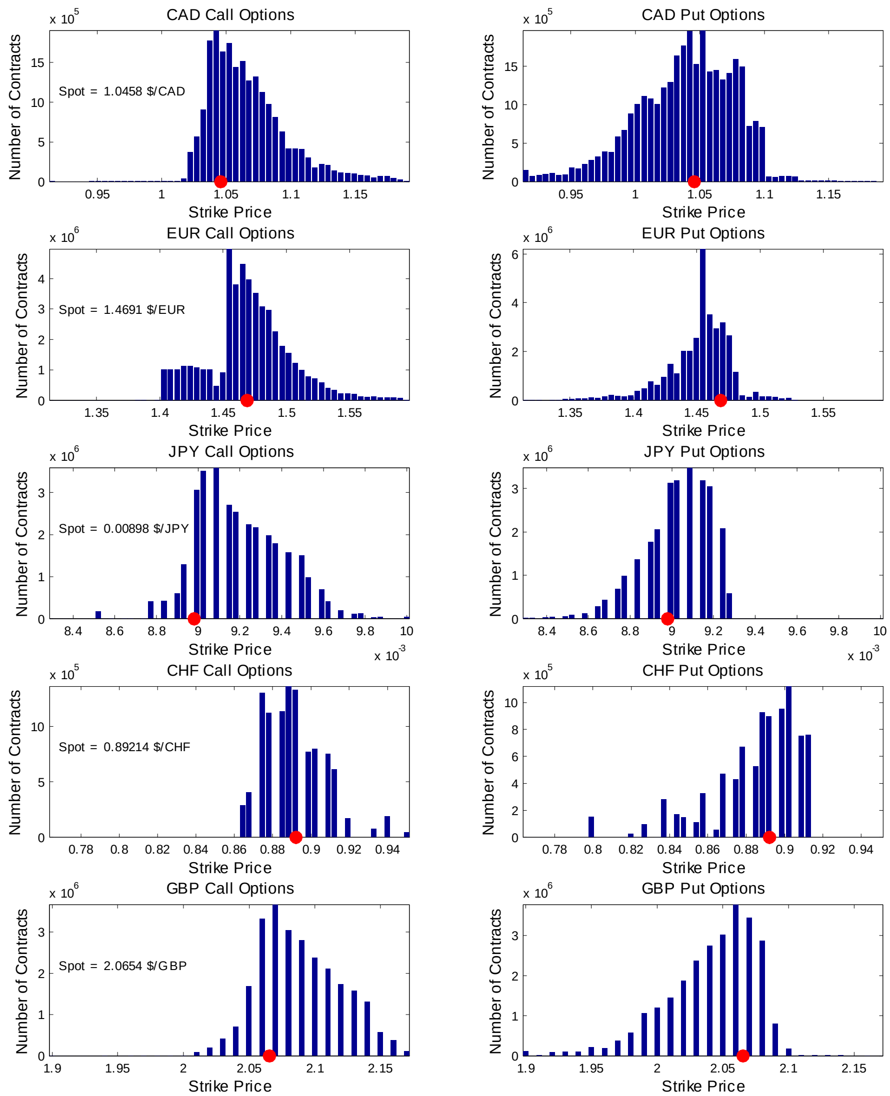
Note: The figure plots the cumulative returns of a trader who begins with 1 dollar in January 1976 and invests his accumulated earnings exclusively in one of the three strategies. For T-bills and US stocks we use the risk free rate and value-weighted market return reported in Kenneth French's database. For the carry trade we assume that the trader invests the initial dollar in T-bills and bets the future nominal value of those T-bills in the carry trade. In each period all proceeds are deposited in the T-bill account, and the future value of the T-bill account is bet on the carry trade.

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



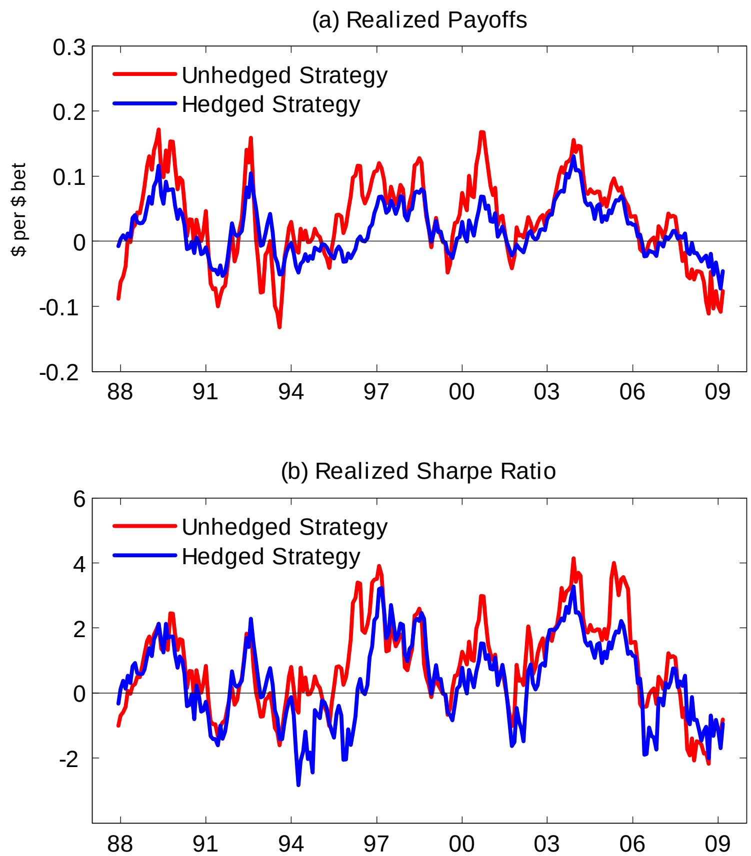
Note: In each case the parmeters μ and b in the SDF $m_t = 1 - (f_t - \mu)' b$ are estimated by GMM using the method described in the text. The risk factors, f_t, are indicated by the title of each plot with details provided in the main text. The predicted expected return is $(1/T)\sum_{t=1}^{T} R_{it}(f_t - \hat{\mu})'\hat{b}$ for each portfolio's excess return, R_{it}. The actual expected return is $\bar{R}_i = (1/T)\sum_{t=1}^{T} R_{it}$. The blue dots correspond to Fama and French's 25 portfolios sorted on the basis of book-to-market value and firm size. The 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. For models (a) and (b) the sample period is 1976M2–2009M7. For models (c) and (d) the sample period is 1976Q2–2009Q2. Expected returns are annualized.

FIGURE 5: The Volume of Calls and Puts and Moneyness
November 14, 2007



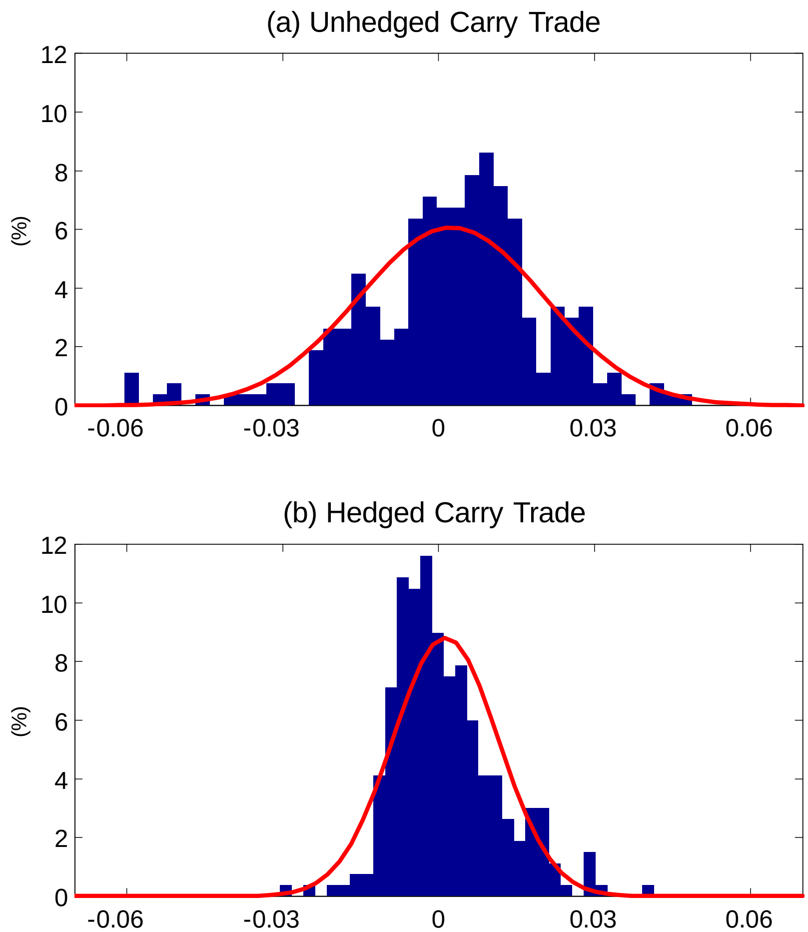
Note: Each plot indicates the number of contracts traded at different strike prices on Nov. 14 2007 for five currencies: the Canadian dollar (CAD), the Euro (EUR), the Japanese yen (JPY), the Swiss franc (CHF) and the British pound (GBP). The closing spot price of each currency is indicated by the red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

FIGURE 6: ANNUALIZED REALIZED AVERAGE PAYOFFS AND SHARPE RATIOS OF THE EQUALLY-WEIGHTED HEDGED AND UNHEDGED CARRY-TRADE PORTFOLIOS
12-Month Rolling Window, February 1987–April 2009



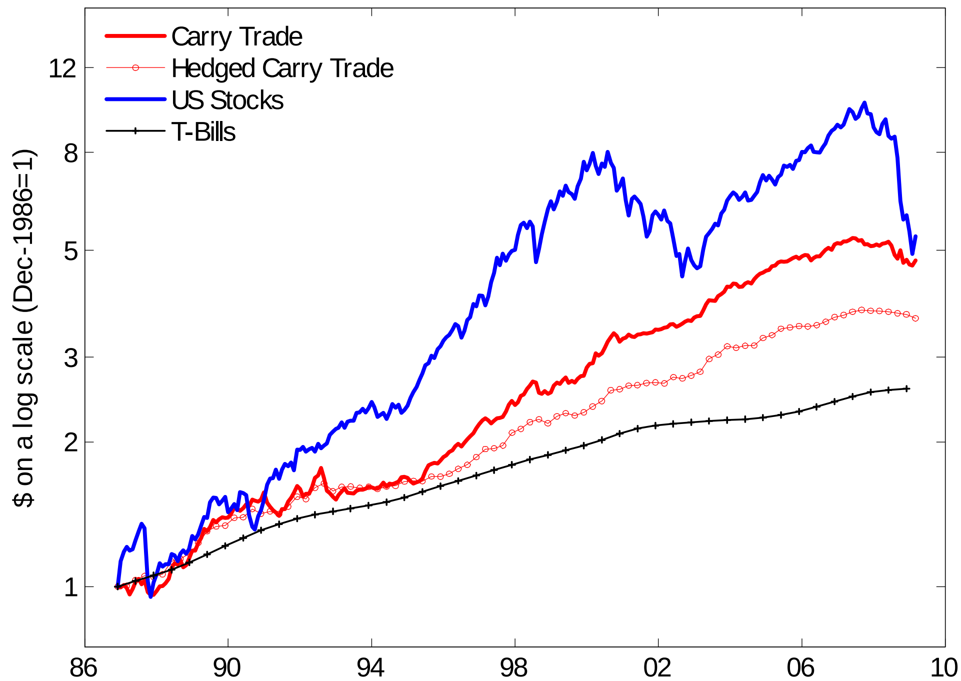
Note: Plot (a) shows the annualized average payoff from month $t-11$ to month t, in US dollars, per dollar bet in the carry trade. Plot (b) shows the ratio of the annualized average payoff, to the annualized standard deviation of the payoff, both being measured from month $t-11$ to month t. The unhedged 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 7: Sampling Distributions of the Payoffs of the Equally-Weighted Carry-Trade Portfolios
February 1987–April 2009



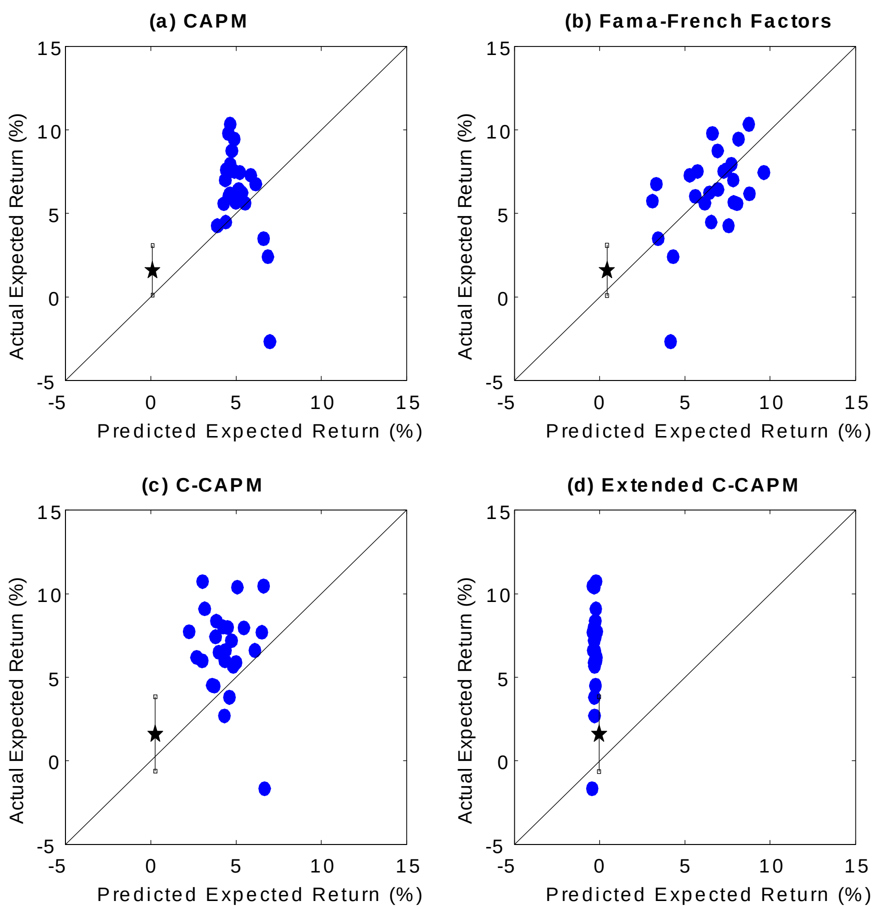
Note: In each plot the red line indicates the histogram implied by a normal distribution with the same mean and standard deviation as in the sampling distribution. The excess returns are computed at the monthly frequency. The carry-trade portfolios are formed as the equally-weighted average of up to 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 8: Cumulative Returns of Various Strategies (January 1987–April 2009)



Note: The figure plots the cumulative returns of a trader who begins with 1 dollar in December 1986 and invests his accumulated earnings exclusively in one of the four strategies. For T-bills and US stocks we use the risk free rate and value-weighted market return reported in Kenneth French's database. For the two carry trade strategies we assume that the trader invests the initial dollar in T-bills and bets the future nominal value of those T-bills in the carry trade. In each period all proceeds are deposited in the T-bill account, and the future value of the T-bill account is bet on the carry trade.

FIGURE 9: Cross-Sectional Fit of Factor Models Estimated by GMM
Test Assets: 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 $(1/T)\sum_{t=1}^{T} R_{it}(f_t - \hat{\mu})'\hat{b}$ for each portfolio's excess return, R_{it}. The actual expected return is $\bar{R}_i = (1/T)\sum_{t=1}^{T} R_{it}$. The blue dots correspond to Fama and French's 25 portfolios sorted on the basis of book-to-market value and firm size. The 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 1987Q1-2009Q1, and expected returns are annualized.

A: Spot and Forward Exchange Rate Data

We obtain our foreign exchange rate data 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 July 2009. 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 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 July 2009. 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.

When we ignore bid-ask spreads we obtain a data set running from January 1976 to July 2009 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. The original data set includes observations on all weekdays. In our basic analysis of the carry trade (Tables 2–5) we measure payoffs using last business day of the month observations.

B: Interest Rate Data and Covered Interest Parity

We obtain our eurocurrency interest rate data from Datastream. They are originally sourced by Datastream from the Financial Times and ICAP. The data set spans the period January 1976 to July 2009. The mnemonics for and availability of each interest rate is indicated in Table A7. The original data set includes observations on all weekdays. To assess whether CIP holds, we sample these data and the exchange rate data, described above, on the last weekday of each month.

To assess CIP we take bid-ask spreads into account. In the presence of bid-ask spreads CIP is given by the following inequalities,

$$\pi_{CIP} = \left(1 + r_t^{*b}\right) \frac{F_t^b}{S_t^a} - (1 + r_t^a) \leq 0, \tag{44}$$

$$\pi_{CIP}^{*} = \left(1 + r_t^{b}\right) \frac{S_t^b}{F_t^a} - (1 + r_t^{*a}) \leq 0. \tag{45}$$

Here 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. Equation (44) 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 (45) 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

CME Options Our first source of options data is 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.

CME options are options against currency futures. The options themselves expire early in each month (two Fridays prior to the third Wednesday in the month). The futures against which the options are written expire on the Monday prior to the third Wednesday (except for the Canadian dollar, for which expiry takes place on the Tuesday prior to the third Wednesday) of March, June, September and December. When we construct hedged positions using options, we use options written against the futures contract with the nearest expiry date that is at least one month ahead. For example, if, in December, we take a bet with a one month horizon the options we use are options on the March futures contract.

We use the following notation for variables measured at time t: the spot exchange rate (S_t), the one month forward exchange rate (F_t), the price of the futures contract with the nearest expiry date that is at least one month ahead (ϕ_t), the strike price on the options contract, K_t, the settlement price of the call option (C_t), and the settlement price of the put option (P_t). In the description that follows, the variables S_t, F_t, ϕ_t, and K_t are measured in USD/FCU, while the variables C_t and P_t are measured in USD per foreign currency unit transacted. CME options contracts are quoted in the same units, and settlement prices on the options are provided directly in the data set and do not have to be obtained by converting implied volatilities.

To be concrete about how we construct hedged and unhedged positions using the CME data, consider the following example, where a trader takes a position in January 2006 that expires in February 2006. In February 2006 the third Wednesday was February 15th. Two Fridays prior to the third Wednesday was February 3rd. We therefore look for transactions that were initiated on January 4th 2006 with expiry 30 days later on February 3rd 2006.[32] Suppose we consider a currency for which $F_t > S_t$. In this case, a trader executing the unhedged carry trade sells $1/F_t$ units of the foreign currency forward and obtains the payoff $(F_t - S_{t+1})/F_t$. In our example we measure S_t and F_t on January 4th and S_{t+1} on February 3rd. We take the values of these variables from the Datastream data set described in Appendix A.[33] A trader executing the hedged carry trade takes the same position in the forward

[32] The only exceptions to this rule for choosing dates is if date t or date $t+1$ is a holiday with no data available. In this case we shift both dates back one day at a time until the data are no longer missing.

[33] Because we have CME options on the Australian dollar dating from 1994, and currency quotes on the Australian dollar sources from WMR are not available on Datastream prior to the end of 1996, we augment our forward and spot exchange rate data for Australia for the period 1994-1996 with data sourced

market as the unhedged trader and in addition purchases X_t/F_t call options on the foreign currency at strike price K_t. The hedged carry trade payoff gross of the cost of the option is, therefore,

$$\frac{F_t - S_{t+1}}{F_t} + \frac{X_t}{F_t} \max\{\phi_{t+1} - K_t, 0\}.$$

To complete our description of the hedged carry trade we next specify the values of X_t and K_t. We set $X_t = (S_t/F_t)^\delta$ where δ is the number of months (unrounded) between the expiry date of the option (February 3rd 2006) and the expiry date of the underlying future (March 13th 2006). We choose the call option with strike price, K_t, closest to $F_t^\delta S_t^{1-\delta}$. Our choices of X_t and K_t are motivated by two considerations. Since the underlying asset is a futures contract, not the currency spot rate, perfect hedging is not possible unless interest rates are constant between date t and the expiry of the futures contract. However, if interest rates remained constant over this period, covered interest rate parity would imply that $(F_t/S_t)^\delta S_{t+1} = \phi_{t+1}$ and the hedged carry trade payoff gross of the cost of the option would be

$$\frac{F_t - S_{t+1}}{F_t} + \frac{1}{F_t} \max\{S_{t+1} - X_t K_t, 0\}.$$

Thus, when the approximation of constant interest rates holds the hedge is perfect in the sense that if the option is in the money the payoff does not depend on the realization of S_{t+1}. Second, if the strike price is exactly $K_t = F_t^\delta S_t^{1-\delta}$ the payoff to the hedged carry trade gross of the cost of the option is

$$\frac{F_t - S_{t+1}}{F_t} + \frac{1}{F_t} \max\{S_{t+1} - S_t, 0\} = \frac{1}{F_t} \max\{F_t - S_{t+1}, F_t - S_t\},$$

implying that the position in the option on the futures contract is equivalent to an option on a spot contract whose strike price is S_t.

We use one-month eurodollar deposit rates from the Federal Reserve Board interest rate database (H.15) to compute the ex-post prices of the options.

J.P. Morgan Options Data Our second source of options data is J.P. Morgan. We obtained daily one-month at-the-money implied volatility quotes, forward points, and spot exchange rates, for ten currencies against the U.S. dollar. These data are available from January 1995 until July 2009 for the following currencies: Australian dollar, Canadian dollar, Danish krone, Euro (beginning January 1999), Japanese yen, Swiss franc, British pound,

by Datastream from Barclay's (BBAUDSP and BBAUD1F are the mnemonics for the spot rate and one month forward rate).

New Zealand dollar, Norwegian krone, and Swedish krone. In the J.P. Morgan data, "at-the-money" one-month options are at the money forward.

We convert the implied volatility quotes to option prices using the Garman and Kohlhagen (1983) formula in combination with the forward points and spot exchange rate data contained in the same data set. We use the last business day of the expiry month as $t+1$, and 30 days prior as date t to compute payoffs. If this choice implies that date t is a Saturday, Sunday, or otherwise missing observation in the data set, we shift both dates back one day at a time until we have a valid pair of business day observations.

VXO Options Data We also use data on options on the S&P 100 index, referred to as the VXO index. These data are available daily between from Datastream (mnemomic CBOEVXO) as implied volatilities. We use VXO data rather than VIX data because they are available over a longer sample period (since January 1986) and behave similarly over the common sample. To generate our monthly data we look for a trade initiation date within each month that is 30 days prior to the third Friday of the following month. We translate implied volatilities to option prices using the Black-Scholes formula. The price of a put option on the S&P 100 index is given by

$$P_t^x = V_t \left[\Phi(-D_{2t})/(1+r_t) - \Phi(-D_{1t})/(1+\delta_t)\right]$$

where

$$\begin{aligned} D_{1t} &= \frac{r_t - \delta_t + \frac{1}{24}\sigma_t^2}{\sigma_t/\sqrt{12}}, \\ D_{2t} &= D_{1t} - \sigma_t/\sqrt{12}, \end{aligned}$$

V_t is the level of the S&P 100 index, the strike price of the option is V_t, δ_t is the dividend yield of the index (on a monthly basis), r_t is the one-month eurodollar rate (on a monthly basis), described above, and σ_t is the implied volatility quote (on an annual basis). We source daily S&P 100 index and dividend yield data from the Global Financial Database (mnemonics OEX, SPY100W).

We measure the unhedged excess return of the S&P 100 index using the total return on the S&P 100 index minus the one-month eurodollar rate (on a monthly basis). We source the total return from the Global Financial Database (mnemonic TRGSPOD). The hedged excess return of the S&P 100 index is

$$\max\left\{\frac{V_{t+1}-V_t}{V_t}, 0\right\} + \frac{D_t}{V_t} - r_t - (1+r_t)\frac{P_t^x}{V_t}.$$

Here D_t/V_t is the total return to the S&P 100 index minus the rate of change of the index. That is, it is the component of the return due to the dividend.

D: Details of the Risk-Factor Analysis

Monthly Risk Factors When working with monthly data, we use nominal payoffs to strategies. 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).

The monthly index of industrial production is from the Federal Reserve Board of Governors (www.federalreserve.gov), Statistical Release Table G.17. We use the growth rate of this series as a risk factor.

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).

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).

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 Pastor and Stambaugh (2003) liquidity factors were obtained from Lubos Pastor's web site http://faculty.chicagobooth.edu/lubos.pastor/research/.

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). The VXO innovation factor was defined by fitting ARMA models up to order 12,12 and choosing the best model on the basis of the Bayesian information criterion. The chosen model was an AR(3) and the residual from the fitted model is our definition of the VXO innovation.

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

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

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 (6)) 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 and described below in more detail.

When we work with currency options data, monthly payoffs are realized early in each month (the median day of the month is the 6th, with no payoffs occuring before the 2nd of the month, and no payoffs occuring after the 9th of the month). Therefore, when defining the returns for the first quarter we accumulate the monthly payoffs (as described above) that were realized early February, early March and early April. For the second, third and fourth quarters returns are defined analogously.

Quarterly Risk Factors Real per-capita consumption growth (used for the C-CAPM model) 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 extended C-CAPM model adds two factors to the C-CAPM model: the real growth rate of the per-capita service flow from the stock of consumer durables, and the market return (Mkt-Rf plus the risk free rate, Rf, in real terms). To estimate the former 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. We obtain Mkt and Rf from Kenneth French's data library. To obtain the quarterly real market return, we proceed as described above for our currency strategies.

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

Real GDP is obtained from the U.S. National Income and Product Accounts. It is converted into per capita terms using the modified quarterly population series described above. It's growth rate is used as a risk factor.

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

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

where 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

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

With these parameter values the model matches the average quarterly equity premium and real risk free rate in our sample.

E: GMM Estimation

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

$$E(R_t m_t) = 0 \qquad E(f_t) = \mu \tag{46}$$

where R_t is an $n \times 1$ vector of excess returns and f_t is a $k \times 1$ vector of risk factors. Define $u_{1t}(b,\mu) = R_t m_t = R_t[1 - (f_t - \mu)'b]$ and let $g_{1T}(b,\mu) = \frac{1}{T}\sum_{t=1}^{T} u_{1t} = \bar{R} - \left(D_T - \bar{R}\mu'\right) b$ where $D_T = \frac{1}{T}\sum_{t=1}^{T} R_t f_t'$ and $\bar{R} = \frac{1}{T}\sum_{t=1}^{T} R_t$. 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 $u_t = (\ u_{1t}' \quad u_{2t}'\ )'$ and $g_T = (\ g_{1T}' \quad g_{2T}'\ )'$. 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

$$a_T = \begin{pmatrix} d_T' W_T & 0 \\ 0 & I_k \end{pmatrix}, \tag{47}$$

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

$$\hat{b} = (d_T' W_T d_T)^{-1} d_T' W_T \bar{R} \quad (48)$$

$$\hat{\mu} = \bar{f}. \quad (49)$$

We consider two-stage GMM estimators. In the first stage $W_T = I_n$. In the second stage, $W_T = (P_T S_T P_T')^{-1}$ where $P_T = \begin{pmatrix} I_n & \bar{R}\hat{b}' \end{pmatrix}$ 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

$$\delta_T = \begin{pmatrix} -d_T & \bar{R}\hat{b}' \\ 0 & -I_k \end{pmatrix}. \quad (50)$$

A test of the pricing errors is based on

$$J = T g_T(\hat{b}, \hat{\mu})(\hat{V}_g)^+ g_T(\hat{b}, \hat{\mu}), \quad (51)$$

where the + sign indicates the generalized inverse and

$$\hat{V}_g = A_T S_T A_T' \text{ with } A_T = I_{n+k} - \delta_T (a_T \delta_T)^{-1} a_T. \quad (52)$$

Equation (46) and the definition of m_t imply that

$$E(R_t) = E\left[R_t (f_t - \mu)'\right] b. \quad (53)$$

Corresponding to the right-hand side of (53) is a vector of predicted expected returns, $\hat{R} = d_T \hat{b}$. The cross-sectional R^2 measure is:

$$R^2 = 1 - \frac{(\bar{R} - d_T\hat{b})'(\bar{R} - d_T\hat{b})}{(\bar{R} - \tilde{R})'(\bar{R} - \tilde{R})}. \quad (54)$$

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

We can rewrite equation (53) as

$$E(R_t) = \underbrace{E\left[R_t (f_t - \mu)'\right] V_f^{-1}}_{\beta} \underbrace{V_f b}_{\lambda}. \quad (55)$$

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	-3.555	0.042	-0.001	-0.843	0.005	76:01-09:07
	(0.002)	(0.745)		(0.001)	(0.608)		
Denmark	0.001	-0.921	0.011	0.000	-0.686	0.005	76:01-09:07
	(0.001)	(0.568)		(0.002)	(0.475)		
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	0.017	-3.100	0.019	0.009	-2.206	0.022	78:06-09:07
	(0.007)	(1.376)		(0.002)	(0.656)		
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	-0.583	0.005	-0.001	-0.448	0.002	76:01-09:07
	(0.001)	(0.544)		(0.002)	(0.505)		
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	0.000	0.036	0.000	0.000	0.360	0.002	76:01-09:07
	(0.001)	(0.598)		(0.002)	(0.692)		
Switzerland	0.008	-1.139	0.010	0.006	-1.308	0.011	76:01-09:07
	(0.003)	(0.583)		(0.003)	(0.680)		
USA/UK	0.004	-1.521	0.013	-0.003	-1.604	0.015	76:01-09:07
	(0.002)	(0.894)		(0.002)	(0.868)		
Euro	0.008	-4.461	0.016	0.003	-3.911	0.031	98:12-09:07
	(0.006)	(3.629)		(0.003)	(1.597)		
Australia	0.000	-1.854	0.004	-0.002	-2.644	0.012	96:12-09:07
	(0.002)	(2.735)		(0.003)	(2.251)		
New Zealand	0.001	0.868	0.001	0.000	-0.030	0.000	96:12-09:07
	(0.004)	(1.923)		(0.006)	(2.579)		
South Africa	-0.013	-1.972	0.011	-0.014	-1.873	0.012	96:12-09:07
	(0.009)	(1.568)		(0.008)	(1.345)		

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: ANNUALIZED PAYOFFS TO THE CARRY-TRADE STRATEGIES
February 1976 to July 2009, British Pound is the Base Currency

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
Austria	0.0109	0.095	0.115	0.0185	0.072	0.259
	(0.0219)	(0.007)	(0.232)	(0.0161)	(0.006)	(0.229)
Belgium	0.0438	0.093	0.470	0.0206	0.067	0.308
	(0.0212)	(0.006)	(0.230)	(0.0164)	(0.005)	(0.243)
Canada	0.0541	0.110	0.490	0.0441	0.088	0.502
	(0.0195)	(0.005)	(0.180)	(0.0159)	(0.005)	(0.181)
Denmark	0.0405	0.092	0.439	0.0305	0.077	0.396
	(0.0175)	(0.007)	(0.182)	(0.0138)	(0.008)	(0.171)
France	0.0571	0.091	0.629	0.0416	0.081	0.516
	(0.0188)	(0.006)	(0.206)	(0.0171)	(0.006)	(0.212)
Germany	0.0213	0.095	0.224	0.0137	0.082	0.166
	(0.0206)	(0.006)	(0.221)	(0.0185)	(0.007)	(0.228)
Ireland	0.0021	0.079	0.026	-0.0024	0.056	-0.044
	(0.0167)	(0.007)	(0.211)	(0.0124)	(0.006)	(0.224)
Italy	0.0229	0.094	0.245	0.0115	0.083	0.139
	(0.0205)	(0.007)	(0.215)	(0.0171)	(0.007)	(0.202)
Japan	0.0180	0.127	0.142	0.0129	0.117	0.111
	(0.0277)	(0.010)	(0.225)	(0.0246)	(0.010)	(0.217)
Netherlands	0.0315	0.093	0.339	0.0201	0.076	0.266
	(0.0201)	(0.006)	(0.218)	(0.0176)	(0.007)	(0.232)
Norway	0.0348	0.087	0.402	0.0305	0.065	0.468
	(0.0137)	(0.005)	(0.155)	(0.0116)	(0.004)	(0.171)
Portugal	0.0442	0.091	0.487	-0.0112	0.057	-0.196
	(0.0232)	(0.007)	(0.242)	(0.0123)	(0.008)	(0.198)
Spain	0.0235	0.094	0.249	0.0082	0.081	0.102
	(0.0229)	(0.008)	(0.249)	(0.0200)	(0.010)	(0.254)
Sweden	0.0394	0.092	0.427	0.0165	0.068	0.243
	(0.0142)	(0.007)	(0.161)	(0.0106)	(0.008)	(0.165)
Switzerland	0.0147	0.105	0.139	0.0006	0.094	0.006
	(0.0204)	(0.009)	(0.198)	(0.0180)	(0.008)	(0.191)
USA	0.0562	0.107	0.528	0.0350	0.095	0.367
	(0.0180)	(0.006)	(0.176)	(0.0178)	(0.007)	(0.192)
Euro	0.0031	0.088	0.035	-0.0121	0.057	-0.210
	(0.0220)	(0.019)	(0.248)	(0.0205)	(0.006)	(0.353)
Australia	0.0479	0.115	0.418	0.0205	0.089	0.231
	(0.0279)	(0.013)	(0.244)	(0.0223)	(0.017)	(0.246)
New Zealand	0.0275	0.121	0.228	0.0366	0.094	0.388
	(0.0275)	(0.016)	(0.226)	(0.0214)	(0.021)	(0.224)
South Africa	0.0409	0.169	0.242	0.0103	0.166	0.062
	(0.0458)	(0.015)	(0.268)	(0.0445)	(0.015)	(0.268)
Average	0.0317	0.102	0.314	0.0173	0.083	0.204

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 78:7-09:07. The Euro is available 98:12-09:07. The Australian dollar, New Zealand dollar and South African rand are available 96:12-09:07. Other currencies are available for 76:01-09:07. Standard errors are in parentheses.

APPENDIX TABLE A3: ANNUALIZED PAYOFFS TO THE CARRY-TRADE STRATEGIES
January 1997 to July 2009, US Dollar is the Base Currency

	No Transactions Costs			With Transactions Costs		
	Mean	Standard Deviation	Sharpe Ratio	Mean	Standard Deviation	Sharpe Ratio
Austria	0.0702	0.093	0.754	0.0646	0.093	0.694
	(0.0670)	(0.009)	(0.691)	(0.0670)	(0.009)	(0.693)
Belgium	0.0704	0.093	0.759	0.0584	0.093	0.628
	(0.0675)	(0.009)	(0.700)	(0.0676)	(0.009)	(0.702)
Canada	0.0122	0.088	0.138	0.0267	0.067	0.398
	(0.0253)	(0.010)	(0.293)	(0.0216)	(0.009)	(0.311)
Denmark	0.0810	0.099	0.816	0.0635	0.097	0.656
	(0.0254)	(0.010)	(0.258)	(0.0249)	(0.010)	(0.254)
France	0.0679	0.093	0.727	0.0640	0.093	0.686
	(0.0664)	(0.009)	(0.682)	(0.0662)	(0.009)	(0.681)
Germany	0.0710	0.093	0.762	0.0666	0.093	0.715
	(0.0671)	(0.009)	(0.691)	(0.0670)	(0.009)	(0.693)
Ireland	0.0261	0.096	0.271	0.0094	0.025	0.373
	(0.0634)	(0.009)	(0.671)	(0.0109)	(0.012)	(0.278)
Italy	-0.1077	0.086	-1.249	-0.0662	0.083	-0.797
	(0.0480)	(0.009)	(0.562)	(0.0508)	(0.012)	(0.543)
Japan	0.0156	0.114	0.137	0.0041	0.111	0.037
	(0.0308)	(0.012)	(0.277)	(0.0319)	(0.013)	(0.288)
Netherlands	0.0736	0.094	0.786	0.0688	0.094	0.734
	(0.0678)	(0.009)	(0.693)	(0.0678)	(0.009)	(0.694)
Norway	0.0476	0.108	0.441	0.0308	0.099	0.312
	(0.0337)	(0.009)	(0.330)	(0.0332)	(0.010)	(0.351)
Portugal	-0.1010	0.086	-1.177	-0.0500	0.071	-0.703
	(0.0607)	(0.007)	(0.689)	(0.0451)	(0.012)	(0.559)
Spain	-0.0473	0.092	-0.513	-0.0440	0.070	-0.627
	(0.0551)	(0.009)	(0.578)	(0.0405)	(0.013)	(0.510)
Sweden	0.0840	0.110	0.764	0.0522	0.093	0.560
	(0.0273)	(0.010)	(0.277)	(0.0236)	(0.009)	(0.266)
Switzerland	-0.0001	0.108	0.000	0.0055	0.092	0.060
	(0.0286)	(0.010)	(0.266)	(0.0246)	(0.009)	(0.268)
UK	0.0275	0.085	0.322	0.0083	0.073	0.114
	(0.0209)	(0.009)	(0.242)	(0.0189)	(0.009)	(0.260)
Euro	0.0831	0.101	0.823	0.0501	0.090	0.556
	(0.0273)	(0.011)	(0.277)	(0.0275)	(0.009)	(0.315)
Australia	0.0716	0.125	0.572	0.0549	0.105	0.521
	(0.0418)	(0.016)	(0.371)	(0.0370)	(0.020)	(0.394)
New Zealand	0.0389	0.133	0.293	0.0483	0.117	0.413
	(0.0449)	(0.016)	(0.344)	(0.0408)	(0.019)	(0.363)
South Africa	0.0502	0.169	0.297	0.0227	0.167	0.136
	(0.0530)	(0.015)	(0.313)	(0.0517)	(0.015)	(0.309)
Average	0.0317	0.103	0.286	0.0269	0.091	0.273

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 98:12-09:07. Other currencies are available 96:12-09:07. Standard errors are in parentheses.

APPENDIX TABLE A4: ANNUALIZED PAYOFFS TO THE CARRY-TRADE STRATEGY
February 1976 to July 2009, US Dollar is the Base Currency

	Mean	Standard Deviation	Sharpe Ratio	Skewness	Kurtosis	Jarque-Bera Statistic
Austria	0.0266	0.117	0.228	-0.149	0.83	9.0
	(0.0264)	(0.006)	(0.229)	(0.177)	(0.41)	(0.011)
Belgium	0.0817	0.114	0.716	0.005	0.94	10.2
	(0.0241)	(0.006)	(0.213)	(0.231)	(0.44)	(0.006)
Canada	0.0199	0.065	0.305	0.005	6.53	714.3
	(0.0113)	(0.006)	(0.184)	(0.772)	(3.01)	(0.000)
Denmark	0.1004	0.107	0.935	-0.058	0.88	13.2
	(0.0201)	(0.005)	(0.192)	(0.137)	(0.35)	(0.001)
France	0.0613	0.110	0.559	-0.033	0.45	2.4
	(0.0234)	(0.005)	(0.215)	(0.155)	(0.31)	(0.308)
Germany	0.0140	0.116	0.121	-0.184	0.51	4.6
	(0.0258)	(0.006)	(0.224)	(0.128)	(0.32)	(0.101)
Ireland	0.0645	0.110	0.587	-0.025	0.36	1.3
	(0.0274)	(0.006)	(0.247)	(0.178)	(0.37)	(0.517)
Italy	0.0304	0.108	0.283	-0.297	1.08	17.4
	(0.0247)	(0.007)	(0.234)	(0.223)	(0.50)	(0.000)
Japan	0.0245	0.121	0.203	-0.611	1.53	59.6
	(0.0230)	(0.006)	(0.194)	(0.239)	(0.83)	(0.000)
Netherlands	0.0405	0.116	0.349	-0.122	0.64	5.4
	(0.0266)	(0.006)	(0.233)	(0.210)	(0.39)	(0.067)
Norway	0.0555	0.103	0.541	-0.363	1.50	46.5
	(0.0186)	(0.005)	(0.190)	(0.208)	(0.51)	(0.000)
Portugal	0.0470	0.111	0.423	-0.053	2.38	65.0
	(0.0248)	(0.006)	(0.224)	(0.378)	(0.98)	(0.000)
Spain	0.0343	0.111	0.309	-0.743	2.05	73.9
	(0.0282)	(0.007)	(0.259)	(0.335)	(1.35)	(0.000)
Sweden	0.0654	0.107	0.608	-0.623	2.73	150.5
	(0.0181)	(0.007)	(0.188)	(0.315)	(1.20)	(0.000)
Switzerland	0.0093	0.124	0.075	-0.324	0.96	22.6
	(0.0230)	(0.006)	(0.186)	(0.214)	(0.47)	(0.000)
UK	0.0644	0.106	0.608	0.034	1.85	57.1
	(0.0176)	(0.006)	(0.169)	(0.327)	(0.84)	(0.000)
Euro	0.0831	0.101	0.823	0.177	1.01	6.1
	(0.0273)	(0.011)	(0.277)	(0.266)	(0.43)	(0.049)
Australia	0.0716	0.125	0.572	-0.817	2.51	56.4
	(0.0418)	(0.016)	(0.371)	(0.425)	(1.26)	(0.000)
New Zealand	0.0389	0.133	0.293	-0.152	2.14	29.4
	(0.0449)	(0.016)	(0.344)	(0.380)	(0.70)	(0.000)
South Africa	0.0502	0.169	0.297	-0.248	0.54	3.4
	(0.0530)	(0.015)	(0.313)	(0.164)	(0.47)	(0.181)
Average	0.0492	0.114	0.442	-0.229	1.571	67.406

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 78:7-09:07. The Euro is available 98:12-09:07. The Australian dollar, New Zealand dollar and South African rand are available 96:12-09:07. Other currencies are available for 76:01-09:07. 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	76:01–09:07	FCU/GBP
Danish krone	DANISHK	DANIS1F	76:01–09:07	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	78:06–09:07	FCU/GBP
Netherlands guilder	GUILDER	GUILD1F	76:01–98:12	FCU/GBP
Norwegian krone	NORKRON	NORKN1F	76:01–09:07	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	76:01–09:07	FCU/GBP
Swiss franc	SWISSFR	SWISF1F	76:01–09:07	FCU/GBP
U.S. dollar	USDOLLR	USDOL1F	76:01–09:07	FCU/GBP
Euro	ECURRSP	UKEUR1F	98:12–09:07	FCU/GBP
Australia	AUSTDOL	UKAUD1F	96:12–09:07	FCU/GBP
New Zealand	NZDOLLR	UKNZD1F	96:12–09:07	FCU/GBP
South Africa	COMRAND	UKZAR1F	96:12–09:07	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	96:12–09:07	FCU/USD
Danish krone	DANISH$	USDKK1F	96:12–09:07	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	96:12–09:07	FCU/USD
Netherlands guilder	GUILDE$	USNLG1F	96:12–98:12	FCU/USD
Norwegian krone	NORKRO$	USNOK1F	96:12–09:07	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	96:12–09:07	FCU/USD
Swiss franc	SWISSF$	USCHF1F	96:12–09:07	FCU/USD
British pound	USDOLLR	USGBP1F	96:12–09:07	USD/FCU
Euro	EUDOLLR	USEUR1F	98:12–09:07	FCU/USD
Australian dollar	AUSTDO$	USAUD1F	96:12–09:07	USD/FCU
New Zealand dollar	NZDOLL$	USNZD1F	96:12–09:07	USD/FCU
South African rand	COMRAN$	USZAR1F	96:12–09:07	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	76:01–09:07
Denmark	ECDKN1M	85:06–09:07
France	ECFFR1M	76:01–98:12
Germany	ECWGM1M	76:01–98:12
Italy	ECITL1M	78:06–98:12
Japan	ECJAP1M	78:08–09:07
Netherlands	ECNLG1M	76:01–98:12
Norway	ECNOR1M	97:04–09:07
Sweden	ECSWE1M	97:04–09:07
Switzerland	ECSWF1M	76:01–07:11
United Kingdom	ECUKP1M	76:01–09:07
United States	ECUSD1M	76:01–09:07
Euro	ECEUR1M	99:01–09:07
Australia	ECAUD1M	97:04–09:07
New Zealand	ECNZD1M	97:04–09:07
South Africa	ECSAR1M	97:04–09:07

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, 1976:1-2009:7			
Belgium	-0.21	-0.21	3	6	0.41	0.33
Canada	-0.11	-0.08	4	6	0.04	0.05
Denmark	-0.11	-0.11	2	2	0.84	0.43
France	-0.14	-0.12	3	6	0.10	0.23
Germany	-0.27	-0.26	0	1		0.03
Italy	-0.16	-0.13	4	8	0.10	0.09
Japan	-0.19	-0.24	1	1	0.00	0.00
Netherlands	-0.32	-0.30	0	1		0.11
Norway	-0.13	-0.12	0	7		0.03
Sweden	-0.11	-0.11	0	1		0.10
Switzerland	-0.34	-0.32	0	1		0.18
USA	-0.07	-0.07	4	8	0.02	0.01
Euro	-0.06	-0.06	0	0		
Australia	-0.11	-0.09	0	1		0.03
New Zealand	-0.15	-0.11	0	1		0.22
South Africa	-0.22	-0.20	0	2	0.04	0.20
Average	-0.16	-0.15	1.3	3.3	0.11	0.09
			1999:1-2009:7			
Canada	-0.09	-0.08	0	1		0.13
Denmark	-0.07	-0.08	0	1		0.45
Japan	-0.06	-0.08	1	1	0.00	0.00
Norway	-0.13	-0.11	0	7		0.03
Sweden	-0.10	-0.11	0	1		0.10
Switzerland	-0.10	-0.11	0	1		0.18
USA	-0.04	-0.03	2	3	0.01	0.00
Euro	-0.06	-0.06	0	0		
Australia	-0.11	-0.08	0	1		0.03
New Zealand	-0.14	-0.10	0	1		0.22
South Africa	-0.22	-0.20	0	1		0.22
Average	-0.10	-0.09	0.2	1.1	0.00	0.04

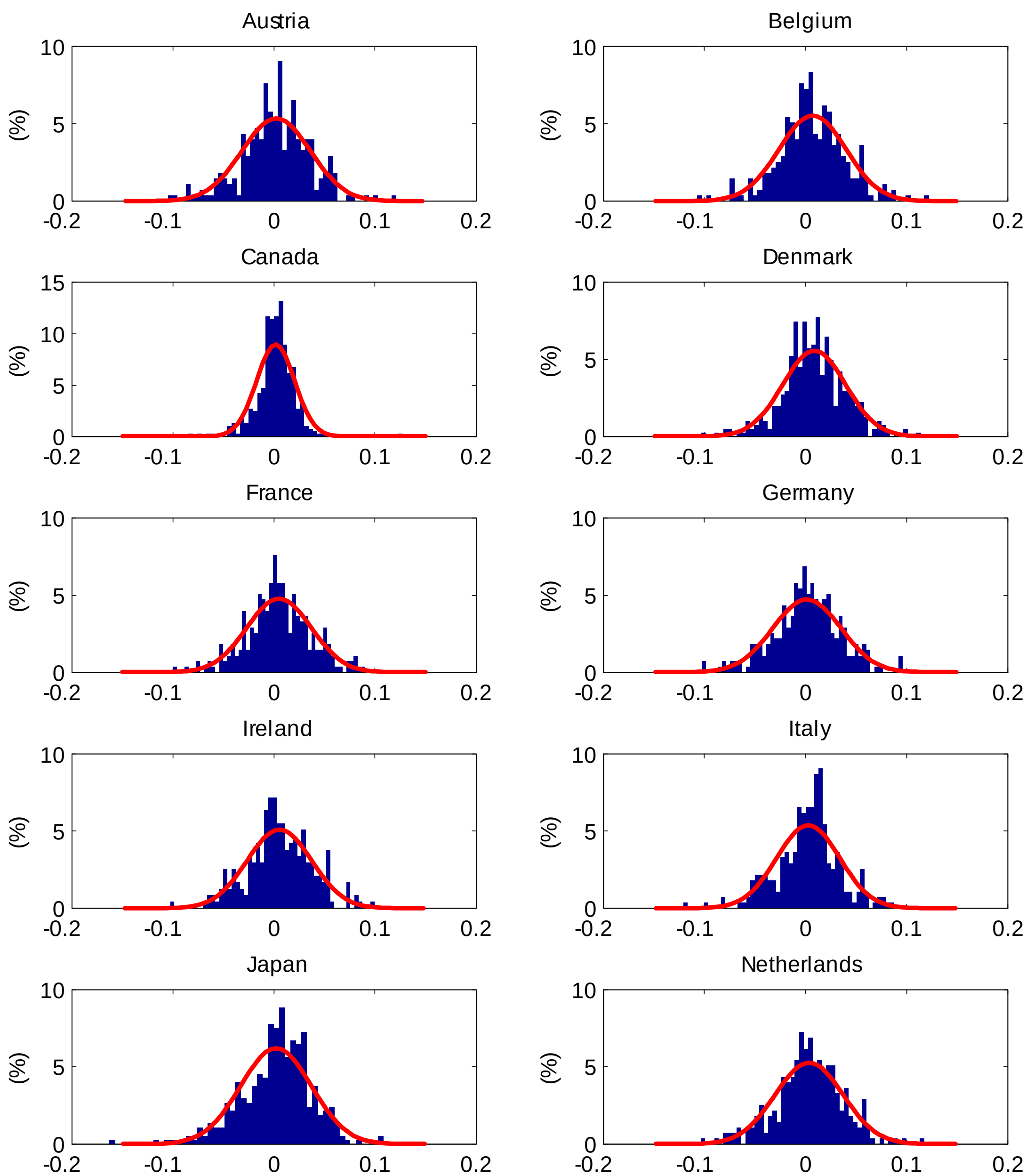
Table A8 is continued on the next page.

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	-0.06	0	0		
Denmark	-0.04	-0.05	5	0	0.01	
France	-0.03	-0.05	1	1	0.02	0.00
Germany	-0.04	-0.05	0	0		
Italy	-0.07	-0.07	0	0		
Japan	-0.03	-0.06	20	0	0.01	
Netherlands	-0.04	-0.06	1	0	0.03	
Norway	-0.09	-0.09	0	0		
Sweden	-0.08	-0.08	2	0	0.03	
Switzerland	-0.08	-0.08	1	0	0.00	
USA	-0.03	-0.04	3	1	0.00	0.00
Euro	-0.03	-0.04	6	0	0.02	
Australia	-0.08	-0.07	1	2	0.04	0.01
New Zealand	-0.12	-0.09	0	1		0.00
South Africa	-0.18	-0.16	0	1		0.24
Average	-0.07	-0.07	2.5	0.4	0.02	0.05

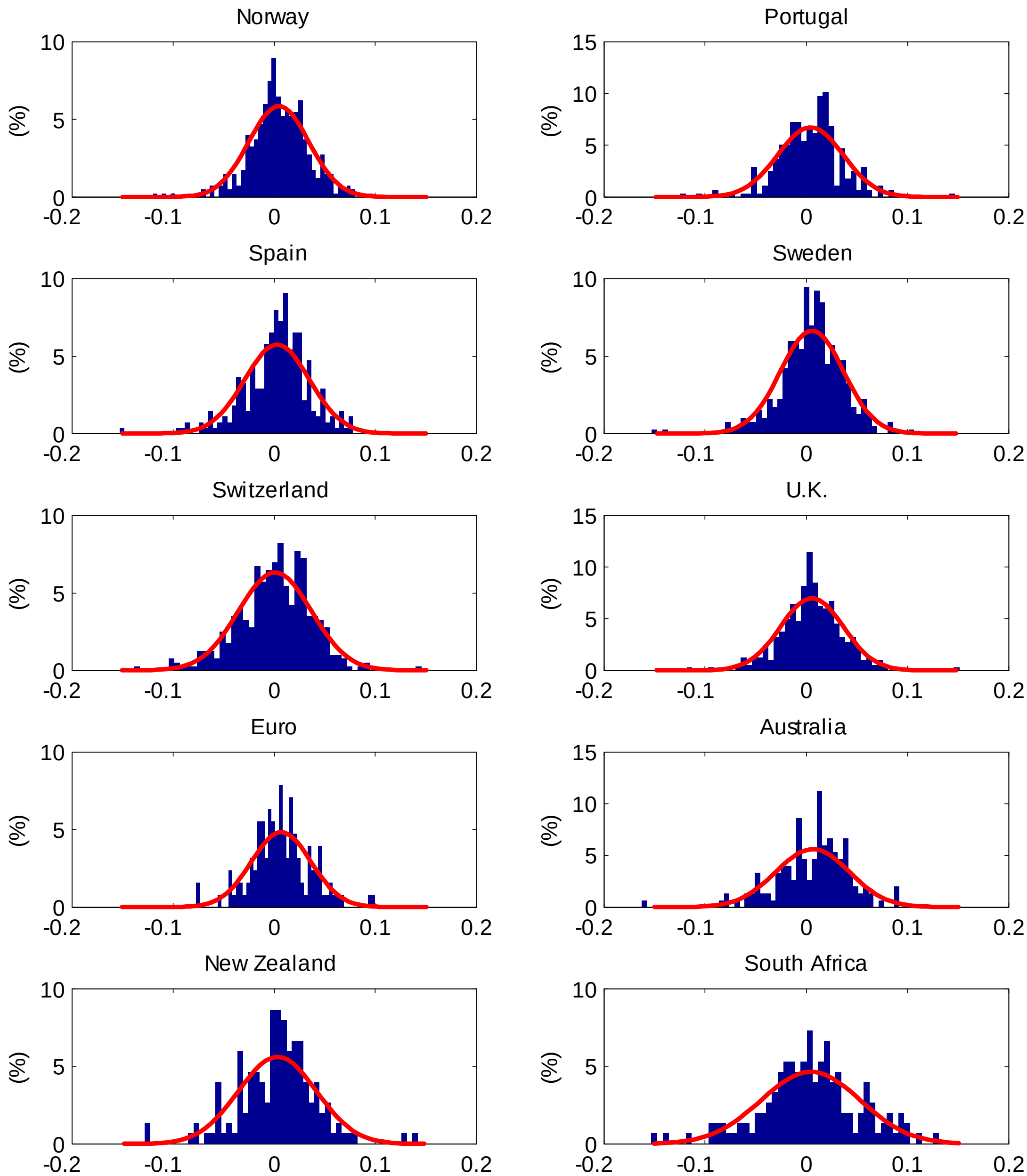
Notes: Part 1 of the table indicates the returns to borrowing British pounds to lend (covered) in foreign currency and the returns to borrowing foreign currency to lend (covered) in British pounds. Part 2 of the table indicates the returns to borrowing US dollars to lend (covered) in foreign currency and the returns to borrowing foreign 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-July 2009)



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–July 2009)



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.