On the Risk and Return of the Carry Trade

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Abstract

The traditional carry trade has historically been highly profitable, but suffered from crash risk, the proverbial “up by the stairs and down by the elevator.” This crash risk was realized in dramatic fashion in the wake of the Lehman bankruptcy, when an investor who was long the Australian dollar and short the yen would have lost 22% in October of 2008.

In sharp contrast, a dynamic diversified portfolio constructed using mean-variance analysis performs well, even during the crash. A portfolio constructed using mean-variance analysis can identify opportunities that a more heuristic method will not detect. Once sufficiently diversified, the carry trade turns out to have been a surprisingly low-risk strategy over the last 20 years.

Keywords: Currency, carry trade, crash risk.

JEL Classification Codes: F31, F37, G11, G12.

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1 Introduction

The carry trade – borrowing in currencies where the interest rate is low and lending where the interest rate is high – has had a disreputable reputation in the financial press as well as the academic literature. Ever since Japan’s economic woes pushed its interest rate below 1% for over a decade borrowing in yen to lend in high-rate currencies such as the Australian or New Zealand dollars provided an easy route to investment wealth. But did the high-return strategy carry a commensurate high risk? The media featured enough stories of Japanese housewives engaging in currency speculation\(^1\) that the carry trade always carried a whiff of speculative excess, a bubble that one day would pop and bring doomsday to anyone foolish enough to engage in it. Doomsday finally arrived in the wake of the Lehman brothers bankruptcy, when a worldwide flight to quality caused the yen to appreciate more than 28% in October 2008 against the Australian dollar. Even a dollar investor who had borrowed in yen saw losses of 20% over the last four months of 2008. The turmoil of the last few years provides a unique opportunity to assess the riskiness of the carry trade.

Since 1990, the simplest carry trade – borrowing in the lowest interest rate currency and lending in the highest – has a respectable risk-return trade-off, with a Sharpe ratio of 0.45. This understates the true risk of this form of the carry trade, which is that the simplest carry trade suffers from “crash risk” – that many small upward moves are paired with the occasionally large downward move. As the market proverb says: the carry trade “goes up by the stairs, but down by the elevator.” (Brunnermeier, Nagel, and Pedersen\(^2\) provide a precise numerical characterization of this aspect of the carry trade. They show that for high interest rate currencies the exchange rate movements are negatively skewed. Even diversification in the form of borrowing in the two or three lowest interest-rate currencies and lending in the two or three highest still suffers from this same crash risk. This suggests a simple story for the high returns on the carry trade: they are compensation for bearing this crash risk.

In this paper, we show that story of the carry trade is not so straightforward. We exhibit a simple dynamic diversified carry trade strategy that provides an even better risk-return trade-off – a Sharpe ratio of over 1. Unlike the simple carry trade, this strategy features returns that are positively skewed. We show that despite being dynamic, that properly implemented the transaction costs of the strategy are quite low.

Since 2007, the difference is even more stark. The simple carry trade did quite poorly, with a Sharpe ratio that is slightly negative, and negatively skewed returns. The dynamic strategy still performs reasonably well (Sharpe ratio of 0.55), with positively skewed returns.


\(^2\)
The mechanism behind carry trade is very simple. In June 2011, the interbank interest rate for a one year yen-denominated loan was 0.56%, while a Australian dollar loan was 5.70%. If the exchange rate remains unchanged, an investor will make a return of 5.14% in one year. But how successful is it, once we take into account exchange-rate risk? An influential economic theory, *uncovered interest parity*, suggests that it shouldn’t be successful at all. Uncovered interest parity predicts that exchange rates will move to close up any possibility of profit. The hypothesis has not fared well when confronted with the data, see Korajczyk (1985) and citations therein. Instead, the empirical evidence shows that in the short run exchange rate movements are unpredictable, and resemble a random walk (Meese and Rogoff (1983)). Thus, while the carry trade investor still faces exchange rate risk, on average the strategy has a positive expected return.

In this paper, we consider an investor who acts as if the random walk hypothesis is true, and see how well he would have actually done over the past 21 years, particularly after the financial crisis. The investor is faced with forming a portfolio of similar assets that vary in their risk-return trade-off. For example, over the sample period, the three lowest interest-rate currencies have been the yen, the Singapore dollar, and the Swiss franc. The yen has had the lowest interest rate, but the Singapore dollar and franc have had lower exchange rate volatility against the dollar, which means on a risk-adjusted basis the latter two currencies may be the better choice. Similarly, the two highest interest rate currencies have been the Australian and New Zealand dollars. They have similar interest rates and their exchange rates are pretty highly correlated, so they are close substitutes, but over the course of years one or the other has had lower volatility against the dollar.

To automate these choices, we construct the portfolios montly on the basis of mean-variance analysis. Over the whole sample period, this dynamic strategy outperforms its simpler counterparts, as well as the US stock market. Post-Lehman, the simpler carry strategies do quite poorly as historical relationships break down. In contrast, an investor who diversifies using mean-variance analysis weathers the sudden economic storm unscathed. Overall, the diversified carry trade over 11 currencies boasts a Sharpe ratio of 1.01.

The academic literature has considered several other explanations for the high returns on the carry trade. Clarida, Davis, and Pedersen (2009) argue that the high returns are a risk premium for time-varying exchange rate volatility. Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) suggest that returns are driven by a peso problem in time-varying discount factors. Verdelhan (2010) advances external habit as a theoretical mechanism that leads to time-varying discount factors. Our paper does not address these alternative explanations.
2 Constructing the Portfolio

There are several financial instruments available to take advantage of the difference in interest rates across countries, such as foreign-currency denominated loans, forward contracts, and swaps. But all other instruments can be synthesized in terms of loans, so we first explain how to construct the diversified portfolio in terms of loans, before discussing alternative and lower-cost implementation methods.

2.1 Expected Return Under Random Walk

First we consider the expected return for a single foreign loan. Let $S_t$ be the foreign currency exchange rate, quoted as the amount of domestic currency necessary to buy one unit of the foreign currency. (For example, if the exchange rate at time $t$ is that 1 Euro equals 1.25 dollars and the dollar is the domestic currency, then $S_t = 1.25$, not 0.8.)

Let $r_t$ be the interest rate when borrowing or lending in the foreign currency. Similarly, let $r_t^d$ be the corresponding risk-free interest rate in the domestic currency. Suppose that the interest rate abroad is higher than the domestic rate, so the investor wishes to lend 1 unit of domestic currency abroad. This equals $1/S_t$ units of the foreign currency. At the end of the loan period, the investor receives $(1 + r_t)/S_t$ in the foreign currency, which when converted back to the domestic currency, is

$$\frac{S_{t+1}}{S_t}(1 + r_t).$$

At time $t$, the rates $r_t^d$ and $r_t$ as well as the exchange rate $S_t$ are known, only the future exchange rate $S_{t+1}$ is unknown. The expected (gross) payoff of the loan abroad in domestic currency is, therefore,

$$\frac{E(S_{t+1})}{S_t}(1 + r_t).$$

Under the assumption that exchange rates follow a random walk the expected exchange rate at time $t + 1$ is just the exchange rate at time $t$, so $E(S_{t+1}) = S_t$ and the expected loan payoff is

$$\frac{E(S_{t+1})}{S_t}(1 + r_t) = 1 + r_t,$$

resulting in an excess return of $r_t - r_t^d$. The risk of the simple carry trade as measured by the variance is

$$\text{Var} \left( \frac{S_{t+1}}{S_t}(1 + r_t) - (1 + r_t^d) \right) = (1 + r_t)^2 \text{Var} \left( \frac{S_{t+1}}{S_t} \right).$$
2.2 Selection of Optimal Carry Trade

We can diversify away some of the exchange risk of the carry trade by investing in a portfolio of risk-free loans denominated in different foreign currencies. We use mean-variance analysis to minimize the volatility of the portfolio.

Consider an investor who is forming a portfolio in \( n \) foreign currencies in addition to a domestic currency. Let the interest rate in the \( i \)-th foreign currency be \( r_i^t \), and its portfolio weight be \( w_i^t \). Since the investor can borrow or lend in different currencies, the weights are unconstrained. The weight in domestic currency loans, \( w_d^t \), is the remainder, \( 1 - \sum_{i=1}^{n} w_i^t \).

The optimal portfolio minimizes the variance of the currency portfolio for a chosen expected portfolio return. The expected portfolio return \( \mu_p^t \) under the random walk hypothesis is

\[
\mu_p^t = r_d^t + w_t' \left( r_t - r_d^t \right).
\]

Using the usual vector notation, and denoting the (column) vector of returns by \( r_t = (r_1^t, r_2^t, \ldots, r_n^t)' \), the vector of weights by \( w_t = (w_1^t, w_2^t, \ldots, w_n^t)' \), and the vector of all ones by \( \iota = (1, 1, \ldots, 1)' \), we can write

\[
\mu_p^t = r_d^t + w_t' (r_t - r_d^t).
\]

The covariance of (gross) returns for investments in the foreign currencies \( i \) and \( j \) is

\[
\text{Cov} \left[ \frac{S_{i+1}^t}{S_i^t} (1 + r_i^t), \frac{S_{j+1}^t}{S_j^t} (1 + r_j^t) \right] = \text{Cov} \left[ \frac{S_{i+1}^t}{S_i^t}, \frac{S_{j+1}^t}{S_j^t} \right] (1 + r_i^t)(1 + r_j^t) \tag{2}
\]

since the interest rates \( r_i^t \) are assumed to be risk-free. Denoting the covariance matrix at time \( t \) by \( \Sigma_t \), the portfolio variance is

\[
(\sigma_p^t)^2 = w_t' \Sigma_t w_t.
\]

If the investor demands a return of \( \mu_0 \) then the portfolio optimization problem at time \( t \) is as follows,

\[
\min_{w_t} \quad w_t' \Sigma_t w_t \\
\text{s. t.} \quad r_d^t + w_t' (r_t - r_d^t) = \mu_0.
\]

The optimal portfolio weights solving this optimization problem are

\[
w_t^* = \frac{\mu_0 - r_d^t}{(r_t - r_d^t)' \Sigma_t^{-1} (r_t - r_d^t)} \Sigma_t^{-1} (r_t - r_d^t).
\]
see Fabozzi, Kolm, Pachamanova, and Focardi (2007). These weights are also the solutions to the Sharpe-ratio maximization problem,

$$\max_{w_t} \frac{w_t^\prime (r_t - r_t^{dt})}{\sqrt{w_t^\prime \Sigma_t w_t}}.$$  

2.3 Carry Trade Implementation

The typical description of carry trades in the financial press as “borrowing in yen and buying dollars” may describe the behavior of retail investors but does not properly convey the trades of professional investors. Successful carry trades require a careful implementation strategy to minimize the effects of transaction costs. Large-scale carry trades are typically implemented through alternate high-volume instruments, such as forwards, or FX swaps. In 2010, forwards had a daily turnover of $475 billion and foreign exchange swaps of $1765 billion. (BIS 2010) (In contrast, the US stock market turnover is around $200 billion.)

A **forward** is a contract to buy or sell a specific amount of currency at a specific date in the future at a fixed price today. No cash changes hands today. The price of a forward, $F^i_t$, is the amount of domestic currency that will be supplied for 1 unit of domestic currency. A forward can be synthesized in terms of one spot transaction and two loans, which allows the price of the forward to be calculated as

$$F^i_t = S^i_t \frac{1 + r^d_t}{1 + r^i_t},$$  

a result known as **covered interest parity**.

An **FX swap** is a contract to buy or sell a specific amount of currency today at the spot price, and a reverse transaction to buy or sell the same amount of currency at a specific date in the future at the forward price. Despite its complexity, the FX swap is one of the central transactions of currency markets. A forward is generally synthesized in terms of a spot transaction followed by an FX swap that reverses the spot transaction. Since it is such a high-volume transaction, it has very low transaction costs, and so it is an important tool in a low-cost carry trade implementation.

Suppose an investor invests 1 unit of domestic currency into a forward. The investor enters into a contract to buy $1/F^i_t$ units of foreign currency for 1 unit of domestic currency. At the future date, the investor converts the foreign currency at the prevailing spot, $S^{i,t+1}_t$, for a net gain of

$$\frac{S^{i,t+1}_t}{F^i_t} - 1,$$  

denominated in future currency. The investor receives a net gain of

$$\frac{S^{i,t+1}_t}{S^i_t} \frac{1 + r^i_t}{1 + r^d_t} - 1.$$
in tomorrow’s currency values. In present value terms, this yields an excess return of
\[ \frac{S_{t+1}^i}{S_t^i} (1 + r_t^i) - (1 + r_t^d). \]
The forward is equivalent to a zero net investment portfolio of being long in the foreign currency, and short in the domestic currency, and thus has the same return.

Forward prices are usually quoted in terms of forward points, which is just the difference between the spot and the forward price,
\[ F_t^i - S_t^i = S_t^i \left( \frac{1 + r_t^d}{1 + r_t^i} - 1 \right). \] (4)
Forward points are also known as the swap rate, since they determine the difference between the two sides of the FX swap. This quoting convention highlights the role the difference in interest rates plays. If the domestic interest rate is higher, then the forward points are positive. If the foreign interest rate is higher, then the forward points are negative. If they agree, then the forward points are exactly zero. We illustrate an investor’s trade with a numerical example.

An investor enters a one-month forward contract selling 1 million USD and buying AUD. Suppose the current spot rate is 0.95 AUD/USD. The one-month interest rate is 0.5% for AUD and 0.04% for USD. The forward points are -43 pips, which is \((1.0004/1.005 - 1) \times 0.95\), and the resulting forward rate is 0.9457, by covered interest parity. Therefore, the investor buys 1’057’472 AUD forward. Now assume that after one month the spot rate is still 0.95 AUD/USD. Then the forward contract delivers 1’057’472 AUD and requires a payment of 1’000’000 USD. The investor can sell his AUD position at a spot rate of 0.95 AUD/USD and obtain 1’004’598 USD. The resulting profit (in one month) of the currency forward is thus 4’598 USD. In future value terms (USD in a year per USD today) the resulting return is \(0.4598\% \times 1.0004 = 0.4600\% = 0.5\% - 0.04\%\). This figure is an excess return since the risk free rate (the domestic interest rate) has already been deducted directly in the forward rate. In other words, 1’000’000/1.0004 is the present value of the USD investment that could be put aside to cover the liability in one month and can be seen as the initial investment size (thanks to interest rate gains, this will be exactly 1,000,000 in one month). The investor realizes his profit or loss at the delivery date. If the spot rate does not change as in the numerical example, then the profit is the interest rate difference.

To illustrate the impact of transaction costs, we show how the investor’s bank implements the currency forward. The bank executes trades on two separate interbank markets. If the investor requests a currency forward buying AUD and selling USD at a future date, then the bank’s spot trading desk buys AUD and sells USD on the spot market today. The bank’s forward trading desk enters an FX swap to buy USD and
Table 1: Half Bid-Ask Spreads (in %) for One-Month Currency Forwards

<table>
<thead>
<tr>
<th></th>
<th>CHF/USD</th>
<th>EUR/USD</th>
<th>JPY/USD</th>
<th>GBP/USD</th>
<th>AUD/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spot</strong></td>
<td>0.016</td>
<td>0.013</td>
<td>0.019</td>
<td>0.012</td>
<td>0.025</td>
</tr>
<tr>
<td><strong>FX Swap</strong></td>
<td>0.004</td>
<td>0.002</td>
<td>0.002</td>
<td>0.003</td>
<td>0.010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>CAD/USD</th>
<th>NOK/USD</th>
<th>SEK/USD</th>
<th>SGD/USD</th>
<th>NZD/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spot</strong></td>
<td>0.014</td>
<td>0.025</td>
<td>0.022</td>
<td>0.050</td>
<td>0.060</td>
</tr>
<tr>
<td><strong>FX Swap</strong></td>
<td>0.005</td>
<td>0.012</td>
<td>0.006</td>
<td>0.002</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Source: Zurich Kantonalbank trading desks.

sell AUD today, and then buy back AUD and to sell back USD at the future date. The difference between the spot price today and the forward price at the future date are the afore-mentioned forward points. In our example, the bank’s spot trading desk sells 1'004'598 USD and buys 1'057'472 AUD (at the spot rate 0.95) on the spot market today. The bank’s forward trading desk enters a swap agreement and trades an FX swap AUD-USD from today to one month at a swap rate of -0.0043. The FX Swap consists of two transactions: Selling 1’057’472 AUD and buying 1’004’598 USD at 0.95 today and buying 1’057’472 AUD and selling 1’000’000 USD in a month at (0.95-0.0043) = 0.9457.

The investor who receives a single price for the currency forward also receives a single transaction cost for the forward. That transaction cost is the sum of the transaction costs for the spot market trade and the FX swap. The following table shows half of the bid-ask spread for one-month currency forwards. Note that spot market trades are considerably more costly than FX Swaps.

If the investor enters a one-month forward contract selling 1 million USD and buying AUD, then he incurs transaction cost of 0.035%. The bank uses an ask price of 0.95*0.99965 and thus charges USD 351.61 (= (1-0.99965)* 1’057’472*0.95). Of these total cost, USD 251.15 (0.025% on 1’057’472 AUD) are for the bank’s spot market trade and USD 100.46 are for the bank’s FX swap (0.010% on 1’057’472 AUD).

In a once-off carry trade, the distinction between the two sources of transaction costs is unimportant, but it becomes important in a dynamic portfolio strategy. If the investor wants to roll over the currency forward for another month, then the initial spot transaction can be avoided. (Rolling over the contract includes a spot transaction today and a reverse spot transaction in a month that exactly offsets today’s amount.) Thus the investor only pays the much lower transaction costs for the FX swap.

The majority of transactions is implemented via FX swaps. However, the forward trader could alternatively buy an interest rate future or a bond. And finally, the bank could decide not to hedge the open position and thus act as the counterparty to the investor.
In the numerical example, recall that the currency forward contract delivers 1'057'472 AUD and requires a payment of 1'000'000 USD. If the investor decides to roll over the forward then he can establish a new forward without a spot market trade by entering a new FX Swap selling 1'057'472 AUD at 0.95 (and receiving 1'004'598 USD) and buying back 1'057'472 AUD in a month by selling again 1 Mio USD (leaving the first-month profit of 4'598 aside and assuming the same AUD-USD spot rate and forward points as before). The transaction cost on the FX Swap are, as before, 100.46 USD.

3 Performance of the Diversified Portfolio

So how well does the diversified carry trade portfolio perform? We test the efficacy of diversification as follows. We take the US dollar (USD) as the domestic currency. We consider a portfolio of 1-month investments (long and short) in the following foreign currencies: Swiss franc (CHF), Euro\(^3\) (EUR), Japanese yen (JPY), British pound (GBP), Australian dollar (AUD), Canadian dollar (CAD), Norwegian krone (NOK), Swedish krona (SEK), Singapore dollar (SGD), and New Zealand dollar (NZD).\(^4\)

We use Bloomberg for currency data and Datastream for US interest rate data. To compute the foreign interest rates, we use the forward rate to back out the interest rate, using covered interest rate parity, \((3)\). Rewriting the relationship between spot and forward rate we obtain

\[
1 + r_i^t = \frac{S_i^t}{F_i^t} (1 + r_d^t).
\]

Each month we use this formula to back out the implied interest rate for each currency, using that currency’s spot and forward rates, and the US one-month interest rate. The sample begins in January 1989. We require one year’s worth of exchange rate data to compute the covariance matrix, so we begin the analysis in January 1990.\(^5\) The last month of our sample is June 2012.

Table 2 presents summary statistics for currencies, sorted by average interest rate. The relationship between interest rates and skewness observed by (Brunnermeier, Nagel, and Pedersen 2009) is readily apparent — lower interest-rate currencies have more positively skewed changes in the exchange rates. For example, historically the yen is more

\(^3\)The Euro was only introduced in January 1999, so as to extend the sample back prior to that, we use the Deutsche Mark.

\(^4\)We initially included the Danish krone, but this actually made our results too good, since the krone is pegged to the Euro, but does not hold the peg perfectly. This makes the krone a terrific hedge for the euro, but at the same time causes numerical problems for mean-variance analysis since the covariance matrix becomes almost singular. We elected to drop the krone to solve the problem.

\(^5\)We repeat the analysis using Datastream currency data, and get broadly similar results. We report Bloomberg because of superior data quality.
Table 2: Currency Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>IR Mean</th>
<th>FX Change Mean</th>
<th>SD</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPY</td>
<td>1.215</td>
<td>3.226</td>
<td>11.104</td>
<td>0.639</td>
</tr>
<tr>
<td>CHF</td>
<td>2.493</td>
<td>2.822</td>
<td>11.553</td>
<td>0.039</td>
</tr>
<tr>
<td>SGD</td>
<td>2.907</td>
<td>1.956</td>
<td>5.800</td>
<td>-0.503</td>
</tr>
<tr>
<td>USD</td>
<td>3.820</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>EUR</td>
<td>4.052</td>
<td>0.966</td>
<td>10.676</td>
<td>-0.212</td>
</tr>
<tr>
<td>CAD</td>
<td>4.323</td>
<td>0.884</td>
<td>7.806</td>
<td>-0.278</td>
</tr>
<tr>
<td>SEK</td>
<td>5.165</td>
<td>0.241</td>
<td>12.002</td>
<td>-0.391</td>
</tr>
<tr>
<td>NOK</td>
<td>5.540</td>
<td>1.056</td>
<td>10.936</td>
<td>-0.344</td>
</tr>
<tr>
<td>GBP</td>
<td>5.560</td>
<td>0.337</td>
<td>9.484</td>
<td>-0.644</td>
</tr>
<tr>
<td>AUD</td>
<td>6.174</td>
<td>1.835</td>
<td>11.598</td>
<td>-0.361</td>
</tr>
<tr>
<td>NZD</td>
<td>6.701</td>
<td>2.009</td>
<td>11.723</td>
<td>-0.225</td>
</tr>
</tbody>
</table>

likely to sharply appreciate than sharply depreciate, while the New Zealand dollar is the reverse. A strategy that is long NZD and short JPY will have negatively skew returns.

Another readily-apparent pattern is that the highest and lowest interest rate currencies have the highest volatility. A mean-variance analysis strategy will naturally try to minimize its expose to that extra volatility, if it can.

For each currency, we compute the expected excess return under the random walk hypothesis, which is just the difference between the currency’s interest rate and the U.S. risk-free rate (see equation (1)). We use equation (2) to compute the entries in the covariance matrix for each currency. For each month, we re-estimate the daily covariance matrix by using the last 250 observations, which then we scale by 22. Each month we rebalance the portfolio.

We choose an annual target excess return of 5%, which roughly matches the excess return on the S&P 500 over our sample period.

3.1 Diversified Carry Trade

Table 3 reports the performance of the diversified carry trade against several alternatives: the simple carry trade with 1 long and 1 short currency, a diversified form of the carry

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6We also tried more complicated procedures to estimate the covariance, such as multivariate GARCH models, but these did not produce substantially better results, so we report the results from the simplest procedure. We also investigated the possibility of using option-implied volatilities, but there was insufficient data for all of our currencies.
Table 3: Full Sample Results

<table>
<thead>
<tr>
<th></th>
<th>Long 1</th>
<th>Long 3</th>
<th>Short 1</th>
<th>Short 3</th>
<th>Dynamic</th>
<th>S&amp;P 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total gross</td>
<td>6.86%</td>
<td>6.45%</td>
<td>10.88%</td>
<td>9.32%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total excess</td>
<td>3.02%</td>
<td>2.62%</td>
<td>7.04%</td>
<td>5.49%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatility</td>
<td>6.68%</td>
<td>4.34%</td>
<td>6.97%</td>
<td>15.18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharpe Ratio</td>
<td>0.45</td>
<td>0.60</td>
<td>1.01</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>-1.31</td>
<td>-0.79</td>
<td>1.46</td>
<td>-0.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kurtosis</td>
<td>4.32</td>
<td>2.01</td>
<td>7.89</td>
<td>1.03</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

trade with 3 long and 3 short currencies, and the S&P 500.

The dynamic carry trade strategy outperforms its three competitors by a considerable margin. The graph in Figure 1 shows the time series of monthly excess returns.
Figure 1: Monthly Portfolio Excess Returns
Table 4: Results Since 2007

<table>
<thead>
<tr>
<th></th>
<th>Long 1</th>
<th>Long 3</th>
<th>Short 1</th>
<th>Short 3</th>
<th>Dynamic</th>
<th>S&amp;P 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total gross</td>
<td>1.26%</td>
<td>2.64%</td>
<td>8.03%</td>
<td>3.14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total excess</td>
<td>-0.40%</td>
<td>0.97%</td>
<td>6.37%</td>
<td>1.48%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatility</td>
<td>8.52%</td>
<td>5.59%</td>
<td>11.53%</td>
<td>18.61%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharpe Ratio</td>
<td>-0.05</td>
<td>0.17</td>
<td>0.55</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>-1.39</td>
<td>-0.47</td>
<td>1.44</td>
<td>-0.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.66</td>
<td>1.64</td>
<td>3.08</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The profitability of the strategy remains even after the financial crisis roiled currency markets, which saw a considerable increase in the volatility of exchange rates. Simultaneously, a world-wide drop in interest rates causes the strategy to increase its bets to hit the target excess return. (See Figure 2 for the change in the dollar weight over time. Immediately after the crisis, the strategy moves the investor out of the dollar and into foreign currencies.) Despite all that, the strategy is still very profitable even on a risk-adjusted basis.

Table 4 reports the performance statistics of the dynamic strategy, as well as the two simple carry trade strategies and the S&P 500. The period sees a dramatic increase in the variance of currencies, but the dynamic strategy remains profitable. In contrast, the two simple carry trade strategies do quite poorly, as does the S&P 500.

Table 5 reports the mean and standard deviation of the weights for each currency over each sample period.

The graphs in Figure 2 show the monthly portfolio weights for all eleven currencies over the entire sample period. We observe that the U.S. dollar is usually the largest holding in the portfolio, and frequently above 1. That’s a result of the typical above-average interest rates in the United States during our sample period. The USD weight falls below 1 during times of below-average USD interest rates such as after the internet bubble burst as well as during the recent recession (the “Great Recession”). The figures in Table 5 as well as the graphs in Figure 2 show that there is substantial portfolio rebalancing from month to month. The two currencies with the largest average short positions have been the CHF and SGD. Most of the time the portfolio has had long positions in the USD, EUR, AUD, and NZD. The graphs in Figure 2 nicely visualize the turmoil in currency markets during and after the financial crisis. The optimal portfolio reacts strongly to changes in interest rates as well as correlations between currencies. For example, note that the popularity of the AUD as a large long currency position is a rather recent phenomenon.
Table 5: Mean and Standard Deviation (SD) of the Monthly Currency Weights

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPY</td>
<td>-0.083</td>
<td>0.182</td>
</tr>
<tr>
<td>CHF</td>
<td>-0.412</td>
<td>0.304</td>
</tr>
<tr>
<td>SGD</td>
<td>-0.401</td>
<td>0.532</td>
</tr>
<tr>
<td>USD</td>
<td>1.181</td>
<td>0.583</td>
</tr>
<tr>
<td>EUR</td>
<td>0.128</td>
<td>0.417</td>
</tr>
<tr>
<td>CAD</td>
<td>-0.093</td>
<td>0.333</td>
</tr>
<tr>
<td>SEK</td>
<td>0.000</td>
<td>0.276</td>
</tr>
<tr>
<td>NOK</td>
<td>0.208</td>
<td>0.360</td>
</tr>
<tr>
<td>GBP</td>
<td>0.134</td>
<td>0.245</td>
</tr>
<tr>
<td>AUD</td>
<td>0.175</td>
<td>0.414</td>
</tr>
<tr>
<td>NZD</td>
<td>0.162</td>
<td>0.248</td>
</tr>
</tbody>
</table>
Figure 2: Weights for Low Interest Rate Currencies
Figure 3: Weights for Medium Interest Rate Currencies
Figure 4: Weights for High Interest Rate Currencies

![Diagram showing weights for high interest rate currencies over time, with lines for NOK, GBP, AUD, and NZD.]
4 Conclusion

The carry trade has long had a reputation for risk. In some ways, this reputation is well-earned. Undiversified portfolios face risks of large losses, risks that were realized in the wake of the Lehman Brothers bankruptcy. For example, an investor who was long the Australian dollar and short the yen would have lost 22% in October of 2008. Even a trader who held a diversified portfolio of only major currencies, such as the dollar, euro, yen, British pound, and Swiss franc would have suffered large losses in the wake of the crisis as historical relationships break down.

In sharp contrast, a diversified portfolio constructed using mean-variance analysis performs well, even during the crash, with a Sharpe ratio over 1 in both periods. A portfolio constructed using mean-variance analysis can identify opportunities that a more heuristic method will not detect. For example, mean-variance analysis recognizes that while the yen has a lower interest rate, the Singapore dollar is a more desirable investment because of its superior risk/return trade-off. Once sufficiently diversified, the carry trade turns out to have been a surprisingly low-risk strategy over the last 20 years.
References


