# 03|2014

# THE CURRENCY CARRY TRADE

## DISCUSSION NOTE

The carry trade in currency markets means that an investor buys a high-yielding currency and finances this by borrowing money in a currency with a low interest rate. The empirical literature on the carry trade indicates that the average return from this strategy is positive and statistically and economically significant. There are, however, also prolonged periods of losses involved with the carry trade, which seems to be consistent with a risk-based explanation.

**Date** 18/03/2014
**ISSN** 1893-966X

NBIM Discussion Notes are written by NBIM staff members.

Norges Bank may use these notes as specialist references in letters on the Government Pension Fund Global. All views and conclusions expressed in the discussion notes are not necessarily held by Norges Bank.

dn@nbim.no
www.nbim.no

# SUMMARY



Average carry trade returns on G10 currencies over the period 1999 to 2013 have been 5.3 percent per annum. With a volatility of 8.5 percent, this leads to an annualised Sharpe ratio of 0.6. Since transaction costs in these developed currency markets are relatively small, the differences between gross and net returns are also small. The Sharpe ratio for the currency carry trade is substantially higher than for equity markets over this period. Including emerging market currencies and using pre-1999 data increase average historical returns on the carry trade.

Due to their low correlation with equity and bond markets, carry strategies have historically improved the risk/return profile of equity and bond portfolios. During the burst of the tech bubble, the carry trade did not contribute to additional portfolio losses. However, the currency carry trade performed particularly poorly during the Lehman crisis, leading to investor losses above 20 percent. During the same period, prices of most risky assets declined, which has sparked the debate on risk-based explanations of currency carry trade returns.

Risk-based explanations include exposure to liquidity risks, volatility risk, downside, crash or rare event risks, currency convertibility risks, trade balance risks, or time-varying risks with regard to stock and bond markets. Explanations with a behavioural or institutional foundation are relatively scarce in this strand of literature. There is no agreement in the academic literature on the source and nature of the profitability of the carry trade.

The literature indicates that the optimal exposure to currencies could also include currency investment strategies such as value and momentum, in addition to the carry trade. The covariance of these currency strategies with other asset classes might also have implications for adopting currency hedging strategies.

# Introduction

The carry trade in currency markets means that an investor invests in short-term deposits in currencies with a high interest rate (the so-called "investment currencies") and finances this purchase with a short-term loan in currencies with a low interest rate (the so-called "funding currencies"). Alternatively, the currency carry trade can be implemented using currency forward contracts. According to uncovered interest parity (UIP), the currency that earns the high interest rate is expected to depreciate by as much as the interest rate differential. UIP assumes that investors are rational and risk-neutral, i.e. that they maximise returns without taking risks into account. If UIP holds, then the expected excess return on the currency carry trade is zero. However, there is a growing body of literature indicating that the carry trade has statistically and economically significant positive excess returns and a Sharpe ratio about double that of equity markets; see, for example, Neely and Weller (2013). Although there seems to be a growing body of literature that finds evidence supportive of risks explaining the profitability of the carry trade, it is as yet unclear what the economic forces behind the proposed risk factors are. The goal of this discussion note is to provide an overview of the state of affairs with respect to the currency carry trade.

We start by giving a short overview of theories related to exchange rate movements in section 2. In section 3 we investigate in more detail the existing empirical evidence on the currency carry trade and compare this with our own empirical research. Section 4 contains a discussion of the possible explanations of the excess returns earned by the currency carry trade. In section 5 we investigate the carry trade in a portfolio context.

# Theories on exchange rates

In this section we describe three different theories of exchange rate determination. We start with covered interest parity (CIP). We show that CIP holds empirically most of the time, with minor deviations in periods of extreme stress in financial markets, when little arbitrage capital is available. Second, we describe uncovered interest parity (UIP), which states that interest rate differentials should be unbiased predictors of future exchange rates. Violation of UIP is the premise of the carry trade in currency markets. Finally, we discuss purchasing power parity (PPP), a theory that links prices of goods in different currencies. We may use PPP as a motivation to arrive at the carry trade using real instead of nominal interest rates.

### Covered interest parity

Arbitrageurs are expected to keep exchange rates and interest rates together through covered interest parity (CIP). They can do this because there are two strategies with different financial instruments that render the same payoffs in each future state of the world. The first strategy is to put 100 euros in a domestic bank account and receive the domestic risk-free interest rate $R^{€}_{t,t+1}$ such that at time $t$+1 the total wealth is €100×(1 + $R^{€}_{t,t+1}$). The second strategy is to convert 100 euros today into a foreign currency, for example

US dollars, using the current exchange rate $S_t^{\$/€}$, earn the foreign risk-free interest rate $R_{t,t+1}^{\$}$, and today decide to convert the principal plus received interest to the domestic currency at *t*+1 using a forward contract. If both strategies would not have the same payoffs at time *t*+1, arbitrageurs would step in and take a long position in the strategy with the higher payoff and a short position in the strategy with the lower payoff, until both payoffs are exactly the same. Of course, in practice there might be frictions that prevent this arbitrage and hence CIP from holding exactly all the time. For example, there are transaction costs, the domestic and foreign interest rates might not be completely risk-free, or arbitrageurs might not have unlimited capacity to take on short positions to finance their long positions.

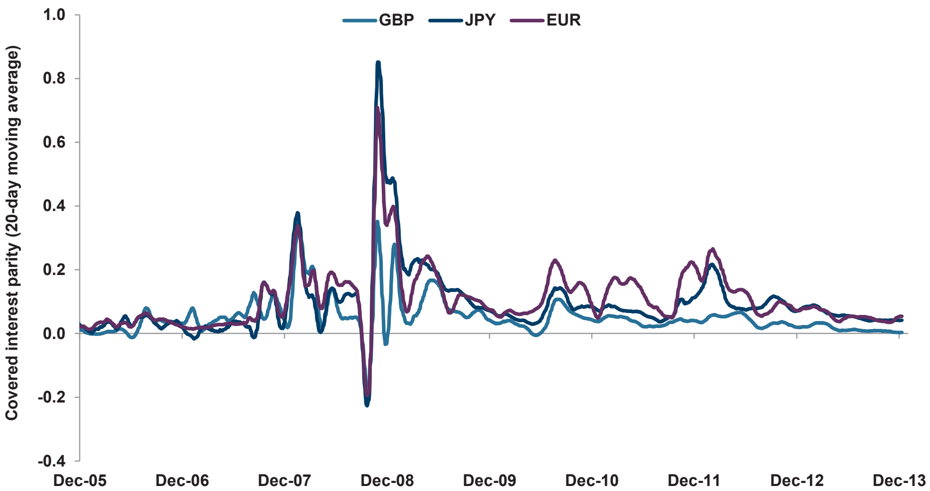
Rewriting this arbitrage strategy leads to the following CIP equation:

CIP: $$F_{t,t+1}^{\$/€} = S_t^{\$/€} \times \frac{(1 + R_{t,t+1}^{\$})}{(1 + R_{t,t+1}^{€})}$$

with $F_{t,t+1}^{\$/€}$ the forward rate at time *t* for conversion at time *t*+1, $S_t^{\$/€}$ the spot rate at time *t*, and $R_{t,t+1}^{\$}$ and $R_{t,t+1}^{€}$ the interest rates on the foreign and domestic currencies at time *t* for period *t*+1.

Frenkel and Levich (1975, 1977) document that between 1962 and 1975 the apparent deviations from CIP between the deutschmark, US dollar and pound sterling can largely be explained by transaction costs. Transaction costs in Frenkel and Levich (1977) are estimated to be 13 basis points for the USD/GBP pair in the tranquil period 1962–1967 and close to 100 basis points during the volatile period 1973–1975. Taylor (1987) uses high-frequency data for the same currencies on 11, 12 and 13 November 1985 and confirms and refines earlier conclusions on CIP by evaluating exactly contemporaneous price quotes. Akram, Rime and Sarno (2008) look at tick data over the seven-month period between 13 February and 30 September 2004, and conclude that there are arbitrage opportunities, but they are short-lived and cannot be detected using data at a daily or lower frequency.

*Figure 1: Covered interest parity (20-day moving average), 2005–2013*




*Source: NBIM, Factset, WM Reuters*

Figure 1 indicates that during the financial crisis there were short periods of deviations from CIP. Given the increased uncertainty in crisis periods, direct transaction costs and indirect transaction costs such as counterparty risks and the lack of sufficient amounts of arbitrage capital might prevent the parity from holding. The magnitude on the y-axis indicates that, generally speaking, the profits of engaging in this type of arbitrage strategies are below 10 basis points in good times, but could be over 50 basis points during crises. Our results are in line with research by Baba and Packer (2009) and Levich (2011) on the absence of violations of CIP before the crisis and their apparent existence during the financial crisis. Mancini-Griffoli and Ranaldo (2011) use high-frequency data on actual market interest rates instead of the commonly used Libor rates, which are surveyed interest rates and not necessarily tradable. They mimic real-life CIP arbitrage strategies and find that substantial arbitrage profits were present in developed currency markets during the Lehman crisis. They attribute these arbitrage opportunities to the lack of funding liquidity rather than increased risk.

### Uncovered interest parity

Uncovered interest parity (UIP) assumes that investors are rational and risk-neutral, which implies that investors maximise returns without taking risk into account. UIP states that differences in interest rates should be compensated by adapting exchange rates such that carry trades should, in expectation, have zero excess returns. Or, stated differently, future spot rates should, in expectation, be equal to current forward rates.

UIP: $$E\left\{S_{t+1}^{\$/€}\right\} = S_t^{\$/€} \times \frac{\left(1 + R_{t,t+1}^{\$}\right)}{\left(1 + R_{t,t+1}^{€}\right)}$$

Note that UIP cannot be enforced with a risk arbitrage strategy, as is the case for CIP. Instead, UIP is a risky trading strategy, in which investors take unhedged positions in currency spot markets. If we put the UIP investment return into a stochastic discount factor framework (see, for example, Cochrane 2001), we can express the return as a function of the risk involved. When the investment return in the domestic currency is defined as $R_{t+1}^{UIP} = S_{t+1}^{\$/€} \times \left(1 + R_{t,t+1}^{\$}\right) \div S_t^{\$/€} - 1$ and the stochastic discount factor $M_{t+1}$, we can see from the fundamental pricing equation that:

$$\begin{aligned}1 &= E_t\{M_{t+1} \times (1 + R_{t+1}^{UIP})\} \\ &= E_t\,\{M_{t+1}\} \times E_t\{1 + R_{t+1}^{UIP}\} + Cov_t\{M_{t+1}, R_{t+1}^{UIP}\}.\end{aligned}$$

When we assume a one-factor model, the conditional expected excess return equals the beta (covariance between the risk factor and returns on UIP, scaled by the variance of the risk factor) times the price $\lambda_t$ of exposure to the risk factor:

$$\begin{aligned}&E_t\{R_{t+1}^{UIP}\} - R_{t,t+1}^{€} \\ &\quad = \frac{Cov_t\{RiskFactor_{t+1}, R_{t+1}^{UIP}\}}{Var_t\{RiskFactor_{t+1}\}} \times \lambda_t\,.\end{aligned}$$

This can be generalised to linear multi-factor models if there are multiple priced factors. It is easy to see that the UIP equation results when the covariance between the UIP returns with respect to priced risk factors equals zero or, alternatively, all risk premiums are equal to zero. An important question in the literature on international finance is whether this assumption of zero covariance to priced risk factors underlying UIP is justified.

Empirical evidence suggests that high interest rate currencies do not depreciate as much as predicted by uncovered interest parity. This apparent irregularity has been called the forward premium puzzle in the academic literature. Menkhoff, Sarno, Schmeling and Schrimpf (2012a) investigate the risk and return of carry trading strategies for 48 currencies over the period 1983–2009 and find excess returns up to 7.2 percent per annum.[1] Historically, it was much more common to investigate the validity of UIP by exploring statistical tests based on regression models, such as in Fama (1984). However, some methodological issues with statistical tests have been put forward. For example, Baillie and Bollerslev (2000) show by means of simulation that traditional regression models as employed by Fama (1984) to detect deviations from UIP overstate statistical significance in relatively small samples with persistent interest rate differentials. Although these critiques might be justified, it is harder to argue with the backtested excess returns from investment strategies. Moreover, when portfolios of currencies are investigated, the volatility of the portfolio indicates that currencies of high (or low) interest rate currencies rise and fall together, and cannot be diversified away. In a regression context, this can only be shown using panel data models, not by evaluating currency pairs in isolation. We review the empirical evidence on carry trade returns in more detail in section 3.

### Purchasing power parity

In addition to the two interest parities described above, currencies are also expected to be bound by prices of tradable goods across countries. The theory behind purchasing power parity (PPP) suggests that if PPP does not hold, then goods traders will buy a good in one currency and sell it in the other currency to obtain a profit. This arbitrage in the goods market should affect the exchange rates or the prices of goods until prices in each country are the same. PPP need not hold when trade barriers (such as import tariffs) are in place or goods are not easily tradable because they are perishable or service-related. Absolute PPP states that prices of goods should be the same once denominated in the same exchange rate:

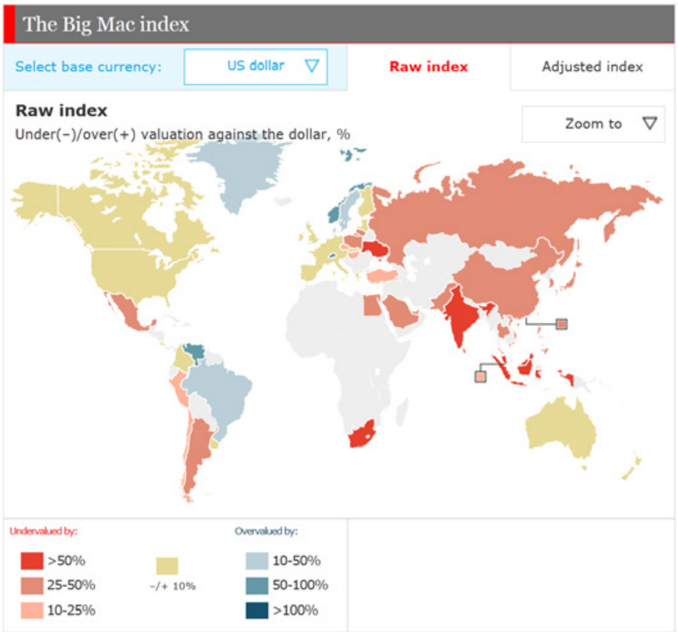
$$\text{PPP:} \quad P_t^{\$} = S_t^{\$/€} \times P_t^{€}$$

where $P_t^{\$}$ and $P_t^{€}$ represent the price of a good in foreign and domestic currency. Since consumption baskets may be different across countries, this relation cannot be easily aggregated for baskets of goods and compared across countries. Deaton and Heston (2010) survey the practical difficulties in measuring PPP and warn users of potential sources of inaccuracies in the measurement of PPP relationships.

*1 A long-term study by Lothian and Wu (2011) provides weak empirical results for violations of UIP for a sample of two centuries (1800 to 1999) for the US dollar / pound sterling and French franc / pound sterling, although a currency carry trading strategy is not explicitly investigated. Doskov and Swinkels (2013) indicate that carry trading strategies generated Sharpe ratios of 0.26–0.38 when using 20 currencies over the period 1900–2012. This is somewhat lower than reported for recent samples that start after the collapse of the Bretton Woods system.*

The value of a currency is sometimes anecdotally expressed in *The Economist's* Big Mac Index, which compares the price of a Big Mac in different countries.[2] Since a Big Mac is a reasonably homogenous product, it should be priced similarly around the globe. Figure 2 shows which currencies are overvalued (blue) or undervalued (red) relative to the US dollar.

*Figure 2: The Economist's Big Mac Index, July 2013*




*Source: The Economist (July 2013)*

Since it is not easy to compare prices of consumption baskets in different countries in absolute terms, sometimes changes in the consumer price index (or inflation) are related to exchange rate movements. The reference to changes instead of absolute levels is often referred to as *relative* PPP. Officer (2012) surveys various other forms of PPP theories that have been derived. Due to frictions in goods markets and difficulties in measuring the price of consumption baskets across countries, it is often argued that PPP should hold in the (very) long run, as exchange rates are forward-looking and highly flexible, while goods prices adjust only slowly. This makes empirical methods to measure such relationships far from straightforward; see, for example, Abuaf and Jorion (1990), Taylor (2002) and Kim and Moh (2010).

The relation between UIP and PPP in combination with persistently higher inflation rates in some emerging markets leads some investors to invest according to real interest differentials instead of nominal interest differentials; see Isaac and De Mel (2001) for an overview of real interest differentials. The reason is that investors expect a better investment performance when they sort currencies on their real interest differentials instead of their nominal interest differentials.[3]

2 *For a more detailed description and interactive tool, see http://www.economist.com/content/big-mac-index.*

3 *Note that the use of real interest differentials is not related to the nominal or real return for the carry trader. For the carry trader, the nominal return of the carry strategy minus the domestic inflation rate yields the real return on the strategy.*

Hazuka and Huberts (1994) used the real interest differential in a model applied to currency trading over the period 1974–1992 and found that using inflation leads to an improved performance, albeit not a statistically significant improvement. De Zwart, Markwat, Swinkels and Van Dijk (2009) apply a trading strategy that invests in currencies with a high real interest rate and funds them with currencies with a low real interest rate. They find that such a strategy generated substantial excess returns over the period 1997–2007, with Sharpe ratios ranging between 0.6 and 1.0, depending on whether the countries in their sample are equally weighted or volatility-weighted. Doskov and Swinkels (2013) report a Sharpe ratio of 0.24–0.48 on real carry trading in 20 currencies over the period 1900–2012. Since the carry trade is usually specified in terms of deviations from UIP, we focus in the remainder of this discussion note on the nominal interest rate differential as the sorting variable of interest.

# Empirical results on the profitability of the currency carry trade

In this section we describe the empirical results for currency carry trading. We first discuss recent studies and then proceed with describing our own empirical results and link them to the previous literature.

### Literature survey

In order to have a somewhat homogenous group of research samples and methodologies, we survey here only the recent literature on the currency carry trade. The overview in this subsection is summarised in Table 1. The early empirical literature, for example Fama (1984), investigates the validity of UIP by using regression analysis and explaining the forward rate relative to the realised future spot rate with the interest rate differential as

$$s_{t+1}^{\$/€} - s_t^{\$/€} = \alpha + \beta \times \left(r_{t,t+1}^{\$} - r_{t,t+1}^{€}\right) + \varepsilon_{t+1}$$

where the lower-case versions of the variables indicate the natural logs of the upper-case variables defined in the UIP equation.

According to UIP, the regression coefficient $\beta$ should be equal to one, and $\alpha$ equal to zero, but in many empirical studies this joint null hypothesis is rejected. More recently, investors have been using the returns on actual trading strategies as an evaluation criterion to investigate whether UIP holds. If UIP holds, the currency carry trade should result in zero excess returns in the long run. Another way to interpret the equation above is to see whether changes in exchange rates are predictable using differences in interest rates as the predictor. The empirical results that we describe below indicate that the predictive power of interest rate differentials is virtually zero. This means that most of the returns on the currency carry trade stem from differences in interest rates. It seems that exchange rates do not respond, or respond only to a very limited extent, to interest rate differences across currencies. This is confirmed by Hassan and Mano (2013), who find that most of the carry profits are due to the alpha intercept in the Fama (1984) regression.

Using an empirical approach, several choices have to be made in the sample selection and the evaluation of trading strategies. The most important choices are the starting and end points of the data sample. Most studies start in the early 1980s and include the financial crisis to a certain extent. Regardless of the exact methodology and sample size, most recent studies find Sharpe ratios for the carry trade between 0.5 and 1.0. This is high in comparison to the Sharpe ratio for the equity market, which is often estimated to be close to 0.3.[4] See Table 1 for an overview of the average returns and volatilities that each of the studies documents.

Menkhoff, Sarno, Schmeling and Schrimpf (2012a) use a large set of 48 currencies (including the separate euro zone countries before the establishment of the euro in 1999), while others focus only on developed currencies (and include only Germany before the euro) in their analyses. It seems that this choice does not materially affect the Sharpe ratios of the trading strategies. This seems to be somewhat at odds with the results of Bansal and Dahlquist (2000). Their UIP regression results suggest that UIP is a much larger puzzle in developed countries than emerging markets over the period 1976–1998. We see that the use of one-month interest rates is the most common, although this might lead to somewhat higher transaction costs because of the monthly rolling of forward contracts compared to, for example, three-month forward contracts. The trading signals are generally very similar for both one- and three-month interest rates, as they move closely together most of the time. Although the usual setup for currency carry research is to investigate UIP using short-term interest rates or forward discounts, several recent papers have tried to link the term structure of interest rates and exchange rates. Chinn and Meredith (2004) and Chinn and Quayyum (2012) find that UIP holds much better for long-term interest rates than for short-term interest rates, meaning that, at longer maturities, beta coefficients in the Fama (1984) regression tend to be positive instead of negative and less likely to be statistically significantly different from zero. Lustig, Stathopoulos and Verdelhan (2013) claim that the bond term premium within a country is negatively related to the carry return that can be earned from exposure to the currency of that country. Sarno, Schneider and Wagner (2012) develop a multi-currency term-structure model for interest rates and try to link time-varying currency risk premiums and bond risk premiums, as they are clearly both important for long-horizon international bond investors.

A methodological difference is the implementation of the trading signal and the position of the US dollar in the trading strategy. Some researchers, for example Burnside, Eichenbaum, Kleshchelski and Rebelo (2011), implement trading signals based on the interest rate differential between the foreign currency and the US dollar. This has the important consequence that when the interest rate on the dollar is relatively high, the strategy is long the US dollar and is short a basket of foreign currencies. This was, for example, the case in the year 2000. When the US interest rate is relatively low, the carry strategy

*4 For example, if the excess return of stocks relative to cash is 5 percent and the volatility of these excess returns is 16 percent, this would result in a Sharpe ratio for the equity risk premium of 0.31.*

*Table 1: Overview of some of the empirical literature on the currency carry trade*

| Authors | Publication | Period | Interest | Currencies | Return | Volatility |
|---|---|---|---|---|---|---|
| Brunnermeier, Nagel and Pedersen | NBER 2008 | 1986–2006 | 3-month | 9 | 6.4% | 10.2% |
| Burnside, Eichenbaum and Rebelo | JEEA 2008 | 1976–2007 | - | 23 | 5.4% | 6.5% |
| Burnside, Eichenbaum, Kleshchelski and Rebelo | RFS 2011 | 1976–2009 | 1-month | 21 | 4.8% | 5.3% |
| Christiansen, Ranaldo and Söderlind | JFQA 2011 | 1995–2008 | 1-day | 10 | 4.6% | - |
| Darvas | JBF 2009 | 1976–2008 | 1-month | 11 | 4.1% | 4.6% |
| Della Corte, Riddiough and Sarno | WP 2012 | 1983–2011 | 1-month | 60 | 5.4% | 8.9% |
| Koijen, Moskowitz, Pedersen and Vrugt | WP 2012 | 1983–2012 | 1-month | 20 | 5.3% | 7.8% |
| Lustig, Roussanov and Verdelhan | RFS 2011 | 1983–2009 | 1-month | 35 | 8.5% | 9.0% |
| Barroso and Santa-Clara | JFQA 2013 | 1996–2011 | 1-month | 27 | 21.4% | 24.3% |
| Menkhoff, Sarno, Schmeling and Schrimpf | JF 2012a | 1983–2009 | 1-month | 48 | 7.2% | 9.8% |
| Rafferty | WP 2011 | 1976–2011 | 1-month | 37 | 7.0% | 8.3% |
| Jurek | JFE 2013 | 1990–2012 | 1-month | 10 | 4.5% | 9.5% |
| | | | | | | |
| *Our results* | *DN 2014* | *1983–2013* | *1-month* | *10* | *5.5%* | *9.1%* |

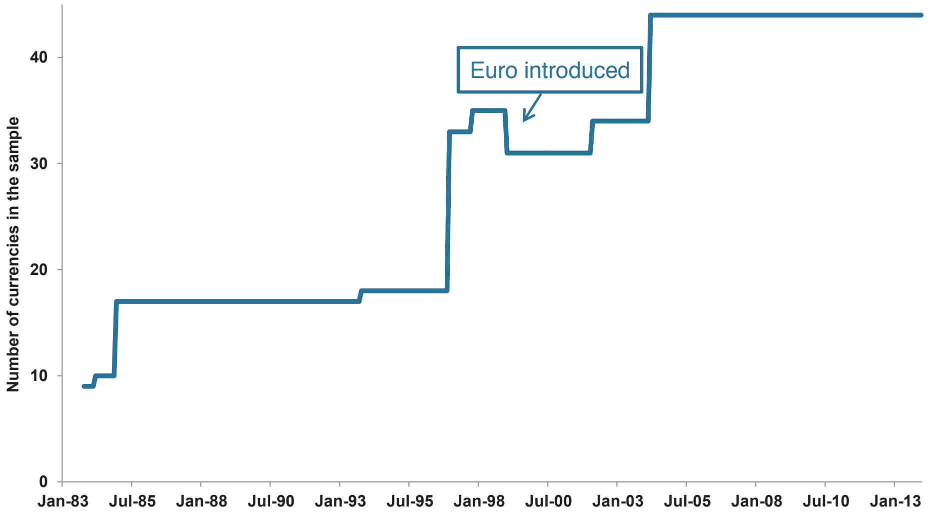
has a large short position in the US dollar and a long position in a basket of foreign currencies. This was, for example, the case in 2003. Such a definition of the trading strategy takes a non-diversified directional position on the US dollar. To circumvent such sensitivity to the US dollar, other studies, such as Brunnermeier, Nagel and Pedersen (2008) and Lustig, Roussanov and Verdelhan (2011), sort currencies on their interest rate and take a long position in a group of high-interest countries and fund this position with a short position in a group of low-interest countries. Although they report average returns on all six portfolios, the carry trade return series is often referred to as the excess returns on the portfolios with extremely high and extremely low interest rates. Such a long-short strategy has the disadvantage that it only uses information on the extreme interest rates and does not make use of the information on the interest rates in the middle, and therefore might be less diversified. This long-short strategy seems to have become the standard in exchange-traded funds that follow carry trade indices, such as the Deutsche Bank Currency Future Harvest Index. An alternative approach is taken by Koijen, Moskowitz, Pedersen and Vrugt (2013), who use a strategy that takes a position in all currencies, but the magnitude of the position depends on the cross-sectional ranking of the interest rate.

### Empirical analysis of the currency carry trade

For our empirical results, we have two sets of returns. First, we analyse the major currencies, also known as the G10 currencies: Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), euro (EUR), pound sterling (GBP), Japanese yen (JPY), Norwegian krone (NOK), New Zealand dollar (NZD), Swedish krona (SEK) and US dollar (USD). These currencies are among the most liquid and may experience the least capacity constraints.[5] Second, we extend this group of countries through time to a total of 48 currencies, as in Menkhoff, Sarno, Schmeling and Schrimpf (2012a). The number of currencies increases considerably over time. Figure 3 shows that the number of currencies is stable around 15 until the middle of 1997. After 2004 there is another large upward jump in the number of currencies. The only decrease can be seen when the euro is introduced in 1999. The full list of currencies is available in the appendix. The forward discounts are based on data from Barclays Bank, the British Bankers' Association and WM/Reuters, obtained through Factset. Although we have daily data available, we use monthly data for most of our analyses. The sample period is from October 1983 to December 2013.

*5 Note that according to the turnover statistics from April 2013 released by the Bank for International Settlements in September 2013, the Mexican peso (MXN) and Chinese renminbi (CNY) were eighth and ninth in the ranking, ahead of the NZ dollar and Swedish krona, and the Russian rouble (RUB) and Hong Kong dollar (HKD) were 12th and 13th, ahead of the Norwegian krone. Source: Triennial Central Bank Survey, Foreign exchange turnover in April 2013: preliminary global results.*

Figure 3: Number of currencies in the sample, 1983–2013

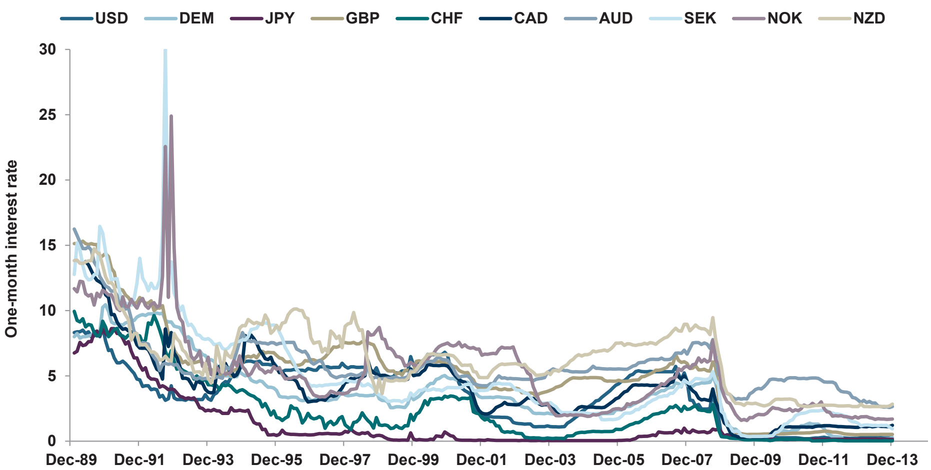



Source: NBIM, Factset, Thomson Reuters, WM Reuters



Figure 4 shows developments in the interest rates of the G10 countries over the period 1990–2013. Until 1993, several spikes in the less liquid currencies can be observed. These spikes are due to the speculation against the Swedish krona and Norwegian krone after they were pegged in the European Monetary System. That these two countries were attacked might have been related to the banking crisis that was unfolding in the Nordic countries. Eventually, in late 1992, the currency pegs were released. After 1993, interest rates generally stay below 10 percent. Until 2008, the highest interest rates are in the range of 5 to 9 percent and the lowest interest rates between 0 and 3 percent. After the Lehman crisis, interest rates have sharply declined. The highest interest rates are between 3 and 5 percent and the lowest interest rates close to 0 percent. Hence, the interest rate differentials in the G10 have declined since the Lehman crisis, making the interest rate buffer smaller before adverse currency movements start to cause losses.

Figure 4: One-month interest rate for G10 currencies, 1990–2013

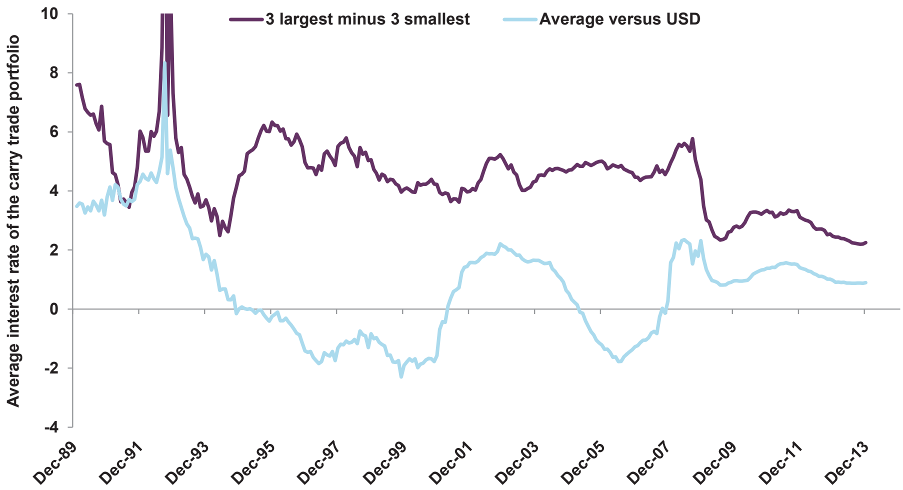



Source: NBIM, Factset, Bloomberg, WM Reuters

Figure 5 shows the average interest rate differentials between the three highest and three lowest interest rates over the period 1990–2013. We clearly see the compression of interest rates after the Lehman crisis to about 2 percent per annum, which is substantially below the 4 to 5 percent differential that is observed most of the time. Interestingly, the period most similar to the current situation is the (short) period in 1993 and 1994 in which interest rates compressed, albeit at substantially higher levels than today.

Also, in Figure 5 it can be seen that the average interest rate versus the US falls below zero several times, indicating that the US sometimes has an interest rate below and above the average of the other nine countries. This leads to time-varying directional exposures to the US dollar for the currency carry strategy used by, for example, Burnside, Eichenbaum, Kleshchelski and Rebelo (2011). The attractive feature of that strategy is that all currencies, and hence all market information, are used. The less attractive feature is that the dollar as base currency plays such an important role.

*Figure 5: Average interest rate of the carry trade portfolio, 1990–2013*

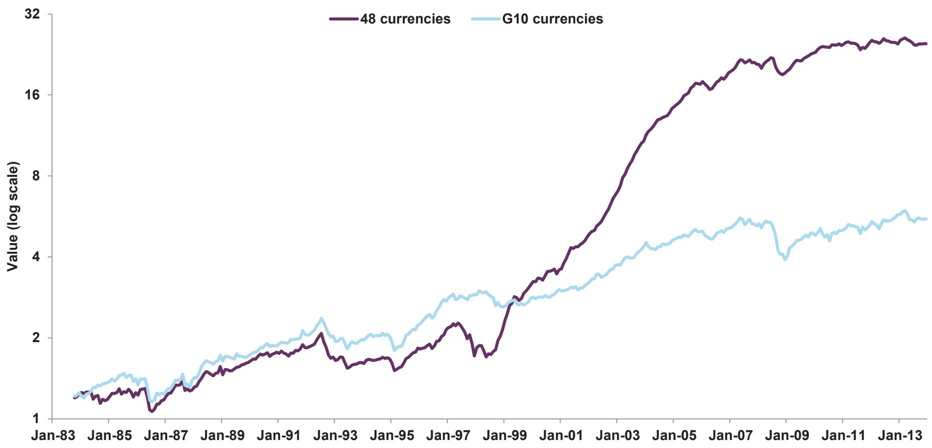



*Source: NBIM, Factset, Bloomberg, WM Reuters*

We now sort the interest rates each month into groups of high, medium and low interest rates. We then take long and short currency positions in the countries with the three highest and three lowest interest rates for G10 currencies. For the sample of 48 currencies, we take the 20 percent highest and lowest interest rates at each point in time, as is standard in this line of literature. We do not take transaction costs into account. As currency markets are generally perceived to be among the most liquid financial markets, this should not affect our results too much. Nevertheless, the results for emerging markets might be overstated, as transaction costs tend to be larger for these markets. Menkhoff, Sarno, Schmeling and Schrimpf (2012a) report that, for their full sample of currencies, the difference between the carry trade returns with and without transaction costs is 79 basis points per annum.[6]

*6 To be more specific, they report 8.02 percent excess return without adjustment for bid-ask spreads, and 7.23 percent excess return with adjustment, over the period from December 1983 to August 2009. For their sample of developed countries only, the difference is smaller at 6.15 – 5.72 = 43 basis points per annum. For developed markets, Darvas (2009) reports transaction costs ranging from 4.8 (USD/GBP) to 15.9 (USD/NZD) basis points for opening a new trade over the period 1999–2008, and generally 25–50 percent higher in the period 1985–1998.*

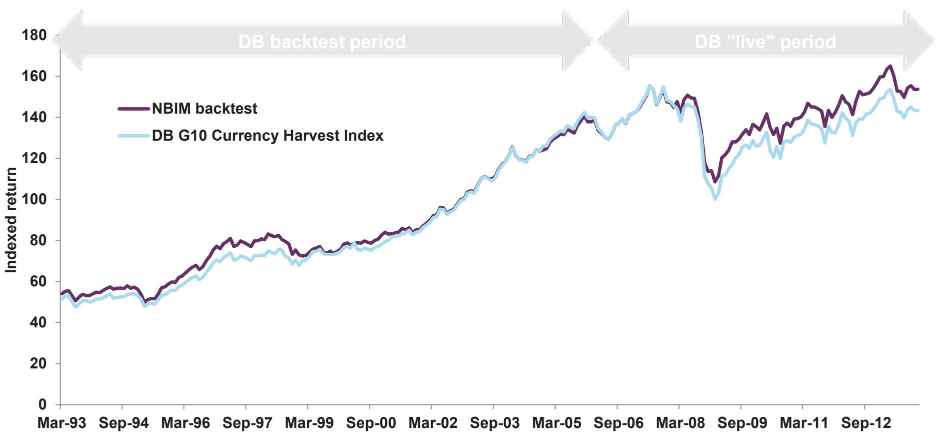
*Figure 6: Cumulative returns on the currency carry trade, 1983–2013*




*Source: NBIM, Factset, Thomson Reuters, WM Reuters*

Figure 6 shows that, for the first 15 years in our sample, the use of the full sample of currencies did not yield higher payoffs from carry trading compared to the G10 currencies.[7] Only in the aftermath of the Asian currency crisis in 1997–1998 does the carry trade using 48 currencies strongly outperform. This was due to a loading on emerging currencies with a relatively high interest rate, and, as we now know, relatively strong exchange rates on average. These results are similar to those reported in Ilmanen (2011). Since the financial crisis of 2007, the returns of both samples are similar again.

*Figure 7: Relation between NBIM backtest and DB Currency Harvest Index, 1993–2013*




*Source: NBIM, Factset, Bloomberg*

The currency trade strategy that we backtested is similar to the strategy that currently provided to retail investors through the purchase of exchange-traded funds.[8] In Figure 7, we show a popular currency carry trade index over the period from 1993 to 2013 and compare its performance to our backtest. We see that the pattern is almost identical, although our backtest is based on

*7 Note that this could be partially attributable to the survivorship bias in our sample construction. The AUD, NZD and NOK were not considered G10 currencies before the introduction of the euro in 1999. Before the introduction of the euro, we use the DEM as a replacement, as is common in this line of literature. This should somewhat reduce the survivorship bias, as the convergence trade from trading Belgium, France, Italy and the Netherlands paid off.*

*8 Pojarliev and Levich (2012) give a more elaborate overview of currency indices and style factors that are popular in the investment community.*

a one-month interest rate and holding period, while the index uses three-month interest rates and holding periods to reduce transaction costs.



# Are the excess returns on carry trades a compensation for risk?

Following the survey of the carry trade by Engel (1996), several new explanations and empirical studies for the excess returns on carry trades have been put forward. Most of these explanations build on the idea that there must be some type of risk involved in the carry trade, although there does not seem to be general agreement on the economic mechanisms that are at work. In this section, we provide an overview of the risk-based explanations that have been put forward in the recent literature.

Most of the research that focuses on risk-based explanations in any asset class deals with estimating a factor model. This factor model then shows that the excess returns are due to exposures to risk factors; once corrected for these exposures, the remaining excess returns – or alphas – are no longer statistically different from zero. The standard methodology is to estimate the significance of the alpha using the regression

$$R_t^e = \alpha + \sum_{k=1}^{K} \beta_{k,t} \times \lambda_{k,t} + \varepsilon_t$$

where $R_t^e$ is the excess return on the carry trade in period $t$, $\lambda_{k,t}$ are the prices of the *k* factors in period $t$, and $\beta_{k,t}$ are the *k* exposures of the carry trade to those priced factors at time $t$. Several papers have put forward ideas on the risk factors or on how to improve estimates of the (time-varying) exposures to these risk factors. The first part of this section elaborates on the different risk factors proposed in the recent academic literature.

### Risk factors from currency markets

Lustig, Roussanov and Verdelhan (2011) postulate a two-factor currency-pricing model that does not use information from other financial markets. Although they do not exclude a possible relationship with risk factors from other markets, they treat currency markets as completely segmented. This seems to be a strong assumption. Their two currency factors are the market or dollar factor, denoted DOL, and the currency carry factor, denoted HMLFX. The first factor is the average return of exchange rates versus the US dollar. This factor seems to explain much of the variability of returns in their forward-discount-sorted portfolios.[9] However, since the coefficient on DOL is often close to one for each of the carry portfolios, it acts more like a constant than a risk factor. The second factor is a portfolio of foreign currencies with high interest rates, minus a portfolio of currencies with low interest rates. This portfolio resembles the carry strategy that we analysed in the previous section. The approach Lustig, Roussanov and Verdelhan (2011) choose is similar to the approach taken by Fama and French (1993) to

*9 Verdelhan (2012) indicates that these two factors can also be used to explain single exchange rates and relate to macroeconomic measures of world integration.*

explain the cross-section of stock returns. Both papers do not economically explain their factors in great detail, but show that they are statistically able to explain the cross-section of asset returns. Another similarity with the Fama and French (1993) model is that it also seems to fail to price portfolios based on past one-year returns, so-called momentum portfolios; see Menkhoff, Sarno, Schmeling and Schrimpf (2012b). Hence, Burnside (2012) concludes that the two-factor model is not appropriate to characterise prices in foreign exchange markets. Another interpretation of this result is that exchange rate movements are unpredictable and that even interest rate differentials cannot be used as a reliable predictor. A new wave of papers is emerging focusing on predicting the exchange rate movements; see, for example, Della Corte, Ramadorai and Sarno (2013).

Menkhoff, Sarno, Schmeling and Schrimpf (2012a) explore a similar two-factor model to Lustig, Roussanov and Verdelhan (2011), but replace the second factor with a global currency volatility factor. This factor is not an excess return on a portfolio, but a factor constructed based on the global average absolute daily currency returns in a month.[10] The factor correlates highly (about 0.8) with the HMLFX factor. When the global volatility factor is orthogonalised to the carry factor it still has explanatory power, but when the carry factor is orthogonalised to the global volatility factor there is little explanatory power left. The advantage of the global volatility factor is that it has at least some economic interpretation related to increased risk aversion or uncertainty.

Another strand of literature investigates the economic rationale for observing excess carry trade returns. For example, countries' net trade position can determine which currencies could be more risky. Della Corte, Sarno and Sestieri (2012) and Della Corte, Riddiough and Sarno (2012) develop a global imbalances risk factor to explain currency returns. The model by Gourinchas and Rey (2007) shows that countries with large (foreign) liabilities are most likely to experience large currency devaluations. Della Corte, Riddiough and Sarno (2012) sort countries based on their net foreign asset position relative to GDP and in a second step distinguish between those which have domestic or foreign liabilities. They find that the riskiest countries in the model by Gourinchas and Rey (2007) are those with the highest interest rates. This gives a macroeconomic rationale for excess returns achieved by currency carry traders.

## Risk factors from bond and equity markets

The factor models specified above view currency markets as segmented from other financial markets as far as their pricing is concerned. Christiansen, Ranaldo and Söderlind (2011) take a somewhat different approach, in the sense that they take the bond and equity markets as their two relevant systematic factors from other important financial markets, and estimate time-varying exposures to these factors. They show that unconditional exposures to these factors are close to zero, and hence do not help to explain

*10 In the presence of outliers, using absolute values on daily returns leads to a more robust estimate of the volatility compared to using the volatility itself. Menkhoff, Sarno, Schmeling and Schrimpf (2012a) also investigate tradable volatility–factor-mimicking portfolios and find similar results.*

the excess returns on carry strategies.[11] Christiansen, Ranaldo and Söderlind (2011) instead use a regime-switching model with currency-implied volatility and TED spread as state variables.[12] In times with high currency-implied volatility, exposure to the equity market increases and exposure to the bond market becomes significantly negative. These time-varying exposures to bond and equity markets explain about one-third of the negative returns in the high volatility state, while two-thirds can be explained by the market volatility factor as discussed by Menkhoff, Sarno, Schmeling and Schrimpf (2012a). Lettau, Maggiori and Weber (2013) and Dobrynskaya (2013) argue that the returns on the carry trade can be explained once the downside risk of the strategy relative to the equity market is accounted for by including a downside risk beta in the asset-pricing model.

A related risk factor from the bond markets that has received relatively little attention in the literature is a credit risk factor. Exceptions are Coudert and Mignon (2013) and Della Corte, Sarno, Schmeling and Wagner (2013). When a country loses creditworthiness, the values of its government bills and bonds usually decrease due to an increased credit spread relative to safer countries. However, countries with their own printing press might not see the full loss of creditworthiness translated into the country's credit spread, as they might be able to print money to avoid a default. This solution to avoid domestic default usually comes at a price of a depreciation of its currency in international markets. Therefore, the time-varying price of credit risk might be a relevant risk factor that the carry trade is exposed to. The difficulty for empirical research is that the price of (sovereign) credit risk is often correlated with the price of equity market risk.

### Exposure to crashes or other rare events

Brunnermeier, Nagel and Pedersen (2008) and Burnside, Eichenbaum, Kleshchlski and Rebelo (2011), among others, have attempted to link the excess returns of the carry trade to extreme tail risks. The former focus on the conditional skewness of carry trades as a measure for crash risk, while the latter suggest that peso problems may explain the profitability of carry trading. The term "peso problems" refers to asset prices that incorporate a small probability of a major crash that has not happened yet.[13]

Brunnermeier, Nagel and Pedersen (2008) indicate that, if a currency pair currently has an interest differential, viewed from the investor in the higher interest rate currency, there is positive exposure to crash risk as measured by the realised skewness of returns in the following week or quarter.[14] They also show that the carry trade portfolio has a positive loading on the implied equity volatility index (VIX), indicating that indeed there is exposure to increases in risk aversion. In this sense, they test a one-factor model with changes in the VIX (or alternatively changes in the TED spread) as a non-tradable factor.

*11 Although there might be timing issues between the daily closing prices of the stock and bond markets (New York time) and the currency markets (London time), the unconditional beta to the stock market is 0.19 and to the bond market –0.06.*

*12 The TED spread is the difference between the interbank interest rate and the interest rate on short-term government debt.*

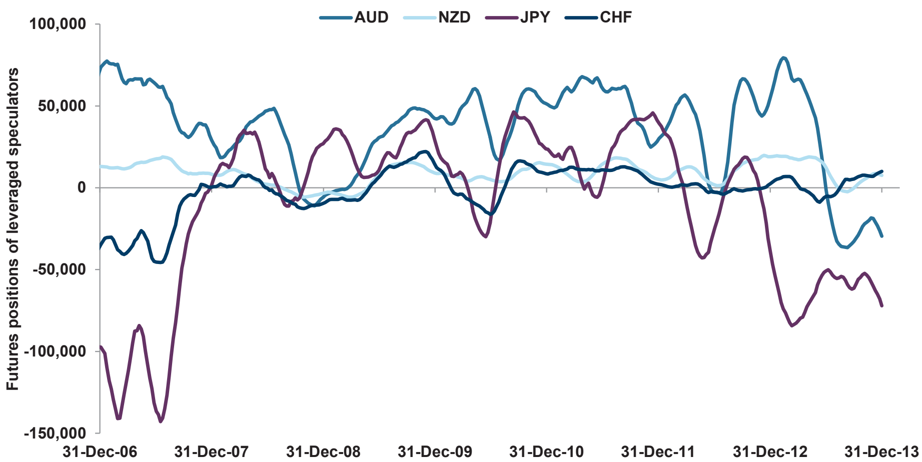
*13 Obstfeld (1987) dates the term "peso problem" back to Kenneth Rogoff when describing the behaviour of Mexican peso futures prices prior to the devaluation in August 1976.*

*14 NBIM (2012) contains an analysis of tail risk estimation using currency options, which can be useful for currency risk management.*

They find a significant negative relation, implying that periods when the VIX increases coincide with periods in which the carry trade incurs losses.[15] However, they do not seem to control for other currency factors in their analysis, such as the dollar factor, as in Menkhoff, Sarno, Schmeling and Schrimpf (2012a). Koijen, Moskowitz, Pedersen and Vrugt (2013) document no crash risk explanations for carry trades outside currency markets. Rafferty (2011) proposes a global currency skewness risk factor to capture crash risk in currency portfolio returns. Mancini, Ranaldo and Wrampelmeier (2013) indicate that the carry trade is exposed to liquidity risk during the period January 2007 to December 2009. Brunnermeier, Nagel and Pedersen (2008) also show that open interest in futures contracts by speculators decreases when the VIX increases (decreases) for currency pairs with positive (negative) interest rate differentials.[16] Note that their data is only until 2006. In Figure 8, we show more recent data (12-week moving average) on the net open interest (defined as the long minus the short positions) from leveraged money managers in the four most typical carry trade currencies: the Australian dollar and New Zealand dollar as investment currencies, and the Japanese yen and Swiss franc as funding currencies.[17] Figure 8 shows clearly that the open interest in both investment and funding currencies is substantially reduced at the end of 2007, and in the case of the yen even reverses. It suggests a strong "flight to safety", or at least a strong "flight out of the carry trade" at the end of 2007. This may have been because leveraged money managers were squeezed out of their futures positions. Since the beginning of 2013, the shorts on the yen have increased again, but this time not accompanied by large long positions in the Australian dollar, suggesting that it is not primarily carry trading that is going on.



*Figure 8: Futures positions of leveraged speculators (12-week moving average), 2007–2013*




*Source: NBIM, CFTC*

*15 We do not report our own results that confirm this contemporaneous relation between carry trade returns and the VIX index. Egbers and Swinkels (2013) suggest that predicting returns on the carry trade with the VIX index is not straightforward. Bakshi and Panayotov (2013) claim that using changes in commodity prices and currency volatility, and liquidity, might be of some help to time the returns on the carry trade.*

*16 Brunnermeier, Nagel and Pedersen (2008) use position data from the CFTC. They admit that this only captures a small part of the market, as many investors use over-the-counter contracts for currency derivatives. Nevertheless, they expect that the positions in the futures markets are positively correlated with those in over-the-counter markets. Breedon, Rime and Vitale (2013) investigate currency order flow and the impact it has on carry trading.*

*17 Note that the categorisation of futures traders before 2006 was less detailed. These less detailed data were used by Brunnermeier, Nagel and Pedersen (2008).*

Brunnermeier, Nagel and Pedersen (2008) and Farhi, Fraiberger, Gabaix, Ranciere and Verdelhan (2013) relate the risks involved in carry trading to the price that has to be paid in the options market to hedge the downside risk of investing in a currency with a higher interest rate. The relative price of a put versus a call option is known as the "risk reversal". This downside risk or "rare event" risk relates to peso problems, or risks that are priced but have not yet materialised. Peso problems as an explanation for the existence of carry trade returns are investigated in more detail by Burnside, Eichenbaum, Kleshchlski and Rebelo (2011). They develop a "hedged carry trade", in which they use currency options to protect the carry investor from downside risk associated with the currency investment. This hedged carry trade seems to lose only modest amounts of money, but since this happens in bad times it still requires compensation during normal times. Jurek (2013) develops a crash-neutral carry strategy using out-of-the-money currency options and suggests that, at most, one-third of the excess returns can be explained by crash risk. These crash risk explanations might be related to the possible currency convertibility restrictions that are imposed in times of crisis. Doukas and Zhang (2013) argue that these convertibility restriction risks can be related to the higher carry profits that are seen in offshore currency markets. They illustrate this with an example of the currency crisis in Iceland in 2008, in which the covered interest differential (the difference between onshore interest rates and offshore futures markets) reached 8 percent.

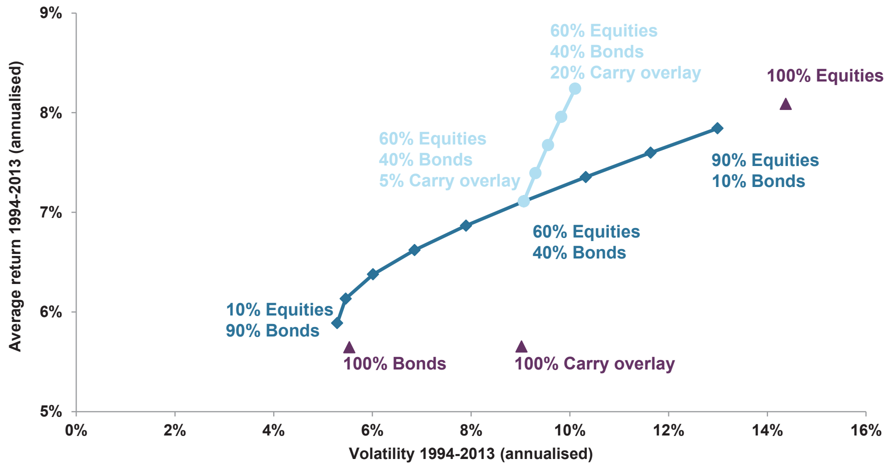
### Potential explanations not based on risk

Several researchers have come up with explanations that are not necessarily risk-based. For example, a behavioural model by Burnside, Han, Hirshleifer and Wang (2011) shows that carry returns may be caused by investor overreaction to their information about future inflation. Yu (2013) uses a model of investor sentiment in which agents over- or underestimate the growth rate of the economy. Spronk, Verschoor and Zwinkels (2011) develop a heterogeneous agent model in which carry traders, fundamental traders and technical traders interact with each other. Their model is able to generate several stylised facts that can be observed in currency markets.

# The currency carry trade in a portfolio context

So far, we have investigated the currency carry trade in isolation. However, investors might also be interested in portfolio considerations, as in the end they care about the total risk and return at the portfolio level. To this extend, we analyse the historical performance of a portfolio consisting of global equities and global bonds and add currency carry trade returns as an overlay strategy. Figure 9 shows these portfolios in historical risk and return space. We use the FTSE World Index to represent global equity markets and the Barclays Global Aggregate Bond Index to represent global bond markets, including government bonds as well as credits. Since the carry trade is an excess return strategy, it is hard to speak of a portfolio weight for this strategy. Therefore, we express the weight as the allocation to the long leg of the portfolio.

*Figure 9: Historical risk and return at the portfolio level, 1994–2013*




*Source: NBIM, Factset, Bloomberg*

It should not come as a big surprise that exposure to the carry strategy adds value, as the correlation with equity and bond markets has been relatively low while the Sharpe ratio of the strategy has been high. Note that the draw-down in the Lehman crisis increases when engaging in this overlay strategy (–11.4 percent in October 2008 for the 60 percent/40 percent portfolio, while this increases to –14.4 percent when 20 percent of the carry overlay is added), while during the burst of the dot.com bubble adding the carry trade did not hurt the portfolio performance (–6.2 percent in September 2002 for the 60 percent/40 percent portfolio, and –6.0 percent when 20 percent of the carry overlay is added). Burnside (2012) shows that carry trade returns are also not exposed to risks stemming from the value and size factors in equity markets. Doskov and Swinkels (2013) show that, in their sample from 1900–2012, there are other years in which equity and carry returns crash simulta-neously (1931 as a notable example), but also many years in which returns on equity markets and currency carry have opposite signs.

In the previous analysis, we took as a starting point the bond and equity in-dices in local currencies. This implies that there is already some exposure to currencies with high interest rates through investments in, for example, Aus-tralian and New Zealand bond and equity markets. There is a long-standing debate in the academic literature and the investment industry over whether or not to hedge currency risks. De Roon, Eiling, Gerard and Hillion (2012) have revisited this question and analysed both the risk and the return dimensions of currency hedging. Their results suggest that hedging currency risks reduc-es risk only when it also comes at the cost of lower returns. Their analysis implies that hedging currency risks reduces portfolio volatility only for inves-tors in countries with relatively safe currencies, which tend to be low–inter-est-rate countries. Hence, reducing the portfolio volatility comes at the cost of lower returns (due to the failure of UIP to hold). They claim that this holds for equities as well as bond investments. This is an argument in favour of investing in local currencies instead of hedging currency risks. However, they do not answer whether investors may want to obtain additional exposure to the carry trade by including additional currency derivatives.

In the previous analysis, we limited our analysis of currency markets to the currency carry strategy only and vice versa. This may be a limitation for the possible carry premiums and currency premiums that can be harvested. Koijen, Moskowitz, Pedersen and Vrugt (2013) show that a portfolio of carry strategies across different asset classes has a Sharpe ratio double that of currency carry trading alone. Barroso and Santa-Clara (2013) suggest that, for currency investing, combining the carry trade with momentum and long-term mean-reversion strategies yields an enhanced risk return profile, avoiding some of the large negative returns from the carry strategy alone. Pojarliev and Levich (2008) also develop a currency four-factor model with carry, trend-following, reversion to PPP, and currency market volatility as systematic factors that currency managers can employ. The construction of an optimal currency portfolio is beyond the scope of this discussion note and we leave this for further research.

# Conclusion

The currency carry trade has historically been well rewarded with a Sharpe ratio above 0.5 for currencies from developed markets. Performances for samples that include emerging markets are even higher. These empirical findings have sparked a new line of academic research that questions the nature and the underlying sources of currency carry trade returns. Most researchers find that the currency carry trade is exposed to various sources of risk. These risk-based explanations include exposures to liquidity risks, volatility risk, downside risk, credit risk, crash or rare event risks, currency convertibility risks, trade balance risks, or time-varying risks with regard to stock and bond markets. Explanations with a behavioural or institutional foundation are relatively scarce in this strand of literature and seem less promising given the empirical evidence on the risks associated with investing in the currency carry trade. As yet, there is no agreement in the academic literature on which risk factor explains the profitability of the currency carry trade. Moreover, there is no consensus on the economic mechanism underlying these risks. This makes further research in this field necessary for investors to increase their understanding of the potential rewards and the associated risks of currency carry trading.

# References

Abuaf, N., and Jorion, P., 1990, "Purchasing power parity in the long run", Journal of Finance 45(1), pp. 157–174.

Akram, Q., Rime, D., and Sarno, L., 2008, "Arbitrage in the foreign exchange market: Turning on the microscope", Journal of International Economics 76, pp. 237–253.

Baba, N., and Packer, F., 2009, "From turmoil to crisis: Dislocations in the FX swap market before and after the failure of Lehman Brothers", Journal of International Money and Finance 28(8), pp. 1350–1374.

Baillie, R., and Bollerslev, T., 2000, "The forward premium anomaly is not as bad as you think", Journal of International Money and Finance 19, pp. 471–488.

Bakshi, G., and Panayotov, G., 2013, "Predictability of currency carry trades and asset pricing implications", Journal of Financial Economics 110(1), pp. 139–163.

Bansal, R., and Dahlquist, M., 2000, "The forward premium puzzle: different tales from developed and emerging currencies", Journal of International Economics 51, pp. 115–144.

Barroso, P., and Santa-Clara, P., 2013, "Beyond the carry trade: Optimal currency portfolios", Journal of Quantitative and Financial Analysis, forthcoming.

Breedon, F., Rime, D., and Vitale, P., 2013, "Carry trades, order flow, and the forward bias puzzle", working paper.

Brunnermeier, M., Nagel, S., and Pedersen, L., 2008, "Carry trades and currency crashes", NBER Macroeconomics Annual, pp. 313–347.

Burnside, C., 2012, "Carry trades and risk", chapter 10 in James, J., Marsh, I., and Sarno, L., (eds.), *Handbook of Exchange Rates*. London: John Wiley & Sons.

Burnside, C., Eichenbaum, M., Kleshchelski, I., and Rebelo, S., 2011, "Do Peso Problems Explain the Returns to the Carry Trade?", Review of Financial Studies 24(3), pp. 853–891.

Burnside, C., Eichenbaum, M., and Rebelo, S., 2008, "Carry trade: The gains of diversification", Journal of the European Economic Association 6(2–3), pp. 581–588.

Burnside, C., Han, B., Hirshleifer, D., and Wang, T., 2011, "Investor overconfidence and the forward premium puzzle", Review of Economic Studies 78(2), pp. 523–558.

Chinn, M., and Meredith, G., 2004, "Monetary policy and long-horizon uncovered interest parity", IMF Staff Papers 51(3), pp. 409–430.

Chinn, M., and Quayyum, S., 2012, "Long horizon uncovered interest parity re-assessed", NBER Working Paper 18482.

Christiansen, C., Ranaldo, A., and Söderlind, P., 2011, "The Time-Varying Systematic Risk of Carry Trade Strategies", Journal of Financial and Quantitative Analysis 46(4), pp. 1107–1125.

Cochrane, J., 2001, *Asset pricing*. Princeton, NJ: Princeton University Press.

Coudert, V., and Mignon, V., 2013, "The 'forward premium puzzle' and the sovereign default risk", Journal of International Money and Finance 32, pp. 491–511.

Darvas, Z., 2009, Leveraged carry trade portfolios, Journal of Banking and Finance 33(5), pp. 944–957.

Deaton, A., and Heston, A., 2010, "Understanding PPPs and PPP-based National Accounts", American Economic Journal: Macroeconomics 2(4), pp. 1–35.

Della Corte, P., Riddiough, S., and Sarno, L., 2012, "Currency premia and global imbalances", SSRN Working Paper 2336049.

Della Corte, P., Ramadorai, T., and Sarno. L., 2013, "Volatility risk premia and exchange rate predictability", SSRN Working Paper 2233367.

Della Corte, P., Sarno, L., Schmeling, M., and Wagner, C., 2013, "Sovereign risk and currency returns", SSRN Working Paper 2354935.

Della Corte, P., Sarno, L., and Sestieri, G., 2012, "The predictive information content of external imbalances for exchange rate returns: How much is it worth?", Review of Economics and Statistics 94(1), pp. 100–115.

De Roon, F., Eiling, E., Gerard, B., and Hillion, P., 2012, "Currency risk hedging, no free lunch", SSRN Working Paper 1343644.

De Zwart, G., Markwat, T., Swinkels, L., and Van Dijk, D., 2009, "The economic value of fundamental and technical information in emerging currency markets", Journal of International Money and Finance 28, pp. 581–604.

Dimson, E., Marsh, P. and Staunton, M., 2013, *The Dimson-Marsh-Staunton (DMS) Global Investment Returns Database*, Morningstar Inc.

Dobrynskaya, V., 2013, "Downside market risk of carry trades", working paper.

Doskov, N., and Swinkels, L., 2013, "Empirical evidence on the currency carry trade, 1900–2012", working paper.

Doukas, J., and Zhang, H., 2013, "The performance of NDF carry trades", Journal of International Money and Finance 36, pp. 172–190.

Egbers, T., and Swinkels, L., 2013, "Can currency carry returns be predicted with implied volatility?", working paper.

Engel, C., 1996, "The forward discount anomaly and the risk premium: A survey of recent evidence", Journal of Empirical Finance 3, pp. 123–192.

Fama, E., 1984, "Forward and Spot Exchange Rates", Journal of Monetary Economics 14, pp. 319–338.

Fama, E., and French, K., 1993, "Common risk factors in the returns on stocks and bonds", Journal of Financial Economics 33, pp. 3–56.

Farhi, E., Fraiberger, S., Gabaix, X., Ranciere, R., and Verdelhan, A., 2013, "Crash risk in currency markets", SSRN Working Paper 1397668.

Frenkel, J., and Levich, R., 1975, "Covered interest arbitrage: unexploited profits?", Journal of Political Economy 83(2), pp. 325–338.

Frenkel, J., and Levich, R., 1977, "Transaction costs and interest arbitrage: tranquil versus turbulent periods", Journal of Political Economy 85(6), pp. 1209–1226.

Gourinchas, P., and Rey, H., 2007, "International financial adjustment", Journal of Political Economy 115(4), pp. 665–703.

Hassan, T., and Mano, R., 2013, "Forward and spot exchange rates in a multi-currency world", working paper.

Hazuka, T., and Huberts, L., 1994, "A valuation approach to currency hedging", Financial Analysts Journal 50(2), pp. 55–59.

Ilmanen, A., 2011, *Expected returns: An investor's guide to harvesting market rewards*, Chichester: John Wiley and Sons Ltd.

Isaac, A., and De Mel, S., 2001, "The real-interest-differential model after 20 years", Journal of International Money and Finance 20(4), pp. 473–495.

Jurek, J., 2013, "Crash-neutral carry trades", Journal of Financial Economics, forthcoming.

Kim, H., and Moh, Y-K., 2010, "A century of purchasing power parity confirmed: The role of nonlinearity", Journal of International Money and Finance 29(7), pp. 1398–1405.

Koijen, R., Moskowitz, T., Pedersen, L., and Vrugt, E., 2013, "Carry", working paper

Lettau, M., Maggiori, M., and Weber, M., 2013, "Conditional risk premia in currency markets and other asset classes", working paper.

Levich, R., 2011, "Evidence on financial globalisation and crises: Interest rate parity", chapter 29 in Caprio, G., (ed.), *The Evidence and Impact of Financial Globalization*. London: Elsevier.

Lothian, J., and Wu, L., 2011, "Uncovered interest-rate parity over the past two centuries", Journal of International Money and Finance 30(3), pp. 448–473.

Lustig, H., Roussanov, N., and Verdelhan, A., 2011, "Common Risk Factors in Currency Markets", Review of Financial Studies 24(11), pp. 3731–3777.

Lustig, H., Stathopoulos, A., and Verdelhan, A., 2013, "The term structure of currency carry trade risk premia", working paper.

Mancini, L., Ranaldo, A., and Wrampelmeyer, J., 2013, "Liquidity in the foreign exchange market: Measurement, commonality, and risk premiums", Journal of Finance, forthcoming.

Mancini-Griffoli, T., and Ranaldo, A., 2011, "Limits to arbitrage during the crisis: funding liquidity constraints and covered interest parity", SSRN Working Paper 1549668.

Menkhoff, L., Sarno, L., Schmeling, M., and Schrimpf, A., 2012a, "Carry trades and global foreign exchange volatility", Journal of Finance 67(2), pp. 681–718.

Menkhoff, L., Sarno, L., Schmeling, M., and Schrimpf, A., 2012b, "Currency Momentum Strategies", Journal of Financial Economics 106(3), pp. 660–684.

Neely, C., and Weller, P., 2013, "Lessons from the evolution of foreign exchange trading strategies", Journal of Banking and Finance 37(10), pp. 3783–3798.

Norges Bank Investment Management, 2012, "Modelling the implied tail risk of foreign exchange positions", Discussion Note 15-2012.

Obstfeld, M., 1987, "Peso Problems, Bubbles, and Risk in the Empirical Assessment of Exchange Rate Behavior," NBER Working Paper 2203.

Officer, L., 2012, "Purchasing power parity in economic history", chapter 6 in James, J., Marsh, I., and Sarno, L., (eds.), *Handbook of Exchange Rates*. London: John Wiley and Sons.

Pojarliev, M., and Levich, R., 2008, "Do Professional Currency Managers Beat the Benchmark?", Financial Analysts Journal 64(5), pp. 18–32.

Pojarliev, M., and Levich, R., 2012, "A new look at currency investing", CFA Institute Research Foundation Publications, December 2012.

Rafferty, B., 2011, "Currency returns, skewness, and crash risk", SSRN Working Paper 2022920.

Sarno, L., Schneider, P., and Wagner, C., 2012, "Properties of foreign exchange risk premiums", Journal of Financial Economics 105, pp. 279–310.

Spronk, R., Verschoor, W., and Zwinkels, R., 2013, "Carry trade and foreign exchange rate puzzles", European Economic Review 60, pp. 17–31.

Taylor, A., 2002, "A century of purchasing power parity", Review of Economics and Statistics 84(1), pp. 139–150.

Taylor, M., 1987, "Covered interest parity: A high-frequency, high-quality data study", Economica 54(216), pp. 429–438.

Verdelhan, A., 2012, "The share of systematic variation in bilateral exchange rates", SSRN Working Paper 2121859.

Yu, J., 2013, "A sentiment-based explanation of the forward premium puzzle", Journal of Monetary Economics, forthcoming.

# Appendix

*List of currencies and long/short positions, 1983–2013*

| | | All currencies | | G10 | |
|---|---|---|---|---|---|
| Country | Currency | Short | Long | Short | Long |
| Australia | AUD | 1 | 106 | 18 | 258 |
| Austria | ATS | 42 | 0 | | |
| Belgium | BEF | 52 | 0 | | |
| Brazil | BRL | 2 | 116 | | |
| Bulgaria | BGN | 6 | 0 | | |
| Canada | CAD | 50 | 4 | 40 | 22 |
| Croatia | HRK | 9 | 19 | | |
| Cyprus | CYP | 21 | 0 | | |
| Czech Rep. | CZK | 54 | 20 | | |
| Denmark | DKK | 38 | 21 | | |
| Egypt | EGP | 0 | 107 | | |
| Euro zone | EUR | 22 | 0 | 165 | 21 |
| Finland | FIM | 60 | 0 | | |
| France | FRF | 17 | 12 | | |
| Germany | DEM | 93 | 0 | | |
| Greece | GRD | 28 | 21 | | |
| Hong Kong | HKD | 156 | 2 | | |
| Hungary | HUF | 0 | 166 | | |
| Iceland | ISK | 0 | 91 | | |
| India | INR | 7 | 87 | | |
| Indonesia | IDR | 18 | 168 | | |
| Ireland | IEP | 2 | 1 | | |
| Israel | ILS | 12 | 0 | | |
| Italy | ITL | 3 | 78 | | |
| Japan | JPY | 308 | 1 | 342 | 2 |
| Kuwait | KWD | 27 | 2 | | |
| Malaysia | MYR | 29 | 77 | | |
| Mexico | MXN | 0 | 144 | | |
| Netherlands | NLG | 60 | 1 | | |
| New Zealand | NZD | 2 | 130 | 11 | 288 |
| Norway | NOK | 35 | 38 | 13 | 177 |
| Philippines | PHP | 9 | 92 | | |
| Poland | PLN | 0 | 31 | | |
| Portugal | PTE | 37 | 0 | | |
| Russia | RUB | 9 | 56 | | |
| Saudi Arabia | SAR | 76 | 0 | | |
| Singapore | SGD | 217 | 1 | | |
| Slovakia | SKK | 18 | 23 | | |
| Slovenia | SIT | 18 | 0 | | |
| South Africa | ZAR | 1 | 313 | | |
| South Korea | KRW | 17 | 0 | | |
| Spain | ESP | 34 | 0 | | |
| Sweden | SEK | 65 | 53 | 58 | 93 |
| Switzerland | CHF | 297 | 0 | 324 | 1 |
| Taiwan | TWD | 127 | 4 | | |
| Thailand | THB | 38 | 30 | | |
| Ukraine | UAH | 2 | 88 | | |
| United Kingdom | GBP | 14 | 29 | 4 | 157 |
| United States | USD | 125 | 0 | 126 | 57 |