# The Rand as a Carry Trade Target: Risk, Returns and Policy Implications[*]

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## Abstract

We analyze the returns to targeting the Australian, New Zealand, and South African currencies, through Japanese yen-funded speculation - with a particular focus on the South African rand, for which the carry trade is often seen as a source of exchange rate volatility. Targeting the rand through forward currency speculation produces returns which are as volatile, but with higher mean, and smaller probability of rare but large losses, than a buy-and-hold investment in the stock market - which is stochastically dominated in the second-order sense by the rand-targeting trade; and generates a larger return-to-volatility ratio than the Australian and New Zealand dollars - the two most common carry targets. Speculative positions and debt flows driven by the carry trade cause an exchange rate process characterized by gradual appreciations punctuated by infrequent but potentially large and rapid depreciations. The consequent level of currency instability is affected by whether inflows cause overheating, and how the central bank responds to the associated inflationary pressure.

Key words: Currency speculation; carry trade; forward premium; skewness and crash risk; exchange rate instability; capital flows

JEL Classification: F31; G15; E58

# 1 Introduction

## 1.1 Background

The forward premium anomaly (i.e. the finding that the forward exchange rate is a biased predictor of the future spot exchange rate), and associated empirical failure of the uncovered interest rate parity hypothesis at short horizons, are well known and documented (Hansen and Hodrick (1980), Fama (1984), Froot and Thaler (1990), Taylor (1995), Engel (1996), Flood and Rose (2002), Chinn & Meredith (2004), Chinn (2006)).[1] Currencies either trading at a forward discount (resp., premium) or, equivalently, with a favorable (resp., unfavorable) interest differential, appreciate (depreciate) on average - though somewhat unpredictably.[2] We draw on recent research which tests the economic significance of this empirical regularity by taking the perspective of a currency trader, and examining the profitability of treating the interest differential as expected return, rather than expected currency depreciation, using the currency forward market - i.e. of exploiting the forward premium anomaly, or short-term deviations from uncovered interest parity (UIP, henceforth).

Burnside, Eichenbaum, Kleshchelski, and Rebelo (henceforth, BEKR) (2006) apply two currency speculation strategies: a "practitioner" or "naïve" carry trade strategy, and a regression-based strategy; each implemented through the forward foreign exchange market, to ten developed country currencies as well as a portfolio of these currencies. They report the return properties of each strategy and find that each yields very high Sharpe ratios (the ratio of mean return to volatility of returns), and the returns are not correlated with common risk factors or monetary variables; but argue that although the returns are high, transaction costs (measured by bid-ask spreads) and the existence of price pressure in spot currency markets, will reduce the speculator's profits to zero.

Two subsequent papers apply the same carry trade strategy to different sets of currencies. Burnside, Eichenbaum, and Rebelo (BER henceforth) (2007) compare payoffs to the carry trade strategy applied to two portfolios. The first portfolio consists exclusively of developed countries, while the second adds a set of emerging markets to the first. Despite far higher transaction costs, including emerging market targets increases the Sharpe ratio from the carry trade substantially - and above the US stock market. The carry trade payoffs

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[1] The unbiased expectations hypothesis (UEH) states that the forward rate is an unbiased predictor of the future spot rate. This is equivalent to uncovered interest parity (which states that the interest rate differential between two countries is equal to the expected depreciation of the high-interest currency) under no arbitrage - technically, the equivalence is ensured by the covered interest parity condition, as explained later in the paper. For an alternative view suggesting country-specific differences and partial support for the UEH, see the interesting contribution of Bansal and Dahlquist (2000). Wesso (1999) provides evidence on the failure of UEH for the South African rand.

[2] A currency is at a forward premium (resp., discount) if its forward value, in terms of another currency, is larger (lower) than its value in terms of the same currency, in the spot market - i.e. the forward exchange rate is lower (resp., higher) than the spot exchange rate, if the exchange rate is defined as units of domestic currency per unit of foreign currency.

are uncorrelated with stock market returns.[3] BER (2008) focus on a subset of the countries used in the previous study, including developed and emerging markets. They consider three variations on the carry trade strategy: an equally-weighted carry portfolio; a currency-specific strategy; and a high-low strategy, taking a position only in the two currencies with the highest forward premium and discount. They show that the diversified portfolio produces a higher Sharpe ratio, mostly due to reduced volatility.

The South African rand is one of the currencies in BER (2008)'s sample. The returns from individually targeting the South African rand documented in BER (2008, p. 584, Table 1) are indeed unattractive: the Sharpe ratio is substantially lower than targeting the Japanese yen or the Swiss franc, which are widely regarded as lower-yielding but less volatile currencies. The rand-targeting strategy is also dominated by numerous alternative targets (including the yen), in the mean-variance sense - i.e. rand-targeting offers lower mean returns *and* higher variance. Hence inclusion of the rand in a carry trade portfolio would be sub-optimal in the mean-variance optimization sense. The study also reports a skewness statistic for the Swiss franc-targeting strategy of negative 0.612 (the lowest in their sample), indicating larger crash risk from investing in the franc than in the rand or any of the other 23 currencies in the study. (See BER (2008), p.587.) These findings are egregiously inconsistent with international reports indicating that the rand is a common carry trade target, while the Japanese yen and Swiss franc are common carry funding currencies.[4]

Targeting portfolios of imperfectly or negatively correlated currencies rather than individual currencies offers the benefit of diversification: a reduction in the variance of returns relative to mean returns, and thus improved Sharpe ratios. However, it is well known that rationalizing the comparison of investments using the first two moments of the distribution of returns, requires that returns be jointly normally distributed, or investors' choices can be characterized by quadratic utility of money functions (Ingersoll (1987), p. 95-97). Quadratic utility might be an inaccurate representation of traders' preferences; and the distribution of returns from the carry trade strategies in BER (2007) and BER (2008) are not Gaussian. BER (2007, 2008) also rely on the US dollar as funding currency, and the sample in BER (2007) does not include any currency crisis period.

## 1.2 This paper's contribution

We implement the currency speculation strategies in BER (2007) and BER (2008), plus a regression-based strategy in BEKR (2006), to focus on the returns

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[3]They attribute the high Sharpe ratios of the developed country portfolios to transaction costs and microstructure frictions, but do not attempt to explain the large Sharpe ratios associated with the portfolios that include emerging markets.

[4]See Galati, Heath and McGuire (2007), and Winters (2008). For financial press reports reflecting international market perceptions, see for example "Yen Rises to 13-Year High as Investors Exit High-Yield Assets," Bloomberg, 24 October 2008; "South Africa's Rand Posts Fifth Weekly Advance on Rate Premium," Bloomberg, 26 April 2008; and "Rand Gains on Bets Carry-Trade Allure to Continue," Bloomberg, 9 November 2010.

and risk from targeting the rand, as well as the Australian and New Zealand dollars, which are the two most widely cited carry trade targets (Galati, Heath and McGuire (2007), Winters (2008)); plus the euro, for perspective. Historically the low interest rates in Japan make the yen a more natural funding currency for the carry trade than either the US dollar or the British pound and we thus use the yen as the funding currency - Japanese interest rates over the past decade are a better proxy for the recent near-zero interest cost of funding the carry trade, using post subprime crisis US or UK rates.

We show that targeting the South African rand is historically highly profitable, using either the naïve strategy or the regression based strategy - the most profitable target in our sample. The figure below contrasts the cumulative payoffs from targeting the rand with the Australian and New Zealand currencies as carry targets (unit initial investment, rand payoff on the left hand scale).

Figure 1: Cumulative Payoffs from Alternative Carry Targets
*CUMRAND: South African rand (left scale)*
*CUMAUD: Australian dollar; CUMNZD: New Zealand dollar*
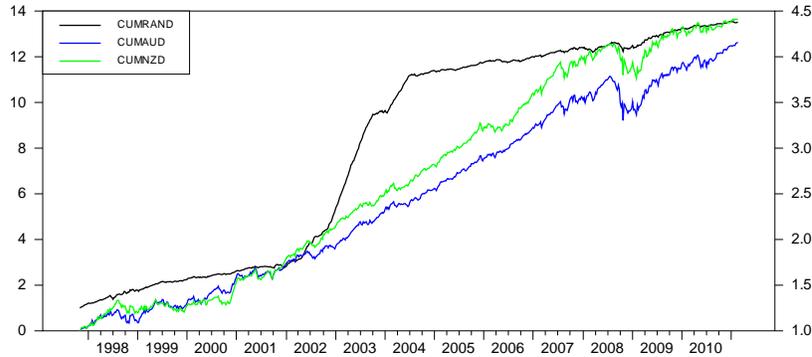


Over the same period and at the same frequency, the Johannesburg Securities Exchange All-Share Index (JSE ALSI, henceforth, which fund managers find difficult to consistently outperform[5]) produced lower mean returns, yet similar variance of returns - resulting in an annualized Sharpe ratio from the rand targeting carry trade approximately four times larger than the JSE-ALSI. Moreover, the skewness from rand targeting in our currency speculation strategies is larger than that from a buy-and-hold investment in the JSE - indicating lower crash risk from the carry than the stock market. The return series are not Gaussian, so we compare the cumulative mass functions of the carry trade payoffs from the alternative targets to each other, and the rand target to the South African stock market. The rand targeting currency speculation strategy comfortably dominates stock market investment in the second-order stochastic dominance sense - i.e. it is a more attractive investment for any risk-averse investor, irrespective of the steepness of the indifference curve representing her

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[5] See Bartens and Hassan (2010) and references therein.

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risk-return tolerance.

We conjecture that a significant portion of rand foreign exchange turnover and fixed income flows to South Africa are due to the carry trade, and discuss the following issues of policy relevance.[6] First, high short-term exchange rate volatility causes carry trade losses; and lower volatility increases the rand's appeal as a carry trade target. Second, the carry trade affects fixed-income portfolio flows, but such flows will only reflect a portion of total carry trade activity. Third, the rand being an attractive carry trade target affects the exchange rate path, contributing to deviations from long-term fundamentals. Specifically, we draw on recent literature on currency crashes, the limits to arbitrage, and slow-moving capital, to argue that being an attractive carry trade target leads to an exchange rate process for the rand characterized by gradual appreciations (with small random disturbances around the path) when the rand turns into an alluring target, punctuated by infrequent but potentially large and rapid depreciations when for example global risk appetite changes or the yield differential turns unattractive, causing carry trade reversals. Inflation-targeting can exacerbate such destabilizing events, if or when carry activity leads to overheating of the South African economy.

The remainder of the paper proceeds as follows. Section two describes the data; briefly gives the theoretic background for the source of the profitability of the carry trade; and explains the currency speculation strategies we implement, as well as their implications for capital flows. Section three presents the results. We compare the mean payoff, volatility, Sharpe ratio and skewness of each country-specific target, and discuss the extent to which crash risk explains the returns from the carry trade. We also use stochastic dominance

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[6]The conjecture is based on necessarily indirect evidence of rand carry trade activity. Direct and comprehensive evidence of carry trade activity targeting any specific currency is difficult to obtain reliably. The are many ways to implement the trade, especially through derivatives, which may be off-balance sheet; reported on-balance sheet positions need not be related to carry trades; participants in the carry trade include unregulated non-bank financial institutions (especially hedge funds and commodity trading advisors); and the rand is heavily traded offshore. But it is possible to obtain indirect evidence. High correlation between foreign exchange turnover and the carry-to-risk ratio (the ratio of the interest-rate differential to expected exchange rate volatility), which is seen as an ex-ante measure of a currency's carry appeal, suggests that turnover is related to carry trade implementation - indirect evidence of carry trade activity. Galati, Heath, and McGuire (2007) report a correlation of 0.36 for the rand, the third highest in their Bank for International Settlements database. In the second half of 2010, approximately 72 percent of total turnover in the South African currency market was attributable to non-residents. Currency derivative transactions (esp. swaps) far outweighed spot transactions; and the former were linked to non-resident activity in the domestic bond market. (SARB (2011b).) The evidence from Turkey suggests that hedge funds and investment banks implementing carry trades are the main swap counterparties. (IMF (2011).) As of June 2010, portfolio fixed-income flows to South Africa were primarily intermediated through a set of financial centres comprising Luxembourg, Jersey, Cayman, British Virgin Islands, Bermuda, Bahamas, and Liechtenstein (IMF (2011)) - jurisdictions where hedge funds (and off balance-sheet structured investment vehicles until recently) are typically domiciled. Interestingly, the largest net flows of yen between 2002 and 2007, were from Japan to the Caribbean financial centres, according to Bank for International Settlements data. (See Galati, Heath, and McGuire (2007).)

for a distribution-free comparison of rand targetting with the stock market. Section four contains discussions on the relationship between exchange rate volatility and the returns from targeting the rand; the interaction between inflation-targeting monetary policy and speculators' actions; the implications of this interaction for exchange rate (in)stability; and a remark on the cost of foreign exchange reserve accumulation.

# 2 Data and currency speculation strategies

## 2.1 Data and spreads

Our data are from Reuters Datastream and cover the period from the 7th of April 1997 to the 21st of February 2011, corresponding to 725 weekly observations for each exchange rate series. Details on mnemonics for specific series are contained in Appendix A. The time frame is approximately 14 years, which includes the South East Asian currency crisis beginning in the second half of 1997, as well as the sub-prime mortgage crisis beginning in the second half of 2007, both of which had substantially adverse effects on carry trade positions held prior to the event. The currencies included are those from: Australia, the euro area, Japan (the funding currency), New Zealand, and South Africa. All currencies in our sample are frequently used in the carry trade. (Galati, Heath, and McGuire (2007), Winters (2008).) The sample includes the two most widely cited carry trade targets, namely the Australian and New Zealand dollars, which are also, like the rand, regarded as commodity-driven currencies. The Japanese yen is used as the funding currency; and the euro is included for comparison with carry targets.

The data set consists of spot and one-month forward exchange rates, and a benchmark stock market index for South Africa (ALSI), used to compare the risk of rand-target with that of a buy-and-hold investment in the stock market. The exchange rates are expressed in foreign currency units (FCUs) per Japanese yen.

The data include bid, offer and average prices. A participant in the inter-dealer market is able to buy and sell currency from a dealer (or, in the absence of dealers, after placing orders in a limit-order book) at the offer (or ask) and bid prices, respectively. The use of bid-ask spreads reflects the implementation costs faced by currency traders and ensures that reported excess returns are not due to a failure to adjust for transaction costs.[7] These spreads are exhibited in Appendix A. As expected, and consistent with BER (2007), the spreads for developed economy currencies are generally lower than emerging market currency spreads.[8] We calculate two measures of the spread: one in relative percentage terms as [100 * log(Ask/Bid)], and the other in absolute terms. South Africa has a disproportionately large spread of 0.8304 percent. We also observe that

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[7]Note however that Reuters bid-ask spreads may be substantially larger than inter-dealer spreads (see Lyons (2001) and Lustig and Verdelhan (2009)).

[8]There is however substantial heterogeneity in spread size across currencies.

the bid-ask spreads are wider in forward markets than in spot markets. This is consistent with the findings in BEKR (2006).

## 2.2 Currency speculation strategies

Let $S_t^a$ and $S_t^b$ denote the ask and bid spot exchange rates respectively. Let $F_t^a$ and $F_t^b$ denote ask and bid forward exchange rates, respectively, for forward contracts maturing at time $t+1$. The variables $S_t$ and $F_t$ denote the averages of $S_t^a$ and $S_t^b$, and of $F_t^a$ and $F_t^b$, respectively. We start with a compact treatment of the theoretic background for the carry trade through the currency forward market. We then consider four speculation strategies: two versions of the naïve carry trade strategy, and two versions of the regression-based strategy - each distinguished by how bid-ask spreads are treated.

### 2.2.1 Theoretic background for the speculation strategies

The well-known UIP hypothesis (we will abstract from bid-ask spreads for the moment) is that the interest differential equals expected depreciation, that is,

$$i_t - i_t^* = E_t S_{t+1}/S_t, \tag{1}$$

where $i_t$ and $i_t^*$ denote domestic and foreign interest rates, respectively, over one period. In the absence of arbitrage opportunities in the market, the covered interest parity condition must hold:

$$i_t - i_t^* = F_t/S_t. \tag{2}$$

The UIP hypothesis is therefore equivalent (in an arbitrage-free market) to a statement about the forward rate as the expected future spot rate:

$$F_t = E_t S_{t+1}. \tag{3}$$

Suppose that the target currency is trading at a forward discount (or the funding currency at a forward premium), $F_t > S_t$. From equation 3, this means that $E_t S_{t+1} > S_t$, i.e. the target currency is expected to, and should on average, depreciate, relative to the funding currency. It does not. Most empirical evidence shows that currencies at a forward discount (resp., premium) tend to appreciate (depreciate). Equivalently, high interest rate currencies to appreciate. (Hansen and Hodrick (1980), Fama (1984), Engel (1996), Chinn and Meredith (2004), Bergman and Hassan (2008).) Target currency appreciation, $S_{t+1} < S_t$, means that $F_t > S_{t+1}$, that is, ex-post, the forward rate for delivery at time $t + 1$ is larger than the spot rate at $t + 1$. The trading implication is straightforward: if the target currency is at a forward discount, $F_t > S_t$, buy the target currency (sell the funding currency) forward, and sell it (converting the proceeds back to the funding currency) at the future spot rate; if instead the target currency is at a forward premium, $F_t < S_t$, sell the target currency (buy the funding currency) forward, and buy it at the future spot rate.

### 2.2.2 Carry trade without transaction costs

This is the baseline naïve carry trade strategy, consisting simply of selling the currency forward when it is at a forward premium, and buying the currency forward when it is at a forward discount. Specifically, we sell $x_t$ units of the funding currency forward according to the rule:

$$x_t = \begin{array}{ll} +1 & if \ \ F_t \geqslant S_t, \\ -1 & if \ \ F_t < S_t. \end{array} \tag{4}$$

When covered interest parity holds (and deviations from covered interest parity are small and rare - see for example Taylor (1987) and BEKR (2006, p.4 and Appendix B)), the payoff from this strategy is proportional (but larger due to fewer transactions) to the more popular understanding of the carry trade, i.e. borrow the low interest funding currency, convert it to the target currency at the current spot rate, invest in the high yielding currency, and then convert back at the future spot rate to repay the short position - benefiting from a favorable yield but facing the exchange rate risk.

The yen-denominated payoff at $t+1$ from the speculative trade is given by:

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

To see this, consider the case where $F_t > S_t$. The trade consists in using $x_t$ units of the yen to buy $xF_t$ units of the target currency, delivered at $t+1$, which are sold in the spot market at time $t+1$ for $xF_t/S_{t+1}$. The payoff in yen is therefore as given by equation 5.

Observe that there is zero net investment at time $t$; and the expected payoff to the speculator is always non-negative if $1/S_t$ is a martingale. That is, if $E_t (1/S_{t+1}) = 1/S_t$, then $E_t z_{t+1} = x_t (F_t/S_t - 1)$, and the non-negativity of the speculator's expected payoff is ensured by the indicator function defining the trading strategy in equation 4.

**Remark 1** *(**Capital flows**.) The zero net investment at time $t$ means that there are no capital flows initiated by the speculator at time $t$. It does not mean that the implementation of the carry trade through the forward market does not cause immediate flows in the spot market. It does, but by the counterparty's hedging, if done through the spot market. The counterparties, which are likely to include large local banks, take the opposite position to the speculator in the forward market. Hedging by the counterparty causes an inflow at the forward contract's initial date, and an outflow at maturity. Concretely: to hedge the forward exposure (e.g., short rand/long yen forward), the counterparty borrows $x/(1 + i_t^*)$ yen at time $t$, converts this to $[x/(1 + i_t^*)] S_t$ rand, invests at the domestic rate $i_t$ between $t$ and $t + 1$, and receives $x [(1 + i_t)/(1 + i_t^*)] S_t$ rand at time $t + 1$. Covered interest parity ensures that $x [(1 + i_t)/(1 + i_t^*)] S_t = xF_t$. Hence, the amount $x [(1 + i_t)/(1 + i_t^*)] S_t$ is used to meet the forward obligation to sell $xF_t$ rand in exchange for $x$ yen, which are used to repay the principal and interest on the loan of $x/(1 + i_t^*)$ yen, contracted at time $t$. The opposite*

*set of transactions (and capital flows) would be put in place when the rand is at a forward premium (i.e. the counterpary is long rand/short yen forward).*[9] *However, carry trade counterparties can also use the derivatives market for their hedging requirements; and may be based offshore. Hence, portfolio debt flows to South Africa will only represent a fraction of total carry trade activity − representing rand-targeting implemented through the conventional approach, and counterparty hedging through the spot markets.*

### 2.2.3   Carry trade with transaction costs

The second version modifies the decision rule and payoff function of the previous strategy, to reflect bid-ask spreads in the spot and forward markets. We sell $x_t$ units of the funding currency forward according to the rule:

$$x_t = \begin{matrix} +1 & if & F_t^b/S_t^a > 1, \\ -1 & if & F_t^a/S_t^b < 1, \\ 0 & otherwise. \end{matrix} \tag{6}$$

The corresponding realized payoff at $t+1$ is:

$$z_{t+1} = \begin{matrix} x_t\left(F_t^b/S_{t+1}^a - 1\right) & if & x_t > 0, \\ x_t\left(F_t^a/S_{t+1}^b - 1\right) & if & x_t < 0, \\ 0 & if & x_t = 0. \end{matrix} \tag{7}$$

Net investment is zero; and the expected payoff is always non-negative if $E_t\left(1/S_{t+1}^a\right) = 1/S_t^a$ and $E_t\left(1/S_{t+1}^b\right) = 1/S_t^b$, which follows from $E_t\left(1/S_{t+1}\right) = 1/S_t$ if the bid-ask spread is stable.

### 2.2.4   BGT regression based strategy

This strategy draws on a small variation on a regression equation used in Backus, Gregory and Telmer (BGT, henceforth) (1993)[10] (who document the degree of auto-correlation in the forward premium), to directly forecast the payoff to selling yen forward from:

$$\frac{F_t - S_{t+1}}{S_{t+1}} = a + b\left(\frac{F_t - S_t}{S_t}\right) + \xi, \tag{8}$$

from which we have

$$E_t\left(\frac{F_t}{S_{t+1}}\right) = 1 + \widehat{a}_t + \widehat{b}_t\left(\frac{F_t - S_t}{S_t}\right). \tag{9}$$

Equation 9 uses the forward premium to project the payoff from selling yen forward, where $\widehat{a}_t$ and $\widehat{b}_t$ are recursive estimates of the coefficients, obtained

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[9] Swap transactions may also be used by the counterparty for the same hedging purposes.

[10] The equation used in BGT (1993) has $S_t$ in the denominator of the left-hand side of equation 8. It is easy to verify that the two equations are nearly equivalent (depending on the size of a covariance term) if $1/S_t$ is a martingale.

using a a 30-week rolling regression, where the first estimate is calculated using the first 30 data points - so the procedure avoids "look-ahead bias."

The strategy consists of selling (resp., buying) the yen forward when the payoff predicted by the regression, i.e. $\widehat{a}_t + \widehat{b}_t\left((F_t - S_t)/S_t\right)$, is positive (resp., negative). Specifically, for the BGT strategy without transaction costs, the speculator follows the rule:

$$x_t = \begin{array}{l} +1 \;\; if \;\; E_t\left(F_t/S_{t+1}\right) \geqslant 1, \\ -1 \;\; if \;\; E_t\left(F_t/S_{t+1}\right) < 1. \end{array} \tag{10}$$

The associated payoff is given by equation 5. Again, the strategy involves zero net investment; and the expected payoff is always non-negative if $E_t\left(1/S_{t+1}\right) = 1/S_t$.

### 2.2.5   BGT regression based strategy with transaction costs

To adjust for the bid-ask spread, the speculator implementing the BGT regression strategy computes the following:

$$E_t\left(F_t^b/S_{t+1}^a\right) = \left[1 + \widehat{a}_t + \widehat{b}_t\left(\frac{F_t - S_t}{S_t}\right)\right]\frac{F_t^b}{F_t}\frac{S_t}{S_t^a}, \tag{11}$$

$$E_t\left(F_t^a/S_{t+1}^b\right) = \left[1 + \widehat{a}_t + \widehat{b}_t\left(\frac{F_t - S_t}{S_t}\right)\right]\frac{F_t^a}{F_t}\frac{S_t}{S_t^b}. \tag{12}$$

These rules follow from 9, coupled with the assumption that the time $t$ bid-ask spread is the best predictor of the time $t + 1$ spread, and from the implication from the BGT regression that,

$$E_t\left(1/S_{t+1}\right) = \left[1 + a + b\left(\frac{F_t - S_t}{S_t}\right)\right]\frac{1}{F_t}. \tag{13}$$

The trading rule analogous to 10 is given by

$$x_t = \begin{array}{l} +1 \;\; if \;\; E_t\left(F_t^b/S_{t+1}^a\right) > 1, \\ -1 \;\; if \;\; E_t\left(F_t^a/S_{t+1}^b\right) < 1, \\ \quad 0 \;\; otherwise, \end{array} \tag{14}$$

and the associated payoff is given by equation 7.

## 3   Results

### 3.1   Return and volatility

Tables 1 and 2 report the average yen payoffs (reported as weekly rates of return), standard deviation, and Sharpe ratio from the carry trade and regression strategies, respectively. The average payoffs to the carry trade and BGT strategies "decrease" approximately by between seven to 30 percent, depending on

the target, when transaction costs are taken into account - except for the euro. (Of course, the payoffs adjusted for the bid-ask spreads are the more realistic payoffs.) Sharpe ratios decrease correspondingly.[11] The bid-ask spread can be large from the viewpoint of the currency trader, particularly when targeting the rand. We will henceforth focus on, and discuss only the payoffs from, the implementation of strategies that reflect bid-ask spreads.

**Table 1: Returns to naïve carry trade (weekly)**

| Target | Before transaction costs | | | After transaction costs | | |
|---|---|---|---|---|---|---|
| | Mean % | SD % | SR | Mean % | SD % | SR |
| Australia | 0.43 | 2.45 | 0.177 | 0.40 | 2.44 | 0.164 |
| Euro | 0.24 | 1.85 | 0.129 | 0.26 | 1.68 | 0.155 |
| New Zealand | 0.48 | 2.51 | 0.190 | 0.41 | 2.51 | 0.164 |
| South Africa | 1.77 | 4.04 | 0.437 | 1.18 | 3.72 | 0.316 |

*SD is standard deviation of weekly returns; SR is the Sharpe ratio*
*Sample period: 03/11/1997 - 21/02/2011*

It is clear from Table 1 that the Australian and New Zealand dollars generate similar mean returns and volatility - and hence similar Sharpe ratios. The euro produces consistently the lower mean return, and is also the least volatile target, with the lowest Sharpe ratio - all expected. The returns from speculating on the rand are the most volatile, with an annualized standard deviation (using the square root of time) of approximately 27 percent, compared to approximately 18 percent for the Australian and New Zealand dollars. But the average return for targeting the rand is also far larger, resulting in a Sharpe ratio, at 0.3 for weekly returns (or 2.2 annualised), approximately twice as large as those from the two more common carry targets.

The BGT regression based strategies produce a similar general pattern. Again, targeting the South African rand generates the highest mean payoff, but with the highest standard deviation, and comfortably the largest Sharpe ratio.

**Table 2: Returns to BGT-regression strategy (weekly)**

| Target | Before transaction costs | | | After transaction costs | | |
|---|---|---|---|---|---|---|
| | Mean % | SD % | SR | Mean % | SD % | SR |
| Australia | 0.28 | 2.48 | 0.114 | 0.28 | 2.44 | 0.114 |
| Euro | 0.21 | 1.84 | 0.116 | 0.23 | 1.79 | 0.129 |
| New Zealand | 0.21 | 2.58 | 0.083 | 0.21 | 2.48 | 0.083 |
| South Africa | 1.60 | 4.19 | 0.387 | 1.06 | 3.63 | 0.293 |

*SD is standard deviation of weekly returns; SR is the Sharpe ratio*
*Sample period: 07/4/1997 - 21/2/2011*

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[11] Curiously, the payoff and Sharpe ratio for the Euro increases when transaction costs are included. The same finding is reported for Germany and the Euro in BEKR (see Table 4 of BEKR (2006)).

In brief, the volatility of the rand (measured by standard deviation), although high, is not sufficiently large to erode its attractiveness as a currency speculation target. On the contrary, by the widely used Sharpe ratio as an informal measure of "risk-adjusted" investment performance, it is a substantially more attractive target than the two other commodity currencies (over the full sample period), namely the Australian and New Zealand dollars, which are widely regarded as the two main carry trade targets (Brunnermeier, Nagel, and Pedersen (2009)).

## 3.2   Crash risk

The previous section shows that the returns to targeting the South African currency in the yen-funded carry trade, implemented through the forward market, remains high once adjusted for the high volatility; and, above all, this volatility is comparable to a passive diversified investment in the stock market, as reported in the next section. But means and standard deviations alone give an incomplete characterization of the risk to expected reward profile if payoffs are not normally distributed. Appendix B contains histograms, cumulative mass function plots, and QQ plots, illustrating the sampling payoff distributions of the carry trade and regression strategies for each target, against the normal distribution. It is immediately apparent that these distributions are not Gaussian. We perform the Shapiro-Wilk test (Shapiro and Wilk (1965)) for each payoff series, and find (statistically highly significant) evidence to reject the null hypothesis that the distributions are Gaussian (see Table 3).

Moreover, risk factors traditionally used to price stock market returns do not price currency market returns (see Burnside (2010)). A plausible explanation for the persistence of carry trade returns is the premium required as compensation for the infrequent occurrence of very large losses.[12] The sudden unwinding of carry trades, due for example to liquidity shortfalls when speculators face funding constraints, causes the distribution of exchange rates between high and low interest rate currencies to be negatively skewed, as documented and discussed in Brunnermeier, Nagel, and Pedersen (2009), Farhi and Gabaix (2009), and Burnside, Eichenbaum, Kleshchelski, and Rebelo (2010). This negative skew, an asymmetry in the distribution of exchange rates, represents crash risk in currency speculation.

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[12] Analysts' use of the term "volatility" can be imprecise, and we realise that in some cases the "volatility" attributed to carry trade returns may (vaguely) refer to crash risk, rather than the second moment of the distribution of returns. This is of course a very loose use of the term. A tightly managed or fixed exchange rate is, by construction, not volatile; but it may still suffer sudden adjustments, or crash.

**Table 3: Skewness and normality**

|  | Carry trade | | BGT regression | |
| --- | --- | --- | --- | --- |
| *Target* | *Skewness* | *SW* | *Skewness* | *SW* |
| Australia | −0.69 | 0.897(0.000) | −0.61 | 0.891(0.000) |
| Euro | −1.03 | 0.918(0.000) | 0.14 | 0.948(0.001) |
| New Zealand | −0.48 | 0.931(0.000) | −1.41 | 0.918(0.000) |
| South Africa | 0.85 | 0.915(0.000) | 1.02 | 0.862(0.000) |

*Statistics reported for returns adjusted for bid-ask spreads*
*SW is the Shapiro-Wilk W test statistic (test significance in parentheses)*

We examine higher order statistical moments. There is clearly crash risk in the returns to the carry trade strategy we implement. The skewness statistic is negative for all country-specific targets, except one, and on average. (See Table 3.) However, the relationship between returns and crash risk is not monotonic: the targets which generate the largest Sharpe ratios are not necessarily the ones with the most negative skewness. This is consistent with the observations in Lustig and Verdelhan (2009), who find that although high interest rates mean monotonically more skewness against the dollar, the skewness of carry trade positions (long high-interest, short low-interest currencies) is not systematically related to returns - the best and worst portfolios generate roughly the same (and positive) skewness, leading them to conclude that "higher interest rates do not seem to imply more skewness against the lowest interest rate currencies" (page 9).[13]

The tentative relationship between carry trade returns and the asymmetry of the returns distribution largely disappears when we use the BGT regression strategy to identify the trading signal. There is no pattern in the skewness of the payoffs from the BGT strategy. Table 3 shows that, except for the New Zealand target, the BGT payoff distributions display skewness values that are larger (less negative) than those of the carry trade strategy, and positive in two cases. Positive skewness represents lower downside risk.[14]

## 3.3   Carry trade versus the stock market

Our findings, regarding the attractiveness of the rand as a carry trade target, are reinforced by comparing the returns from targeting the rand with the returns from a buy-and-hold investment in the South African stock market through the JSE ALSI – a market capitalisation-weighted index of the shares listed on the Johannesburg Stock Exchange. The skewness of stock market returns is normally used as a benchmark to determine how large is the crash risk in the

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[13]Lustig and Verdelhan (2009)'s findings are more a clarification than a refutation of Brunnermeier, Nagel, and Pedersen (2009), who suggest a clear relationship between carry trades and negative skewness. The latter (i) do not implement carry trade strategies which would be pursued by speculators; and (ii) their sample only includes developed market currencies, only two of which are common carry trade targets (the Australian and New Zealand dollars).

[14]Downside risk is variance below the mean, and the skewness of a symmetrical (e.g. normal) distribution is zero.

carry trade. (Lustig and Verdelhan (2009).) Table 4 collects the results for this comparison. Over the same time period and at the same frequency, the ALSI rand-denominated return has a standard deviation of 3.12 percent, which is roughly comparable to (but marginally lower than) our currency speculation strategies. However, the ALSI's average return was much lower: 0.35 percent. As a result, the Sharpe ratio from rand-targeting speculation is approximately three to four times larger than the Sharpe ratio from investing in the stock market, of 0.11, on weekly returns, which corresponds to an annualized ratio of 0.8 before subtracting the risk-free rate, or 0.5 assuming (modestly) an annual risk-free rate of 6 percent, compared to 2.2 for the carry trade - a result with non-trivial implications for the cost of reserve accumulation by the South African Reserve Bank and the allocation of investment funds in South Africa.[15]

### Table 4: Stock market comparison

| Investment | Mean % | SD % | SR | Skewness | Kurtosis |
|---|---|---|---|---|---|
| ALSI (Rand) | 0.35 | 3.12 | 0.11 | −0.09 | 3.64 |
| ALSI (Yen) | 0.29 | 4.43 | 0.06 | −0.06 | 4.82 |
| Rand carry (naïve) | 1.18 | 3.72 | 0.32 | 0.85 | 2.64 |
| Rand carry (BGT) | 1.06 | 3.63 | 0.29 | 1.02 | 3.43 |

*SD is standard deviation of weekly returns; SR is the Sharpe ratio*
*Sample period: 07/4/1997 - 21/2/2011*

The attractiveness of the carry trade is even more remarkable when the returns and risk from the investment in the stock market are expressed in yen, to be consistent with the reported yen-denominated payoffs from the carry trade. The weekly Sharpe ratio from the naïve rand-carry is five times larger than the yen-denominated ratio for the stock market. The figure below illustrates the cumulative returns from the rand-targeting strategy (left hand scale) and the aggregate stock market (right hand scale). The statistics in Table 4 indicate that the magnitude of weekly gains and losses (i.e. the variance of weekly returns) is similar to both investments, but the mean weekly payoff from the rand-targeting strategy is substantially higher. Hence the difference in cumulative returns: a very respectable three-fold increase through the JSE ALSI, compared to a terminal payoff thirteen times the initial investment through currency speculation over the same time period.

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[15] When calculating the Sharpe ratio, the risk-free rate is not subtracted from the mean return to the currency speculation strategies because these are zero net investment positions, when implemented through the forward markets.

Figure 2: Cumulative Payoffs: Rand Target vs JSE
*CUMCARRY: Rand target; CUMJSE: JSE (in yen)*
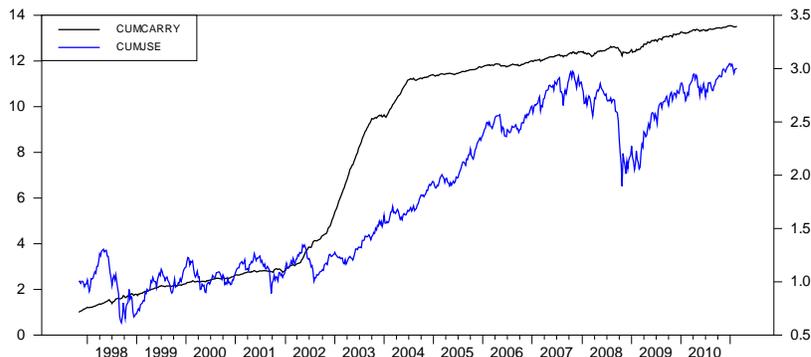


The larger Sharpe ratios from the rand-targeting carry trade strategies are not entirely explained by higher crash risk. The skewness from rand-targeting is (unusually) positive; whilst the skewness from the stock market investment is negative.[16] Again, this result is consistent with Lustig and Verdelhan (2009), who report lower crash risk from a carry trade portfolio than a buy-and-hold investment in the US stock market.[17] Table 4 also shows the kurtosis for the carry trade and stock market payoffs. Large positive kurtosis reflects the concentration of mass in the tails ("fat tails") and centre ("peakedness") of the distribution. It is clear that the carry trade exposes traders to more extreme payoffs, or large movements up and down, than what would be observed under a normal distribution, i.e. the payoff distributions have fat tails and high peaks, with less mass in the "shoulders" of the distribution - which is not surprising, since skewed distributions are always leptokurtic ("fat in the tails") (Wuensch (2005)). But again, for the South African target, not more so than a passive investment in the stock market.

Thus, although the currency speculation strategies expose the trader to crash risk, for the South African case this risk is markedly lower than the crash risk from buy-and-hold investment in the stock market - which produced a markedly lower average return. In sum, crash risk only partly explains the returns to the carry trade; and may be manageable, through less naïve strategies. Targeting the rand through un-hedged currency speculation produced a return profile which is as volatile, but with higher mean return, and smaller probability of rare but large losses, than investing in the stock market.

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[16] Note that the skewness statistic is time-varying, and our results are influenced by concentrated periods of exceptionally high returns. A complete answer to this question requires a closer look at the time series behavior of the crash risk proxy.

[17] Note that currency portfolio diversification does not necessarily reduce skewness. See Brunnermeier, Nagel, and Pedersen (2009).

## 3.4 Stochastic dominance

A natural objection to the preceding arguments may be that the attractiveness of the rand only applies to investors with a relatively high level of risk tolerance, since despite the large Sharpe ratio compared to other carry targets, some investors may be unwilling to tolerate such a high level of volatility. (Put differently, the excess return may not offer sufficient compensation for the volatility.) Non-normal distributions of payoffs limit the reliability of comparing alternative investments using mean-variance analysis - and hence the Sharpe ratio. Specifically, if we cannot assume that traders' preferences for risk and return are accurately described by quadratic utility, nor that returns are normally distributed, mean-variance optimization is difficult to justify on the grounds of rational expected utility maximization. (See for example Ingersoll (1987).) We use stochastic dominance to obtain a comparison of alternative payoff distributions which is valid for any risk-averse trader, irrespective of the slope of her utility of money function.

Figure 3 below contrasts the cumulative mass functions of the returns from each target, and permits a clear distribution-free comparison of the rand-target to a buy-and-hold investment in the South African stock market. It is clear that the rand-targeting strategy dominates a buy-and-hold investment in the JSE in the second-order stochastic dominance sense - i.e., it is a superior investment (in the sense of maximizing expected utility) for any risk-averse trader, irrespective of the trader's preferences for risk and return, other than requiring a return premium for taking risks, and irrespective of the distribution of returns.

Figure 3: Cumulative Mass Functions
Carry Trade Targets and JSE-ALSI
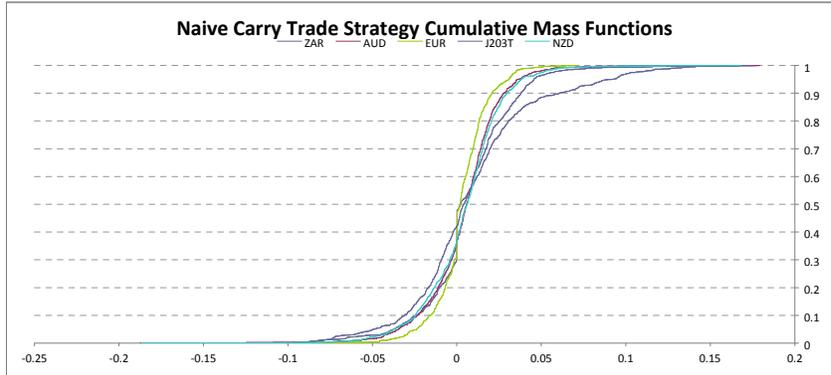


The dominance of rand-targeting does not however apply to alternative currency targets - less risk-tolerant traders will not necessarily prefer targeting the rand relative to the Australian and New Zealand dollars. Variations in volatility and covariance between the returns from the different targets will determine the optimal weight of each target in a carry-trade portfolio.

# 4  Discussion

## 4.1  Rand attractiveness as a carry trade target

In South Africa, market analysts have suggested that the attractiveness and thus role of the carry trade on the rand is "a myth", because the allure of a favorable interest differential is easily eroded by the currency's high volatility.[18]  As a general statement, this view is false. Targeting the rand *using the derivatives market* is (on average) historically profitable, despite its high volatility; and the crash risk is lower (yet the average returns substantially higher) than that from a buy-and-hold diversified investment in the stock market, as well as more common carry targets (Australian and New Zealand dollars).

In contrast, policy analysts have simultaneously recommended "reducing the carry" and moving towards an exchange rate target band.[19]  Targeting an exchange rate band (in addition to other difficulties) would lead to limits on the size of exchange rate losses faced by speculators chasing the yield differential. Reducing rand volatility without reducing the interest differential will increase further the attractiveness of the rand as a carry trade target.  (Speculators targeting the rand would only incur temporary losses as the rand moves down in value towards the band.)

## 4.2  Effect of short-term volatility on carry trade returns

Periods of high volatility, in the currency and financial markets more generally (domestic or international), are associated with capital flow reversals, away from high-interest/target currencies, and into low-interest/funding currencies. (Brunnermeier, Nagel, and Pedersen (2009)). Such reversals lead to carry trade losses for speculators who maintain long positions in high-interest currencies, and short positions in low-interest currencies. Clarida, Davis, and Pedersen (2009) provide compelling evidence of a strong and systematic inverse relationship between exchange rate volatility and un-hedged carry trade returns.

Our discussion has focused on un-hedged carry trades. Traders can buy currency options to hedge the exchange rate exposure component (i.e. buy protection against unfavorable exchange rate movements). When volatility decreases, the price of these options, and hence the cost of hedging against unfavorable exchange rate movements, decreases - making the carry trade more attractive, for a given yield differential.  The policy implication is that interventions to reduce *high-frequency/short-term* rand volatility (which could be desirable on other grounds), would have a perverse effect: options-hedged targeting will become cheaper; and un-hedged targeting will become less risky. Both forms of

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[18] See for one example, "Blame the carry trade alone?  Urban legend with risks", in Moneyweb, 20 November 2009. Regular releases from the international financial press suggest a different view - see for example "South Africa's Rand Posts Fifth Weekly Advance on Rate Premium", Bloomberg, 26 April 2008; "Rand Gains on Bets Carry-Trade Allure to Continue," Bloomberg, 9 November 2010; "Rand Weakens Versus Euro on Speculation ECB Rate Rise May Cut Carry Trade", Bloomberg, 4 April 2011.

[19] See for example " Manage the float", in the Financial Mail, 1 October 2010, p.37.

the carry trade would become more attractive.

We estimate rand-yen exchange rate volatility using the GARCH(1,1) model with a t-distribution for the error term (Bollerslev (1987)), to account for the excess kurtosis in the distribution of the exchange rate. Figure 4 below shows that peaks in exchange rate volatility coincide with sharp carry trade losses; and the period producing the largest and most persistent gains to the speculator (circa 2002-2003), is accompanied by a sharp decrease in exchange rate volatility.

Figure 4: Rand Carry Returns and Exchange Rate Volatility
*CARRY: rand target; VOL: rand-yen rate volatility*
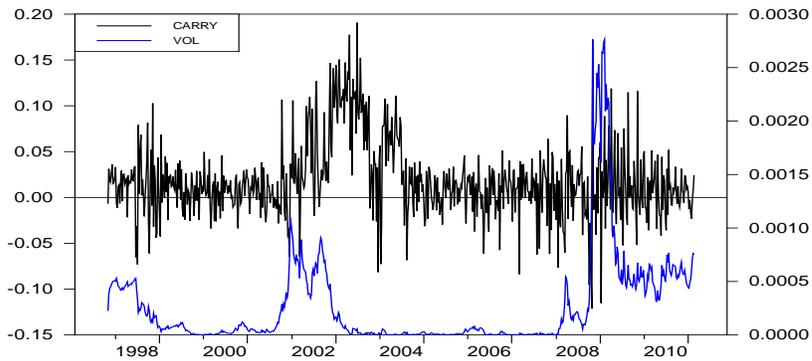


Nevertheless, heavy rand-targeting through the currency carry trade can cause periods of gradual appreciation, possibly beyond "fundamental" value, punctuated by irregular but fast and large depreciations - leading to medium to long-term volatility. The next sections explain how.

## 4.3 The carry trade and currency market instability

### 4.3.1 Up the stairs, down the elevator

Carry trade activity driving foreign exchange turnover and capital flows means the currency under-reacts to positive shocks to the interest differential in the short-run. As articulated in Brunnermeier, Nagel, and Pedersen (2009), in a world where traders face liquidity constraints, after an unanticipated increase in a currency's carry appeal (due to changes in the expected interest differential or global risk appetite), the currency will not immediately jump in response to the textbook fiction of instantaneous and unconstrained capital flows, and then depreciate to restore UIP. The reason is that keeping liquid capital in "standby" mode is costly for arbitrageurs in terms of foregone profitable opportunities. (See Mitchell, Pedersen, and Pulvino (2007), and Acharya, Shin, and Yorulmazer (2009)). Instead, capital moves gradually, so the currency can continue in an appreciating trend for a period, occasionally perturbed by depreciations as some participants withdraw to "cash-in". This appreciation adds to the return earned from the interest differential, attracting further targeting

or inflows (by carry as well as momentum traders), appreciating the currency further, possibly leading to currency over-valuation and/or a bubble.

Smart speculators will not necessarily reverse their positions and thus push the currency towards fundamentals even if they believe the currency is mispriced (here, overvalued), as long as they believe other traders will continue buying - the synchronization risk modeled in Abreu and Brunnermeier (2003), and the limits to arbitrage in markets for non-replicable securities (see Barberis and Thaler (2003), and Gromb and Vayanos (2010) for reviews). Hence, the appreciation and mispricing can persist for long, though unpredictable, periods of time.

In the absence of news on the target (or funding) currency's fundamentals, the situation is only reversed when an external shock occurs, or speculators hit funding constraints - e.g. during currency or/and financial crises, or other less extreme periods of market turbulence and increased risk aversion, usually reflected in the VIX index (implied volatility from US equity market options). When this occurs however, the carry trade reversal causes an abrupt, potentially large, and rapid depreciation of the target currency relative to the funding currency.[20] The same synchronization risk and limits to arbitrage may then keep the exchange rate under-valued for long periods of time.

The consequence is the "up the stairs, down in the elevator" pattern often observed in exchange rate dynamics, and formalized in Plantin and Shin (2011). This will be reflected by high volatility over medium to long horizons; but does not necessarily translate to more short-term volatility, as measured by the second moment of the distribution.[21]

Figure 5 shows the evolution of the value of the rand in terms of Japanese yen over our sample period. Of course that factors other than currency speculation affect exchange rate dynamics; but the "up the stairs, down the elevator" pattern is periodically clear through much of the sample, and especially over the first decade of the 21st century.

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[20]The limited availability of standby capital, which delays targeting high-interest currencies and causes appreciations to be gradual, does not restrict the unwinding of the trade. On the contrary, margin calls and fire sales in extreme cases, can accelerate reversals.

[21]Some high-frequency volatility may be tolerable, if it limits the rand's allure as a carry target, helping to keep it closer to its long-term fundamentals-driven path, and reducing the size of large depreciations when the carry trade is abruptly reversed. That is, high frequency of relatively small movements up and down in the exchange rate, may reduce the strength and frequency of more destabilizing episodes caused by rand-targeting, characterized by sustained, stable and steep appreciations, followed by rapid and aggressive depreciation

Figure 5: Rand-Yen Exchange Rate (Inverted Scale)

*RAND: Yen-value of South African rand*
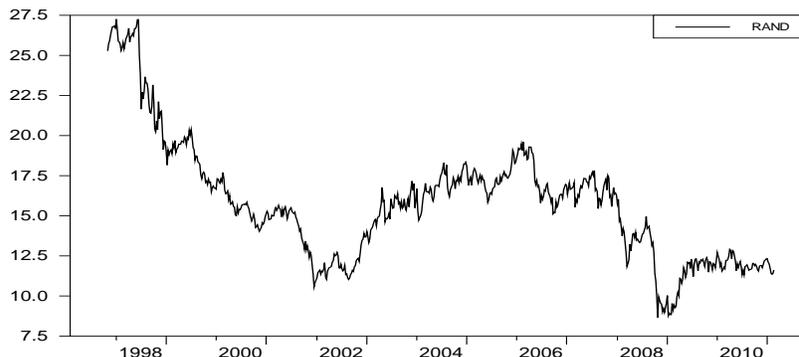


Abrupt reversals of large speculative positions can be destabilizing. The extent of such destabilizing events, and specifically the magnitude of sudden depreciations, will depend largely on the monetary policy reaction to overheating caused by large capital inflows driven by the carry trade.

### 4.3.2 Connection to monetary policy

If the inflows cause overheating, building inflationary pressure, an inflation-targeting central bank responds by increasing interest rates. This will increase the interest differential if funding currency rates remain unchanged, and attract further targeting and inflows, appreciating the currency further, creating a cycle. The depreciation, once the carry trade is reversed, will be larger, and the carry trade will be destabilizing - because of the central bank's inflation-targeting response, which would be complementary to speculators' actions.[22]

In a number of emerging market economies recently, large carry-related debt inflows have caused overheating and inflationary pressure. (IMF (2011).) The monetary authorities of these countries are forced to increase interest rates to prevent inflation; but in doing so, they further increase the attractiveness of their currencies as carry targets, attracting more capital inflows[23] – a tension between inflation-targeting and the maintenance of financial stability.

South Africa experienced large capital inflows in 2010, particularly in the fixed-income market. Yet, by early 2011 there were no signs of overheating: capital inflows reduced bond yields and therefore the cost of capital, but there was no marked increase in private sector investment; the additional liquidity was not followed by a marked increase in bank lending; the rate of change in house prices (which affect consumption through the wealth effect) started falling in mid 2010 and turned negative by February 2011; and the appreciation of the currency

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[22] See Plantin and Shin (2011) for a formal treatment.

[23] This reduces the effectiveness of measures introduced by the same countries to curb capital inflows.

helps to dampen inflationary pressures. (Marcus (2011), South African Reserve Bank (2011a, 2011b).) Hence, capital inflows have not led to overheating; and the South African Reserve Bank does not need to increase interest rates in order to subdue inflationary pressures due to (carry trade driven) capital inflows. (Recent threats to the inflationary outlook stem from international commodity prices, not capital inflows.)[24]

## 4.4 Remark on the cost of reserve accumulation

The stock of foreign exchange reserves held by the South African Reserve Bank, although low compared to other emerging markets with heavily traded currencies frequently under speculative attack (e.g., major Latin American and South East Asian economies), has increased steadily over the last decade, from a precarious level of 7.5 billion US dollars in January 2000, to 47 billion by February 2011. The pace of reserve accumulation increased markedly in the more recent period, with an increase of approximately 20 percent in the twelve months to February 2011. (See SARB (2011b).)

When accumulating reserves of safe haven currencies, the Reserve Bank is buying low-yielding currencies. For sterilized interventions, this investment is financed through the issue of high-interest South African securities - exactly the opposite of targeting the rand in a carry trade funded by the reserve currency. That is, the returns to speculators from targeting the rand through the carry trade are proportional to, and correlated with, the costs to the Reserve Bank from accumulating reserves of low-interest currencies. In periods of high returns to currency speculation, the costs of reserve accumulation will be correspondingly high. Financial instruments which synthesize carry trade payoffs may permit a reduction in the cost of reserve accumulation, and/or smoothing oscillations in the Bank's balance sheet.

## 5 Conclusion

Academic research has documented the empirical failure of UIP, which is the source of carry trade profits, since Hansen and Hodrick (1980) and Fama (1984); yet the excess returns from this simple currency speculation strategy have increased over the last three decades (Lustig and Verdelhan (2009)). Carry trade returns drive a non-trivial part of international capital flows and foreign exchange market transactions. Understanding carry trade returns is therefore important for understanding exchange rate behavior - particularly of very high, and very low interest rate currencies. The South African rand is a high interest-rate currency. The returns from targeting the rand (and other indirect evidence) are consistent with a significant portion of foreign exchange turnover and fixed-income speculative flows to South Africa being driven by the carry trade; and

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[24]Indeed, the reversal of the carry trade can be more inflationary than the rand-targeting inflows due to the pass-through from the depreciated exchange rate to domestic prices. (See Aron, Farrell, Muellbauer, and Sinclair (2010).)

with the weight of speculative non-resident initiated transactions in the foreign exchange market. Large speculative positions affect exchange rate dynamics; and are affected by changes in the interest-rate differential. Thus, the interaction between inflation-targeting interest-rate setting, and speculators' actions, is an important determinant of exchange rate behavior, and can influence the maintenance of macro-financial stability.

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# 7 Appendix

## 7.1 Appendix A: Data mnemonics and bid-ask spreads

**Table A1. Data menemonics for weekly data from Datastream**

| Currency | Spot | Forward | Sample period |
|---|---|---|---|
| Australian dollar | BBAUDSP | BBAUD1F | 07/04/1997-21/02/2011 |
| Euro | BBEURSP | BBEUR1F | 07/04/1997-21/02/2011 |
| Japanese yen | BBJPYSP | BBJPY1F | 07/04/1997-21/02/2011 |
| New Zealand dollar | BBNZDSP | BBNZD1F | 07/04/1997-21/02/2011 |
| South African rand | BBZARSP | BBZAR1F | 07/04/1997-21/02/2011 |

Notes. Suffixes (EB), (EO), and (ER) added to exchange rate mnemonics give bid, ask (offer), and mid (average) quotes, respectively. Dates are in the form dd/mm/yyyy. Mnemonic for the South African All Share Index (ALSI) is JSEOVER~R.
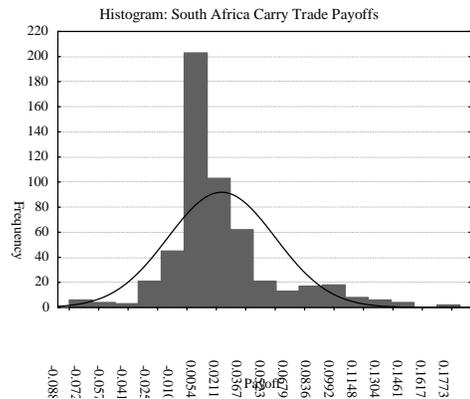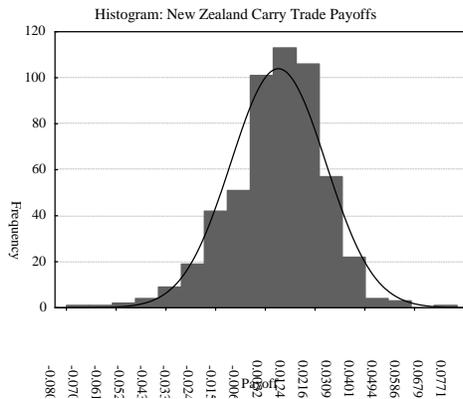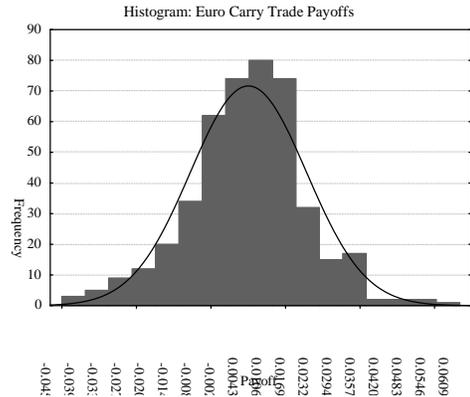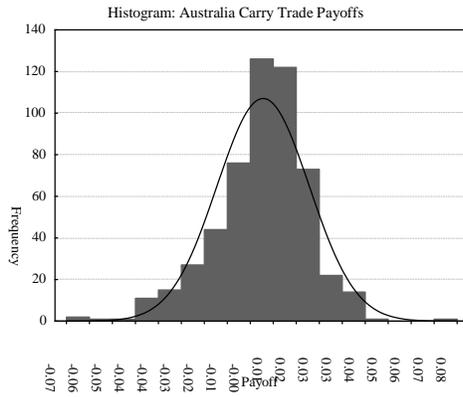
**Table A2. Median bid-ask spreads**

| Currency | $100 \times \ln(Ask/Bid)$ | | Foreign currency units | | Units |
| --- | --- | --- | --- | --- | --- |
| | Spot | Forward | Spot | Forward | |
| Australian dollar | 0.0929 | 0.1398 | 0.17 | 0.2 | Cents |
| Euro | 0.0390 | 0.0554 | 0.03 | 0.05 | Cents |
| Japanese yen | 0.0554 | 0.0950 | 0.06 | 0.11 | Yen |
| New Zealand dollar | 0.1316 | 0.1743 | 0.24 | 0.31 | Cents |
| South African rand | 0.6581 | 0.8029 | 5 | 5.2 | Cents |

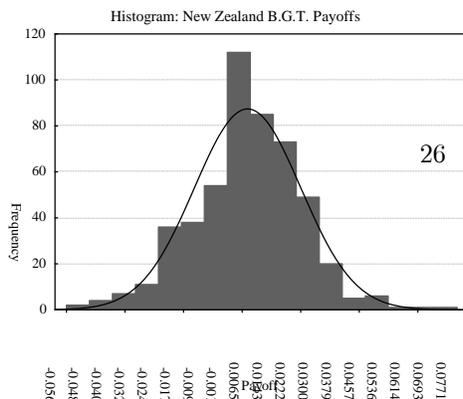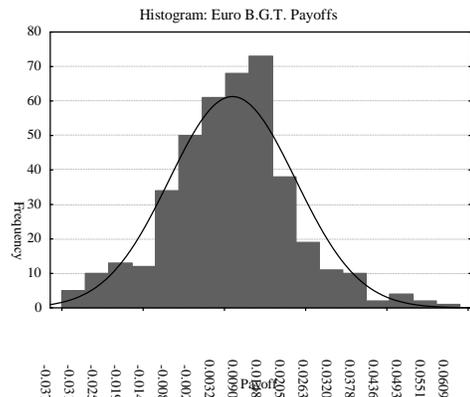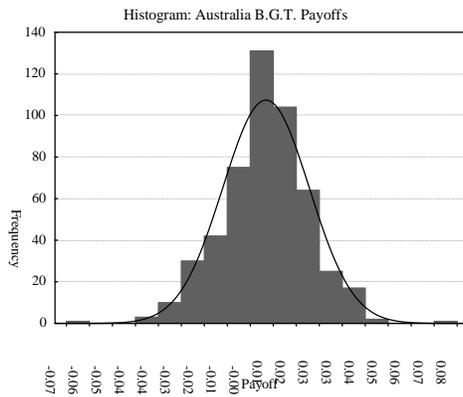Forward denotes the one-month forward exchange rate

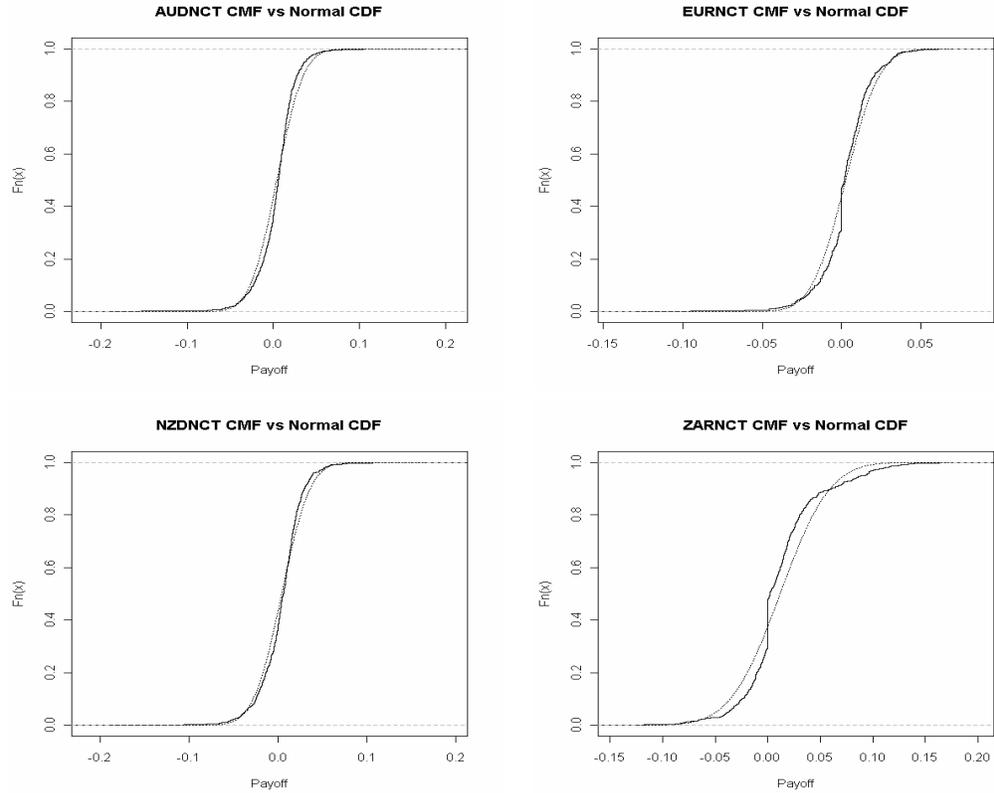## 7.2 Appendix B: Histograms, cumulative mass functions,

# and QQ plots

## B.1. Histograms: Naïve carry trade payoffs


Histogram: Australia Carry Trade Payoffs


Histogram: Euro Carry Trade Payoffs


Histogram: New Zealand Carry Trade Payoffs


Histogram: South Africa Carry Trade Payoffs

## B.2. Histograms: BGT regression strategy payoffs


Histogram: Australia B.G.T. Payoffs


Histogram: Euro B.G.T. Payoffs


Histogram: New Zealand B.G.T. Payoffs

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Histogram: South Africa B.G.T. Payoffs
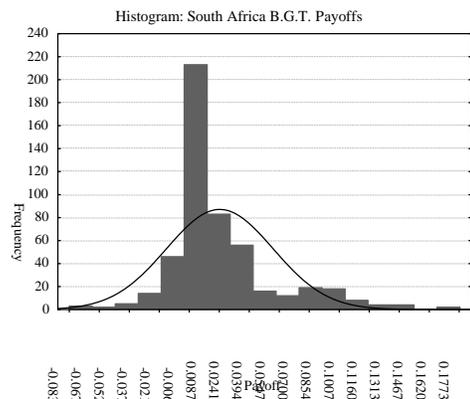
## C.1. Cumulative mass functions: naïve carry trade payoffs



**AUDNCT CMF vs Normal CDF**

**EURNCT CMF vs Normal CDF**

**NZDNCT CMF vs Normal CDF**

**ZARNCT CMF vs Normal CDF**

## C.2. Cumulative mass functions: BGT regression strategy payoffs



**AUDBGT CMF vs Normal CDF**

**EURBGT CMF vs Normal CDF**

**NZDBGT CMF vs Normal CDF**

**ZARBGT CMF vs Normal CDF**

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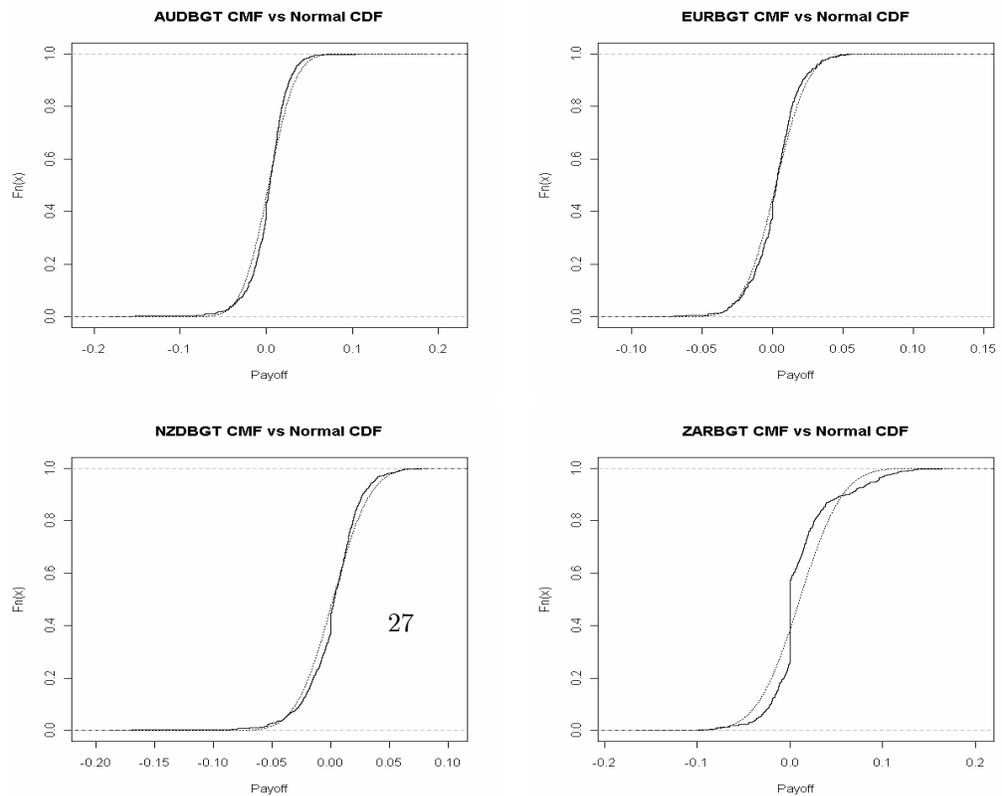
## D.1. Q-Q Plots: Naïve carry trade payoffs



**Q-Q Plot: AUDNCT**

**Q-Q Plot: EURNCT**

**Q-Q Plot: NZDNCT**

**Q-Q Plot: ZARNCT**
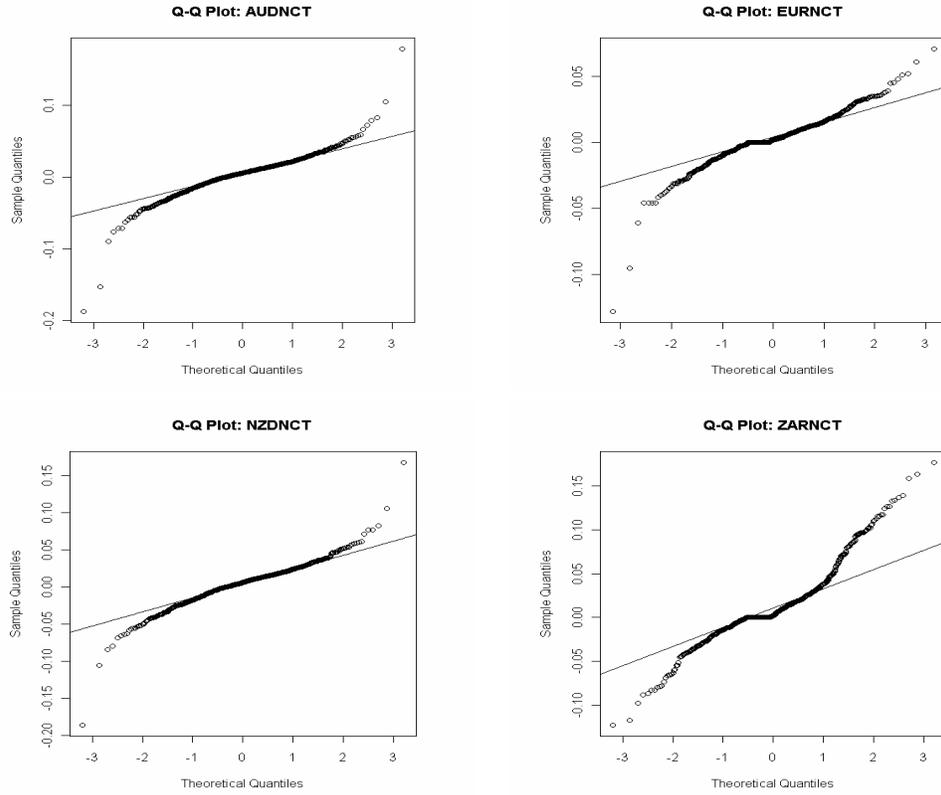
## D.2. Q-Q Plots: BGT regression strategy payoffs



**Q-Q Plot: AUDBGT**

**Q-Q Plot: EURBGT**

**Q-Q Plot: NZDBGT**

**Q-Q Plot: ZARBGT**

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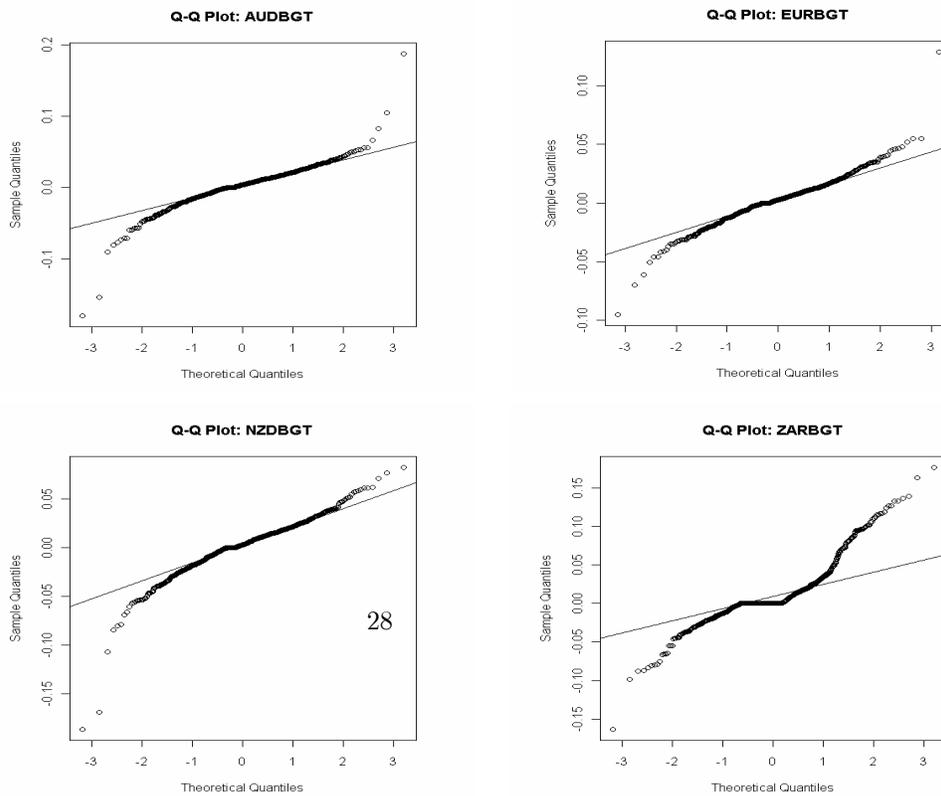
Q-Q Plots not falling on the (normal) straight line indicate a non-normal distribution