Risk and return in carry trade

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A consequence of the failure of uncovered interest parity (UIP) is that profit can be made by going short on a low-interest currency (the funding currency) and long on a high-interest currency (the target currency). This is because the failure of UIP means that the target currency does not depreciate against the funding currency by a percentage that wipes out the interest rate differential. If this does not happen, positive return will be produced, and this is why Gyntelberg and Remolona (2007) describe carry trade as "essentially a bet against UIP"[1].

On the profitability of carry trade, Burnside et al. (2006) conclude that although the operation produces very large Sharpe ratios (because of the substantial failure of UIP), the amount of money produced is rather small because of transaction costs and price pressure limits. They point out that the high Sharpe ratios cannot be interpreted as compensating market participants for bearing risk because the payoff is uncorrelated with the traditional risk factors. They find that carry trade produces higher Sharpe ratios than the Standard and Poor's 500 index even after taking into account transaction costs. However, they point out that the payoff, in terms of the sums of money obtainable from carry trade, is relatively small.

In their study of the profitability of carry trade, Gyntelberg and Romolona (2007) use the yen and Swiss franc as funding currencies, pointing out that carry trade is pursued when the interest differential is wide enough to compensate traders for the underlying foreign exchange risk. They find evidence supporting the view that downside risk is an important feature of carry trade and that using measures of downside risk (as opposed to the standard deviation) reduces the Sharpe ratio, though it remains higher than those obtainable from stock markets. Like Gyntelberg and Romolona (2007), Hottori and Shin (2007) find evidence indicating that volumes of carry trade involving the yen are high when interest differential against the yen are high. The objective of this paper is to assess the risk and return in carry trade by using two low-interest funding currencies (Japanese yen, JPY, and Swiss franc, CHF) and three high-interest target currencies (U.S. dollar, USD, British pound, GBP, and Canadian dollar, CAD). Several measures of return and risk are used for this purpose.

Measures of return and risk

Let i_x and i_y be the interest rates on currencies x and y respectively, such that $i_x < i_y$. Also, let S be the spot exchange rate between the two currencies measured as the x price of one unit of y, which means that a rise in S implies appreciation of y, and vice versa. If at time t-1, short and long positions are taken on x and y respectively, the return on this operation (realized at t) is given by $\pi_t = (i_{y,t-1} - i_{x,t-1}) + \hat{S}_t$ (1), where the term in parentheses is the interest rate differential at time t-1 and $\hat{S}_t$ is the percentage change in the exchange rate between t-1 and t. Note that uncovered interest parity implies that $(i_{x,t-1} - i_{y,t-1}) = \hat{S}_t$, which means that $\pi_t = 0$. It also implies that the low-interest currency appreciates against the high-interest currency. This means that $\hat{S}_t < 0$ when $(i_{y,t-1} - i_{x,t-1}) > 0$. Profit will be made on carry trade if $\hat{S}_t > 0$ or $\hat{S}_t < 0$, provided that $|\hat{S}_t| < (i_{y,t-1} - i_{x,t-1})$. Loss will be made if $\hat{S}_t < 0$ such that $|\hat{S}_t| > (i_{y,t-1} - i_{x,t-1})$.[2]

Several measures of return and risk will be reported. For a sample size n, where t = 1,⋯,n, the mean value of the return is given by $\bar{\pi}_t = 1/n\ \Sigma_{t=1\to n}\ \pi_t$ (2). The cumulative return is calculated as the total return over the sample period obtained by compounding an initial amount of one unit at π_t. Thus, the cumulative return is calculated as $CR = [\Pi_{t=1\to n}(1+ \pi_t)] - 1$ (3). The average compound rate is defined as the constant annual rate that gives the value (1+CR) at the end of the sample period when it is used to compound a principal of one unit. Hence, it is calculated as $AACR = [\Pi_{t=1\to n}(1+ \pi_t)]^{4/n} - 1$ (4).

Measures of risk include the standard deviation of the rate of return, its downside semi standard deviation, and value at risk (VaR). The standard deviation and downside semi standard deviation are calculated as $SD = \sqrt{[1/(n-1)\ \Sigma_{t=1\to n}\ (\pi_t - \bar{\pi})^2]}$ (5). $DSSSD = \sqrt{[1/(n-1)\ \Sigma_{t=1\to n}\ (x_t - \bar{\pi})^2]}$ (6), where $x_t = \pi_t$ when $\pi_t < 0$ and $x_t = 0$ otherwise. The value at risk is calculated as the percentile of the empirical distribution of the rate of return

1 In a survey of 75 published estimates, Froot and Thaler (1990) report few cases where the sign of the coefficient on interest rate differential is consistent with UIP. Flood and Rose (2002) argue that "a strong consensus has developed in the literature that UIP works poorly." Gyntelberg and Remolona (2007) argue that "in a world of risk, UIP is almost certainly false." However, it is important to note at the outset that the violation of UIP does not necessarily imply profitable carry trade, as we are going to see later.

2 Note that the condition $|\hat{S}_t| > (i_{y,t-1} - i_{x,t-1})$ implies that UIP does not hold, which means that the violation of UIP does not necessarily imply profitable carry trade, as it is often suggested in the literature.

corresponding to a prespecified confidence level, thus avoiding the assumption of normality as required by the parametric approach to value at risk.

The Sharpe ratio is used to measure the risk-adjusted return on carry trade. Following Burnside et al. (2006) and Gyntelberg and Remolona (2007), the Sharpe ratio is calculated as the ratio of the mean to the standard deviation of the rate of return, which gives SR = $\overline{\pi}/[SD(\pi_t)$ (7).

It is noteworthy that this definition of the Sharpe ratio is different from that used in portfolio performance evaluation, which is the ratio of the mean excess return to the standard deviation of total return. The problem with this definition in this case is the choice of the risk-free rate, as two rates are associated with each currency pair[3]. Furthermore, using the definition suggested by Burnside et al. (2006) and Gyntelberg and Remolona (2007) facilitates the comparison of the results obtained in this paper with their results. All of the measures of risk and return will be calculated for six currency combinations in the following section.

Data and empirical results

Measures of risk and return are calculated using quarterly historical data covering the period 1995:4-2006:4. Six currency combinations are used: JPY/USD, JPY/GBP, JPY/CAD, CHF/USD, CHF/GBP, and CHF/CAD. Thus the data sample covers the six underlying spot exchange rates at the end of the period and the three-month interest rates on the four currencies[4]. The (annualized) rate of return on carry trade is calculated for 44 quarters starting at 1996:1 and ending at 2006:4.

Figure 1 reports measures of risk and return in carry trade. To start with, the figure reports the mean interest rate differential over the sample period, showing that the highest differential is offered by the JPY/GBP combination. Then it shows the percentage of positive changes in the exchange rate, which is a sufficient condition for the profitability of carry trade (since the interest differential is always positive). It also implies the violation of UIP, since a positive change in the exchange rate means appreciation of the target currency. On balance, there seems to be a fifty-fifty chance of positive changes in exchange rates. Since carry trade can be profitable even with a negative change in the exchange rate, provided that the change is not greater than the interest rate differential, it follows that the frequency of positive returns must be higher than the frequency of positive changes in the exchange rate. Indeed, the results show that the frequency of positive returns can be 10% higher than the frequency of positive changes in the exchange rate. This leaves quite a hefty percentage of negative rates of return, implying that high risk is involved in carry trade.

Figure 1 also shows that the annualized rate of return ranges between 3.40% and 9.04% compared with 2.40%-12.49% for Gyntelberg and Remolona (2007) and 1.32%-6.48% for Burnside et al. (2006)[5]. All measures of return show that the JPY/GBP combination, which produces the highest interest

	JPY/USD	JPY/GBP	JPY/CAD	CHF/USD	CHF/GBP	CHF/CAD
Mean interest differential	3.84	5.05	3.62	2.55	3.75	2.37
Positive change in exchange rate (%)	61.40	59.09	61.36	50.00	52.27	52.27
Positive return (%)	70.45	70.45	70.45	56.81	70.45	56.81
Mean annualized return	5.61	9.04	7.03	3.40	6.63	4.83
Cumulative return	75.26	154.93	103.97	37.41	100.10	59.84
Average annual compound rate	5.23	8.87	6.65	2.93	6.50	4.36
Standard deviation	19.65	19.16	19.96	20.21	15.21	21.18
Downside semi standard deviation	15.87	16.61	16.46	14.85	11.02	16.75
99% Value at risk	42.66	39.98	46.19	34.71	19.37	39.48
95% Value at risk	23.65	18.49	27.15	32.01	15.25	24.18
Sharpe ratio	0.29	0.47	0.35	0.17	0.43	0.23

Figure 1 – Measures of return and risk

3 It is possible in this case to calculate the Sharpe ratio from two different perspectives corresponding to the high and low interest rates.

4 The data were obtained from the DX database.

5 Differences in the results are due to the use of different currency pairs and different time periods.

rate differential, is the most profitable. This combination produces an average annualized return of 9.04 and an average annual compound rate of 8.87. The combination that produces the lowest return is CHF/USD, but this is not the combination offering the lowest interest differential. Thus, there is no strict one-to-one correspondence between the interest rate differential and the profitability of carry trade. Figure 2 displays the period-by-period annualized rate of return on carry trade, showing that changes in exchange rates can be so dramatic that negative returns in excess of 40% may be produced. Although carry trade can be highly profitable over a long period of time, significant losses can be incurred on a single occasion. A significant loss could put a carry trader out of business, so that there is no scope for benefiting from the long-run profitability of carry trade.

Measures of risk and return are combined by calculating the Sharpe ratio. To put the results into perspective, we compare them with what is produced by the Dow Jones Industrial Average using quarterly observations over the same time period, which produces a mean return of 9.23% with a standard deviation of 33.42, giving a Sharpe ratio of 0.28. Figure 3 displays measures of risk and return from carry trade compared with those obtained from the Dow Jones. It is shown that over the same time period, the DJIA produced both higher risk and higher return than carry trade. In terms of the Sharpe ratio, the Dow Jones produces a Sharpe ratio that is higher than what is produced by carry trade using two currency combinations and lower than carry trade based on the other four combinations. These results are close to those of Burnside et al. (2006), showing that carry trade does not always outperform stock market investment. This is not so for the results of Gyntelberg and Remolona (2007), which show that irrespective of the measure of risk and stock price index, carry trade is always superior to stock market investment.

Figure 4 displays radar charts relating the interest rate differential to the mean return, standard deviation, and Sharpe ratio. Close correspondence would be indicated by closeness of the shapes describing the two underlying variables. For example, the upper part of the figure shows similar shapes, hence indicating close (though not perfect) correspondence

Figure 2 – Return on carry trade

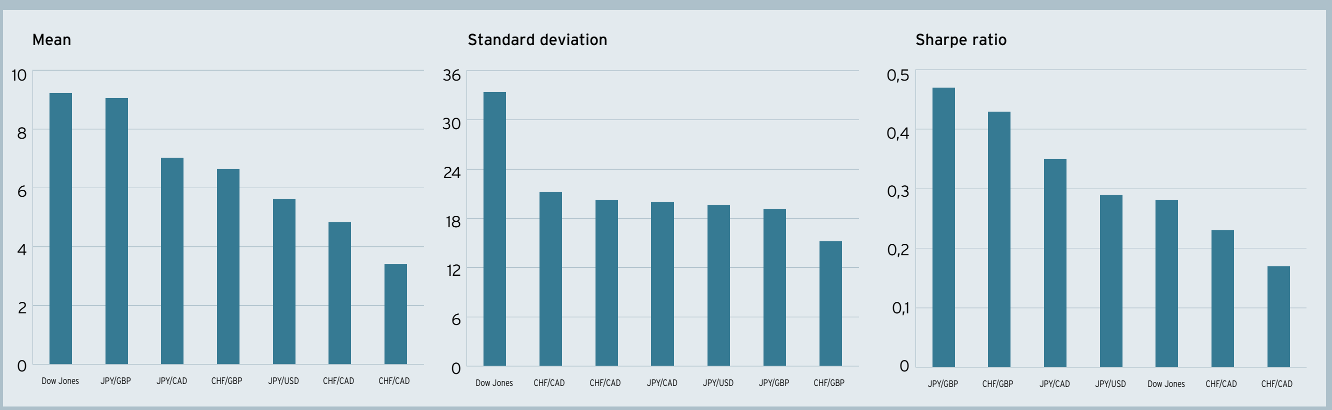

Figure 3 – Measures of risk and return (carry trade versus Dow Jones)

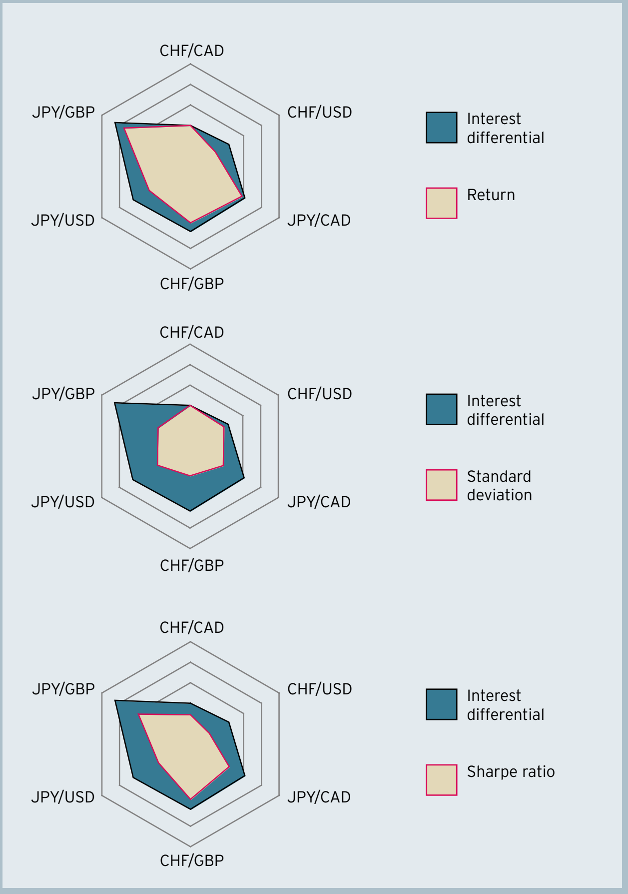

Figure 4 – Measures of risk and return against the interest rate differential

between the interest rate differential and the mean return on carry trade. Notice, however, the dissimilarity of the shapes representing the interest differential and standard deviation. This means that higher risk, as measured by the standard deviation, is not matched by higher return. The absence of the risk-return trade off in the traditional sense can be attributed to the complexity of the relationship between the interest rate differential and exchange rate volatility. The lower part of the figure shows how the interest differential and Sharpe ratio are related. The correspondence is close but not as close as that between the interest rate differential and the mean return.

Monte Carlo simulations

The last exercise to be conducted in this study involves the performance of Monte Carlo simulations on the rate of return on carry trade just to confirm, or otherwise, that the results reported so far are not due to chance resulting from small sample bias. For this purpose, distributions are fitted to the interest rate differentials and percentage changes in exchange rates to obtain a distribution for the rate of return. Since it appears that there is no relationship between the interest rate differential and the percentage change in exchange rate, we will assume that the two processes are independent and embody this assumption in the simulation exercise, which involves 100,000 iterations[6].

6 We have seen from the previous results that given a positive interest rate differential the exchange rate between the two underlying currencies is as likely to rise as it is to fall. Allowing for dependence between the two variables is not a big deal, but there is no compelling reason in this case to assume anything but the independence of the two variables.

Figure 5 reports the fitted distributions using the Kolmogorov-Smirnov test to pick the most appropriate distribution out of a list of over 15 possible (continuous) distributions. The figure also reports the parameters defining the fitted distributions, which are calibrated by using the estimated values of return shown in Figure 2. As we can see, in no case is the return normally distributed, which is not surprising[7]. In most cases, the rate of return follows a distribution that is similar to the distribution followed by the percentage change in the exchange rate, which is the source of risk in carry trade.

Figure 6 reports the results of Monte Carlo simulations using the fitted distributions. The certainty level is basically the frequency of positive return or the probability that a positive rate of return will be produced by any single carry trade operation for the underlying currency pair. These certainty levels can be too low for comfort. All measures of dispersion are high, showing that significant risk is associated with carry trade. Most of the distributions have positive (excess) kurtosis, thus heavier tails than under a normal distribution, but skewness is negligible[8]. Apart from the Sharpe ratio associated with the JPY/USD combination, all Sharpe ratios are very close, if not equal to, those calculated from actual data.

Currency Combination	Distribution	Parameters* 1	2	3	4
JPY/USD					
Interest differential	Min Extreme	4.64	1.35		
Exchange rate	Logistic	2.61	10.72		
JPY/GBP					
Interest differential	Logistic	5.01	0.55		
Exchange rate	Weibull	230.70	243.02	15	
JPY/CAD					
Interest differential	Beta	2.05	5.72	0.85	1.14
Exchange rate	Min Extreme	12.48	15.69		
CHF/USD					
Interest differential	Beta	0.41	4.08	0.42	0.30
Exchange rate	Normal	0.84	19.64		
CHF/GBP					
Interest differential	Logistic	3.70	0.59		
Exchange rate	Logistic	2.13	7.93		
CHF/CAD					
Interest differential	Logistic	2.32	0.47		
Exchange rate	Beta	47.10	47.51	2.19	1.99

* The parameters are as follows: min extreme (likeliest, scale), logistic (mean, scale), Weibull (location, scale, shape), beta (min, max, alpha, beta), and normal (mean, standard deviation).

Figure 5 – Fitted distributions

	JPY/USD	JPY/GBP	JPY/CAD	CHF/USD	CHF/GBP	CHF/CAD
Certainty level (%)	64.6	71.6	70.03	56.7	67.6	58.6
Mean	6.61	8.87	7.12	3.35	5.83	4.90
Median	6.59	11.38	10.43	3.34	5.84	5.28
Std Dev	19.49	19.31	20.13	19.74	14.36	20.75
Minimum	-110.48	-128.85	-152.92	-85.11	-106.22	-45.89
Maximum	131.06	60.73	53.96	82.35	118.43	51.20
Range	242.1	189.58	206.89	167.46	224.65	97.09
Skewness	0.03	-0.79	-1.13	0.01	-0.01	-0.07
Kurtosis	4.15	4.01	5.29	2.99	4.25	2.18
Mean standard error	0.06	0.06	0.06	0.06	0.05	0.07
40% Percentile	2.13	6.55	5.62	-1.70	2.63	-0.87
50% Percentile	6.59	11.38	10.43	3.34	5.84	5.28
60% Percentile	10.93	15.82	14.76	8.36	9.08	11.36
Sharpe Ratio	0.34	0.46	0.36	0.17	0.41	0.23

Figure 6 – Results of Monte Carlo simulations of carry trade returns (100,000 Iterations)

Concluding remarks

By using six currency combinations involving two funding currencies and three target currencies, analysis of historical data from the recent past and Monte Carlo simulations show that carry trade can be profitable if conducted over a long period of time, but the risk involved can be high. The risk-return trade off does not exist in the rational sense (a high interest differential is not necessarily associated with a high volatility of interest rates, and vice versa), since there is no clear-cut relationship between the interest rate differential and the movement of exchange rate. With a positive interest rate differential the exchange rate is as likely to rise as to fall, thus a positive differential (no matter how big) is no guarantee of positive return. A significant adverse movement in the exchange rate could wipe out the carry trader on a single occasion.

The results show that carry trade may or may not outperform stock market investment, but on average the former seems to fare better than the latter. However, there are caveats that must be taken into account when one attempts

7 Gyntelberg and Remolona (2007) found that "carry trade returns are not normally distributed".

8 Gyntelberg and Remolona (2007) found positive kurtosis and negative skewness in their distributions.

to reach a conclusion of this sort. To start with, the rates of return on carry trade reported in this study may be overestimated because the bid-offer spreads are overlooked, as the reported mid-rates are used. In reality carry traders have to contend with the bid-offer spreads in interest and exchange rates, which means that they borrow at the higher offer interest rates, lend at the lower bid interest rates, buy currencies at the higher offered exchange rates and sell currencies at the lower bid exchange rates. Using bid and offer rates, rather than the mid-rates used in this exercise, would produce lower rates of return than those reported in Figure 1.[9]

Other caveats pertain to two points raised by Burnside et al. (2006). The first point is that although the Sharpe ratios associated with carry trade may look high, the amount of money that can be made out of this operation is relatively small. On the basis of their results, they find that to generate an average annual pay off of one million pounds, the speculator must bet 28.6 million pounds every month. In general, very large sums of money are needed to generate profit of reasonable magnitude, which limits the usefulness of carry trade for individual investors, who are typically unable to raise this kind of money. In the aftermath of the subprime crisis, not even most institutional investors can raise this kind of money. What makes things even worse is that the bid-offer spreads are increasing functions of order size, which means that the rate of return on carry trade declines as the transaction size increases. A factor with a similar effect is price pressure, which drives a wedge between average and marginal Sharpe ratios. This means that as the transaction size increases, the marginal Sharpe ratio declines towards zero, although the average Sharpe ratio remains positive. Big transactions are needed to earn more money from carry trade, but the rate of return declines as the transaction size increases because of the bid-offer spreads and price pressure.

Another problem with carry trade is that, unlike stock market investment, high Sharpe ratios do not necessarily represent compensation for risk because the payoff is not associated with standard risk factors. If we consider the interest rate differential as the source of return and the volatility of the exchange rate as the source of risk, then (as we have seen) the risk-return trade off in a traditional sense disappears. Finally, we must not forget that returns on stock market investments do not only come from capital appreciation (rising stock prices) but also from dividends, which are ignored in this exercise.

Carry trade has become very popular because of the perceived profitability of the operation. However, it seems that carry traders have been oblivious to the risk inherent in such an operation while concentrating on the interest rate differential. Excessive enthusiasm about carry trade has been a reflection of herd behavior, similar to what happens in any market bubble (although carry trade is not necessarily associated with a bubble). However, it seems that taste is changing away from carry trade, as reports surface about large-scale unwinding of carry trade positions by institutional and individual investors. If Dennis (2007) is correct in saying that "carry trade falls out of favour," then it is likely that a lot of people have realized, in hindsight, that carry trade is not as lucrative as it once appeared to be.

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9 It is sometimes suggested that the bid-offer spreads are so small that it is reasonable to ignore them. However, Burnside et al. (2006) argue that the bid-offer spreads are of the same order of magnitude as the pay off associated with two-currency speculation strategies. This means that for a currency speculator, the bid-offer spreads are indeed large.