AN EMPIRICAL STUDY OF CURRENCY CARRY TRADE STRATEGIES

By

Kalman G. Szabo

Submitted to Central European University Department of Economics

In partial fulfilment of the requirements for the degree of Master of Economics

Supervisor: Professor Peter Kondor

Budapest, Hungary 2011

Abstract

This study examines the risk-return trade-off in currency carry trade positions. I calculate the dependence of two different risk measures, skewness and the probability of a bigger than 10% loss on a set of variables, including the previous period return and find that high returns in carry trades induce the crash risk to grow in the next period. Crash risk is the price investors of carry positions have to pay for the high expected excess returns. Estimations were carried out on the entire sample as well as a sub-sample and I found that results tend to vary significantly depending on the used time periods.

Acknowledgments

I am thankful to my supervisor, Professor Péter Kondor, for his invaluable support,

suggestions and comments during the process of writing this study.

Special thanks to my parents for their help and unshakeable belief in me.

Table of Contents

INTRODUCTION AND LITERATURE REVIEW 2
MONETARY POLICY IMPLICATIONS
DATA DESCRIPTION
METHODOLOGY
EMPIRICAL RESULTS
CONCLUSION
APPENDIX
BIBLIOGRAPHY

Introduction and Literature review

The carry of an asset is the benefit one receives (if it is positive) or the cost one incurs (if it is negative) by holding it for a period of time. One can think of commodities where the holder of the asset incurs the cost of storage (grain silo rent, bank vault rent for gold bullion, etc.). We have positive carry in case of currency pairs if we take long position in the currency with the higher interest rate (investment currency) and a corresponding amount of short position in the currency with the lower interest rate (funding currency). This is not a case of arbitrage: arbitrage means risk-less profit but in the case of carry trade the trader only achieves profit if the market does not move against the carry position. Interest rates might change for the two currencies involved and exchange rate changes might turn an initially profitable position into a losing one.

Positive carry profits seem attractive, however our economics intuition tells us that there is no free lunch. Therefore we assume that in case of positive carry, profits from the carry position should be offset by a corresponding loss due to an adverse change in the exchange rates. This hypothesis is called the uncovered interest rate parity (UIP) assumption. This logic behind the UIP assumption is appealing, however empirically we see quite the opposite happening: the investment currency even tends to appreciate compared to the funding currency (Burnside et al (2006, 2007)). The violation of the UIP is considered to be a foreign exchange market anomaly and is referred to as the "forward premium puzzle". This is exactly the phenomenon that makes carry trade remarkably profitable: there is a consensus in the literature that the carry trade strategy yields high average payoffs as well as Sharpe ratios that are significantly higher than those of equity investments in the U.S. stock market (Burnside, Eichenbaum, Kleshchelski, Rebelo (2011)). Because of its importance, both practical and theoretical it is one of the most thoroughly researched areas in finance. While the practical importance is obvious, there is significant amount of money left on the table, the theoretical importance is more elusive, albeit similarly important: if we can not find a rational explanation to the violation of the UIP we should drop the Efficient Market Hypothesis altogether.

Monetary Policy Implications

Research interest is due partly to the profit opportunities inherent in carry positions but also due to its monetary policy implications. If higher interest rates fuel the build-up of carry positions then it is questionable that raising interest rates can be of any help to prevent an economy from overheating since higher interest rate differentials would lure more speculative capital into the asset markets of the economy and thus further exacerbate the situation (Moutot and Vitale (2009)). One such example, the case of Colombia was mentioned by Kamil (2008, pp. 6-7.):

Foreign investors, realizing that the central bank would eventually focus on taming inflation (and eventually let the exchange rate appreciate), took unprecedented amounts of leveraged bets against the central bank (and the dollar) in the derivatives market—thereby limiting the effectiveness of intervention. Paradoxically, then, the BdR's [Banco de la República, Central Bank of Colombia] perceived strong commitment to inflation actually undermined its ability to influence the exchange rate.

Instead, monetary policy should rather aim to control or credibly threat to control the flow of speculative capital as this is more effective in restoring a stable exchange rate (Plantin and Shin (2011)).

Some however, including Milton Friedman (1953) argue, however that capital flows driven by speculative activity may actually have stabilizing effect on the economy, saying that arbitrageurs, expecting a reversal in the trend of prices will take positions to exploit it and thus force the prices to return to the level that their fundamentals would suggest. Plantin and Shin (2011) develop a model which is fixed to economic fundamentals in the long-run but allow short-term fluctuations in exchange rates due to speculative dynamics. Their model explains both the stabilizing and the destabilizing effect of speculative carry trade activity. The latter is explained by a coordination game among speculative investors: as more investors engage in the carry trade the more its attractiveness increases. Plantin and Shin (2011) show that under the right conditions the reflexive relationship between the monetary policy and carry trade activity can induce a boom-bust cycle which can result in a currency crisis.

As an extreme example they mention Iceland where this happened recently (2008). The most important part of the reflexive mechanism was that the large difference in interest rates between the Icelandic Krona and the Japanese Yen (the single most important funding currency throughout the 2000's) fuelled capital inflows via the banking sector and so-called glacier bonds (Jonsson, p. 70) which caused a housing boom. The rise of housing prices caused a subsequent rise in the Consumer Price Index and thus a strong inflation pressure. Such way the link between the carry trade activity and the resulting inflation was direct. The situation only got worse when the Central Bank started raising interest rates and everything was set for a disaster.

However Iceland is undoubtedly the most extreme example of the destabilizing effects of currency carry trade recently, the case is far from unique. As a matter of fact, carry trades have become so commonplace in the previous decade that numerous tradable benchmarks (indices) and structured foreign exchange (FX) derivative products were introduced based on carry trade positions. These benchmarks consist of a long position in one or more highyielding and corresponding short position in one or more low-yielding currencies. The structured FX derivative products are even more interesting: they are called collateralized foreign exchange obligations (CFXO), which are collateralized debt obligations based on the cash flow from the underlying carry trades (Merrill Lynch (2007)). Investors are paid in the order of their seniority, with the most senior trenches getting paid out first while the most junior trenches the last – much like in the case of Collateralized Debt Obligations.

Possible Solutions of the "Forward Premium Puzzle"

Despite the large number of independent research carried out the consensus over the possible reasons of the violation of the UIP is still not full. One explanation says that carry trade itself weakens the currency that is borrowed, since investors sell the borrowed currency by converting it to other currencies. As mentioned above carry trade investments yield significantly higher Sharpe ratios than U.S. equity investments and as Burnside, Eichenbaum, Kleshchelski and Rebelo (2011) show, this can not be explained by linear stochastic discount factors built from conventional measures of risk. Other authors (Bekaert and Hodrick (1992) and Backus, Foresi, and Telmer (2001)) also conclude that we can reject consumption-based asset-pricing models for currency exchange rate data. Other scholars argue that the predictable average profits from carry positions are some sort of a compensation for the significant negative skewness of exchange rate returns. Skewness is a measure of asymmetry, the size of the third standardized moment. Negative skewness means that the probability distribution of exchange rate returns have a longer left tail, which means that large negative returns are more likely than positive returns of the same size. This is the reason why skewness is used as a measure for crash risk.

This finding is in agreement with the popular saying among foreign exchange traders: "exchange rates go up by the stairs and down by the elevator" (Breedon (2001)). By this they mean that due to the slower build-up process of carry positions investment currencies appreciate slowly compared to funding currencies while they drop significantly over short periods of time due to the fast unwinding of these positions (IMF (1998), Béranger et al (1999), Cairns et al (2007)). The unwinding of these positions does not necessarily occur because carry positions are not profitable any more but usually because of an increase in risk factors (Roubini (2009)) and the ensuing tighter margin requirements. There are several possible reasons for it including a sudden increase in market uncertainty, interest rate changes, political turmoil, liquidity crises, change in margin requirements, etc. The importance of changes in margin requirements is not to be underestimated since carry positions are usually taken using high leverage. As a side note, we should also mention that the profitability of carry trade is highly dependent on the leverage used (Darvas (2008)). As Darvas (2008) showed, for a diversified portfolio of currency pairs leverage initially increases the annualized returns but then as the leverage gets higher the risk of going bankrupt gradually kicks in and we encounter serious losses. Also, he finds that the initially high Sharpe ratio declines gradually as the leverage is increased. This might be an explanation to the unusually high Sharpe ratios that others found for non-leveraged carry trade returns. Darvas (2008) also mentions the lack of research on leveraged carry trade since most of the papers only consider the profitability of non-leveraged trading. Future papers should definitely address this issue since currency traders almost always employ high leverage in order to boost profits – leverage of 10 is considered to be normal, while neither that of 25 or 30 is unheard of (even investment professionals occasionally use higher ones than these but the author of this paper does not consider this practice to be prudent and would never recommend it to anyone).

In agreement with Darvas (2008), Brunnermeier, Nagel and Pedersen (2009) argue that the negatively skewed distribution of carry trade returns can be a deterrent for most speculators to take on big enough positions that would enforce the UIP. Their findings are in agreement with those of Farhi and Gabaix (2008) who suggest that the non negligible probability of rare disasters (peso effects) can account for the excess returns inherent in carry trade. This argument seems to stand on stable grounds as it can explain most of the findings about carry trade so far in the literature.

Further research on carry trades should concern the effects of leverage as well as finding more efficient monetary policy measures to deal with the destabilizing effects of speculative capital flows.

Data description

In this study I use daily currency exchange rate time series downloaded from Yahoo Finance on May 22, 2011. The individual currencies are the following: US Dollar (USD), Japanese Yen (JPY), Swiss Franc (CHF), British Pound (GBP), Norwegian Krone (NOK), Australian Dollar (AUD) and New Zealand Dollar (NZD). In the last two decades the JPY and the CHF where the two currencies with consistently the smallest interest rates, making them the most popular funding currencies for carry trade positions. I will be using these two as funding currencies to analyze the return characteristics of the following ten currency pairs: AUD/JPY, AUD/CHF, NZD/JPY, NZD/CHF, GBP/JPY, GBP/CHF, NOK/JPY, NOK/CHF, USD/JPY, USD/CHF.

The time series of interest rates for each individual currencies where taken from the website of the corresponding country's central bank. Unfortunately the Swiss National Bank only posts its historical interest rate targets since January 2000, therefore the returns of the five CHF funded currency carry positions I could only analyze from January 1, 2000 till May 21, 2011. However, since data was available for the JPY target interest rates for a longer period, I analyzed the returns on the five JPY funded currency carry positions from January 1, 1990 to the same end date.

Since the target of the research was the returns from the carry trade positions, the exchange rates themselves are of little importance. Instead, the sum of the carry profits and the returns of the exchange rates are more important. Therefore for each currency pair I constructed an index in the following way: In case of JPY funded currency pairs I took the exchange rates as of January 1, 1990 and calculated the index assuming an investment on January 1, 1990 with the profits from the interest rate difference daily compounded. In case of

CHF funded currency pairs the base of the index and start of the investment period is of course January 1, 2000.

The following formula explains the value of the index at time t + 1 (days):

$$I_{t+1} = I_t \cdot (Exch_{t+1}/Exch_t) \cdot (1 + (i_t^* - i_t)/100)^{1/365}$$
(1)

In equation (1) I_t is the Index of the currency pair at time t, Exch_t is the exchange rate at time t, i_t^* is the yearly interest rate in percentage of the target currency and i_t is the yearly interest rate in percentage of the funding currency.

Once we have the daily series of the indices for all ten currency pairs we should carry out unit-root tests to find out whether the time series are stationary or not. In case we find that the indices of the currency pairs are stationary, we will need to carry out unit root tests for the series of interest rate differences. This is important since in case both types of series are nonstationarity, it would cause spurious regressions, meaning that from the results we would assume a direct causal connection between variables when in fact there is no such. The reason of this usually is the coincidence of changes in the two time series, most commonly a trend in both variables. To detect non-stationarity I carry out Augmented Dickey-Fuller (ADF) tests. The results of these tests are published in the Appendix. We find that all the currency indices are non-stationary, therefore we should check their first differences as well, to find out the level of their integration. We find that all currency indices are first order integrated processes, meaning that they first differences are stationary. Practically this means that if we take the returns of the currency indices calculated as the differences of the natural logarithms of the indices themselves we get a stationary time series. To make sure that the first differences of the currency indices are stationary I also carry out Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests (Kwiatkowski et al. (1992), Bhargava, A. (1986)). Making the KPSS test

together with the ADF test is useful since it tests stationarity as a null hypothesis as opposed to the ADF test which tests for the null hypothesis of unit root. Sometimes the data is not sufficiently informative to decide whether they are stationary of integrated. Thus carrying out both tests we can be sure about the stationarity of our time series. The KPSS tests confirm the stationarity of the first differences of the currency indices.

I find that all interest rate difference series are non-stationary – both the ADF and the KPSS tests confirm this. This means that to avoid spurious regressions I will need to use the first differences of the currency pair indices.

Methodology

The aim of this study is to find the risk-return trade-off in currency carry positions and to see how the recent financial crisis changed this trade-off. Therefore I will carry out the estimations both on the entire sample as well as on the sub sample of January 1, 1990 – December 31, 2007 and January 1, 2000 – December 31, 2007 for JPY and CHF funded carry positions, respectively. This will give us an idea about how rare disasters can influence the profitability of currency carry positions and thus help us explain the high expected excess returns we experience in carry trades.

I will follow the methods used by Brunnermeier, Nagel and Pedersen (2009) but implement numerous modifications to their model. First and foremost, in their article Brunnermeier et al (2009) estimate quarterly skewness of daily returns (see Appendix) and I will mainly focus on monthly skewness and monthly return, however I will also estimate the quarterly return. In my opinion estimating the monthly figures makes more sense since a portfolio manager would review and rebalance his portfolio more often than once in a quarter if necessary, which is especially the case in times of crisis. Therefore the results of the monthly return are of bigger importance in my opinion. Also, my data spans a longer time period, most importantly the period of the late 2000's financial crisis is also included. This broader set of data, especially since it includes the period of the crisis is likely to modify much of the original results.

I will follow Brunnermeier et al (2009) in using panel methods with cross-section fixed effects to estimate the monthly skewness of daily returns, the monthly return itself and an additional risk measure, the probability of "blow up", which is the probability of a huge loss – which I will set to be 10%. The observed "blow up" variable is a binary one: its value is 1 in case the currency pair index suffered a maximum loss of more than 10% during the next month and 0 if it did not. The rationale for this risk measure is that if the carry portfolio of an

investor is highly leveraged then a sudden and unpredictable adverse movement can wipe out the entire capital within a few days and even though the exchange rates would recover by the end of the month it is too late since the investor would have suffered a forced liquidation at the worst possible time.

In this sense the "blow up" probability is very similar to skewness – they intend to grasp the same idea, however there are some differences which make the use of the "blow up" probability more attractive for us: most importantly skewness is a risk measure which does not give us any information on the mean around which the tails are distributed. Relying solely on the value of the skewness can be misleading, which is easily demonstrated through the following example: if the exchange rate is falling in a month with a large negative mean daily return but the distribution of the daily returns has a longer right than left tail, meaning that positive returns or negative returns of a smaller magnitude than the sample mean are more common than negative returns of a bigger magnitude than the sample mean, we will get a positive skewness. This case is however very different from the situation when both the mean and skewness are positive – an ideal scenario for investors.

This explanation might seem overly theoretical and of little importance in real world returns, however the opposite is the case: in case of stock market returns we often see short covering (SC) rallies: the price movement of the stock which came under selling pressure can reverse for a short period of time when the holders of short positions take their profits and unwind their positions which makes others do the same. Soon a short covering spiral takes place. Similar process can happen in the foreign exchange markets during a sovereign debt crisis or a global financial crisis.

Because of the above reasons I prefer "blow up" probability as a risk measure to skewness; however I should note that it also has its limitations. The problem is with the sample size and it is the usual problem we face when analyzing extreme events: such events do not happen often enough to have a sample of reliable size and to draw statistical conclusions that stand on firm grounds. Because of the questionable reliability of estimating the "blow up" probability I carry out the calculations for skewness as well.

I add another variable to the regressions, a dummy named RAISE, with which I intend to differentiate between time periods when the interest rate differential between the rates of the investment and the funding currency grows and those in which it shrinks. This variable can account for different strategies an investor would follow in times when central banks raise their interest rate targets and in those when they lower them.

My assumption is that usually when they raise their interest rates they do it in order to curb inflation and cool down an overheated economy – these are times of economic growth in which I assume that capital flows from the centers of the financial world towards the more peripheral countries. I also assume that this time coincides with the build-up of carry trade positions in higher interest rate currencies such as AUD, NZD, GBP, NOK and USD (as compared to JPY and CHF in our case). And since higher interest rate currencies tend to have higher nominal raise in their interest rates because of proportionality, the interest rate differential of investment and funding currencies tends to grow in these times. Conversely, the time periods in which central banks cut their interest rate targets are times when they want to stimulate an ailing economy or they aim to provide extra liquidity in order to deal with a financial crisis.

Historically we see that in these times capital flows to safer assets, therefore I assume that in these times investors tend to unwind their carry trade positions. Another explanation of the inclusion of the variable is that it shows whether carry trade positions tend to become more or less attractive due to higher or lower interest rate differentials than before.

To avoid data mining I will assign the values of the dummy the following way: if its previous value is 0, meaning we were in an interest rate cutting period, it will switch to 1 as

soon as the interest rate differential between the given two currencies will be at least 50 basis points higher than it was at its lowest in the previous rate cutting period. And similarly, if its previous value is 1, meaning we were in an interest rate raising period, it will switch to 1 as soon as the interest rate differential between the given two currencies will be at least 50 basis points lower than it was at its lowest in the previous rate raising period. The reason of this treatment of the dummy is that such way I avoid data mining in the sense that I do not use any such information an investor does not know at the point of time he decides about his investment decision.

This way the RAISE dummy occasionally gives us false signals as well; this happens if the interest rate difference changes by at least 50 basis points in the opposite direction it was moving previously but then soon reverts back. The reason of such false signals is that central banks do not synchronize their monetary policy decisions but the 50 basis points threshold in the change is big enough to filter most of these occasions and only a few false signals remain – these wrong signals are also more common in currency pairs in which the investment currency has a larger interest rate volatility. Knowing this, an investor could apply different thresholds for different currency pairs but in this study I stick to this simple rule just to be on the safe side of risking using too much ex post information.

It is commonly accepted that the price investors in currency carry trade positions have to pay for a positive interest rate differential is negative skewness. To illustrate this, Figure 1. shows the trade-off between the sample average of interest rate difference and the sample average of skewness for each examined currency pair.



Figure 1. Average sample skewness as a function of average interest rate difference

The regression results in Table 1. confirm the linear relationship.

	Average Skew	$ness = \alpha + \beta \cdot Ave$	$rage(i*-i) + \varepsilon$	
	Coefficient	Std. error	t-stat	p-value
Avg(i*-i)	-0.059413***	0.012176	-4.879720	0.0012
α	0.097068*	0.047614	2.038662	0.0758
R^2		0.74	8520	
Adjusted R ²	0.717085			

Table 1. OLS Regression results of average skewness as a function of average interest rate difference. *, *** mean statistical significance at the 10% and at the 1% level, respectively.

I use Panel Least Squares method to estimate the skewness and the monthly/quarterly

return and Panel Binary Probit to estimate the "blow up" probability.

In the Panel Least Squares estimation of skewness and return I use fixed effects in the cross-section dimension and White cross-section coefficient covariance method with an adjustment for serial correlation with a Newey-West covariance matrix with 10 lags (Newey, West (1994)). The reason of the latter choice is that this estimator is robust to errors having contemporaneous cross-equation correlation and heteroskedasticity (Wooldridge (2002, p.

148-153) and Arellano (1987)). The contemporaneous cross-section correlation is the main issue here since without taking it into account the simple Panel Least Squares method underestimates the standard error of the coefficients thus the regression shows higher statistical significance than there actually is. This method effectively deals with this problem.

To estimate the "blow up" variable I use Panel Binary Probit with Huber-White robust covariances. Even though this method is robust to certain model misspecifications it is not robust to heteroskedasticity in binary dependent variable models. This is a limitation of the model used which we have to take into account when interpreting the results.

Empirical Results

Table 2. below contains the results of the estimation for the monthly returns for the entire sample and the sub-sample excluding the late 2000's financial crisis.

Estimation of monthly return: R_{t+1}

Time period of the unbalanced panel estimation:

Long time period:

January 1, 1990 – May 21, 2011 (JPY funded currency pairs) January 1, 2000 – May 21, 2011 (CHF funded currency pairs)

Short time period:

January 1, 1990 – December 31, 2007 (JPY funded currency pairs) January 1, 2000 – December 31, 2007 (CHF funded currency pairs)

	Long time period	Short time period
	-0.022050	-0.041619
R _t	(-0.406084)	(-0.788110)
	[0.6847]	[0.4308]
	0.000415	0.001642
Skewnesst	(0.236161)	(1.098102)
	[0.8133]	[0.2723]
	0.000528	0.001649**
$i_t^* - i_t$	(0.611277)	(2.077014)
	[0.5411]	[0.0380]
	-0.000130	-0.0000609
VIX _t	(-0.408180)	(-0.168521)
	[0.6832]	[0.8662]
	-0.000926	-0.000287
ΔVIX_t	(-1.438582)	(-0.520018)
	[0.1504]	[0.6031]
	0.004400*	0.004758*
RAISEt	(1.697661)	(1.802878
	[0.0897]	[0.0716]
	0.000187	-0.004935
С	(0.026541)	(-0.681836)
	[0.9788]	[0.4954]

Each cell above contains the following data: coefficient, (t-statistic), [p-value] *, ** mean statistical significance at the 10% and 5% level, respectively				
R^2	0.023702	0.020767		
Adjusted R ²	0.016091	0.011065		
F-statistic	3.114012	2.140553		
Prob. (F-stat)	0.000047	0.006625		

Table 2. Next period's (1 month) currency index return as dependent variable for the whole sample and the sub-sample.

 R_t is the 1 month nominal return of holding the currency pair at time period t (1 month) in decimal form,

Skewnesst is the sample skewness of the daily returns in month t,

 $i_t^* - i_t$ is the interest rate difference between the investment currency and the funding currency given in percentage form: e.g. $i_t^* - i_t = 10$ if the interest rate difference is 10%, VIX_t is the Chicago Board Options Exchange Market Volatility Index, a popular measure of the implied volatility of S&P 500 index options. The higher the VIX_t index, the higher volatility we expect in the near future (next 30 days),

 Δ VIX_t is the change in the Volatility index from the last 1 month:

 $\Delta VIX_t = VIX_t - VIX_{t-1}$

RAISE_t is the above explained dummy variable.

We see that the model is doing very poorly in explaining the next period return but this is not surprising; in fact the opposite would be unusual since it would mean that returns are overly predictable which is in contradiction with the Efficient Market Hypothesis. We see that the whole sample which lasts only about 3 years longer than the sub-sample gives very different result on the coefficient of the interest rate differential. While on the sub-sample it is

significant on the 5% level, it is not even marginally significant on the whole sample (p-value of 0.5411). This is due to the financial crisis and mainly to the October 2008 crash – even though in "normal" times the interest rate differential explains the next period return well, relying solely on it in our decisions exposes us to unpleasant surprises. The above results well illustrate the enormous effect of highly unlikely events – so-called "black swans" (Nassim Taleb (2007)).

Table 3. shows the estimation results of the quarterly return, similarly for the entire and the sub-sample. While for the next 1 month's return the RAISE dummy variable was just marginally significant, in the longer run we experience very high statistical significance on both the entire- and the sub-sample with p-values higher than 0.0001. Similarly, we see that the importance of the interest rate differential vanishes once we take the entire period into account.

Estimation of quartely retu All variables are on quarte	ırn: R _{t+1} rlv basis	
1	<u> </u>	
	Long time period	Short time period
	0.019311	-0.067664
R_t	(0.339106)	(-1.423814)
ť	[0.7346]	[0.1547]
	0.003088	0.004945*
Skewnesst	(1.01774)	(1.769435)
	[0.3123]	[0.0770]
	0.001191	0.003289**
$i_t^* - i_t$	(0.832794)	(2.179628)
	[0.4051]	[0.0294]
	0.000836*	-0.0000313
VIX _t	(1.942315)	(-0.062545)
	[0.0522]	[0.9501]

ΔVIX_t	-0.001584* (-1.648846) [0.0993]	0.0000807 (0.072577) [0.9422]	
RAISE _t	0.016714*** (3.833355) [0.0001]	0.024837*** (5.503701) [0.0000]	
С	-0.025262** (-2.568262) [0.0103]	-0.015542* (-1.701240) [0.0891]	
Each cell above contains the following data: coefficient, (t-statistic), [p-value] *, **, *** mean statistical significance at the 10%, 5% and 1% level, respectively			
R^2	0.040158	0.078199	
Adjusted R ²	0.032556	0.068881	
F-statistic	5.282722	8.392745	
Prob. (F-stat)	0.00000	0.00000	

Table 3. Next period's (quarter) currency index return as dependent variable for the whole sample and the sub-sample.

Table 4. shows next month's skewness of daily currency pair index returns. Here we clearly see the trade-off between the return and the skewness of the carry position: positive return induces the next period skewness to be negative and the coefficient is significant at 5% level (for the entire sample). This means that profits from carry trade positions raise the crash risk in the next time period. The interest rate differential is also significant marginally with a p-value of 0.0695 on the entire sample.

	Long time period	Short time period
	-1.529608**	-1.753090*
R _t	(-1.975539)	(-1.667397)
ť	[0.0483]	[0.0956]
	-0.026947*	-0.022648
$i_t^* - i_t$	(-1.816133)	(-1.224670)
	[0.0695]	[0.2209]
	0.000888	0.002998
VIX _t	(0.213335)	(0.492550)
	[0.8311]	[0.6224]
	-0.001517	-0.001489
ΔVIX_t	(-0.206266)	(-0.119326)
	[0.8366]	[0.9050]
	0.004510	0.021461
RAISEt	(0.101948)	(0.414234)
	[0.9188]	[0.6788]
	-0.043150	-0.108456
С	(-0.403715)	(-0.869721)
	[0.6865]	[0.3846]
Each cell above contains th	ne following data: coefficient, (t-st	atistic), [p-value]
r, rr, rrr mean statistical	significance at the 10%, 5% and 1	% level, respectively
R^2	0.016360	0.013473
Adjusted R ²	0.009280	0.004475
F-statistic	2.310743	1.497401
Prob. (F-stat)	0.003773	0.104145

Table 4. Next period's (1 month) skewness of daily currency index returns as dependent variable for the whole sample and the sub-sample.

To see the risk-return trade-off from another angle I publish the regression results on the binary "blow up" variable as well (Table 5.)

	Coefficient	z-statistic	Prob.	
R _t	0.770149	0.500814	0.6165	
$i_t^* - i_t$	0.113424***	3.157792	0.0016	
VIX _t	0.042231***	4.912671	0.0000	
ΔVIX _t	0.030718**	1.987991	0.0468	
RAISE _t	0.043992	0.257742	0.7966	
С	-3.651505***	-11.56201	0.0000	
*, **, *** mean statistic	*, **, *** mean statistical significance at the 10%, 5% and 1% level, respectively			
McFadden R ²	0.184455			
LR-statistic	71.95795			
Prob. (F-stat)		0.00000		

Table 5. Next period's (1 month) "blow up" probability as dependent variable.

Since we have a Probit model here, these coefficients do not represent the slope parameter in the probability but only in the Probit estimate. We can calculate the probability the following way:

$$P = \Phi(z), \tag{2}$$

where z is the Probit estimate and $\Phi(z)$ is the cumulative distribution function of the standard Normal distribution.

The Probit estimate is nevertheless indicative itself since the cumulative distribution function is strictly monotonous, therefore the results I are easy to interpret even without calculating the probability itself: the interest rate differential is highly significant and the higher it is, the more likely the carry position will suffer a big loss during the next month. This is the same risk-return trade-off we saw in case of the skewness, even though here the total return of the position is not significant. The Volatility Index and its change from last month are also highly significant. This is also easy to understand: the more volatile the market we expect the market to be in the next month, the more likely we will suffer big losses.

In the next figures I graph the probability of "blow up" as a function of the interest rate differential while leaving other variables constant:

Let $VIX_t = 20$ (moderate volatility), $\Delta VIX_t = 0$ (no change in volatility from t-1) and R_t = 0 (no return in previous month – this is of no importance since the coefficient on R_t is insignificant). Figure 2. shows the "blow up" probability separately for interest rate cutting and raising periods. Recall that "blow up" means a loss of more than 10% in a month, meaning that a 10-times leverage portfolio would be totally wiped out.



Figure 2. Risk - carry return trade-off (entire sample)

We see that at high interest rate differentials the possibility of losing our entire capital in the next month is non negligible – over 10%. However, it is important to remember that the results are less reliable for interest rate differences over 10% since these happened only in the case of the AUD/JPY and the NZD/JPY currency pairs and only for a short period of time.

Also, these outcomes are clustered in times of market turmoil. It is interesting to see the same probability function for the sub-sample excluding the global financial crisis therefore I included that one as well (Figure 3.). The results are rather similar but we should not forget that the number of extreme events in the sub-sample is more limited, therefore the results can be very biased.



Figure 3. Risk – carry return trade-off (sub-sample)

Conclusion

In this study I examined the risk – return characteristics of currency carry trade investments and found that investors have to pay a high price for the attractive profit opportunities provided by the difference in interest rates between currencies. The risk of the strategy lies within the large skewness of returns which can cause severe losses in short periods of time. Hence the saying among traders: "exchange rates go up by the stairs but come down by the elevator".

I estimated an alternative risk measure as well, the "blow up" probability, which measures the probability of losing more than 10% within a month. I call it "blow up" probability since carry trades are usually implemented using high leverage and therefore an adverse change of 10% can effectively wipe out the entire portfolio. This measure shows us more directly the crash risk, however it also has its limitations since its statistics are less reliable. We must be very cautious with the results here since the number of observations is small, therefore the results are intended to be used qualitatively rather than quantitatively.

We have also seen that by estimating on the sub-sample we get very different results from those we got on the entire sample, therefore we must conclude that the estimated coefficients are not able to forecast the future. This is evident from the fact that adding only 3 more years to a sample of 18 years (or 8 years in case of CHF funded currency pairs) can significantly change the predicted values of the returns.

This is in agreement with the Black Swan Theory developed by Nassim Taleb, which argues that hard to predict and rare events which are beyond the realm of normal expectations have a disproportionate role in the course of history.

This study can be extended in numerous ways, the most obvious one is to carry out the calculations for investment currencies of emerging market countries as well, to extend the time period and to examine different sub-samples.

Appendix

Sample skewness is calculated the following way:

$$g_1 = \frac{m_3}{m_2^{3/2}} = \frac{\frac{1}{n} \sum_{i=1}^n (x_i - \overline{x})^3}{\left(\frac{1}{n} \sum_{i=1}^n (x_i - \overline{x})^2\right)^{3/2}} ,$$

Where \overline{x} is the sample mean, m_3 is the sample third central moment, and m_2 is the sample variance.



Figure A1. Skewness. Negative skewness means that the probability distribution of the return has a longer left tail, while positive skewness means that it has longer right tail.

Unit root test for the currency-pair indices:

ADF and KPSS test results.

Time period:

January 1, 1990 – May 21, 2011 (JPY funded currency pairs) January 1, 2000 – May 21, 2011 (CHF funded currency pairs)

		t-statistic (ADF test) H ₀ : time series has a unit root	LM statistic (KPSS test) H ₀ : time series is stationary
	Test statistic	-0.955693	3.300115
AUD/JPY	Probability	0.9468*	N.A.
	Test statistic	-0.755851	0.588822
AOD/CIII	Probability	0.9662*	N.A.
NZD/IDV	Test statistic	-1.164855	2.314374
NZD/JI I	Probability	0.9146*	N.A.
NZD/CHF	Test statistic	-0.254720	1.421018
NZD/CHF	Probability	0.9912*	N.A.
GBP/JPY	Test statistic	-1.636241	1.625592
	Probability	0.7760*	N.A.
GBP/CHF	Test statistic	-0.269167	2.183772
	Probability	0.9908*	N.A.
NOK/JPY	Test statistic	-0.420274	2.403660
	Probability	0.9864*	N.A.
NOK/CHF	Test statistic	-1.372774	1.870293
NUK/UHF	Probability	0.8647*	N.A.
USD/JPY	Test statistic	-1.233871	1.985870
	Probability	0.9007*	N.A.
USD/CUE	Test statistic	0.153358	1.208330
USD/CHF	Probability	0.9974*	N.A.

*MacKinnon (1996) one-sided p-values

Critical values:	ADF test (max. lag = 15) (using trend and intercept)	KPSS test (using trend and intercept)
1% level:	-3.994310	0.216000
5% level:	-3.427476	0.146000
10%level:	-3.137059	0.119000

Table A.1. Unit root tests for the level of currency pair indices.

ADF and KPSS test results for first differences.

Time period:

January 1, 1990 – May 21, 2011 (JPY funded currency pairs) January 1, 2000 – May 21, 2011 (CHF funded currency pairs)

t-statistic (ADF test)

LM statistic (KPSS test)

		H ₀ : time series has a unit root	H ₀ : time series is stationary
AUD/JPY	Test statistic	-9.365015	0.038499
	Probability	0.0000*	N.A.
	Test statistic	-5.082911	0.333726
AUD/CHF	Probability	0.0000*	N.A.
NZD/JPY	Test statistic	-4.579098	0.048375
	Probability	0.0002*	N.A.
NZD/CHF	Test statistic	-4.613195	0.224497
	Probability	0.0002*	N.A.
GBP/JPY	Test statistic	-4.538587	0.047914
	Probability	0.0002*	N.A.
GBP/CHF	Test statistic	-386.8346	0.313524
	Probability	0.0001*	N.A.

NOK/JPY	Test statistic	-6.812131	0.032857
	Probability	0.0000*	N.A.
NORICITE	Test statistic	-3.775028	0.331549
NOK/CHF	Probability	0.0040*	N.A.
	Test statistic	-12.63637	0.189463
USD/JF I	Probability	0.0000*	N.A.
USD/CHF	Test statistic	-392.8503	0.345539
	Probability	0.0001*	N.A.

*MacKinnon (1996) one-sided p-values

Critical values:	ADF test (max. lag = 15) (using intercept)	KPSS test (using intercept)
1% level:	-3.455786	0.739000
5% level:	-2.872630	0.463000
10%level:	-2.572754	0.347000
	2 4 7 4122 2	

Table A.2. Unit root tests for the first difference of currency pair indices.

Bibliography

Arellano, M. (1987), "PRACTITIONERS' CORNER: Computing Robust Standard Errors for Within-groups Estimators." Oxford Bulletin of Economics and Statistics, 49: 431–434.

Backus, D. K., S. Foresi, and C. I. Telmer (2001), "Affine Term Structure Models and the Forward Premium Anomaly". *Journal of Finance* 56: 279–304.

Bekaert, G. (1996), "The Time-variation of Expected Returns and Volatility in Foreignexchange Markets: A General Equilibrium Perspective". *Review of Financial Studies* 9: 427-70.

Béranger, F, G Galati, K Tsatsaronis and K von Kleist (1999): "The yen carry trade and recent foreign exchange market volatility", *BIS Quarterly Review*, March, pp 33–7.

Bhargava, Alok (1986) "On the Theory of Testing for Unit Roots in Observed Time Series," *Review of Economic Studies*, 53, 369–384.

Breedon, Francis (2001) "Market Liquidity under Strees: Observations in the FX Market", http://www.bis.org/publ/bppdf/bispap02g.pdf

Brunnermeier, M K, Nagel, S and Pedersen, L H, Carry Trades and Currency Crashes, (April 2009), NBER Macroeconomics Annual 2008, Volume 23

Burnside, C, M Eichenbaum, I Kleshehelski and S Rebelo (2006): "The returns to currency speculation", *NBER Working Papers*, no 12489, August.

Burnside, C, M Eichenbaum and S Rebelo (2007): "The returns to currency speculation in emerging markets", *AEA Papers and Proceedings*, vol. 97(2), pp 333–8.

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

Cairns, J, C Ho and R McCauley (2007): "Exchange rates and global volatility: implications for Asia-Pacific currencies", *BIS Quarterly Review*, March, pp 41–52.

Darvas, Zs. (2008), "Leveraged Carry Trade Portfolios", Journal of Banking and Finance, Volume 33, Issue 5, May 2009, Pages 944-957

Farhi, E and Gabaix, X, "Rare disasters and Exchange Rates", (February 2008), NBER Working Paper No. 13805

Friedman, Milton (1953), Essays in Positive Economics, Chicago University Press

International Monetary Fund (1998): World economic outlook: financial turbulence and the world economy, October.

Jonsson, Asgeir (2009), "Why Iceland?", McGraw-Hill, New York

Kamil, Herman, Is Central Bank Intervention Effective Under Inflation Targeting Regimes? The Case of Colombia (April 2008). IMF Working Papers, Vol., pp. 1-42, 2008.

Kwiatkowski, Phillips, Schmidt, and Shin (1992): Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root. Journal of Econometrics 54, 159–178.

MacKinnon, J. G. (1996), "Numerical distribution functions for unit root and cointegration tests", Journal of Applied Econometrics, 11, 601 608.

Merrill Lynch (2007): "CDOs go beyond credit: FX CDOs, CCOs, EDS and CDOs", European Structured Finance, CDO, March 2007.

Moutot, P and Vitale, G, (2009) "Monetary Policy Strategy in a Global Environment" ECB Occasional Paper 106, <u>http://www.ecb.int/pub/pdf/scpops/ecbocp106.pdf</u>

Newey, Whitney K. and Kenneth D. West (1994). "Automatic Lag Length Selection in Covariance Matrix Estimation," *Review of Economic Studies*, 61, 631-653.

Plantin, Guillaume and Shin, Hyun Song, Carry Trades, Monetary Policy and Speculative Dynamics (February 2011). CEPR Discussion Paper No. DP8224.

Roubini, Nouriel, "Mother of all carry trades faces an inevitable bust." Financial Times November 1, 2009.

Taleb, Nassim Nicholas, "Black Swans and the Domains of Statistics." The American Statistician. August 1, 2007, 61(3): 198-200.

Wooldridge, Jeffrey M. "Econometric analysis of cross section and panel data." Cambridge, MA: MIT Pres