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Master Thesis

"The Carry-Trade Phenomenon in Foreign Exchange Market"

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Abstract

In this paper we document different aspects of carry trades. Carry trade is a strategy based on the failure of the UIP. We provide a detailed discussion about *the forward premium puzzle*, an anomaly in F.X market which implies that excess returns on foreign currency investments are predictable. In addition we document the puzzle in a large currency sample, using the *least square* method. Furthermore the term *efficient market* is under consideration. Investors search for inefficiencies within the market. We apply *co integration* and *Granger Causality* tests on exchange rates to test the *weak form* of F.X efficiency. Finally carry trade returns are analyzed and we figure out that investors are subject to a "crash risk".

...Carry trade is like "picking up nickels in front of steamrollers": you have a long run of small gains but eventually get squashed. (The economist, "Carry on speculating", February 22, 2007)

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Contents

Introduction

A currency carry trade is defined as leveraged cross-currency position making profits exploiting interest rates differentials and exchange rates changes. The strategy suggests borrowing a low-yielding asset and buying a higher-yielding asset denominated in another currency. The low interest rate currency is often called *funding currency* and the high interest rate currency that we invest, is called *target currency.*

Actually, carry trade is based on the violation of the uncovered interest rate parity (UIP), which states that there should be no difference of expected returns on comparable financial assets denominated in two different currencies. Thus, according to the (UIP) we should expect a depreciation of the high-yielding currency equal to interest rate differential. However, empirical findings support the violation of (UIP).

Carry trade strategies are very sensitive to exchange rates fluctuations. Investors put their money when they think (UIP) will not hold. Alternatively, they are searching for short term inefficiencies that there are necessary in order to develop trading strategies. Interest rate differentials must be high enough to compensate them from exchange rate fluctuations. If a greater depreciation, than the expected, on the high-yielding currency occurs then all the profits will be offset and traders will face losses.

The strategy is implemented in Spot and Derivatives market. In the spot market an investor exchanges borrowed funds into the target currency which is held in a bank deposit or as a foreign asset. Through the derivatives market, the investor can goes long or take a short position on forward foreign exchange contracts, futures or more complex options. The later market is usually used for hedging purposes.

Carry trade involves currencies with high returns such as New Zealand dollar, Australian dollar, Turkish Lira, Brazilian real, Swedish krona and Pound Sterling. On the other hand, funding currencies are those with very low interest rates such as Japanese Yen and Swiss franc and US dollar. The later between 2001 and 2004 was funding currency and before and after this period it was used as a target. However with the advent of recent crisis (2007) and the subsequent recession there was a decline in interest rates and USD became a funding currency again.

According to a survey from the B.I.S[1], there was a massive increase on the daily currency trading activity over the past years. The causes for that growth are many. First, is the expansion in the activity of a variety of specialized investment groups including hedge funds. Second, a trend for institutional investors with a longer term investment horizon holding more internationally diversified portfolios. And third, an increase in the levels of technical computer-based trading-most notably algorithmic trading.

As a rule, carry trade is implemented by large Financial Institutions and Commodity trading advisors. They have the knowledge and the ability to achieve the best possible outcome, e.g. they have a variety of usefully data and complex software which determines the strategies. Moreover, due to the size of the transactions they accomplish lower transaction costs.

More recently, the presence of retail investors has increased. They use margin accounts and take leveraged positions on various currencies. The size of these investors is relatively small and compared with large Financial Institutions they have a small influence in the market.

Strategies are distinguished from their complexity level. The range varies from a simple buy and hold strategy to complex algorithms which determine when to enter on a carry trade, how to allocate the funds between currencies and when to close our position. With the development of technology and the automation of markets the later had become popular the last years.

Carry trades play a significant role on exchange rate fluctuations. Massive investments in particular currencies, result on their slow appreciation and a possible-sudden unwind of carry trades have unfavorably effects on financial stability. Unfortunately, tracking carry trades is impossible through the available data but these data offer useful evidence to approach the activity[2].

The Bank for International Settlements (BIS) banking statistics department provides a good series of data, which include a currency breakdown of banks international assets and liabilities that are useful to gauge carry trade activity. Moreover, statistics about foreign exchange derivatives it is a valuable source to capture the activity. In addition, U.S Commodity Futures Trading Commission CFTC and BIS statistics derivatives are a rich source of information.

The structure of this paper is the following:

On **Chapter 1** we analyze *the forward premium puzzle*. Moreover we regress the future exchange rate change of many major currencies pairs on their corresponding interest rate differentials in order to test if the (UIP) holds. We find significant evidence about the failure of (UIP), the effect of time horizon of the investment and the effect of interest rates on future exchange rates. Finally we present some indicative papers which try to explain the puzzle.

On **Chapter 2** a detailed discussion is made about *foreign exchange market efficiency*. Investors search for short term inefficiencies within the market in order to build their strategies. Apart from the failure of (UIP), we examine exchange rates for the existence of *co integration* between them. If a long run relationship exists between exchange rates expressed in the same currency then one exchange rate is predictable from the past prices of the other. Thus *the weak form of market efficiency* is rejected. In order to draw stronger assumptions Granger Causality tests are also applied. Finally we present some important researches about F.X market efficiency.

On **Chapter 3** carry trades returns and risk are taken into account. We analyze the returns and point out that carry trades are subject to a *crash risk*. Although carry trade has high returns, if the risk associated with this strategy is measured properly then the strategy looks less attractive. In addition we submit some significant researches about risk in carry trades. Finally, as carry trade strategy has been so famous especially the previous years, there was a development of products that underlying this strategy. In the last section of chapter 3 we demonstrate most of these products.

Finally we draw the conclusions about carry trade.

Chapter1: The Forward Premium Puzzle

1. Forward Premium Puzzle

In a large body of empirical literature, (UIP) seems to fail almost universally for short time horizons. High interest rate currencies tend to appreciate, rather than depreciate as the (UIP) shows. Alternatively, currencies that command a forward premium tend, on average, to depreciate, while those with a forward discount tend to appreciate. This empirical paradox in foreign exchange market is known as "*The Forward Premium Puzzle"* and continues to pose a challenge to international economists.

There is an ambiguity among researchers on whether forward premium puzzle is a necessary condition to put on carry trade or if it is a consequence of it. In addition, many observers argue that recent movements among major currencies are actually caused by carry trade strategies.

Forward Discount Puzzle implies that excess returns on foreign currency investments are predictable. This excess returns, usually, reflect a risk premium. This predictability can be exploited by actively managed portfolios, as we see later, with a significant cost.

Logically, the puzzle must reflect the failure of one or both features of the joint hypothesis of efficient market and risk neutrality. Much of the literature attempting to solve the puzzle has focused on the fact that a risk premium exists in forward exchange market.

Eugene F. Fama[3] showed that high interest rate currencies tend to appreciate. A regression of the future change in the log of the spot exchange rate on the forward premium is expected, in efficient markets, to yield a coefficient of unity. Instead, regression estimates of the forward premium yield a coefficient that is less than unity and frequently negative. One possible explanation for this puzzle is a time-varying risk premium.

Uncover interest rate parity holds in a world without risk. According to UIP expected returns would be equal regardless of risk. However, there is a variety of risk among currencies, thus expected returns should account to their corresponding risks.

1.2 Documenting the puzzle

According to UIP any expected gain from interest rate differentials between two currencies would be offset from the depreciation of the high yielding currency. If

(UIP) holds then the following equation should yield a coefficient b equal to unity

and a constant c equal to zero.

$$lnS_t\text{-}lnS_{t-1} = c + b(i\text{-}i^*) + u_t \quad (1)$$

Where: 1) S_t is the exchange rate at time t expressed in USD

2) i is the interest rate of the home currency

3) i^* is the interest rate of the foreign currency

4) u_t is a white noise error

The data used in this study are from DataStream. Two samples are considered, with different home and foreign currencies but also different sample period. The sample period in the second sample is shorter due to restrictions in the availability of some data.

Our first sample contains daily, monthly and annual data from 1/1/1990 to 22/12/2010. All currency pairs are expressed in terms of United States dollar (USD). We consider eight different currencies the Australian dollar (AUD), the Canadian dollar (CAD), the Japanese Yen (JPY), the Norwegian Korone (NOK), the New Zealand Dollar (NZD) ,the Swiss Franc (CHF), the Thailand Baht (THB) and Turkish Lira (TRY) . The corresponding interest rates are similar to the 3-month T-bill rate (USD) for each country respectively and have been adjusted to daily and monthly data by dividing them with the corresponding data e.g. monthly interest rate is divided by twelve.

The period range, daily to annual data, will help as to see the magnitude of the puzzle depending on the investing time horizon.

We will regress the logarithm of exchange rate change at t on the lagged interest rate differential, at t_{-1} applying the *Least Squares* method from E-views. The following

matrixes contain the constant c, the coefficient b and their corresponding p-values.

Matrix 1

Daily data

Target Currencies				
	c	b	Prob c	Prob b
AUD	*-2,77E-05*	*-0,641468*	*0,8782*	*0,6564*
CAD	4,26E-05	0,470132	0,5843	0,6564
JPY	0,000211	-2,499259	0,0547	0,0388
NOK	0,000113	1,168593	0,3910	0,2316

NZD	4,28E-05	-0,002605	0,8548	0,9987
CHF	0,000120	-1,281901	0,2427	0,2618
THB	2,20E-05	1,241839	0,5360	0,0536
TRY	0,001008	1,214691	0	0
Source: **DATASREAM** **Calculations: E-Views OLS method**				

Matrix 2

Monthly data

Target Currencies				
	c	b	Prob c	Prob b
AUD	*0,000239*	*-0,342759*	*0,9495*	*0,8046*
CAD	0,001169	0,622015	0,4744	0,5296
JPY	0,004780	-2,480217	0,0430	0,0375
NOK	0,001961	0,849685	0,4550	0,3362
NZD	0,005796	1,665485	0,2638	0,3050
CHF	0,002220	-0,923044	0,3137	0,4076
THB	0,000844	0,817232	0,7725	0,2110

TRY	-0,013110	0,157420	0,0033	0,0173
Source: **DATASREAM** **Calculations: E-Views OLS method**				

Matrix 3

Annual data

Target Currencies				
	c	b	Prob c	Prob b
AUD	*8,35E-05*	*-0,284347*	*0,9987*	*0,8414*
CAD	0,011475	0,557085	0,6640	0,6368
JPY	0,024082	-0,286360	0,44471	0,8186
NOK	-0,009867	-0,457822	0,7932	0,6440
NZD	-0,024212	-0,989907	0,7594	0,6220
CHF	0,014276	-0,375661	0,5769	0,7137
THB	0,011516	0,709512	0,8579	0,4832

TRY	-0,031899	0,345997	0,7791	0,0498
Source: **DATASREAM** **Calculations: E-Views OLS method**				

It is clear that the majority of the regressions yield a negative coefficient b which depicts the puzzle. In addition the puzzle seems to be affected from the time horizon of the investment, over longer horizons the puzzle fades; this is consistent with Guy Meredith and Yue Ma (2002).

High p-values[4] for both coefficients in almost all currencies shows that the dependent variable, the logarithmic difference of exchange rates is not described from independent variable, the difference between country interest rates. Constant c is very close to zero in all cases. Moreover the fact that c and b are different from zero and unity, respectively, shows features of inefficiencies within the market. Bellow we analyze separately each currency pair.

For the USD/AUD the coefficient b is negative for all periods considered. This means that the high yielding currency, AUD, appreciates towards USD instead of depreciating at time t. In particular as the time horizon expands from daily to annualized data the puzzle seems to fade. In addition, due to high prob., interest rate differential does not affect exchange rate movements.

The USD/CAD pair has a constant c almost zero and a coefficient b between 0,47 and 0,55 from daily to annual horizons. This is close to the ideals of zero and unity. High p-values shows that the independent variables fail to describe the depended variable.

USD/JPY has a coefficient b equal to -2,4992 for the daily data, which means that when interest rate differential predicts a depreciation of the high yielding currency, this currency appreciates 2,49 times the interest rate differential against the low yielding currency. The puzzle fades as we look a year ahead and coefficient b becomes -0,2863. This is consistent with a large part of literature that argues that the puzzle fades as time horizons expands. In addition it is interesting that coefficient b has a prob. smaller than 0,05 for daily and monthly data which means that interest rate differential is able to describe changes in the corresponding interest rates.

USD/NOK for daily and monthly data has an almost zero c and a very close to unity b. This depicts a form of efficiency in the market. On the other hand coefficient b turns to negative as annual data is concerned.

The USD/NZD coefficient b is negative for daily and yearly data and positive for monthly. This is a weird fluctuation.

USD/CHF has a negative b equal to -1,281901 which is close to zero as annual data is concerned. Another example that the puzzle fades as time horizon expands.

USD/THB has a coefficient b very close to unity for all time periods concerned.

Moreover, coefficient c is almost zero. It seems that uncover interest rate parity holds for this currency pair. On the other hand high prob. for both coefficients depict the failure of independent variables to describe exchange rate changes.

Finally USD/TRY does not show any signs of the puzzle. b is very close to unity for daily and yearly data. In addition low p-values for both c and b coefficients, as daily and monthly data is concerned, show that independent variables describe the exchange rate changes.

Our second sample contains daily, monthly and annual data from 1/1/1996 to 31/12/2010. All currency pairs are expressed in terms of Japanese Yen (JPY). We consider seven different currencies the Australian dollar (AUD), the Canadian dollar (CAD), the United States dollar (USD), the Norwegian Korone (NOK), the New Zealand Dollar (NZD) , the Thailand Baht (THB) and the British pound . The corresponding interest rates are similar to the 3-month T-bill rate (USD) for each country respectively and have been adjusted to daily and monthly data by dividing them with the corresponding data e.g. monthly interest rate is divided by twelve.

The following matrixes depict the coefficients c and b and their corresponding p-values of equation (1), as in the first sample but the home currency is the Japanese Yen (JPY) and British pound (GBP) has been added to foreign currencies. Data was not available for (TRY) for the period we consider. Data are considered on daily, monthly and annual basis.

Matrix 4

Daily data

Target Currencies				
	c	b	Prob c	Prob b
AUD	0,001159	*5,851153*	*0,1845*	*0,1839*
CAD	-6,55E-05	-0,789642	0,8281	0,7505
USD	-0,000333	-2,649110	0,0815	0,0796
NOK	0,000322	2,238697	0,3816	0,2782
NZD	0,000241	1,131696	0,6764	0,6389
THB	-5,48E-05	0,518846	0,9798	0,4954
GBP	-0,000185	-0,748603	0,6127	0,7104

Source: **DATASREAM**

Calculations: E-Views OLS method

Matrix 5

Monthly Data

Target Currencies

c

b

Prob **C**

Prob b

AUD

0,030376

7,126617

0,0742

0,0709

CAD

0,001441

0,499150

1.3 Explaining the puzzle

While great strides have been made in documenting the puzzle, very little progress has been made in explaining it.

Avik Chakraborty and **Stephen E. Haynes (2005)**[5] explore both non-rationality and risk premium explanations that account for the puzzle. Their findings indicate that the puzzle is not solely a consequence risk premium. By regressing future spot exchange rate changes on the forward premium they stated that the bias in the slope coefficient, with frequent sign reversal, can be explained by non-rationality but no a risk premium, as the bias stems from a negative covariance between the forecast error and the forward premium. In addition, they regressed future spot exchange rate on the current forward rate and they find that any modest deviation from unity on the coefficient of forward rate becomes greatly magnified in the forward premium coefficient because of the stationary- non stationary properties of the relevant variables. Despite their conclusion that the key reason for the bias in the coefficients is non-rational expectations of the agents, they do not rule out the possibility for the existence of a risk premium.

Guy Meredith and **Yue Ma (2002)**[6] examined the biasness of forward premium over short term horizons. They assumed interest rates endogenous to exchange market shocks and they find that monetary policy endogeneity can explain the puzzle. The puzzle requires a correlation between interest rates and exchange market shocks. Short-term interest rates are the operating instrument of monetary policy. Shocks that cause the current exchange rate to depreciate also cause output and prices to rise, leading to higher interest rates. The subsequent reversal of these shocks is associated with exchange rate appreciation, explaining this odd relationship between lagged interest rates and ex post exchange rate movements. However, over longer horizons the bias fades due to policy endogeneity declines relative to longer-term model dynamics that are consistent with the (UIP) e.g. inflation differentials.

If interest rates assumed to be exogenous to exchange market shocks, the causation of the puzzle runs from interest rates to either risk premia or non-rational expectations errors.

Philippe Bacchetta and **Eric van Wincoop (2006)**[7] investigate to what extent incomplete information processing can explain the puzzle. Most models assume that portfolio decisions incorporate all new information and made on a continuous basis (along with the arrival of new information). Portfolio decisions are usually not made on a continuous basis, thus information incorporated incompletely into portfolio decisions. In addition, many of the most active trades use only very limited information to predict future exchange rates, more precisely they assume that exchange rates are random walks. Incomplete information processing can take two forms: 1) infrequent information processing, were investors make portfolio decisions infrequently and 2) partial information processing, were investors use only a subset of all available information. In their model, they incorporated both predictability and infrequent portfolio decisions and shown that the latter can cause the former. They concluded that due to transaction cost, there is no significant gain from active managing portfolios. Infrequent decisions by investors lead to delayed impact of interest rate shocks on exchange rates and that's the main cause of "*delayed overshooting*"[8] which gives rise to excess return predictability. And finally, future excess returns continue to be predictable by the current forward discount, with the magnitude of the predictability declining as time goes on.

Greg Burnside, Martin Eichenbaum and **Sergio Rebelo (2007)**[9] argue that adverse-selection problems between participants in foreign exchange markets can account for the *"forward premium puzzle"*. They assume that foreign exchange market is not a Walrasian[10] in nature and that risk is not at the centre of the puzzle. By using a model which is based in **Glosten** and **Milgrom (1985)** microstructure approach, they conclude that adverse-selection considerations between market makers and traders can account for the *forward premium puzzle*. The authors argue that private information, many traders have, actually prevents market makers from quoting the correct-fair price on forward contracts. For example, if uninformed traders have the same information with market makers, both based on public information, and they expect pound to depreciate. Logically, they would take short position on a forward contract. Now we assume that informed traders also participate in the market. When the market maker receives an order he doesn't know whether it comes from an informed or uninformed trader. So if the market maker receives a buy order he attaches high probability that the order came from an informed trader who expects pound to appreciate. Consequently, the market maker will quote a higher price than the correct. The forward ask rate is high when the pound depreciates, so the puzzle is captured by the model. On the other hand, the authors don't explain for how long the puzzle exists due to private information.

More recently, **Markus K. Brunnermeir, Stefan Nagel and Lasse H.Pedersen (2008)**[11] attributed the puzzle to currencies crash risk. Speculators may be discouraged from taking large enough positions in order to enforce (UIP). Thus, crash risk may be a reason that explains the violation of (UIP).

Chapter 2: Foreign Exchange market Efficiency

Introduction

The foreign exchange market is the mechanism by which participants transfer purchasing power between countries, obtain or provide credit for international trade transactions, and minimize exposure to the risks of exchange rate changes.

The F.X market is the largest and most liquid market in the world. According to a BIS survey, on April 2010 average daily turnover in global F.X market was estimated on 3.98 trillion dollars including F.X swaps and other derivatives. Participants vary from large Financial Institutions, commercial banks and security dealers, to retail F.X brokers and non-bank F.X companies.

Although F.X market is very active, with lots of participants, there is an ambiguity about its efficiency. In this chapter a detailed discussion will be made on the aspect of foreign exchange market efficiency. There is a voluminous literature that examines whether the F.X market is efficient or not. On the following section we will present some essential researches and their results. On chapter 1 we documented *the forward premium puzzle* and certainly that was a sign of inefficiency within the market. In this chapter we test the weak form of efficiency on F.X. market by applying co integration and Granger Causality tests on exchange rates.

2.1 Market Efficiency

The term "efficient market" was introduced in a 1965 paper by **E.F.Fama** who stated that, on average, competition will cause full effects of new information on intrinsic values to be reflected "instaneously" in actual prices.

The Efficient Market Hypothesis (E.M.H) suggests that profiting from predicting future price movements is very difficult and unlikely. The factor which affects price changes is the arrival of new information, which are absorbed rapidly and in their entirety. Consequently, prices reflect all available information at any given point in time.

Market efficiency is subdivided into three categories: *the weak form* where the information set includes only past prices, *the semi-strong form* where the information set comprises past prices and all publicly available information relevant to the pricing process and *the strong form* which includes what semi-strong includes but also private information.

Competition among individuals is the key reason of the existence of market efficiency. Many investors spent money and time, trying to detect market anomalies for example unexplained high exchange rates. As more and more analysts compete against each other they decrease the possibility to profit. E.M.H does not imply that investors cannot outperform the market. What E.M.H suggests is that no one should be expected to outperform the market consequently or with a predicted way.

2.1.1 F.X Market Efficiency

Many participants in F.X markets consider that F.X markets are "efficient" which means that forward exchange rates are "unbiased predictors" of future spot exchange rates. If true, the expected value of the future spot rate at time 2 should equal the present forward rate for time 2 delivery, $E^{1}(S^{2})=F_{1,2}$.

If "the efficient market hypothesis" holds then the mean of the distribution of possible actual spot rates in the future should match the forward rate. Forward rate may never be equal to future spot rate. Unbiased predictor simply indicates that the forward rate will, on average, overestimate and underestimate the actual future spot rate in equal frequency and degree.

Market efficiency takes for granted that: 1) all investors absorb quickly and simultaneously all available information about future spot prices, alternatively all forward prices reflect all available information about future spot prices 2) assets denominated in different currencies are perfect substitutes for each other and 3) transaction costs are absent or very low.

If the F.X market is efficient, profits from forecasting future exchange rates are impossible or very hard to be made, because current prices in the forward market reflect all that is presently known about likely future rates. Although future exchange rates may well differ from the expectation contained in the present forward market quotation, we cannot know today which way actual future quotations will differ from today's forward rate. The expected mean value of deviation is zero. The forward rate is therefore an "unbiased" estimator of the future spot rate.[12]

Investors cannot profit using old information or patterns of past price changes. Under this hypothesis exchange rate movements should look like a random walk[13] when plotted over a period of time. Exchange rates respond to shocks, any new information can cause them fluctuate at any direction. Individuals absorb any other information, than unpredictable events, and adjust their expectations.

Another issue related to the efficiency of F.X markets is that of risk premium. If the joint hypothesis of market efficiency and no risk premium holds then $S_{t+1} - F_{t,1} = 0$. If the expectations assumed to be rational (the expected value of future spot rate is equal to the actual future spot rate plus some random forecasting error), whenever the value of $S_{t+1} - F_{t,1}$ is predictably different from zero, there is evidence of the existence of risk premium, market inefficiency or both.[14]

The risk premium can take both positive and negative values, according to its contribution to the investor's portfolio. For example if an assets return co varies positively with overall portfolio returns then positive risk should be paid.

If the F.X market hypothesis does not hold, individuals are expected to pay significant amounts at forecast services, in order to make money, exploiting anomalies in foreign exchange market and developing profitable strategies.

Many papers that test the efficiency of F.X market have yielded conflicting results as we will discuss later. Nevertheless, a consensus is developing that rejects the efficient market hypothesis. It appears that the forward rate is not an unbiased predictor of the future spot rate and that it does pay to use resources to attempt to forecast exchange rates.

2.2 Testing F.X Market Efficiency

In this section we will test the weak form of F.X market, by applying co integration tests on exchange rates and then we will examine for Granger Causality among exchange rates. By focusing on the weak form of market efficiency, problems concerning the joint hypothesis of risk premium and market efficiency can ruled out.

In order to evaluate the other two forms of market efficiency, a more complex model is required which should takes into account any other impact that may affect prices. Hence wrong conclusions can be drawn if the model is mispesified.

Two or more series are said to be co integrated if they each share a common type of stochastic drift that is, on long term fluctuations they share a certain type of behavior. If two asset prices are co integrated it is possible that the movement of one price is linked to the movement of other asset price.

Co integration analysis is useful to test market efficiency, at least on its weak form. On an active and high compatible market as the F.X market, a pair of exchange rates cannot be co integrated if the market is efficient because co integration would imply that the future exchange rate of one currency is based on past the past prices of the other currency. This fact contradicts the weak form of market efficiency.[15]

If two series are co integrated then their long-run relationship can be utilized to develop a dynamic model- an error correction model. This dynamical model has the characteristics that the deviation of the current state from its long-run relationship will be fed into its short-run dynamics. This implies that if a stable long-run relationship between asset prices exists, market participants are in the position to forecast future prices. Moreover the price of an asset does not only depend on its past prices but also on past prices of the other co integrated asset, thus the weak form of market efficiency would be violated.

On the other hand, correlation does not necessarily imply causation in any meaningful sense of that word. The econometric graveyard is full of magnificent correlations, which are simply spurious or meaningless. Interesting examples include a positive correlation between teachers' salaries and the consumption of alcohol and a superb positive correlation between the death rate in the UK and the proportion of marriages solemnized in the Church of England. Economists debate correlations which are less obviously meaningless.

The Granger (1969) approach to the question of whether x causes y is to see how much of the current y can be explained by past values of y and then to see whether adding lagged values of x can improve the explanation. Y is said to be Granger-caused by x if x helps in the prediction of y, or equivalently if the coefficients on the lagged x's are statistically significant. Note that two-way causation is frequently the case; Granger x causes y and y Granger causes x. [16]

If Granger Causality exists among exchange rates then the weak form of market efficiency is violated because the prediction of one currency future exchange rate will be possible from the past exchange rates of other currency.
Our sample contains five currencies all denominated in United States dollar (USD) , our sample period runs from 1/1/1990 to 4/1/2011 and covers daily, monthly and annual data. The currencies under observation are the Australian dollar (AUD), the Canadian Dollar (CAD), the Japanese Yen (JPY), the British pound (GBP) and the Swiss Franc (CHF).

Firstly we examine exchange rates for the existence of unit roots. A *Unit roots test* tests whether a time series variable is stationary or not. A well-known test that is valid in large samples is the **augmented Dickey–Fuller test** which is applied to the exchange rates in levels and first differences. In the following table we demonstrate the results.

Matrix 7
Unit Root Test

Augmented Dickey-Fuller test (*daily data*)

Null Hypothesis: ***time series has a Unit Root***

Currencies	**Prob.**
	Levels
USD/AUD	0,7874
USD/CAD	0,82
USD/JPY	0,5942
USD/GBP	0,1871
USD/CHF	0,7398
	1st Differences
USD/AUD	0,0001
USD/CAD	0,0001
USD/JPY	0,0001
USD/GBP	0,0001
USD/CHF	0,0001
Source: DataStream	

Matrix 8

Unit Root Test

Augmented Dickey-Fuller test (*monthly data*)

Null Hypothesis: ***time series has a Unit Root***

Currencies	**Prob.**
	Levels
USD/AUD	0,7874
USD/CAD	0,8536
USD/JPY	0,6132
USD/GBP	0,1674
USD/CHF	0,7819
	1st Differences
USD/AUD	0
USD/CAD	0
USD/JPY	0
USD/GBP	0
USD/CHF	0
Source: DataStream	

Matrix 9

Unit Root Test

Augmented Dickey-Fuller test (*annual data*)

Null Hypothesis: ***time series has a Unit Root***

Currencies	**Prob.**
	Levels
USD/AUD	0,6497
USD/CAD	0,7240
USD/JPY	0,6227
USD/GBP	0,0589
USD/CHF	0,8394
	1st Differences
USD/AUD	0,0018
USD/CAD	0,0002
USD/JPY	0,0216
USD/GBP	0,0004
USD/CHF	0,0037

Source: DataStream	

A time-series is said to be integrated of order p, I(p), when the minimum number of differences required to obtain a stationary series is p. All stationary processes are I(0). E.g. x_t is non stationary, it has a Unit Root, but $y_t=x_t-x_{t-1}$ is. Y_t is also I(1) which means that the first differences of x_t generate a stationary series.

We have conducted the **augmented Dickey–Fuller test** in levels and first differences on daily, monthly and annual data, to test whether exchange rate are stationary processes or not. From the above matrixes we show that the null hypothesis of the existence of a Unit Root in levels does not rejected for all currency pairs on daily, monthly and annual data. In addition, the null hypothesis of Unit Root in first differences is not rejected. This means that the first differences of the series produce stationary series. Exchange rates are integrated of order 1, alternatively are I(1) series.

If two or more series are individual integrated but some linear combination among them has a lower order of integration then the series are said to be co integrated. In particular we will examine for the existence of a combination among exchange rates which is stationary I(0). If such a combination exists, that signifies a relationship between exchange rates.

We will regress each exchange rate on other using the OLS method, we will run ten regressions as the number of currency pairs and then we will test the residuals of each regression for Unit Roots. If the residuals are stationary then, co integration exists among exchange rates.

Matrix 10

Test for Unit Roots in residuals

Augmented Dickey-Fuller test (*__daily data__*)

Null hypothesis: Residuals have a Unit Root

Currency Pairs	Prob
AUD	
CAD	0,0587
JPY	0,3617
GBP	0,8407
CHF	0,0032
CAD	
JPY	0,5848
GBP	0,7269
CHF	0,0386
JPY	
GBP	0,4176
CHF	0,1267
GBP	
CHF	0,4555
Source: DataStream	

Matrix 11

Test for Unit Roots in residuals

Augmented Dickey-Fuller test (*monthly data*)

Null hypothesis: Residuals have a Unit Root

Currency Pairs	Prob
AUD	
CAD	0,082
JPY	0,3594
GBP	0,8697
CHF	0,0076
CAD	
JPY	0,6291
GBP	0,8047
CHF	0,0501
JPY	
GBP	0,4369
CHF	0,1310

GBP	
CHF	0,4491
Source: DataStream	

Matrix 12

Test for Unit Roots in residuals

Augmented Dickey-Fuller test (*annual data*)

Null hypothesis: Residuals have a Unit Root

Currency Pairs	**Prob**
AUD	
CAD	0,1237
JPY	0,1333
GBP	0,9240
CHF	0,0018
CAD	
JPY	0,3247
GBP	0,9916
CHF	0,0237
JPY	
GBP	0,9613
CHF	0,1186
GBP	
CHF	0,0792
Source: DataStream	

As we can observe from the above figures the null hypothesis is hardly rejected for almost all currency pairs. In particular, the following currency pair residuals have a unit root which means that they are non-stationary processes. These pairs are the AUD/CAD, the AUD/JPY, the AUD/GBP, the CAD/JPY, the CAD/GBP, the

JPY/GBP, the JPY/CHF and the GBP/CHF. For all of these pairs the null hypothesis is not rejected for daily, monthly and annual data and their residuals are non stationary-processes. Based on this finding we can assume that among these pairs co integration does not occurs. In addition we can draw the assumption that the weak form of market efficiency among these pairs holds.

On the other hand, for the AUD/CHF and the CAD/CHF the null hypothesis of Unit Root on their residuals is rejected. Their residuals are stationary processes, which mean that co integration between these pairs occurs. This finding is in line with the rejection of market efficiency at least on its weak form.

In order to draw more useful assumptions we apply *Granger Causality tests* on our previous sample. The Granger causality test is a statistical hypothesis test for determining whether one time series is useful in forecasting another. A time series *X* is said to Granger-cause *Y* if it can be shown that those *X* values provide statistically significant information about future values of *Y*.

If an exchange rate is found to be Granger-caused by another exchange rate denominated in the same currency, then the weak form of market efficiency is rejected because future prices of an exchange rate will be explained by an information set of past prices of another exchange rate.

The following matrixes show the results of the tests for daily, monthly and annual data. P-values lower than 0,05 indicate the rejection of null hypothesis and simultaneously denote the existence of correlation between currency prices.

Matrix 13

Granger Causality test (daily data)

Currency pairs	Null Hypothesis	Prob
AUD/CAD	*CAD does not Granger Causes AUD* *AUD does not Granger causes CAD*	0,1049 0,6219
AUD/JPY	*JPY does not Granger Causes AUD* *AUD does not Granger causes JPY*	0,0805 0,0003
AUD/GBP	*GBP does not Granger Causes AUD* *AUD does not Granger causes GBP*	0,3528 0,5854
AUD/CHF	*CHF does not Granger Causes AUD* *AUD does not Granger causes CHF*	0,0030 0,3892
CAD/JPY	*JPY does not Granger Causes CAD* *CAD does not Granger causes JPY*	0,0912 0,0008
CAD/GBP	*GBP does not Granger Causes CAD* *CAD does not Granger causes GBP*	0,6061 0,1432
CAD/CHF	*CHF does not Granger Causes CAD* *CAD does not Granger causes CHF*	0,0382 0,0450
JPY/GBP	*GBP does not Granger Causes JPY* *JPY does not Granger causes GBP*	0,7240 0,0011
JPY/CHF	*CHF does not Granger Causes JPY* *JPY does not Granger causes CHF*	0,2601 0,0070
GBP/CHF	*CHF does not Granger Causes GBP* *GBP does not Granger causes CHF*	0,2035 0,3689
Source: DataStream		

Matrix 14

Granger Causality test (monthly data)

Currency pairs	Null Hypothesis	Prob
AUD/CAD	*CAD does not Granger Causes AUD* *AUD does not Granger causes CAD*	0,2802 0,0202
AUD/JPY	*JPY does not Granger Causes AUD* *AUD does not Granger causes JPY*	0,2438 0,4457
AUD/GBP	*GBP does not Granger Causes AUD* *AUD does not Granger causes GBP*	0,4785 0,0161
AUD/CHF	*CHF does not Granger Causes AUD* *AUD does not Granger causes CHF*	0,0198 0,7714
CAD/JPY	*JPY does not Granger Causes CAD* *CAD does not Granger causes JPY*	0,4336 0,2458
CAD/GBP	*GBP does not Granger Causes CAD* *CAD does not Granger causes GBP*	0,8054 0,2100
CAD/CHF	*CHF does not Granger Causes CAD* *CAD does not Granger causes CHF*	0,0692 0,2757
JPY/GBP	*GBP does not Granger Causes JPY* *JPY does not Granger causes GBP*	0,9080 0,2019
JPY/CHF	*CHF does not Granger Causes JPY* *JPY does not Granger causes CHF*	0,0710 0,8143
GBP/CHF	*CHF does not Granger Causes GBP* *GBP does not Granger causes CHF*	0,6498 0,5387
Source: DataStream		

Matrix 15

Granger Causality test (annual data)

Currency pairs	Null Hypothesis	Prob
AUD/CAD	*CAD does not Granger Causes AUD* *AUD does not Granger causes CAD*	0,0933 0,0908
AUD/JPY	*JPY does not Granger Causes AUD* *AUD does not Granger causes JPY*	0,2965 0,4650
AUD/GBP	*GBP does not Granger Causes AUD* *AUD does not Granger causes GBP*	0,4011 0,6832
AUD/CHF	*CHF does not Granger Causes AUD* *AUD does not Granger causes CHF*	0,0069 0,3429
CAD/JPY	*JPY does not Granger Causes CAD* *CAD does not Granger causes JPY*	0,3628 0,2160
CAD/GBP	*GBP does not Granger Causes CAD* *CAD does not Granger causes GBP*	0,3060 0,6428
CAD/CHF	*CHF does not Granger Causes CAD* *CAD does not Granger causes CHF*	0,0261 0,7466
JPY/GBP	*GBP does not Granger Causes JPY* *JPY does not Granger causes GBP*	0,9770 0,8910
JPY/CHF	*CHF does not Granger Causes JPY* *JPY does not Granger causes CHF*	0,3726 0,8846
GBP/CHF	*CHF does not Granger Causes GBP* *GBP does not Granger causes CHF*	0,8198 0,5431
Source: DataStream		

As we can observe from the above results, for six currency pairs the null hypothesis of no Granger-Causality among these pairs is rejected based on annual data. As the time horizon expands, the number of currency pairs that reject the null hypothesis decreases. In particular three currency pairs reject the null hypothesis, when we base on monthly data ant two when we based on annul data. This means that as time horizon expands, the weak form of market efficiency holds at least for most currency pairs according to Granger causality tests.

In order to draw more concrete conclusions, we will compare the results of each test for all currency pairs and we point out differences and similarities.

For AUD/CAD pair co integration does not exist for all periods examined. This result is in line with Granger causality tests apart from monthly data which indicate that AUD Granger causes CAD. We conclude that the weak form of market efficiency holds for daily and annual data and is debatable for monthly.

For the AUD/JPY co integration also does not occurs for all data. In addition no evidence of Granger causality is found for monthly and annual data but it seems that AUD helps in the prediction of JPY if daily data are taken into account. The weak form of market efficiency cannot be rejected for monthly and annual data where is dubious for daily.

AUD/GBP has the same features as AUD/CAD. No contestation is found for all data tested and also no Granger causality for daily and monthly data.

CHF is found to Granger causes AUD for all data concerned. This means that CHF lagged prices are useful in the forecast of AUDs future prices. Moreover when we regressed AUD to CHF, their residuals found to be stationary for all periods concerned, signifying the presence of co integration so the weak form of market efficiency for this currency pair is strongly rejected.

No co integration between CAD and JPY exists for all data periods tested. Furthermore, no Granger causality is found for monthly and annual data but CAD found to Granger cause JPY when daily data had been taken into account. Both methods coincide that the weak form of market efficiency holds for monthly and annual data.

Between CAD and GBP also no co integration were found for all data periods under consideration. In addition neither currency found to Granger cause the other. We can draw the assumption that the weak form of market efficiency holds among these currencies.

CHF is found to Granger cause CAD for daily and yearly data, moreover CAD Granger causes CHF when daily data is under consideration. This feature is in line with the presence of co integration for daily and annual data. Thus, the weak form of market efficiency does not hold for daily and annual data.

Between JPY and GBP no co integration is found for all data under consideration. Furthermore, Granger causality exists only in tests with daily data. So, as monthly and annual data is under consideration the weak form of market efficiency holds.

Also co integration is absent between JPY and CHF for all data periods. In addition, apart from daily data Granger causality does not exist. Weak form of market efficiency is dubious when daily data is under consideration but hold for monthly and annual data.

Finally, for GBP and CHF neither co integration nor Granger causality exists for all periods under consideration. Weak form of market efficiency holds in all cases.

Based on co integrations and Granger causality tests we observe that between most currency pairs neither co integration nor Granger causality exists. In addition as time horizon expands any signs of Granger causality decreases. From the above tests we can conclude that the weak form of market efficiency holds, especially when annual data are taken into account.

To sum up weak form of market efficiency holds for the majority of currency pairs under consideration, moreover stronger indications of efficiency were drawn when annual data were investigated. However, semi-strong and strong form of market efficiency hadn't been examined due to the complexity of the model required and the possibility of false inferences.

2.3 Contradicting Empirical Results

From the advent of floating exchange rates in 1973, many researchers have concerned with the efficiency in F.X markets contributing conflicting results. Early tests focused on the hypothesis that the forward rate is an unbiased predictor of the future spot rate. **Baillie et al. (1983)**[17]**, Hodrick (1983)**[18]**, Hsieh (1984)**[19], all of them have rejected the efficiency providing results based on both different time periods and currency samples. However they failed to identify whether this luck of efficiency was due to risk premium, failure of rational expectations or both.

In his paper: *Forward and spot exchange rates* **(1984) Eugene F. Fama**[20] measured the variation in the premium and the expected future spot exchange rate. Any forward rate can be interpreted as the sum of a premium and an expected future spot exchange rate. He figured out that most of the variation in the forward rates is due premium. In addition the expected future spot rate and the premium are negatively correlated.

Kenneth A. Froot and Richard H. Thaler (1990)[21] found no positive evidence that the forward discount bias is due to risk. They found no sign for risk premia of being systematically related to the predictable excess returns derived from the regressions. On the other hand they suggested that the bias is attributable to expectational errors and not to a time-varying risk. However, they don't explain the cause which generates the expectational errors.

P.C Liu and **G.S Mandala**[22] on their paper (1992) used co integrations methods to detect the cause of failure. When co integration exists in systems of spot exchange rates, the market efficiency hypothesis does not hold. By using weekly and monthly data from a five year sample (Oct 1984- May 1989) they tested the Rational Expectations Hypothesis and the Market Efficiency. They rejected the R.E.H for the one month ahead forecast but they do not for the weekly data. In addition, they rejected M.E.H for both weekly and monthly data when they applied the same co integration tests on the forward rate and its corresponding future spot rate. Though the two series were co integrated, the residual was not a white noise process. Finally, they concluded that the failure of M.E.H on the weekly data is due to risk premium rather than expectations errors. For monthly data they found that the failure of M.E.H is due to both expectetional errors and risk premium for the US/BP, US/SF, US/DM but for US/JY was entirely due to expectational errors.

On the other hand, **Crowder (1994)**[23] stated that the co integrating relationship may simply reflect a common feature: a time-varying currency risk premium evident in several currency returns. According to Crowder, the co integration of spot rates is neither a necessary nor a sufficient condition to account for the lack of F.X. market inefficiency. Moreover his findings support the hypothesis of an efficient market.

In support to Crowder, **John Barkoulas & Christopher F. Braum & Atreya Chakraborty (2001)**[24] found forward premium to be stationary which implies the existence of a time varying risk premium. The presence of common stochastic trends among spot exchange rates could serve as proxies for a currency risk premium.

Lotfi Belcasem et al (2005)[25]**,** investigated the weak form of efficiency hypothesis in the case of Tunisian exchange market. They used fractional co integration tests on spot and forward exchange rates of the Tunisian Dinar (TND) vis-à-vis the United States dollar (USD), the EURO and the Japanese YEN (JPY). Their sample based on daily spot and one-month daily forward data between 1999 and 2003. They found a fractional co integration relationship to exist between forward and spot rates for TND/GBP and TND/EURO and based on this finding, they concluded that the weak form of market efficiency for Tunisian exchange market holds.

Michael Kuhl (2007)[26] examined the weak form of market efficiency on the F.X market by applying co integration tests on exchange rates. In particular he investigated if the introduction of EURO has resulted in inefficient markets. His analysis based on Johansen (1988, 1991) approach. The author took a sample of seven major currencies, daily exchange rates all denominated in USD. The period under observation was between 1999 to 2006. He figured out that, apart from a small number of exchange rate pairs, for the majority of currencies market efficiency exists in the sense of Granger (1986).

Apparently, the evidence for inefficiency are ambiguous. In particular, when we assume a risk neutral world with no transaction costs we can say with certainty that we have evidence for a lack in efficiency. However, currencies exhibit volatility and though risk, more over transaction costs should be taken into account.

The investigation for evidence against or in favor of market inefficiency, although still in progress, seems to conclude on the rejection of efficiency. Signs in favor of this argument are also the assumptions we made on chapter 1 with the documentation of the forward premium puzzle and the failure of (UIP).

However, market seems to be efficient at least on its weak form. Many researches had made that assumption. Moreover our results from section 2.2 are in favor of the weak form of market efficiency.

Chapter 3: Risk- Performance of Carry Trade Strategies

Introduction

A carry trade strategy can be a great way for a F.X investor to reap terrific profits on his investment but that doesn't mean there are no risks. With a carry trade, there are two objectives. The first is obviously to make money on the interest rate differential. The second objective is to gain a profit from the capital appreciation. If the carry trade pair appreciates in value, it is a better return on the initial investment. There is a risk involved by not meeting one objective or the other, or both.

The biggest risk in a carry trade strategy is the absolute uncertainty of the exchange rates. If the carry trade pair declines more in percentage than the gain in the interest rate, traders can still lose money in capital while gaining in interest. This can cause an overall loss even though there are profits from the interest rate differential.

Carry trades are meant to be long term investments, and the currency can depreciate as well as appreciate. These variations can cause a carry trade that was an excellent return opportunity to turn sour and become a bad investment which loses money instead of gaining it. This creates a risk for F.X. traders who can lose money when this happens. No foreign currency is completely stable, and fluctuations in the foreign currency exchange create risks for investors when dealing with carry trades.

At the following sections we will present the returns of many carry trade currency pairs and we will create a portfolio which consists of high and low yielding currencies. More over we analyze some special features such as *kurtosis*[27] and *skewness*[28], and we show that investors are exposed to crash risk.

3.1 Performance

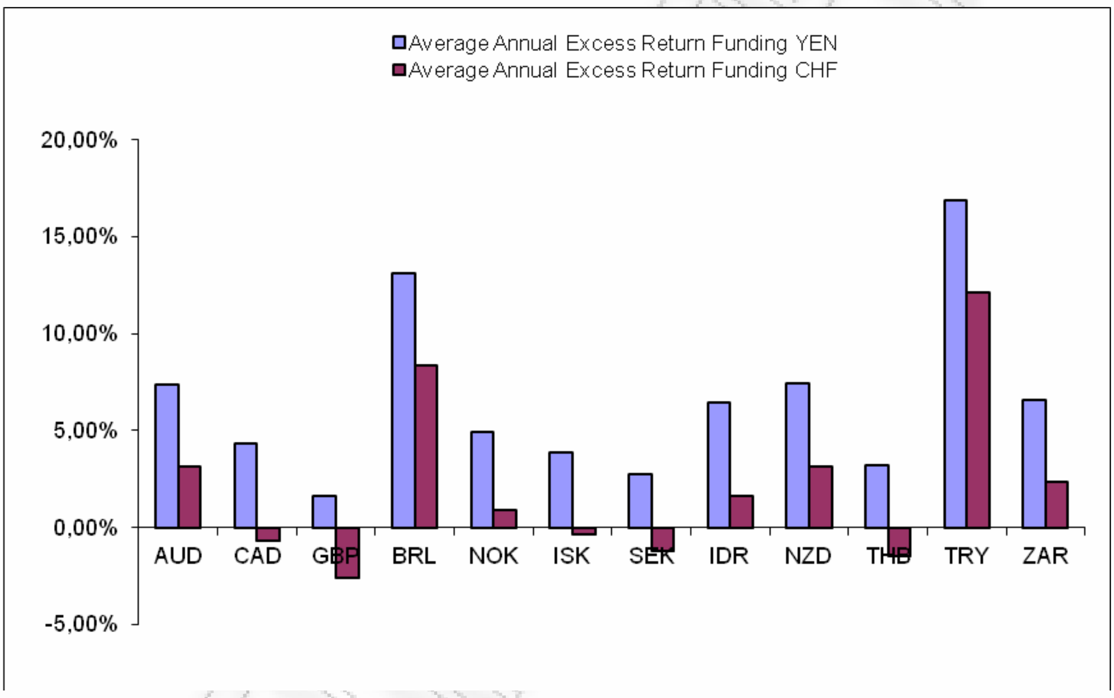
Carry trades have been shown to perform well quite consistently for long periods and have thus become a fairly common strategy. These strategies are profitable only when the interest rate differentials are wide enough to compensate for the foreign exchange fluctuations. Thus, they usually involve weak rather than major currencies.

Based on a sample of 12 target currencies, the Australian dollar (AUD), Canadian dollar (CAD), pound sterling (GBP), Brazilian real (BRL), Norwegian krone (NOK), Icelandic krona (ISK), Swedish krona (SEK), Indonesian rupiah (IDR), New Zealand dollar (NZD), Thailand baht (THB), Turkish lira (TRY), South African rand (ZAR) and on 2 Base-Funding currencies the Japanese Yen (JPY) and the Swiss Franc (CHF) we create 24 currency pairs.

Bloomberg makes daily returns for these currency pairs available on page FXCT. These daily returns are calculated using three-month euro deposit rates for the funding as well as the target currencies. The period that our sample is based is from January 2000 to December 2010. The following graph exhibits the *average annual excess returns*[29] for our target currencies using JPY as funding currency in the first case and CHF in the other.

Graph 1

Average annual excess returns



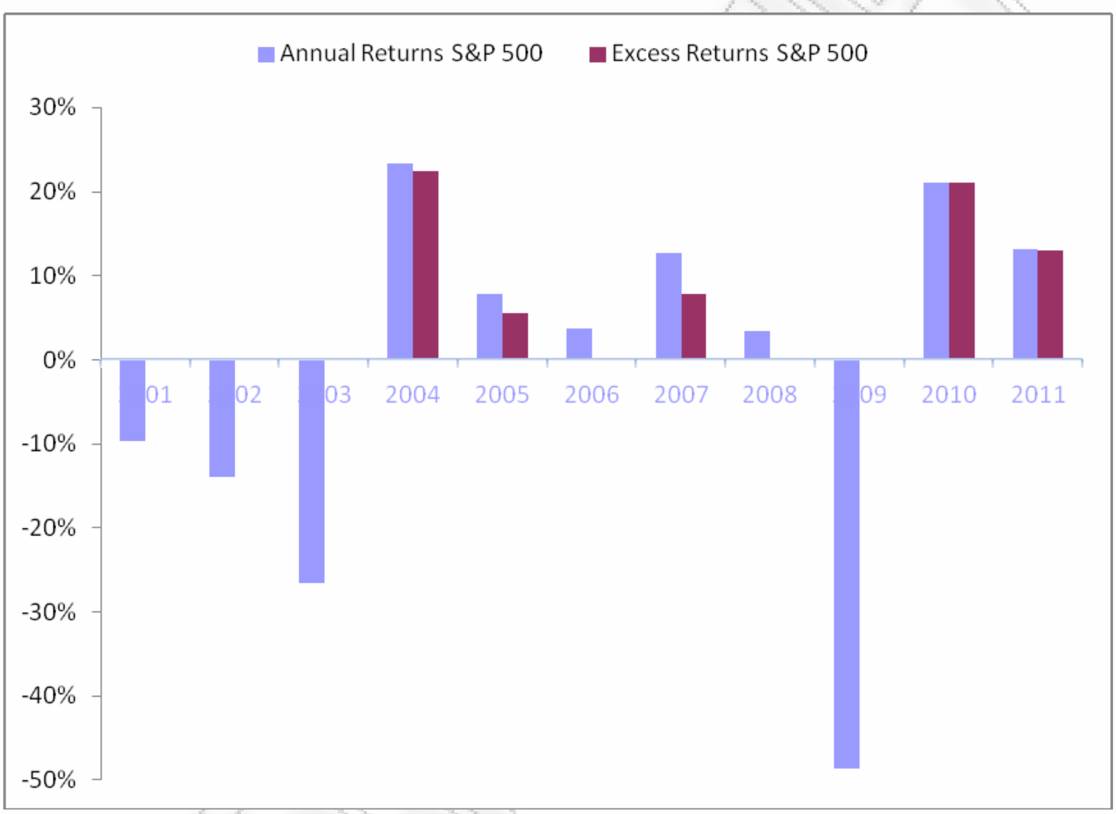
Source Bloomberg

Clearly, the currency pairs with JPY as funding currency have higher returns than those with the CHF as funding currency. That feature can be attributed to the wider interest rate differential as Switzerland's interest rates were higher than Japans. In addition, TRY and BRL seem to have the highest excess returns. Moreover if these returns are compared to the corresponding excess returns of the index S&P 500 we can realize how profitable a carry trade strategy can be.

The following graph shows annual returns and annual excess returns of the S&P 500. Data are from DataStream from 2000 to 2010. For the calculation of the excess return[30] we subtract from the returns the annual three-month T-bill rate. Over the decade the average annual return of S&P 500 was -1,22%.

Graph 2

Annual returns & excess returns of S&P 500



Source DataStream

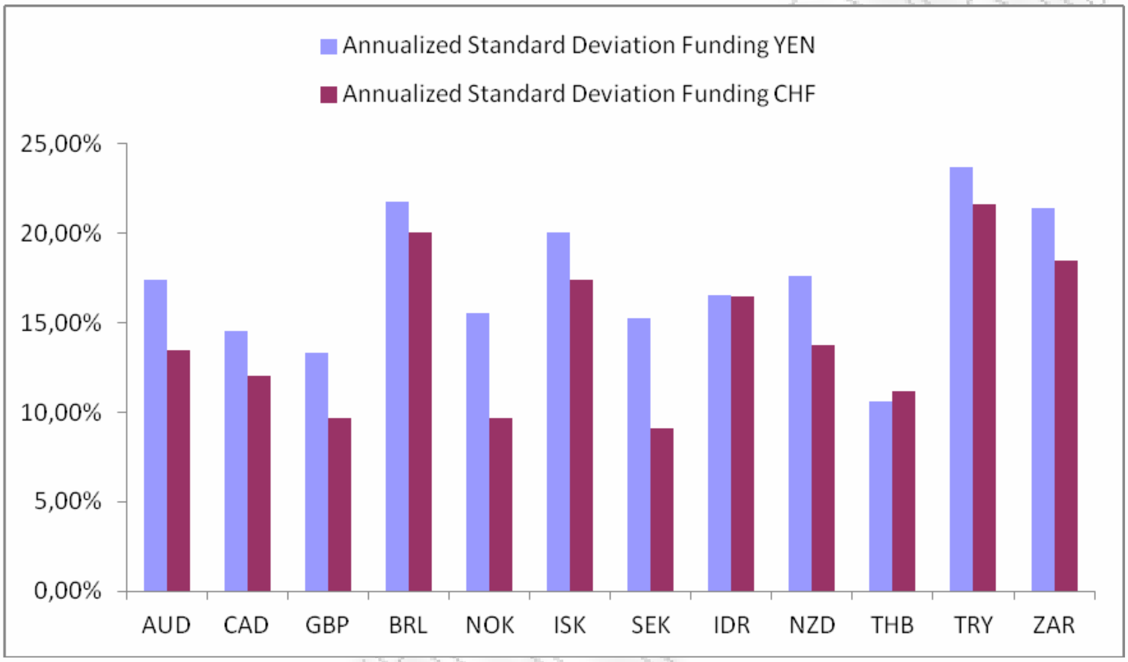
Focusing on graph 1 and graph 2 we can draw the assumption that carry trade is a very profitable strategy. Furthermore, our assumption is enhanced if we observe the following Sharpe ratios. Nonetheless, this strategy is subject to a *crash risk* that we discuss later.

The following graphs shows annualized *standard deviation, sharp ratio* and *downside deviation* for the above currency pairs.

The *standard deviation* on the rate of return on an investment is a measure of the volatility of the investment. It is a representation of the risk associated with the returns of the investment. Standard deviation provides a quantified estimate of the uncertainty of future returns.

Graph 3

Annual standard deviation



Source Bloomberg

From the graph 3 we can observe that currencies with higher returns, such as TRY, have high *standard deviation*. If standard deviation is considered as a measure of risk, then from the above graph we notice that returns are in line with its corresponding risks.

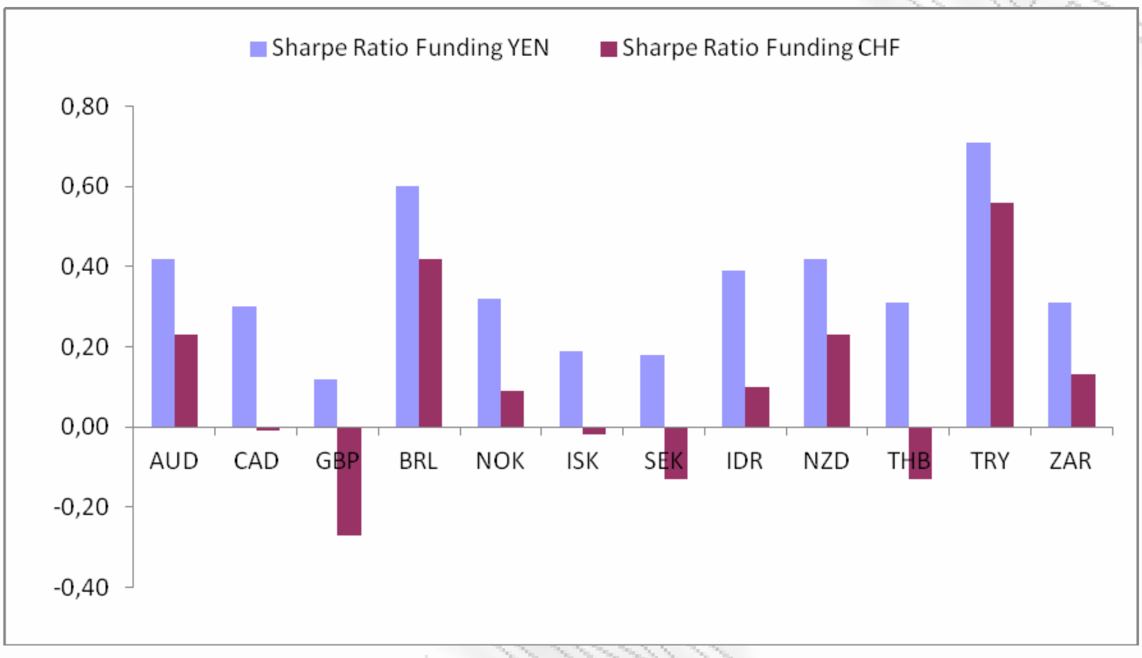
The following graph shows Sharpe ratios for the corresponding currency pairs. Sharpe ratio is calculated as:

$$s = \frac{R - RF}{\sigma}$$

Where R is the asset return, RF is a benchmark, the risk free rate of return and σ is the standard deviation of the assets return.

Graph 4

Sharpe Ratios



Source Bloomberg

The *Sharpe ratio* is used to characterize how well the return of an asset compensates the investor for the risk taken. Higher *Sharpe ratio* means that the asset has high return relative to its imposing risk. We can observe from the above graph that when the Japanese YEN is used as a funding currency higher *Sharpe ratios* are achieved. BRL and TRY has the highest *Sharpe ratios* with 0,6 and 0,71 respectively.

Burnside et al (2007)[31] concluded that high Sharpe ratios from the failure of (UIP) doesn't corresponded to the amount of money produced due to the transaction costs and price pressure limits. In terms of sum of money, payoffs are uncorrelated with the traditional risk factors. The author suggested that payoffs from carry trade strategies, when risk is taken into account are relatively small.

Graph 5 presents the *downside deviation* for the currencies concerned. *Downside deviation* is a value representing the potential loss that may arise from risk as measured against a minimum acceptable return by isolating the negative portion of volatility. It is similar to standard deviation, but considers only returns that fall below the minimum acceptable return.

Downside deviation is calculated as:

$$d = \sqrt{\int_{-\infty}^{t} (t-r)^2 f(r)\, dr}$$

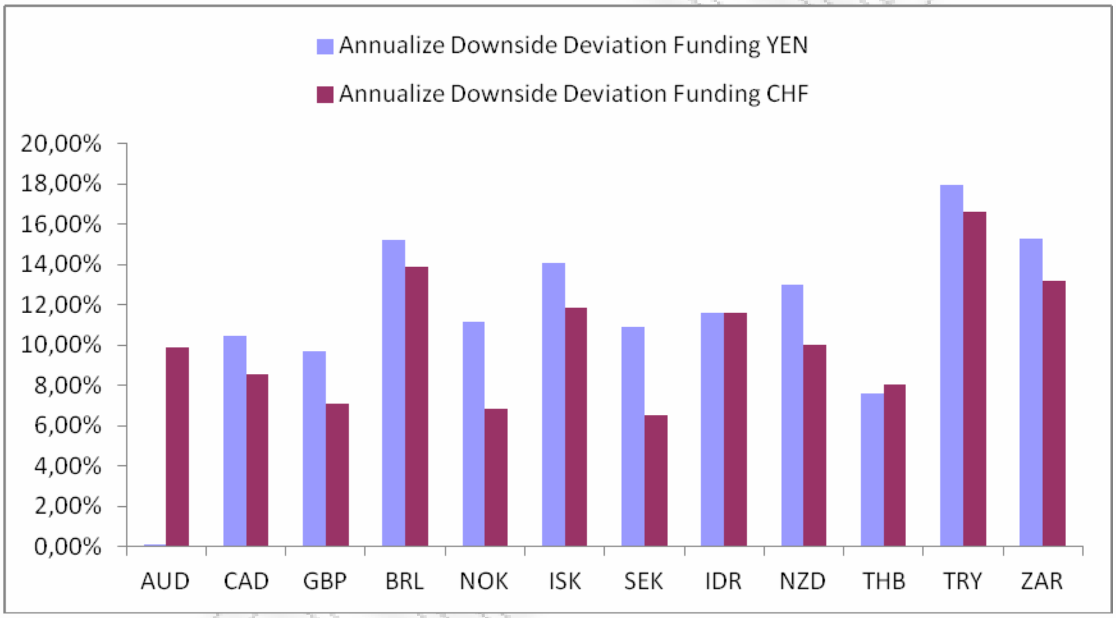
t = the annual target return, originally termed the minimum acceptable return, or MAR.

r = the random variable representing the return for the distribution of annual returns *f*(*r*),

f(*r*) = the three-parameter lognormal distribution **wikipedia**

Graph 5

Downside deviation



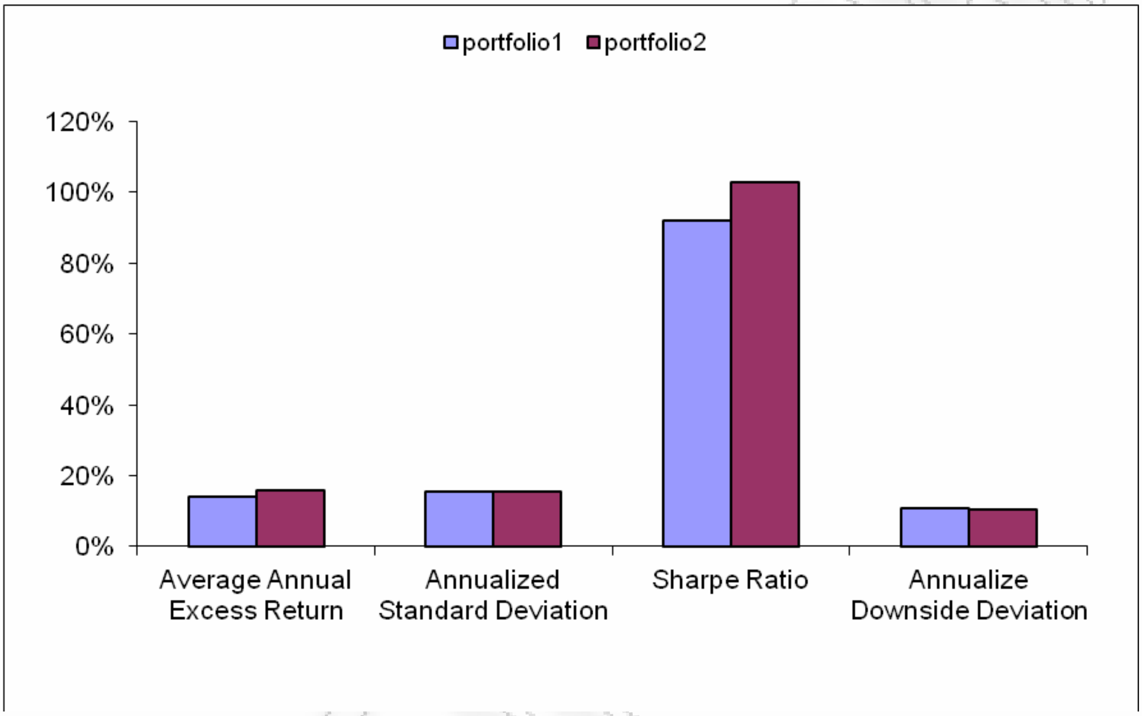
Source Bloomberg

It worth's mentioning that for the period under consideration, AUD has almost zero downside deviation when the Japanese Yen is used as funding currency.

Finally we construct two portfolios which consist of a long position on AUD, TRY, BRL, NZD the first and ZAR plus the currencies of the first portfolio the second and a short position on YEN and CHF both. Funds allocated in equal weights. The sample period is the last two years. Target currencies are chosen with yielding criteria, we chose the highest versus lowest yielding currencies. The first portfolio is recommended by Bloomberg, on the second basket we add ZAR and we observe the changes in the results.

Graph 6

Currency portfolios



Source Bloomberg

We observe that the addition of ZAR in the second portfolio increases the average annual return from 14,22% to 15,89% without any change in the volatility of the returns, standard deviation is 15,38% for both portfolios. Moreover *Sharpe ratio* is increased from 0,92 to 1,03. Finally the *downside deviation* is slightly decreased from 10,64% to 10,55%

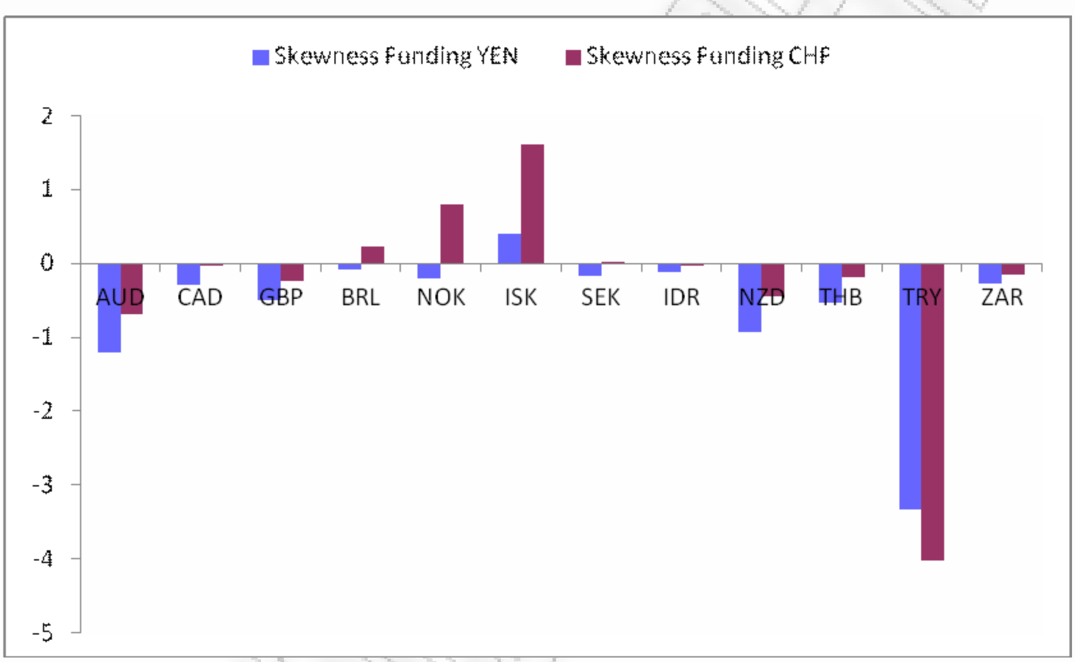
3.2 Return Distributions

Skewness and *Kurtosis* are useful to understand the general tendency in carry trade market. Carry trade returns are not normally distributed. The following graphs, which are based on our previous 10year sample with 24 currency pairs, show that the returns tend to be negatively skewed and have positive kurtosis.

Negative skewness reflects the presence of occasional large negative returns, it confirms the argument: *going up by the stairs and down in the elevator*. A negative skew indicates that the *tail* on the left side of the probability density function is longer than the right side and the bulk of the values (including the median) lie to the right of the mean. Negative skewness can be considered as the risk for speculators.

Graph 7

Skewness



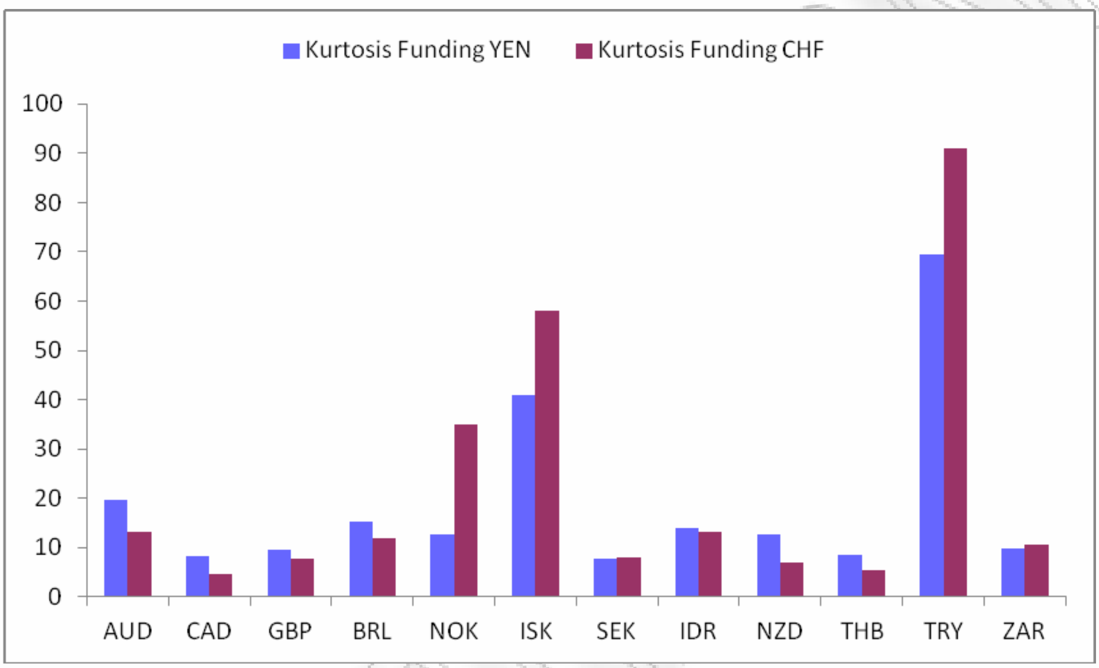
Source Bloomberg, Calculations using E-VIEWS

The above graph shows that for the period under consideration, the negative skew is most pronounced for target currencies such the AUD, NZD and TRY. It is interesting that the BRL, which also has high returns, has a slightly negative skewness when Japanese YEN is used as base currency and slightly positive when the CHF is used as funding currency.

Kurtosis measures the extent to which the returns are more peaked or more flat relative to a normal distribution. A distribution with high kurtosis has a distinct peak near the mean, declines rather rapidly and has heavy tails- fat tails. Higher kurtosis means more of the variance is the result of infrequent extreme deviations, as opposed to frequent modestly sized deviations. The “fat tail” metaphor explicitly describes the situation of having more observations at either extreme than the tails of the normal distribution would suggest; hence, the tails are "fatter."

Graph 8

Kurtosis



Source Bloomberg, calculations using E-VIEWS

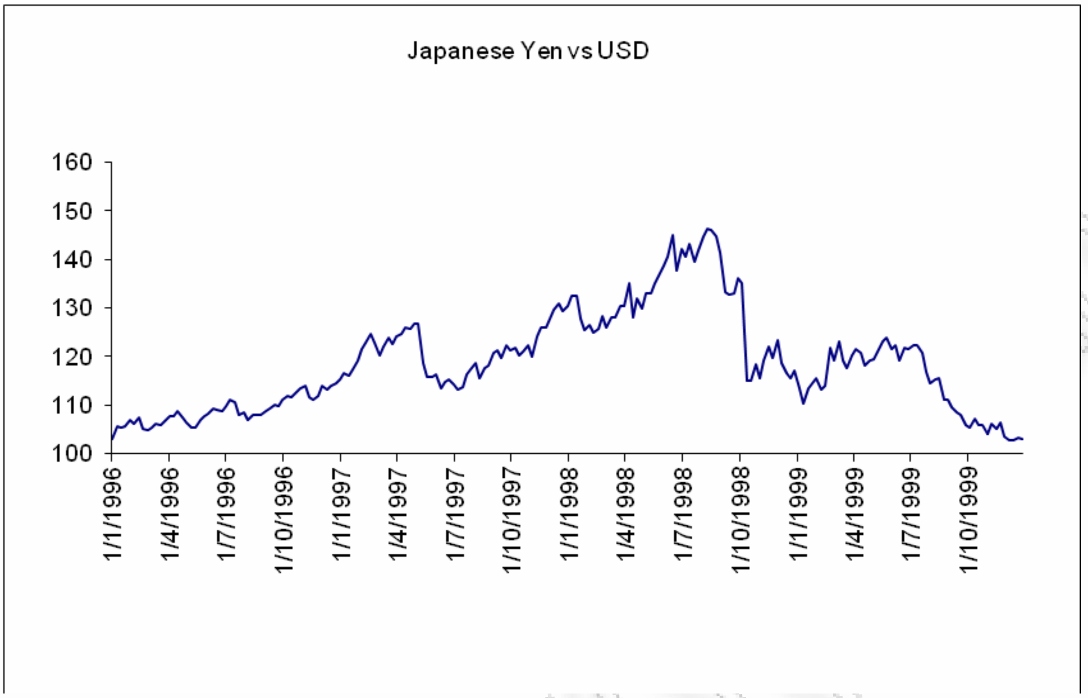
All target currencies seems to have high positive kurtosis, with TRY, ISK and NOK to exhibit the highest with 90,96 , 58,12 and 34,92 respectively.

3.3 Crash Risk

As mentioned above, returns have positive Kurtosis and are negative skewed. Negative skewness means that currencies are disposed to a crash risk and positive high kurtosis that the distribution of returns is fat tailed. Investors are exposed to high negative returns which are occurred rapidly. They have small gains for protracted periods and huge occasional negative returns.

Markus K. Brunnermeir, Stefan Nagel and Lasse H. Pedersen (2008)[32] investigated the relationship between carry trades and dramatic exchange movements. On October 7th and 8th of 1998, USD suffered a huge depreciation against the Japanese Yen.

Graph 8
Yen vs USD



This sudden move wasn't related with the announcement of fundamental news. The authors conjecture that this phenomenon can be attributed to the unwinding of carry trade. (When speculators face funding constrains, reduce the demand for the target currency, leading it to depreciate). This is consistent with the existence of "bubbles" within the market.

In the long term, as speculators hold on to their positions, the target currency is prevented from depreciating as suggested by (UIP), leading to a "bubble". Holding on to carry trades is profitable for each individual, since he doesn't know when others unwind their positions. Finally, the correct price is delayed and occurs as a sudden crash in the market.

Most asset markets exhibit slow booms and sudden crashes. During periods of crisis like the Asian crisis 1997, peso crisis in Mexico 1994, Russia crisis 1998 etc crashes were shorter and sharper than any boom of equal magnitude. This feature exists in almost every emerging market.

Laura L. Veldkamp (2004)[33] explains sudden crashes by presenting a model were agents undertake more economic activity in good times than in bad. This activity produces public information about the state of the economy. If the state changes when times are good and information is abundant, changes incorporated quickly in asset prices and a sudden crash occurs. When times are bad, scarce information and high uncertainty slow agents reactions as the economy improves and a slow boom occurs.

The literature proposes several explanations for the carry trade performance such as exposure to illiquidity spirals, crash risk, risk factors etc.

Jacob Gyntelberg & **Eli M Remola (2007)**[34]**,** focused on the risk profile of target currencies in Asia and the Pacific. Based on their return distributions, which wasn't normal because they exhibit skewness and kurtosis, concluded that high returns couldn't be explained in terms of their corresponding volatilities. They suggested that appropriate measures for risk associated with these strategies would be those that focus on downside risk. They consider two measures of downside risk, VaR and expected shortfall. They find that both measures lead to similar risk-return trade-offs across carry trade strategies. Their findings suggests that carry trade returns reflect downside risk. In addition, they show that the difference between risk-return trade-offs for carry trade strategies and those trade-offs for equity markets remain wide regardless of the risk measure used. Equity markets and carry trades belong to different asset classes, for which risks are priced differently.

Imad A. Moosa (2007)[35] measured risk and return for six currency pairs using quarterly historical data from 1995 to 2006. The funding currencies were the JPY and the CHF, while target currencies were the USD, the GBP and the CAD. From the analysis of data, the author concluded that carry trade can be profitable if conducted over a long period of time, however the risk involved is high. Moreover he stated that a high interest rate differential doesn't necessarily with high volatility in interest rates. It is worth mentioning that the authors estimations may not be accurate because bid-ask spreads were overlooked and this could lead to false inferences. E.g. when bid-ask spread gets wider the rate of return declines.

According to **Markus K. Brunnermeir et al (2008)**[36] currency crashes are positively correlated with increases in implied stock market volatility VIX and the TED spread (the difference between the interest rates on interbank loans and short-term U.S. government debt ("T-bills"), which are indicators of funding illiquidity. Moreover they find that currencies with similar interest rate co-move with each other, which is evidence that carry trades affects exchange rate movements.

The findings of Markus K. Brunnermeir et al depicted the need for new macroeconomic models in which risk premia are affected by market liquidity and funding liquidity issues.

Charlotte Christiansen, Paul Soderlind and **Angelo Ronaldo (2010)**[37] try to explain the carry trade performance using an asset pricing model in which factor loadings are regime-depended rather than constant, thus their model provides a significantly smaller pricing errors than traditional models. More precisely, the risk exposures are allowed to change according to one or more state variables in order to explain non-linear and regime depended risk-return payoffs. They find that risk exposures of the carry trade returns are highly regime depended. The beta related to the stock market is positive in "normal" times and much more during turbulent times. More over returns are more predictable (mean-reverting) during turmoil and have a direct exposure to a volatility factor. In addition the performance of carry trade strategy during high market volatility is one third driven by exposure to traditional risk factors (equity and bond returns) and two thirds driven by exposure to the volatility factor itself. More over foreign exchange market volatility and funding liquidity are the two variables which affect most directly the systematic of carry trade. Finally, the authors argued that once carry trade is correctly priced by means of regime depended models, it looks much less attractive.

Carry trades can offer significant profits to an investor. However when the risk associated with this strategy is measured comprehensively it seems that carry trades are less attractive.

3.4 Carry Trade Products[38]

Carry trades have in recent years become a familiar and mainstream strategy that the market has created tradable benchmarks for them and has introduced structured FX instruments referencing these indices. These indices evolved rapidly and very differently from bank to bank.

Carry trade indices emerged from the trading models banks developed to profit from the strategy of carry trade. As depicted in the section with the performance of carry trade, over time this strategy makes money. Equity and bond investors had been looking for diversified sources of income and the nature of indices, as a simplified form of investment, makes them an ideal entry point to the market.

Different type of indices suits to different type of investors. The downside and potential underperformance of carry trade strategies in a highly volatile trading environment is possible. Individuals should invest in an index that suits their view and risk profile.

Only large banks preserve these indices, no-one else sees the flow, or has the back data needed to construct the complex models required. In fact, this is a rare example of diversification between the top banks in today's foreign exchange market.

Each bank has chosen a different methodology in constructing its indexes. These indices combine a long position in one or more high-yielding currencies with a short position in one or more low-yielding currencies. The key differences are the number and type of currencies used and the degree to which an index is optimized in order to take into account the effects of volatility or the correlation between currencies.

We will demonstrate indices of five large Financial Institutions by applying the methodology of construction of each one and the differences between them. This banks are 1) Deutsche Bank 2) Barclays Capital 3) Credit Suisse 4) Citigroup and 5) JP Morgan

Deutsche Bank has named its product *Harvest Suite*. It consists of three indices, the first is the *G-10* where each month buys the G-10 currencies with the highest interest rate and goes short on the three G-10 currencies with the lowest. Its *Balance index* takes a long position on the five highest and sells the five lowest yielders from a global basket of currencies although the two must be G-10. Finally, its *Global index* buys and sells five high and low from an unconstrained basket of currencies. The simplicity of the model, positions are equally weighted and no portfolio theory is used, makes it high transparent and open to more upside in good environment. On the other hand it exposes indexes in periods of high volatility.

Barclays Capital launched *the intelligent carry index* in September 2006. It uses a model that determines the optimal currency allocation by weighting each G-10 currency from -100% to 100% in terms of suitability for positive carry. With the sum of positive and negative positions being equal, the index takes long positions which are financed by short positions. Barclays Capital also has an Asian currency index which consists of Asian target currencies. It uses portfolio theory to determine the weights of each currency. Moreover it offers a variety of currencies from major to Asian with very high yields. Unfortunately, due to its optimization method it limits upside in a good environment.

Credit Suisse's Rolling *Optimized Carry Indexes.* It uses US dollar, Euro, pound sterling and Swiss Franc as funding currencies. Every month the bank constructs G-10 and G-18 (which includes the most liquid emerging market currencies) indices for each of these base currencies, buys the higher and sells the lowest yielding units in each case through cash-settled one month forwards. Target volatility is 5% and the allocation to each currency is optimized by mean-variance. On the pros side is that due to optimization high protection is achieve in periods of high volatility. On the other hand a possible rebound in volatility doesn't absorbed efficiently.

JP Morgan launched *Income FX* and *Income EM* in 2005 and 2007 respectively. The first is for G-10 currencies the second for emerging markets. The G-10 index selects four G-10 pairs using an algorithm that determines the highest yield per units of risk. The portfolio then is leveraged or de-leveraged, to achieve target volatility of 5%; the maximum leverage is 200%. The difference between Income FX and Income EM is that the later selects five currency pairs from 20 emerging market currencies, has a target volatility 10% and maximum leverage 300%. Positions are equally weighted for both indexes.

Citigroup offers the *Beta 1 index* which includes components of carry, momentum and Purchasing Power Parity. There are two sub-indexes the Beta 1 G-10 which is based on the 13 most liquid tradable currency pairs that are not subject to government control and the emerging market sub-index which is based in nine currency pairs. In each pair the index buys the higher yielding and sells the lower yielding currency. On the benefits of the index is that a range of indexes offered for variety of risk tolerance. On the other hand diversity of portfolio could limit the performance in good times.

The major dissimilarity between those indices lies on the fact of optimization. There is an ambiguity between Financial Institutions on whether or not should optimize their indexes. On one side of the debate are Deutsche Bank and JP Morgan, who doubt the optimization. Barclays Capital and Credit Suisse believe that optimized indexes are necessary, especially in a volatile market. Citigroup stands somewhere in the middle, its range of Beta 1 is not optimized but the bank has a sister range of carry-based indexes that are optimized, the Alpha 1 range.

All major banks mentioned above, offer structure products and options on their indices that allow their clients to express their negative view about carry trade. Derivatives gives proponents and challengers of carry trade the chance to bet on the viability of carry trade and whatever their opinion is, if correct, to make money.

Another interesting product that bases on carry trade is *CFXOs (Collateralized Foreign Exchange Obligations)*. Experiencing from the recent subprime crisis, the demand for collateralized products which are less exposed to the weak credit market is growing. Most major Financial Institutions have the intention to plan the popular securitization techniques away from the risky credit market by applying them to other asset classes. This is the case of Collateralized Foreign Exchange Obligations (CFXOs) which make use of Collateralized Debt Obligation technology based on the FX markets.

A CFXO is collateralized dept obligation based on the cash flow from underlying carry trades. CFXOs are based on the 10 major currencies or in combinations of these and other regional currencies, like carry trade indices. There is a priority on payments. First senior investors are paid and last equity holders.

Major international rating agencies such as Fitch Ratings issue methodology documents and guidelines on how they rate CFXOs and similar instruments based on carry trade.

There is a great variety of products underlying carry trade strategy. Each product is designed to suit the view and risk profile of every individual. Whatever the view of the viability of carry trade, these products are becoming popular among investors.

Conclusions

Carry trade strategies became very popular the previous years, due to high returns they were offering. Actually carry trade is a bet against *Uncover Interest Rate Parity (UIP)* which states that higher-yielding currencies will tend to depreciate against lower-yielding currencies at a rate equal to the interest rate differential. Thus any gain from investing in a high yielding currency will be offset from the future depreciation of the currency.

However (UIP) seems to fail almost universally. As we depict in chapter 1 most high interest rate currencies tend to appreciate instead of depreciating. This is known as *the Forward Premium Puzzle* and a voluminous literature attempts to explain it. A conclusion we made is that in most cases the puzzle seems to fade as the investment horizon expands. In short time horizons interest rates do not determine exchange rates as the (UIP) predicts. However, (UIP) assumes a world without risk; the condition assumes that expected returns would be equal regardless of risk. In addition, many researchers attribute the puzzle to a consequence of carry trade strategies. Continues demand for weak currencies results on their appreciation. Other explanations are *incomplete information processing* **Philippe Bacchetta** and **Eric van Wincoop (2006)** or *adverse-selection problems* between participants in foreign exchange markets **Greg Burnside, Martin Eichenbaum** and **Sergio Rebelo (2007).** Certainly a combination of causes results the puzzle, researches are in progress to make concrete assumptions for the solution of the puzzle.

Another aspect under consideration is that of *market efficiency*. Investors search for inefficiencies within the market in order to build their strategies. Although, the empirical results proposed by the literature are contradicting, over the years a consensus that rejects the efficiency is formed. However testing *the strong form* of efficiency requires a complex model which takes into account lots parameters. Thus if the model is mispesified we could make wrong assumptions. We have tested the weak form of market efficiency by applying *co integration* and *Granger Causality* tests on exchange rates of different currency pairs. The sample period contained daily, monthly and annual data. For the majority of currency pairs neither co integration nor Granger Causality found. Thus, we draw the assumption that market efficiency holds at least on its weak form.

Finally, carry trade returns are negatively skewed and have positive kurtosis. This means that investors are subject to *crash risk*. They enjoy many small gains but also they face few but large losses. This is like “going up by the stairs and down by the elevator”. Standard deviation of the returns does not provide a clear picture of the risk associated with the strategy. Thus high Sharpe ratios associated with the strategy are not indicative. When risk is properly measured then carry trades looks less attractive.

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[1] See BIS statistics- Foreign Exchange quarterly reviews
[2] For a more detailed approach see "Evidence of carry trade activity" Gabriel Galati et al. 2007
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[13] Random walk is a mathematical formalization of a trajectory that consists of taking successive random steps.
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[27] kurtosis is a measure of the "peakedness" of the probability distribution of a real-valued random variable, although some sources are insistent that heavy tails, and not peakedness, is what is really being measured by kurtosis Higher kurtosis means more of the variance is

the result of infrequent extreme deviations, as opposed to frequent modestly sized deviations.

[28] skewness is a measure of the asymmetry of the probability distribution of a real-valued random variable. The skewness value can be positive or negative, or even undefined. Qualitatively, a negative skew indicates that the *tail* on the left side of the probability density function is *longer* than the right side and the bulk of the values (including the median) lie to the right of the mean. A positive skew indicates that the *tail* on the right side is *longer* than the left side and the bulk of the values lie to the left of the mean. A zero value indicates that the values are relatively evenly distributed on both sides of the mean, typically but not necessarily implying a symmetric distribution.

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[30] When returns are negative excess returns are zero
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