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Currency Carry Trades – Prudent Investments or Just a Lottery?

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ABSTRACT

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Objectives: The objective of this study is to find out whether currency carry trades are prudent investments or a pure lottery. To consider currency carry trades as a prudent investment strategy they have to fulfill at least one of the following two criteria

- The risk-adjusted performance of currency-carry trades should match or outperform the risk-adjusted performance of the equity indices. I.e. higher risk should be awarded with adequately higher profits.
- Currency carry trades should be suitable as an alternative investment. I.e. the correlation between the stock market and the currency carry trade returns should be small or negative, especially in times of declining stock markets.

Theoretical Framework: According to the Uncovered Interest Parity (UIP) a strategy that involves borrowing in a low yielding currency and investing it in a high yielding currency should not generate excess return. The high yielding currency is therefore expected to decrease. Thus previous studies all concluded that the UIP does not hold.

Data and Methodology: The empirical part uses the one month interbank interest rate and the mid-rate for the exchange rate. The time horizon is from Jan. 1st 1993 until April 27th. We used three different methods to evaluate the risk-adjusted performance (Sharpe ratio, reward-to-VaR and conditional Sharpe ratio). To test the suitability as an alternative investment we applied the linear correlation and the exceedance correlation.

Results and Findings: The findings support the research hypothesis that the risk-adjusted measures of currency carry trading portfolio outperform the equity indices. Currency carry trades function as an alternative investment partly since criteria is not entirely fulfilled. In bear markets correlation is high, whereas in bull markets it is low.

Keywords: Currency carry trade, Return on Carry, Uncovered Interest Parity, exceedance correlation, risk-adjusted performance measure

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1. Introduction

1.1 Background

The currency carry trade utilizes the forward premium puzzle by borrowing in low interest rate currencies (funding currency) and investing in currencies with high interest rates (target currency). While the investor captures the interest rate differential between the two currencies, it leaves the investor exposed to deviations in the foreign exchange market.

After the technological development in the financial sector, foreign exchange trading and furthermore currency carry trading, has also become the practice of households and institutional investors - no longer just business of banks and financial institutions. Starting in mid 1990's, currency carry trading popularity made the market to create tradable benchmarks as well as related structured foreign exchange instruments to make currency carry trading easier. Although currency carry trades have struggled with the financial market as a whole during the recent economic crisis, the market has experienced yet another "comeback" of currency carry trading in the spring of 2009. (Bloomberg, 2009). The hedge fund industry has involved currency carry trading as a major part of its assets-under-management. The volume of these currency carry trades has been so large that it has had a significant effect on the prices of currency exchange- and interest rates globally (BIS, 2008). The impact of the carry trades locally have resulted in increasing control over countries' monetary policies. Jylhä et al (2008) determine that by 2008 of all the hedge funds' assets under management, currency carry trading has taken a share of approximately 5% of the M2[1] money supply of the major currencies traded.

A good example of this is the largely popular carry trade of using the Japanese Yen as the funding currency, which appreciated over 30% versus the Euro in the period of a couple of days in October 2008. This resulted as concern about the volatility of the yen among

[1] M2 includes the total of all physical currency part of bank reserves in addition with the amount in demand accounts, most savings accounts, money market accounts, retail money market mutual funds, and small denomination time deposits (certificates of deposit of under $100,000). (Federal Bank of New York, 2008)

the financial ministers of the group of seven different major industrial countries. (Fackler, 2008).

1.2 Problem discussion

It seems to be a mystery how many people have executed currency carry trades, a strategy that according to macroeconomic theory, should not be profitable. The uncovered interest parity (UIP) in theory lies within the assumption of high interest rate currencies depreciating vis-à-vis low interest rate currencies. To specify let's assume that the target currency has x % higher annualized interest rate than the funding currency. According to the UIP, the target currency should have depreciated exactly x % relative to the funding currency, which leads to a profit/loss of zero.

Nevertheless there are several older studies that reject the UIP, see for example, Hodrick (1987), Froot and Thaler (1990), Engel (1996), as well as more recent studies by Flood and Rose (2002), Baillie and Bollerslev (2000) and Sarno et al. (2006). Some studies like Bekaert (1998) or Bansal and Dahlquist (2000) have proven even the contrary - instead of depreciating vis-à-vis the low interest rate currencies, the high interest rate currencies tend to appreciate. Going back to our example, the target currency would appreciate by y % in relation to the funding currency. A carry trader would not only profit from the interest rate differential, but also from an appreciation in the target currency. Therefore the investors return after one year would be:

$$(1+x\ \%)*(1+y\ \%)-1$$

This is the basic idea behind a simple currency carry trade. This paper will not focus further on questioning the violation of the UIP since it is out of the scope of this study. The violation of the UIP will therefore be taken as given.

Only since the recent years, studies have been conducted regarding the profitability of currency carry trading strategies. Baz et al (2001) as well as Burnside et al (2006) have

investigated the profitability of the carry trade approach. Although these studies conclude a higher profitability to currency carry trades than stock indices, there is less information about how good the risk-return relation of that strategies is.

Currency carry trades are regarded as highly speculative investment strategies. The general opinion is that the foreign exchange market is too risky and therefore the strategy is dangerous for unsophisticated investors. There are only few researches conducted that describe the risk of such strategies. Burnside et al (2007) have measured the relation between risk and return for emerging market currency carry trades by using the Sharpe ratio with data from 2001 and 2007. Surprisingly they found much higher value of Sharpe ratio for currency carry trades then for the S&P 500- index. The Sharpe ratio, which measures the risk adjusted performance of a portfolio (stock) tells us basically whether a portfolio's (stock's) returns are due to smart investment decisions or a result of excess risk. The greater the Sharpe ratio value is the better its risk-adjusted performance has been. The problem of the Sharpe ratio is that it uses the standard deviation as a risk measure, which requires a normal distribution. The returns of currency carry trades are likely to be negatively skewed with fat tails and therefore non-normal distributed (Brunnermeier et al., 2008)

According to our best knowledge no studies explore the risk-adjusted profitability measures of currency carry trades within the 10 major currencies, taking into consideration other risk measures besides volatility.

1.3 Purpose and Objectives

The purpose of this thesis is to explore if currency carry trades (in a simple form) are prudent investment strategies or just a lottery. We define a prudent investment strategy as a strategy where a risk averse person would under given circumstances invest. On the contrary, a lottery is defined as a strategy that only attracts irrational and/or risk neutral or

loving persons as they do not take risk as a factor or have risk as a preference while making investment decisions.

To consider currency carry trades as a prudent investment strategy they have to fulfill at least one of the following two criteria.

- The risk-adjusted performance of currency-carry trades should match or outperform the risk-adjusted performance of the equity indices. I.e. higher risk should be awarded with adequately higher profits.
- Currency carry trades should be suitable as an alternative investment. I.e. the correlation between the stock market and the currency carry trade returns should be small or negative, especially in times of declining stock markets.

To clarify our criteria, an example that does not fulfill any of the criteria: An extreme case would be a currency carry trade that has a correlation of 1 (fully correlated) with equity indices. Furthermore the risk-return of that currency carry trade would be poorer (same risk, but lower return) than the of the equity indices. A rational investor would therefore have no motivation to invest in such a strategy, since he/she would be better with the equity indices in any situation. A situation where ceteris paribus the return is the same, but has higher risk, would just attract risk lovers.

1.4 Structure of the thesis

In order to answer the research questions posed in part 1.3 we have decided to have the following structure:

In Chapter 2 we begin by presenting the currency carry trade as a phenomenon and the violation of the macroeconomic theory, more specifically the uncovered interest parity. In Chapter 3 we present the theoretical background of the currency carry trade as an investment. Chapter 4 presents the methodology used to analyze the data. In Chapter 5, our objective is to analyze the risk-return relation of currency carry trades combining

different combinations of the 10 major currencies (G10). These include the Australian Dollar (AUD), Canadian Dollar (CAD), Swiss Franc (CHF), Euro (EUR), Pound Sterling (GBP), Japanese Yen (JPY), Norwegian Krone (NOK), New Zealand Dollar (NZD), Swedish Krona (SEK), and US Dollar (USD). After this we explore the suitability of currency carry trades as alternative investments. Thus we analyze the correlation of the carry trade returns with the stock market returns. We also discuss whether the correlation is symmetric. In Chapter 6 we have the concluding remarks and possible ideas for future research.

1.5 Limitations

For this thesis we have chosen to take an approach that follows combining all possible single currency pairs summing the total of 45. In addition we have two portfolios, one with the lowest and highest interest rates at each point in time, and the other one which involves volatility. We do not conduct more sophisticated trading strategies than the mentioned. The thesis' aim is to present a simple model of currency carry trade pairs and portfolios. We do this for the following reason; we want to compare the currency carry trade combinations with equity indices such as the S&P 500 and not with actively managed equity funds.

Another possible limitation is related to the decision of different currencies included in the research part of this paper. We have decided to choose the 10 mostly traded currencies and structure the portfolios according to them. We acknowledge that other currencies than the ones used in this paper could bring up different results. For other currencies, say those of emerging markets, the validity of the data might issue problems due to instabilities of the currency by other factors.

2. Currency carry trades and their environment

The first chapter gave a brief introduction to the concept of currency carry trading. It also gave an insight about the basics of currency carry trades, which is: borrowing from a currency with a low interest rate and investing in a currency with high interest rate. In this chapter we give the reader a more extensive picture of the phenomenon as a whole and its related macroeconomic environment. Therefore we present the concept of carry trades before we discuss relevant background information about the foreign exchange market. For an extensive research on the anomalities in the foreign markets, see Sarno and Taylor, (2002). Finally we discuss the macroeconomic theory and show how it relates to currency carry trades.

2.1 The general concept of carry trades

To start with analyzing carry trades it is important to clarify the concept of the "carry trade" comprehensively. A carry is the obtained return from holding an asset (if positive), or the cost of holding it (if negative). To explain, commodities like agricultural products are usually negative carry assets, as they cause storage costs. However commodities can also be positive carry asset, when the benefits of the availability are greater than the storage costs.

Money is a typical positive carry asset. It does not cause any storage costs, and the market is willing to pay a premium for its availability, mostly in form of an interest rate. If we lend our money to someone, we loose the availability and earn as compensation the interest rate. On the other hand we are willing to pay an interest rate for the availability of money = credit. These interest rates normally cover beside the premium for availability, also a risk premium. When we discuss the interest rate in the following, we refer to a risk free interest rate to eliminate the interest rate risk premium.

A simple carry trade is as follows: borrow a low carry asset (small premium for availability) and lend a higher carry asset (higher premium for availability). The investor of such a carry trade would earn the difference between the two premia for availability. Currency carry trades are the most common, but not the only form of carry trades. Another common form is a carry trade between different maturities of interest rates. For instance, the traditional income stream from commercial banks is to borrow cheap (at the low overnight rate) and lend out expensive (at the long-term rate, which is usually higher than the short-term rate).

2.2 Features of currency carry trades

Because the term "currency carry trade" has been used very loosely in popular discussion, it is important to stress that it refers strictly to leveraged trades that exploit interest rate differentials across currencies by betting on the failure of the uncovered interest parity. Furthermore it is a zero-investment where funds are borrowed by low interest rate currencies (funding currency) and invested in high interest currencies (target currency). The motivation for currency carry trades is to take advantage of the chances of gaining profits from low carry costs in funding currencies and high carry returns in target currencies. Hence a currency carry trade investor tries to capitalize on the differential in the premia for availability for different currencies.

Unlike the interest carry trades mentioned above, the simple currency carry trades uses normally a borrowing and lending instrument with the same maturity. Furthermore an investor knows the interest rates already in advance and is therefore not exposed to an interest rate risk.

2.3 The Foreign Exchange Market and its interrelationship with interest rates

A simple currency carry trade borrows and lends in risk free assets. Therefore the interest rates are known at the time the investment decision is made. Hence the investor is only exposed to the risk in the Foreign Exchange Market. To clarify the risk and to give the reader a better understanding of currency carry trades, we will present some background information about the Foreign Exchange Market and the related macroeconomic parities.

2.3.1 Background about the Foreign Exchange Market

The Foreign Exchange market has some unique characteristics. For example the trading volume, the extreme liquidity to the market, the geographical dispersion, the long trading hours (24h, except on weekends) and the use of leverage, to mention the most important characteristics. The foreign exchange market is by far the largest.

Bank for International Settlements (BIS) conducts a report on FX-market characteristics including trading activity on a three year interval. This is the most valid overall market information, since whether or not FX-trading is reported depends on the country. According to the latest BIS report from 2007, growth in turnover was broad-based across instruments. For example the growth in foreign exchange swaps grew 80%, when it in the previous three year period was 45%. The reason for the growth may have been hedging of foreign exchange swap instruments. Forward contracts increased with 73% and the turnover of the spot markets by 59%.

The BIS survey also shows an average daily turnover of $3.2 trillion in 2007. This is an increase of 69% since 2004. As a comparison we can consider the New York Exchange's biggest trading day. This was the Black Monday on October 19, 1987 and reached with a turnover $21 billion; not even 1% of the above mentioned average foreign exchange turnover 2007. (BIS, 2007)

The major participants in the foreign exchange market are commercial banks, foreign exchange brokers in the interbank market, multinational corporations, and central banks. The latter intervene in the market from time to time to maintain target exchange rates. (Shapiro, 2006)

Banks normally do not charge a commission on their currency transactions, but they profit form the spread between the bid and ask rate. Almost all newspapers print daily lists of bid and ask exchange rates. These lists of exchange rates include, beside the spot rates, often also 30-day, 90-day and 180-day forward rates. Forward rates can be expressed in two ways: While commercial customers usually use the actual price (also known as the outright rate), in the interbank market dealers quote the forward rate only as a discount from, or a premium on, the spot rate. This premium/ discount is calculated as follows:

Forward premium or discount on foreign currency = (Forward rate - Spot rate)/spot rate * 360/Forward number of contracts.

where positive results are called as premiums and negative as discounts.

2.3.2 The covered interest parity

Spot and forward rates are connected to each other and to the interest rates in different currencies through the concept of arbitrage. According to the covered interest rate parity: 1) the returns from borrowing in one currency, 2) exchanging that currency for another currency and 3) investing in interest-bearing instruments of the second currency, while simultaneously purchasing a forward contract to convert the currency back at the end of the holding period should not generate any excess profit. I.e. the profit should be equal to a strategy where an investor borrows in the home currency and invests that money in an interest-bearing instrument in the home currency.

This for the reason that the currency of the country with a lower interest rate should be at a forward premium in terms of the currency of the country with the higher rate and vice versa. In an efficient market with no transaction costs the interest rate differential should be equal to the forward premium. This will be shown in the following manner.

$$(1+rd)/(1+rf) = (F/S) ,$$

where

rd = domestic interest rate for maturity t

rf = foreign interest rate for maturity t

F= the forward exchange rate implied by a Forward Contract maturing at time t

S= Spot exchange rate

After taking the natural logs of both sides we will get:

$$rd-rf = \ln(F/S),$$

where the interest rates are now continuously compounded and ln(F/S) is the risk premium/discount expressed in the percentage difference between the forward rate and the spot rate.

If the covered interest parity would not hold, an arbitrage transaction could, in theory, produce a risk-free return. In practice there can be deviations from the covered interest parity because of the imposition of taxes on interest payments to foreigners or transaction costs. Sarno and Taylor (2002) provide a broad empirical proof supporting the assumption that the CIP holds. Deviations tend to be small and short lived (Shapiro, 2006).

2.3.3 The uncovered interest parity

According to the uncovered interest parity (UIP) the forward rate for time t provides an unbiased estimate of the future spot exchange rate for time t+1:

$$E[St+1] = F$$

This implies that the difference between the expected spot price at time t+1 and the actual spot price is equal to the difference in interest rates. Hence any interest difference is offset by currency movements.

$$E(St+1) = ((1+rd)*St)/(1+rf)$$

We first move the spot rate to the left hand side and then take the natural logarithm,

$$\ln(E[st+1]/st) = rd - rf,$$

where the interest rates are now continuously compounded and, ln(E(st+1)/st) is the expected percentage change in the spot exchange rate.

Several studies have rejected the UIP, for instance in Hodrick (1987), Froot and Thaler (1990) and Lewis (1996). This failure of UIP is nowadays so established that it has got its own name, "**the forward premium puzzle**". It is a common finding that the forward rate is a biased predictor of the future spot exchange rate. Nevertheless they disagree regarding the reasons for the biasness of the puzzle. For example Sarno et al. (2006) sees the reason for the rejection of the UIP in the nonlinearities of the exchange rates. They showed that deviations detected from UIP using linear regression can be misleading. On the contrary Cumby (1988) explored the biases as a time-varying risk premium that separates the forward discount from the expected depreciation. Bilson (1981) has gone with his “new empirical paradigm" a step further: expected depreciation is always zero, and changes in the forward discount instead reflect changes in the risk premium. Unfortunately none of these can be said to convincingly explain the failure of UIP. Since we will not investigate the reasons for the forward premium puzzle any further, we take

the violation of UIP as given. Instead we explore what chances the failure of the UIP implies for an investor.

As a conclusion, we can determine that while the covered interest parity holds relatively, the uncovered interest parity does not.

2.4 Premia of currency carry trades

In chapter 2.1 we discussed the general concept of carry trading; borrowing a low carry and lending a high carry. We also explored that the carry value depends on the premium of availability that the market is ready to pay. In the example of the traditional commercial bank that borrows at the low overnight rate and lends at a higher long-term rate this relation is relatively clear. It is intuitive that the premium is higher for a longer maturity. Therefore as long as the yield curve is an increasing function of time, the commercial bank can generate profits. The risk is here that the yield curves become inverted. For that risk the commercial banks request beside the premium for availability, also a risk premium. For further details about the yield curves and the related interest rate risks see Brigo and Mercurio (2001).

Unlike the interest carry trades mentioned above, the simple currency carry trades uses normally a borrowing and lending instrument with the same maturity. Furthermore an investor knows the interest rate already in advance and is therefore not exposed to an interest rate risk. A currency carry trade tries to capitalize the differential in the premia for availability for different currency. A common macroeconomic explanation for differences in these premia is the Fisher hypothesis (Fisher effect, FE), which states that the real interest rate (r) equals the nominal interest rate (i) minus the expected rate of inflation (π^e).

$$r_r = r_n - \pi^e$$

Note that in this equation all the rates are continuously compounded. Therefore according to the Fisher hypothesis, the different inflation rates are responsible for the difference in the premia for availability. The Fisher hypothesis has been tested for different countries, yielding mixed results in the literature. The majority of the studies come to the conclusion that the fisher hypothesis can not be rejected for the industrialized countries, see for example Ahmed and Rogers (1996), Crowder and Hoffman (1996), Mishkin (1992), Peng and Wensheng (1995) and Yuhn (1996). Nevertheless Carneiro et al (2001) and Berument et al (2006) conclude that the hypothesis does not necessarily hold for developing countries.

The different inflation rates are connected to the future spot exchange rate through the relative purchasing power parity (PPP). According to the PPP, the currency with the higher inflation should depreciate in the future vis-à-vis to the currency with the lower inflation. Nevertheless economists agree that the PPP does not hold in the short run. The failure of PPP (PPP-Puzzle) is summarized by Roggoff (1996). Note that the Fisher hypothesis and the PPP together, should provide the same estimation for future exchange spot rate as the uncovered interest parity. Figure 1 explains the interrelationships.

While the Fisher hypothesis provides an explanation for the premium for availability in different currencies, the PPP can not explain the connection between inflation rate and future spot exchange rate sufficiently. In other words, the size of the availability premium in form of the interest rate can be only partly explained by the inflation rate. Nevertheless, the fact that currencies with high interest rates do not necessarily depreciate vis-à-vis to currencies with low interest rates is a macroeconomic puzzle that no theory can explain convincingly. Therefore researchers have been examining other reasons for interest rate differential. For example Cavaglia et al (1994) and Taylor (1989) conclude that the differential between the interest rates are a risk premium for foreign exchange market exposure. However Frankel and Froot (1989) disagree on this.

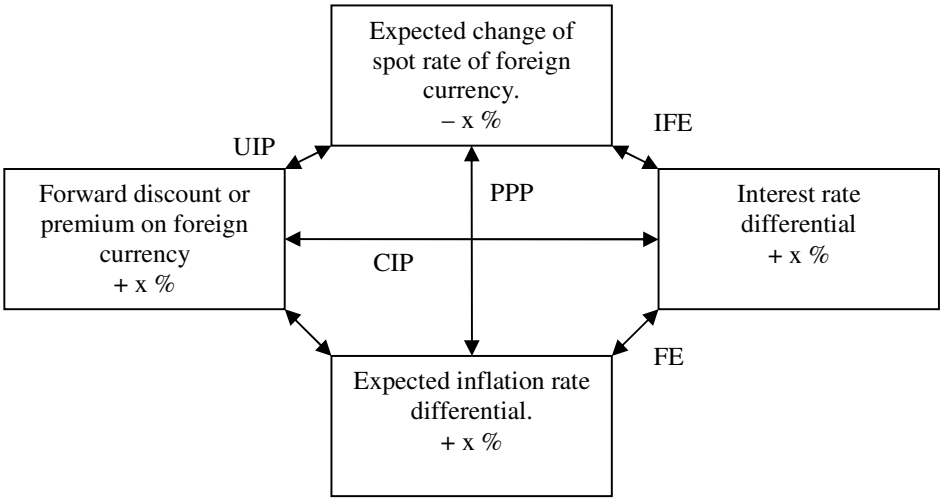

Figure 1. Five key theoretical relationships among spot rates, forward rates, inflation rates, and interest rates. (Shapiro, 2006)

3. Currency carry trades as investment opportunities

In chapter 2 we provided a theoretical background for the concept of currency carry trading and the related macroeconomic puzzles. In this chapter we give the reader a more in detail picture of currency carry trading instruments and different strategies of executing carry trades. We also discuss the theoretical framework of risk measures and risk-adjusted performance measures as well as correlation methods.

3.1 Currency carry trading instruments and benchmarks

Currency carry trading has been recognized in the financial media quite often. Mostly the discussion has been regarding the Yen carry trade and the Swiss franc carry trade. The increased popularity has lead to a variety of new instruments designed purely for the purposes of currency carry trading. For example, the Deutsche Bank's G10 Carry Spot index represents a long carry portfolio within the G10 currencies. The strategy of this index is being long in the three highest yielding currencies versus short in the three lowest yielding currencies within the basket of the G10 currencies.

Several carry trading indices entered the market in March - April 2007. These indices can be distinguished in structural terms from involving simple and more sophisticated currency carry trade allocation rules. More complex indices than the Deutsche Bank's G10 Carry Spot index, are the CSFB and Barclays indices which use mean-variance optimization for selecting the index weights. This means that they have lower aggregate weights for highly correlated currencies. (BIS, 2008)

The CSFB rolling optimized currency trade index reallocates every ten months the mostly traded currencies in addition with some emerging markets indices. The Deutsche Bank

(DB) Harvest index reallocates the 10 major currencies and 11 EM currencies. The Intelligent Carry Trade Index indulged by Barclays does reallocation on a monthly basis across the 10 major currencies.

More recently, structured FX instruments based on currency carry trades have also been introduced in the form of collateralized foreign exchange obligations (CFXOs). The first trades were completed in spring 2007. A CFXO is a collateralized debt obligation based on the cash flow from underlying currency carry trades (Merrill Lynch, 2007). Investors are paid in order of priority, starting with senior investors and ending with equity holders. An additional indication that carry trades are becoming a standard asset type in the global financial market is the fact that major international rating agencies have issued or are in the process of issuing methodology documents as well as guidelines on how they rate CFXOs and similar instruments. So far only Fitch Ratings has published guidelines and descriptions of the methodology used in their ratings, while S&P and Moody's will probably do so in the future. Similar to carry trade indices, CFXOs typically reference either only 10 major currencies or combinations of these and other typically regional currencies.

3.1.1 Market Participants

As mentioned in the introductionary part of this thesis, currency carry trades have been subject to larger institutional traders in the past approximately 15 years. Commodity trading advisors (CTA's) and hedge funds are the most common carry traders (Galati and Melvin, 2004). Nevertheless retail investors have appeared in the market operating with margin accounts and taking leveraged positions in across currencies. According to Financial Times (2009), the amount of these accounts in Japan grew between 2003 and July 2007 from less than 2000 to over 120,000. The deposits on these accounts netted worth over 700 million USD. Even though compared to the institutional traders, the retail traders who do not play a significant overall role, the exchange rate of the Yen was also affected by the retail carry-traders, cited in the market commentaries. (BIS, 2008)

3.2 Carry trading strategies

3.2.1 The Simple Carry Rule

The simple currency carry trading strategy rarely requires rebalancing due to minimal transaction costs. Theoretically a simple currency carry trades is implemented in the manner of the following hypothetical example (see figure 2).

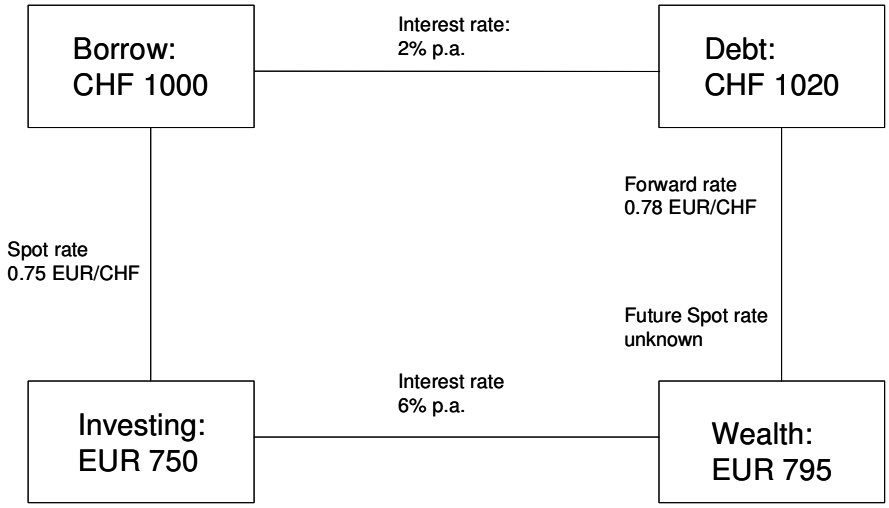

Figure 2. Example of a simple currency carry trade

An investor tries to capitalize on the 4% interest rate differential between the EUR and the CHF by borrowing CHF 1000 and investing them in EUR. The interest rates have a maturity of 1 year and are fixed. An investor has therefore only a foreign exchange market risk. According to the UIP the forward rate (calculated with the CIP) is an unbiased predictor of the future spot rate.

When the UIP holds the future spot rate would be 0.78 EUR/CHF and therefore the return of this currency carry trade would be equal to zero. This example clarifies that a currency carry trade always implies a bet against the UIP.

If the spot exchange rate does not change, the investor will make a profit of 40 CHF or 30 EUR. In the case that the EUR would appreciate, the profit would be even larger. On the other hand if the USD depreciates by more then by 3.92% (spot rate 0.78 EUR/CHF) the investor makes a loss.

The same currency carry trade can also be build with forward rates, where the simple carry rule is to sell at the forward rate if $F_t > S_t$ and to buy forward rate if $F_t < S_t$. In this case we can determine that the returns gained with this simple carry trading strategy is:

$$F_t - S_{t+1}, \text{ if we sell the forward rate,}$$

$$\text{and } S_{t+1} - F_t, \text{ if we buy the forward rate.}$$

Using the covered interest party, which normally holds, we get the forward rate F for our example:

$$F = (1.06)*0.75/1.02 = 0.78$$

The forward rate is higher than the actual spot rate, thus a currency carry trader would sell the forward rate. If the spot exchange rate does not change the investor can buy 1 CHF for a price of 0.75 EUR and sells them according to its forward contract for 0.78 EUR

In practice, currency carry trades are typically implemented through a combination of foreign exchange spot and swap transactions to obtain a “synthetic” forward position that is long in the high-yielding currency and short in the low-yielding currency. This is done synthetically, rather than through an outright forward position, largely for liquidity reasons. Importantly, such trades are leveraged because they do not involve any cash outlay up front.

3.2.2 Threshold Carry Rule

Bilson (2003) introduces an adjustment to the simple carry rule. This rule implies that if an investor takes a carry position, it is only viable if the higher interest rate compensates for the expected inflation differential. Bilson (2003) demonstrates this by using the difference in long term government bond (10y) yields as an alternative for the differential in the expected inflations. Pojarliev (2005) calls this the threshold carry rule. The formula for the threshold is as follows:

$$Tt+1 = y10dt- y\ 10ft,$$

where y10 refers for the 10 year government bond yield, dt to domestic and ft to foreign.

The threshold carry rule is to go long in a high yield currency (selling the forward rate) only if the carry is larger than the threshold, otherwise the investor should go short in the high yield currency (buying the forward rate). This rule leads to the following return:

$$Ft - St+1, \text{ if we are long in the high yield currency,}$$

$$\text{and } St+1 - Ft, \text{ if we are short in the high yield currency.}$$

Unlike the simple carry rule and the volatility carry rule, we are not going to apply the threshold rule in our analysis part. As we have shown in chapter 2, the connection between inflation and future spot exchange rate is contradictionary (PPP-puzzle). Therefore we reject the inflation rates as an investment factor regarding currency carry trades.

3.2.3 Volatility Carry Rule

As mentioned in this thesis earlier, there exists criticism towards currency carry trading investors, that volatilities involved in exchange rates are considerably high. An investor that holds a currency carry trade position collects the interest rate differential and is

exposed to the possible changes in exchange rates. Therefore it is naive to consider only the interest rate differential and not to take the underlying volatility into account. This can be measured through the carry-to-risk or in this case carry-to-volatility ratio; dividing the interest rate differential with the expected volatility. To get a better picture of this, we go back to our example in Figure 2. The Euro interest rate is on a given date 6% p.a. the CHF rate at the same date is 2%, therefore the interest rate differential is 4%. The simple carry rule determines that on this date the investor should be short on CHF versus the EUR. The volatility carry rule goes more in depth; let's assume that on the same date the USD interest rate was 4%, giving an interest rate differential of 2% between the EUR and the USD. An investor following only the simple carry rule strategy would choose the currency pair with the higher differential i.e. EUR vs CHF. If we apply the carry to volatility rule for the given date, the volatilities for the exchange rates for EUR/CHF was 6.5% and for EUR/USD only 2.5%. Here we get the involved ratio for shorting EUR vs CHF as (6%-2%)/6,5 = 0.62, and long EUR vs USD (6%-4%)/2.5% = 0.8. Hence a rational investor chooses the latter due to lower risk-return. The simple carry trade rule adjusted with volatility gives the investor a more reliable view on the risk related to the carry trade.

3.3 Measuring risk and performance of currency carry trades

This sub-chapter will provide only a short introduction to different risk measures regarding the currency carry trade investments. The risk of the currency carry trades have commonly been measured by using the volatility of the returns. See for example Dowd (2002). Our objective in this thesis is to measure risk by: 1) Volatility, 2) Value at Risk and 3) Expected Shortfall. Other acknowledged risk measures that could be involved are implied volatilities for deep-out-of -the money call options and also risk reversals. The latter measures have the profit of looking forward in the future but the problem with them

is that they also contain risk premia and thus can give potentially misinterpretations of the measures risk.

VaR and ES are considered as so called downside risk measures. A downside risk measure is defined as. "An assessment as to the extent that a security could decline in value - considering all possible factors that could affect the security's market price." (Dowd, 2002)

Volatility functions well when returns are normally distributed. VaR in the other hand can be considered as a contingent on two arbitrarily chosen parameters – a confidence level α, which indicates the likelihood that we will get an outcome no worse than our VaR, and which might be any value between 0 and 1; and a holding or horizon period, which is the period of time until we measure our portfolio profit or loss. It is a common standard measure of risk in credit markets where return distributions show small probabilities of large losses. On the other hand VaR does not provide any information about the shape of the tail or the expected size of loss beyond the confidence level. In this sense it is a very unsatisfactory risk measure. Of more interest is the expected shortfall (ES) also known as conditional VaR. Historical simulation methods which make no assumptions of normality are particularly suitable for calculating ES. ES is also considered as a coherent risk measure, which means that the risk measure satisfies properties of monotonicity, sub-additivity, homogeneity, and translational invariance; and always captures benefits from diversification. For more see Dowd (2002) and Artzner(1997).

The Sharpe ratio tells us whether a portfolio's returns are due to smart investment decisions or a result of excess risk. Sharpe ratios are used widely by academics and practitioners. Nevertheless they also involve some commonly known limitations. Sharpe (1994) Lo (2002) stated that the Sharpe ratios are non-comparable when calculated for different investment horizons. A more significant problem for the purpose of our study is that Sharpe ratios are inappropriate when returns are not normally distributed. (Götzmann et al., 2002). The advantage of the Sharpe ratio is that its results are statistically testable. Jobson and Korkie (1981) designed a method to test whether the difference of two Sharpe

ratios are significantly difference from zero. An explanation of how to apply this test will follow in the methodology chapter. The drawback of the test lies in the nature of the Sharpe ratio, the assumption of normality.

By taking the VaR (calculated with a non-parametric historical approach) instead of the standard deviation as a risk measure, we have normality no longer as an assumption. This method is known as reward-to-VaR. Gordon et al. (2003) demonstrated that, under normality, the reward-to-VaR ratio gives the same ranking for the risk adjusted performance as the Sharpe ratio. Nevertheless they also proofed that under non-normality the ranking differs from the Sharpe ratio. The use of a VaR-based performance measure of currency carry trades is rather tempting. First, this type of risk measure is widely recognized by practitioners. Second, the VaR measure evaluates downside risk and can be used for non-normal distributions. Therefore it has gained widespread popularity and is often also used in empirical studies. (see Zakamouline, 2009) The drawback of the reward-to-VaR ratio is that it does not imply information about the shape of the tail or the expected size of loss beyond the confidence level. If the expected shortfall is the major concern of an investor, the conditional Sharpe ratio, using ES as the denominator instead of standard deviation, is a better method to quantify the risk-adjusted performance.

We have to bear in mind that none of these methods provide a universal performance measure, but simply act as complements for each other. All of the methods mentioned above are applied in the empirical part of this thesis.

3.4 Currency carry trades as an alternative investment

Foreign exchange investing involves a fair amount of foreign currency risk. The investor normally has three choices: accept the risk of exchange rate movements as given, use foreign currency derivatives as a method to hedge against foreign exchange risk, or see this risk involved as a potential source of additional return. The last choice categorizes currency carry trading as an alternative investment, since the investor is in search for

yield. Huttman and Harris (2006) present in their findings that as equity and bond management, also active currency management can be distinguished as an alternative investment class. The authors also declare that an active currency manager has several different techniques of making transactions. Currency managers can buy or sell currency pairs according to the direction the market is expected to move. Yield-seeking managers search for low-yielding currencies and simultaneously invest in relatively high-yielding currencies. The last type of transaction is trading the volatility by applying an option strategy and arbitraging from the over-the-counter cash currency market and exchange-traded currency future markets. Huttman and Harris (2006) conclude that actively managed currency carry returns show little correlation with the traditional equity indices and provide the desirable diversification effect when added to traditional portfolios.

The simplest way to measure the correlation is the concept of linear correlation. The drawback of this method is a possible asymmetry of the correlation. A more sophisticated method to solve this problem is the exceedance correlation. Ang and Chen (2002) define exceedance correlation as the correlation between two standardized variables whereby both of these deviate from their mean by a certain threshold level. In other words the exceedance correlation compares the correlation in joint market upwards and downwards at different levels. More explanation about the statistical application will be given in the methodology chapter. Kohler (2008) applied this method while investigating the correlation of four different currency carry trades, all using the CHF as funding currency. He concluded that all his currency pair had larger joint market downturn correlation then joint market upward correlation. This is an undesirable effect. An investor that held currency carry trade as an alternative investment wants to be hedged especially against market downturn. A linear correlation measure would underestimate the correlation in bear markets.

3.5 Recent events regarding currency carry trading

In this sub-chapter we discuss recent events and the effect of the financial crisis on currency carry trading. It is also fair to state for the reader that the following is based on approximations rather than solid facts.

The most commonly discussed currency carry trade in articles has been the so called "yen-carry trade". The low interest rates in Japan attracted investors starting mid-1990s. The yen was purchased short and then invested in high interest yielding currencies such as the Australian- and New Zealand Dollars. As a consequence, foreign-currency denominated bonds (so called Uridashi-bonds) were issued in Japan and bought by Japanese investors. The Uridashi bonds offer a relatively high yield and have been denominated mainly by Australian, New Zealand, and US dollars. The unwinding of these trades was experienced in July 2007 where after an approximately 80% fall in the actual carry trade positions within the following 10 months. Not only hedge funds but also Japanese day traders got rid of their currency carry trade positions which lead to the high appreciation of the yen by 30% vs. the US Dollar (all-time high since 1973).

In March 28th, 2009 the Financial Times predicted the comeback of the carry trades as the rising of Japanese shares would be likely to increase the risk appetite of Japanese retail investors, encouraging them to send funds abroad in search of yield. "Japanese margin accounts are heavily long on the yen and when this position is reversed the New Zealand dollar will benefit most."(FT.com, 28/3/09)

The success of currency carry trading strategies does not lie solely on the interest rate differential but also on the stability of the asset markets, where a yield advantage of a low interest rate currency can be lost by the fall in the value of investors' target investments. Additionally, the reaction of the funding currency is usually appreciation. The latest havoc in the financial sector caused investors to unwind their positions, which caused the Yen for example to appreciate sharply in September 2008 with 17% and 28% rise against the New Zealand and Australian dollars until March 2009. It is needless to say that investors were intimidated by this quick appreciation, while disorientation hit the market.

Obviously, a carry trader holding a short position in yen does not appreciate countercyclicality, since it leaves him with a larger debt burden in times of stock market downturns. (FT.com, 27/3/2009).

Recent market statistics prove that since then the New Zealand Dollar has depreciated 14% and Australian Dollar 8% against the Yen, which has caused the currency carry trade positions to leverage up again.

4. Methodology and Data

The previous chapter provided a theoretical background based on a vast earlier literature study. In this chapter we present the methodology and hypotheses needed to answer the initial research questions.

4.1 Hypotheses

In order to give a valid set of results it is important to clarify the hypotheses for conducting the analysis at this stage. The latter chapters provided a theoretical background for the analysis; we will now provide extensive motivations for the purposes of our study. In total we have four hypotheses, of which the first two are the "main" hypotheses and the two latter, the "sub"-hypotheses. The hypotheses are as follows:

Hypothesis 1

The excess return of the currency carry trade portfolios should outperform equity indices. Furthermore the risk-adjusted performance measures of currency carry trade portfolios should be as good as or better than the risk-adjusted performance of the equity indices.

Hypothesis 2

In order to be a viable alternative investment, the currency carry trade portfolios and the equity indices should have a low correlation with each other in joint market upwards and downwards.

The second hypothesis relies that the investor can take use of currency carry trading portfolios to increase the diversification effect of his/her portfolio.

Hypothesis 3

Since the UIP does not hold, the currency carry trade should be positively correlated to the underlying interest rate differential. Therefore the switching portfolio should generate excess returns.

Hypothesis 4

With a carry-to-volatility-strategy the risk should be smaller than in other currency carry trade portfolios.

4.2 Data

For the empirical part of this thesis, we use the G10 currencies (see table 1). These were chosen as they are the most commonly traded currencies in the global foreign exchange market. We chose not to involve emerging markets currencies in our research due to several reasons. These include the limited data, central bank and political instabilities, the so called "peso problem"[2], and hyper inflation.

Table 1 presents the abbreviations of the G10 currencies. Euro was initially introduced in the beginning of 1999. That is also when it replaces DEM in the research part of this thesis.

[2] The peso problem refers to a market anomaly, for example a sudden price fall, that is infrequent (rare event, fat tails, extreme occurrence) but that leads to extreme consequences that can be disastrous.

ISO CODES	
Australian $	AUD
Canadian $	CAD
Euro €	EUR
German Mark	DEM
Japanese ¥	JPY
New Zealand $	NZD
Norwegian Krone	NOK
Swedish Krona	SEK
Swiss Franc	CHF
United Kingdom £	GBP
United States$	USD

Table 1. Currency ISO- abbreviations

We use in our research part inter-bank interest rates with the maturity of one month. The short interest rates give the investor a certain amount of flexibility compared to longer interest rates. As for the spot exchange rate, we use the mid-rate prices for the 10 currencies per USD. The other spot exchange rates are calculated via cross rates. As a benchmark of the equity markets we choose the S&P 500, the FTSE 100, the NIKKEI 225 as well as the MSCI World.

Historically stocks have shown the greatest risks and the highest returns among the traditional investments (stocks, bond, cash). Nevertheless the investment regulations for pension funds worldwide are for stocks much weaker then for structured products such as currency carry trades (OECD). This could lead to the misinterpretation that stocks are a conservative investment instrument while currency carry trading implies extensive risk for being a prudent investment. For determining whether the currency carry trade as an investment is prudent or not, we decided to use the stock market as a benchmark. An advantage of using the stock market as a benchmark is that it also acts as an indicator of social mood. It allows us to differ between bull and bear markets. (OECD)

The data set was acquired from DataStream. The starting point of our data analysis is January 1st ,1993 and ends April 27th, 2009. The starting point we chose was after the recession that struck the industrialized countries in the early 1990's. After the recession, investors started to take profit of the low interest rates in Japan. Since then, the proportion of currency carry trades has grown significantly.

We decided not to take into consideration the bid-ask spreads, transaction costs or commissions. In the last two decades, the technological improvements and globalization has lead to lowered transaction costs and making foreign exchange trading less costly. Taking transaction costs into consideration could therefore result in proportionally smaller returns in the earlier years. This could lead to the misinterpretation that the true returns became more attractive over time. Including the bid and the ask rates also implies some undesirable effects. For example Huang and Masulis (1999) state that the bid-ask spread in the foreign exchange market increases with growing volatility and vice versa. This would make the results less comparable to the equity indices. One could argue neglecting the transaction costs would give excessive returns. On the contrary other tradable instruments also involve transaction costs. Furthermore equity benchmarks, for example S&P 500, disregards any form of transaction costs related when displaying results. For the purpose of our research problem the transaction costs do not play a significant role since we want to present pure risk-return relation comparisons as well as correlations with the equity indices.

4.3 Currency carry trade strategies

The range of currency carry trading strategies varies from simple to more sophisticated models. Beside the 45 possible single currency carry trade pairs, we also construct two more enhanced portfolios. The first one is the switching portfolio, from which we expect to have above par mean returns. The second portfolio we construct is the carry-to-volatility portfolio, which is expected to have a lower than average risk involved. These portfolios are examined in order to answer our research question, whether or not currency

carry trades are prudent investments. We demonstrate that an investor is able to control risk and returns with intuitive strategies. Furthermore the risk and returns in currency carry trades are to a certain level predictable instead of random. It was our intention to have these strategies as intuitive and simple to minimize the potential impact of data snooping biases brought by looking into the total space of trading rules for the best performing strategies. To conclude, it should be noted that the goal of this study is not portfolio optimization.

4.3.1 Simple currency carry trade pairs

For the research part we used simple currency trade pairs. We build portfolios consisting of a short position in a low interest rate currency (funding currency) and a long position in a higher interest rate currency (target currency). Note that selling one currency is always connected with buying another currency. We will build all possible pairs (45 possibilities) of the G10 currencies, and measure the returns ex post.

This strategy is implemented by using the spot exchange rate S_t and a synthetic forward rate F_t. The currency carry rule is to sell the forward rate if $F_t > S_t$ and to buy the forward if $F_t < S_t$.

The achieved return with this strategy at period t is:

$$R_{t+1} = \ln(F_t) - \ln(S_{t+1}), \text{if } F_t > S_t$$

or

$$R_{t+1} = \ln(S_{t+1}) - \ln(F_t), \text{ if } F_t < S_t$$

We calculated the synthetic Forward Rate F_t according to the Covered Interest Parity (CIP):

$$F_t = \frac{(1 + r_t^*)S_t}{(1 + r_t)}$$

where r_t^* is the target currency interest rate and r_t is the funding currency interest rate.

Using the synthetic forward rates instead of the listed forward rates gives us the advantage of eliminating any timing mismatch between interest rates and exchange rates we use in this thesis. To have synthetic forward rates gives the advantage of having a constant number of trading days per month over the whole data sample. In addition an important observation is that the forward rates generated using CIP were extremely close to the listed forward rates. The above described trading strategy is dependent over the contravention of the UIP. The failure of UIP is necessary in order to generate positive returns.

In total there are 45 currency pairs for the G10 currencies. Table 2 presents the annualized monthly mean returns of all possible pairs. Note that when discussing the different currency carry trades in this thesis, the order of the ISO codes in the matrices and tables are interchangeable, i.e. EUR/USD = USD/EUR and so forth.

Matrix of Monthly Mean Returns (Annualized)

	AUD	*CAD*	*CHF*	*GBP*	*EUR (DEM)*	*JPY*	*NOK*	*NZD*	*SEK*	*USD*
AUD	*									
CAD	1,16 %	*								
CHF	2,82 %	2,56 %	*							
GBP	2,75 %	0,77 %	1,51 %	*						
EUR(DEM)	0,86 %	2,39 %	0,68 %	1,83 %	*					
JPY	3,81 %	2,39 %	0,34 %	2,96 %	2,14 %	*				
NOK	0,40 %	1,16 %	1,67 %	3,40 %	0,52 %	3,13 %	*			
NZD	1,94 %	3,12 %	3,76 %	2,61 %	1,53 %	5,25 %	0,47 %	*		
SEK	1,74 %	3,68 %	0,14 %	3,09 %	1,20 %	1,60 %	2,12 %	2,13 %	*	
USD	5,60 %	0,70 %	1,37 %	-0,05 %	5,00 %	4,06 %	3,00 %	3,72 %	6,24 %	*

Table 2: Matrix of monthly mean returns (annualized).

4.3.2 Switching position carry trade portfolio

A notable finding is that the currency carry trade returns are in average growing with increasing interest rate spread. To demonstrate this we ran a regression with the interest rate differentials on the X axis and currency carry trade returns on the Y axis. The table below presents the results of the regression.

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0,000685888	0,00027026	2,53788	0,011157	0,000156171	0,001216	0,000156171	0,001215605
Beta	0,801954623	0,111417423	7,197749	6,23E-13	0,583573717	1,020336	0,583573717	1,02033553

Table 3. Regression analysis of currency carry trade returns and the interest rate differential. (Random sample of 38132 observations, including all currency pairs.)

We can summarize from the regression that the null hypothesis of beta value being zero can be rejected at any confidence level. Therefore there exists positive correlation between the size of the interest rate spread and the currency carry trade returns. For this reason we constructed a portfolio that tries to capitalize from the correlation mentioned. To make this functional, we built a model that selects the G10 currencies that have the lowest and the highest interest rates in each period of time t and combine them together. Funds are borrowed from the low-yielding currency and converted into the high yielding currency, where they are invested. The term switching stands for the fact that the involved currencies switch over time. With this strategy the portfolio profits from the biggest interest rate differential at every time period. According to our regression (table 3) this portfolio should generate excess returns. The portfolio is referred as “Hi/Lo” from now on. The return is calculated in the same manner as in the simple currency carry trade example i.e. using the spot and the synthetic forward rate.

4.3.3 Carry-to-Volatility portfolio

The carry-to-volatility portfolio is a more sophisticated version of the switching portfolio. It does not only take the interest rate gap into consideration, but also the volatility.

Similar to the switching portfolio all the possible 90 (2*45 currency pairs) interest rate differentials are calculated at each time. Additionally the volatility of the exchange rate spot prices is measured in form of the standard deviation. The currency pair with the highest ratio (interest rate spread/standard deviation) will be chosen at each time period.

We implemented this strategy by using a rolling one month standard deviation. We chose the one month standard deviation since we also invest with the one month interest rate and are therefore exposed to the corresponding exchange rate risk.

By taking the volatility into consideration we expect lower risk. The portfolio is referred as C-T-V from now on.

4.3.4 Equity indices as benchmarks

As explained in the data part of this chapter, equity indices were chosen as benchmarks. To make the equity indices more comparable with the currency carry trades we made some modifications. Therefore we constructed zero-investment index portfolios, i.e. we take a long position in the equity index and a short position in the interbank interest rate for the underlying currency.

$$R_t = \ln(I_t) - \ln(I_{t-1}) - \ln(r_t)$$

Where I stands for the equity index and r is the interbank interest rate.

4.4 Return distribution

The returns were calculated according to the strategies described in detail above using daily data within (overlapping) monthly time frames. To discover the risk faced by currency carry trading investors, we evaluate the return distribution of our currency carry trade portfolios. In this context we can present an initial finding that almost all the returns

are negatively skewed. Another concern is the kurtosis, which measures the fatness of the tails, for example a high kurtosis displays a chart with fat tails and a low, even distribution, whereas a low kurtosis displays a chart with skinny tails and a distribution concentrated toward the mean. Figure 3 presents the return distribution from our switching position carry trade portfolio, where we can clearly see the negative skewness. Further discussion regarding the return distributions will be presented in the analysis part of this thesis.

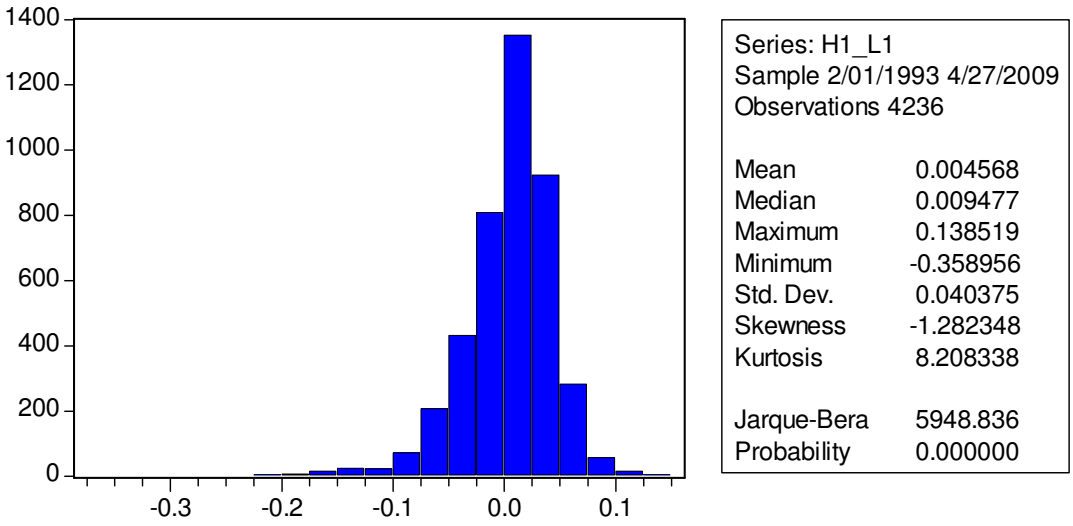

Figure 3 Hi/Lo Return Distribution with descriptive data. (Eviews histogram)

4.5 Risk measures of currency carry trades

The most common risk measure that appears in previous papers considering currency carry trades has been volatility. Volatility is indeed an appropriate risk measure for the Sharpe ratio when the returns are normally distributed, whereas our research shows that this in fact is not the case in currency carry trade returns. Therefore, in addition to volatility we will also apply the Value-at-Risk (VaR) and the Expected Shortfall (ES) methods, which both are common risk measures in the credit markets. For the VaR we apply the non-parametric approach. The main advantage of this approach is that we try to

let the return data speak for themselves as much as possible, and use the recent empirical distribution of the returns – not the normal distribution – to estimate our risk measures. For more information regarding VaR approaches, see Dowd (2002). In section 3.3 of this thesis, we presented further justification for involving the applied methods.

The most common non-parametric form for the VaR is the historical simulation (HS). To clarify, HS is based on a return histogram. It is also conceptually simple, widely used due to easy implementation, and has a fairly good historical record. It is also fundamentally non-parametric in the sense that it does not require any assumption of the distribution of the returns. VaR and ES are calculated using a 95% confidence-interval. VaR is then given by the x – value that cuts off the 5% of the low-end of the returns (losses).

ES estimates the potential size of the loss exceeding VaR. Artzner et al. (1999) argue that expected shortfall, as opposed to Value-at-Risk, is a coherent risk measure. The expected shortfall is therefore the expected size of the loss that exceeds VaR. It is calculated as the average of the returns that are beyond the VaR; the average of the lowest 5% of total returns. The risk measures are compared using the 1-month interbank interest rate.

4.6 Risk-adjusted performance measures

A risk-adjusted performance does not only take return, but also risk into account. As discussed in Chapter 3, there is unfortunately no universal performance measure. Therefore we decided to apply three different approaches. It is important to note that these methods act as complements to each other, not as substitutes.

The risk-adjusted performances will be calculated on the basis of the volatility as well as on the basis of the VaR and ES and be compared versus the ones of the stock market indices (MSCI World, S&P 500, FTSE 100, NIKKEI 225).

Referring back to the first underlying criteria for our research problem, the risk-return profile of currency carry trade should be at least as good as the one of equity indices. Therefore we test the null hypothesis that the risk-adjusted performances of the stock

indices and the ones of the currency carry trades are significantly not different from zero. The alternative hypothesis is that their difference is significantly different than zero.

4.6.1 The Sharpe Ratio

The Sharpe-ratio is commonly used by academic researchers as well as investors and traders. It measures the risk-adjusted returns and is defined as follows:

$$SR = \frac{r_i - r_f}{\sigma_i}$$

where r_i is the return of portfolio i, r_f is the risk-free rate, and σ_i is the standard deviation of portfolio i. A drawback regarding the application of the Sharpe ratio as a performance measure for our study is the fact that it assumes normality. Normality nevertheless is violated for currency carry trades according to our results which will be discussed in the analysis part of this thesis. More about Sharpe ratio, see Sharpe (1966) or Sharpe (1994).

The main advantage of the Sharpe ratio is that its statistical significance is testable. To evaluate the null hypothesis presented above, we apply the Z-test according to Jobson and Korkie (1981) in the following manner:

$$Z = \frac{\sigma_a * r_b - \sigma_b * r_a}{\sqrt{\Theta}}$$

where r_a and r_b are the excess returns of portfolio a and b respectively, and σ_a and σ_b are the standard deviations of portfolios a and b. Θ is calculated as follows:

$$\Theta = \frac{1}{T}\left[2 * \sigma_a^2 * \sigma_b^2 - 2\sigma_a * \sigma_b * \sigma_{ab} + \frac{1}{2} * r_a^2 * \sigma_b^2 + \frac{1}{2} * r_b^2 * \sigma_a^2 - \frac{r_a * r_b}{2 * \sigma_a * \sigma_b} * (\sigma_{ab}^2 + \sigma_a^2 * \sigma_b^2) \right]$$

where T is the number of observations and $\sigma_a, \sigma_b, \sigma_{ab}$ are estimates of the standard deviations and covariance's of the excess returns of the portfolios over the evaluation period. A significant Z-statistic would reject the null hypothesis of equal risk-adjusted performance and furthermore would suggest that one of the investment strategies outperforms the other. The background of the Jobson-Korkie test was discussed in the Chapter 3.

4.6.2 Reward to VaR

The methodology of reward to VaR is introduced by Dowd (2000). The formula replaces standard deviation as the denominator with VaR:

$$RtVaR = \frac{r_i - r_f}{VaR_{0.05}(i)}$$

where $VaR_{0.05}$ represents the Value at Risk of the portfolio return i at the significance level of 5%. This performance measure has the advantage that it just takes the downside risk, but not the upside risk into consideration.

4.6.3 Conditional Sharpe Ratio

The concept of conditional Sharpe ratio, sometimes also called as the Reward to conditional VaR, was brought up by Agarwal and Naik (2004). Again, we use the Sharpe ratio as a basis but replace standard deviation by the ES (a.k.a. Conditional VaR).

$$CSR = \frac{r_i - r_f}{ES_{0.05}(i)}$$

where $ES_{0.05}$ is the Expected Shortfall of the portfolio return i. This ratio includes all the advantages discussed in the chapter regarding Expected Shortfall.

4.7 Correlation between currency carry trade and stock market returns

In order to evaluate whether currency carry trade portfolio are suitable as an alternative asset class we will measure their correlation to the stock market indices. It is necessary to keep in mind that correlation especially in bear markets is undesirable, since an investor wants to be hedged versus market downturns. The linear correlation coefficient does not take this fact into consideration. The linear correlation is normally used as a measure between risky variables that are elliptically distributed. If risk factors are not elliptically distributed, then linear correlation no longer tell us the necessary things we need to know about dependence, especially in the left side of the tails where it hurts the most.

To capture this phenomenon we apply an exceedance correlation model according to Longin and Solnik (2001). Exceedance correlation is done by the following steps:

- Step 1. Standardize data $si = (Si - \mu) / \sigma$
- Step 2. Select sub-samples: $si > \theta$, $si < -\theta$
- Step 3. Corr ($si > \theta$, $sj > \theta$), Corr ($si < -\theta$, $sj < -\theta$)

The value of the threshold θ used to define return exceedances ranges from -10 percent to 10 percent (percentage points).

4.8 Additional information

A notable change is in 1999, where DEM is replaced by Euro. We will also compare the whole sample and post-euro returns separately in order to discover the possible changes that the Euro has caused the foreign exchange markets since its introduction in 1999.

The 1-month interbank interest rates are shown in Figure 4 below. Euro and German Mark are shown on the same line. Both black curves indicate the high and low interest

rates, which are used for the Hi/Lo switching portfolio. From the curves we see also that the Hi/Lo portfolio uses mainly JPY and CHF as the funding currency. The most common target currencies over the period of time are the both Scandinavian currencies (NOK, SEK) as well as the Pacific currencies (AUD, NZD).

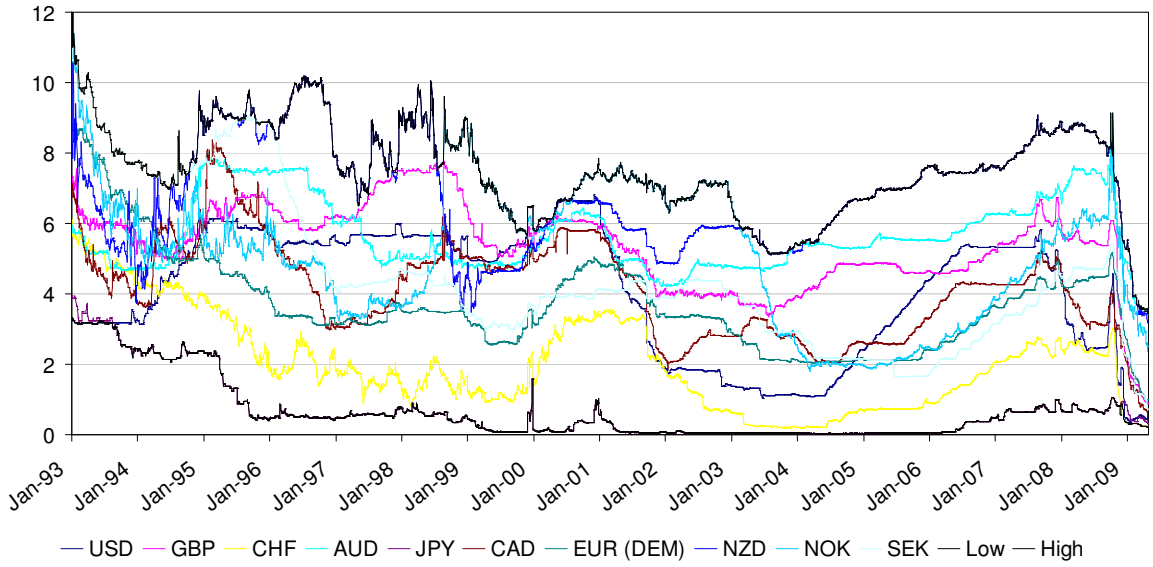

Figure 4. 1-month interest rates of currencies, daily changes.

4.9 Reliability and validity of the method

The raw data for this thesis was collected from DataStream, which is a commonly used source of financial data. It is arguable though, that for example the Swedish interbank – interest-rates were not available as of before January 1st, 1993, that how extensive is the reliability of the DataStream as a source. To have a robust data set, we also applied same methods for collecting the different interest and exchange rates. The Bank of International Settlements (BIS) provides the most information regarding statistics of currency carry trading.

The calculations are conducted by applying standard econometric models and rules. The correctness of these methods was double-checked to prevent mistakes and ran in a systematic manor.

The methods that are applied are considered mostly reliable and commonly used. The Sharpe ratio for example is used by academics and practitioners to measure risk-adjusted returns. The underlying criticism is also acknowledged. There is a certain amount of concern for the statistical significance testing of the Sharpe ratio since some researchers tend to neglect it as a whole. In addition, the strategy used is less dynamic than it would be in reality. Concerning the exclusion of for example the bid-ask spread and commissions involved as factors, it is of more importance to perform an unbiased research and including them would not fulfill this.

The secondary data, such as newspaper articles can be considered more speculative than factual. Even so, the importance of them as giving theory supporting background information is necessary.

Validity as a term expects us to find out whether the analysis really extracts the intended information. As our research topic is fairly new as a phenomenon, we also found out some contradicting results related to the theory. The theoretical framework and the hypothesis set should provide valid results of the initial research questions. We will refer back to this part in the summary of Chapter 5.

5. Empirical results

In this chapter we present and analyze the empirical findings of this study. The presentation of the results is two-fold; the first results concentrate on the risk-return profile of the currency carry trade pairs and portfolios. This involves the excess returns of the currency carry portfolios and the different risk measures, as well as discussion on the return distributions. The latter part focuses in presenting currency carry pairs and portfolios as an alternative asset class. The findings are presented using the 1-month interest rate. In the end of this chapter we will summarize the main empirical findings. In the end of this chapter we present concluding remarks on our research questions and the underlying hypotheses.

To make a clear structure for the analysis and empirical findings, as well as a more compact evaluation we will present the results of the following currency carry trade portfolios and pairs:

- Hi/Lo switching portfolio
- Carry-to-volatility portfolio
- SEK/USD with the highest mean return and the highest risk-adjusted performance
- EUR/USD with the second highest risk-adjusted performance
- EUR/CHF with the smallest standard deviation
- AUD/JPY and NZD/JPY, both commonly traded currency pairs by practitioners.

All the possible carry trade combinations are evaluated as well and the returns will be presented in the appendix. Nevertheless if interesting results of other than the above mentioned currency combinations should arise, they will be presented in the context of the findings.

5.1 Profitability of the currency carry pairs

As a general finding we discovered that out of the total 45 currency carry trade pairs, 44 provided positive mean returns. Also the two portfolios, Hi/Lo and C-T-V, generated positive excess returns. Figure 5 displays the results as an index (100 points per Jan 1993) of the highest, the lowest and the two currency carry trade portfolios (displayed as H1/L1 and C-T-V in the figure) and the excess returns of the equity benchmarks S&P 500, FTSE 100, and NIKKEI 225. From the figure we can see that the currency carry trades provided in average higher returns than the equity indices for the time horizon. Furthermore the figure shows that the S&P 500, FTSE 100, and NIKKEI 225 had negative excess return for the same period of time. The introduction of the Euro in 1999 was a major event that affected the foreign exchange market; later on in this chapter we analyze the post euro returns. We analyze the total period of time namely 1993-2009, and the post euro era 1999-2009 separately.

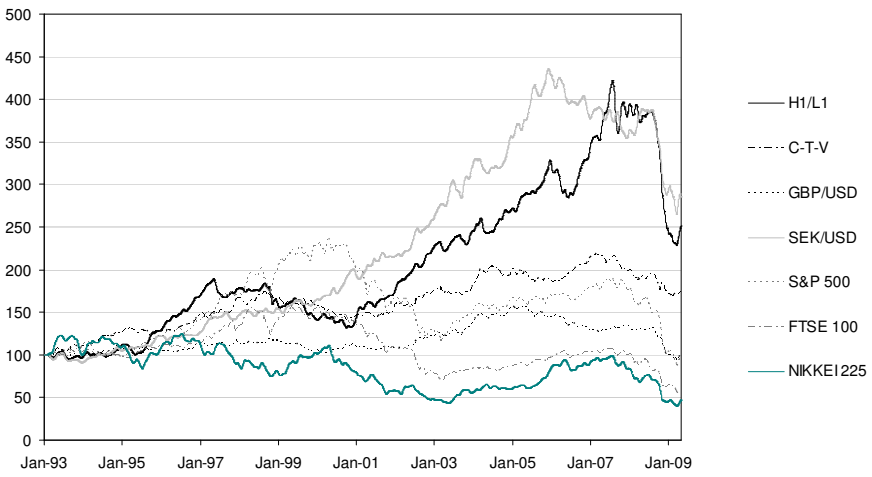

Figure 5. Index of excess returns. Jan 1993 – Apr 2009

Table 2 in Chapter 4 presented the 1-month annualized returns per each currency pair. From the table we can see that the SEK/USD currency pair has generated the most

average profits in our time frame between January 1993 and April 2009, 6.24%. This finding is rather surprising since the a majority of the background theory has suggested that currency carry trades involving JPY and CHF have been the most commonly traded funding currencies. Furthermore, in this case the effect of the exchange rate is evident, since the JPY or the CHF as a funding currency would have provided a higher interest rate differential. The lowest-yielding currency pair was the GBP/USD trade, which generated in average -0.05% monthly annualized returns. This is also the only single currency pair that has yielded negative returns. This small deviation from zero could imply favor to the non-violation of the UIP. On the same time none of the stock market indices were able to generate excess returns.

In the time horizon of the study nearly all of the currency carry trade pairs and portfolios outperformed the equity indices. The returns on our switching portfolio (H1/L1) had the annualized mean returns of 5.5% whereas the S&P 500 stock index had annualized excess returns of -0.1%. The annualized mean return of the C-T-V portfolio was 3.3%. The performance of the Hi/Lo portfolio is well above the average of the returns of all of the single currency pairs. It also follows quite closely the popular NZD(long)/JPY(short) carry trade, seen in Figure 4.

Some quite interesting remarks concerning the construction of the Hi/Lo portfolio can be seen in the whole sample period. In the beginning of the time period in 1993 the strategy was to be short on USD and long in SEK. During the same year, the funding currency changed to JPY which it remained until end of 2008. Most of the time until late 1998, NZD was the target currency. For the time between 1998 and 2003 the strategy was to be long on NOK where after it changed back to NZD. For the recent months (starting December 2008) the portfolio was short on CHF and long on NZD. The C-T-V used for the most time JPY as the funding currency, as well as short in CAD and long in GBP. The C-T-V portfolio also never uses the CHF as funding currency.

As a general finding, we can also state that the JPY as a funding currency generates in average strong returns across different target currencies with the exception of the CHF which itself is also a low interest rate currency. The CHF as a funding currency

nevertheless did not demonstrate as high cross currency returns. A reason for this is the interest rate differential which in the Japanese Yen has been larger than the differential in the CHF. This finding is consistent with our regression analysis, which stated that there is a positive relationship between the size of the interest rate differential and the currency carry trade returns. (See Table 3).

5.1.1 Return distribution

The return distributions of the currency carry trade pairs and portfolios were evaluated and compared to the major equity indices.

An obvious finding was that the currency carry trade returns were not normally distributed, since the Jarque-Bera test rejects the null hypothesis of normality in all of the cases well under the significance level of 1%. Most of the currency carry trading pairs demonstrated strong negative skewness. Figure 6 displays the skewness and kurtosis of the currency carry trade returns. The negative skewness implies that there exists a higher occurrence of large negative returns, more specifically larger downside risk. The kurtosis in the other hand is above three (Note that normal distribution has a kurtosis of three) which reflects that the returns have fatter tails than a normal distribution.

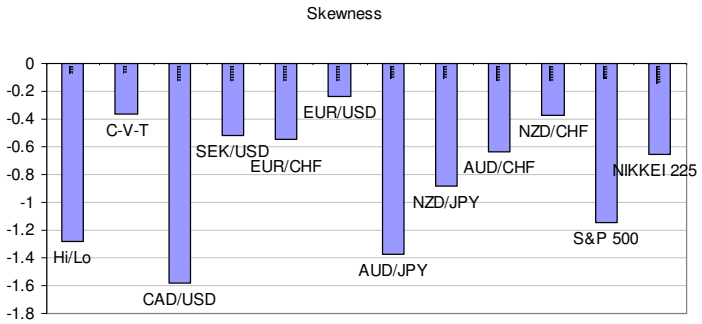

Figure 6. Skewness of the monthly returns

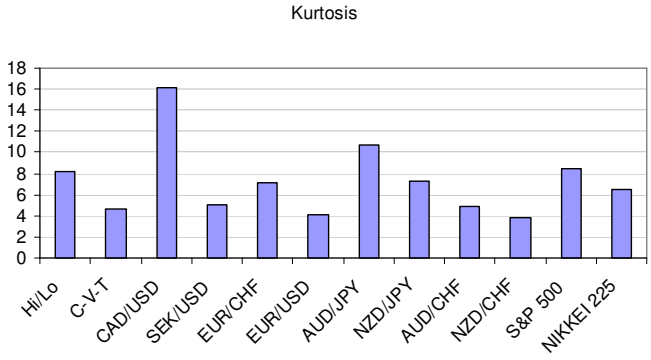

Figure 7. Kurtosis of monthly returns.

These findings imply that the currency carry trades have a higher crash risk than normal distributed returns. As an addition for our previously mentioned carry trade pairs, also included is the CAD/USD pair that displayed the highest negative skewness and highest kurtosis. The NZD/CHF and the EUR/USD pairs are slightly negatively skewed and have a kurtosis close to three, which implies relative closeness to normal distribution. JPY as a funding currency also shows relatively higher downside risk compared to having CHF as the funding currency. The results between the Hi/Lo and the C-V-T portfolios are interesting; The Hi/Lo portfolio has a rather a high kurtosis and high negative skewness while the C-V-T has one of the lowest kurtosis and negative skewness out of the sample. This is strong evidence that taking volatility as a factor in portfolio constructing minimizes relatively the crash risk.

5.2 Risks of currency carry trades

To remind the reader, the risk measures applied for the currency carry trade returns in this thesis are: volatility, VaR, and ES. The currency pairs that showed the highest volatility are the AUD/JPY, NZD/JPY, and SEK/JPY respectively. The first two are known to be currency pairs that are largely traded, also having above average returns. Table 4 presents the volatility matrix of the currencies.

	AUD	CAD	CHF	GBP	EUR (DEM)	JPY	NOK	NZD	SEK	USD
AUD	*									
CAD	0,0261	*								
CHF	0,0377	0,0331	*							
GBP	0,0319	0,0262	0,0249	*						
EUR(DEM)	0,0327	0,0293	0,0122	0,0221	*					
JPY	0,0442	0,0383	0,0333	0,0373	0,0349	*				
NOK	0,0324	0,0284	0,0232	0,0243	0,0182	0,0391	*			
NZD	0,0210	0,0296	0,0348	0,0308	0,0307	0,0431	0,0325	*		
SEK	0,0311	0,0288	0,0241	0,0247	0,0193	0,0398	0,0201	0,0303	*	
USD	0,0333	0,0210	0,0309	0,0249	0,0290	0,0327	0,0304	0,0342	0,0312	*

Table 4. Volatility Matrix of Currencies. 1993-2009

Of the most commonly used funding currencies, we see that in average JPY is more volatile than the CHF, with an average monthly volatility of 0,038 compared to 0,028 respectively, using the average of all possible target currencies.

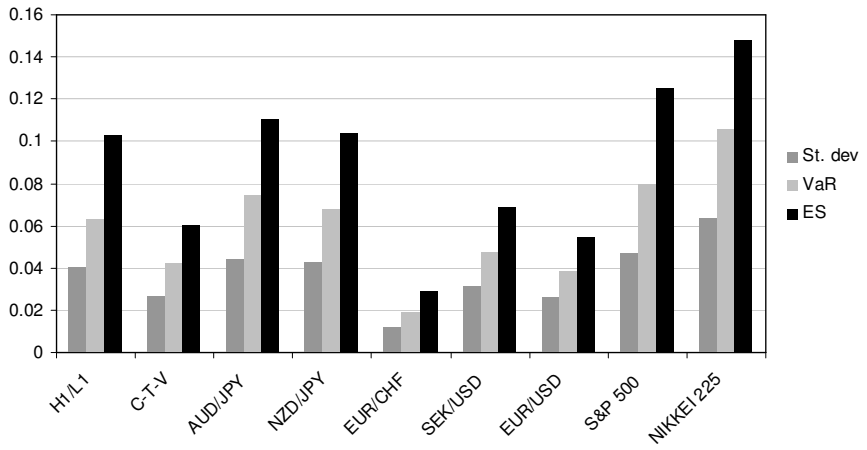

Figure 8. Volatility, Value-at-Risk, and Expected Shortfall of currency carry trade returns and equity indices.

By examining figure 8, we see that the sample currency pairs have relatively lower risk involved regardless of the risk measures, than the equity indices. This finding is quite

surprising as currency carry trades not only for laymen but also for practitioners have had the image of being riskier than the stock indices. Otherwise the investment regulations of pension funds would not be stricter for currency carry trades than for equities. The lowest risk is in the EUR/CHF currency pair, again with any of the risk measures used. As predictable the C-T-V portfolio lies also at the lower range of riskiness-scale, being remarkably less risky than the Hi/Lo portfolio. The NIKKEI 225 index is in the other end of the risk range, showing relatively large downside risk.

Furthermore, Figure 8 could lead to the wrong conclusion that a risk ranking is independent of the risk measure. To clarify, Figure 9 shows this misinterpretation, where all three risk measure provides a different ranking.

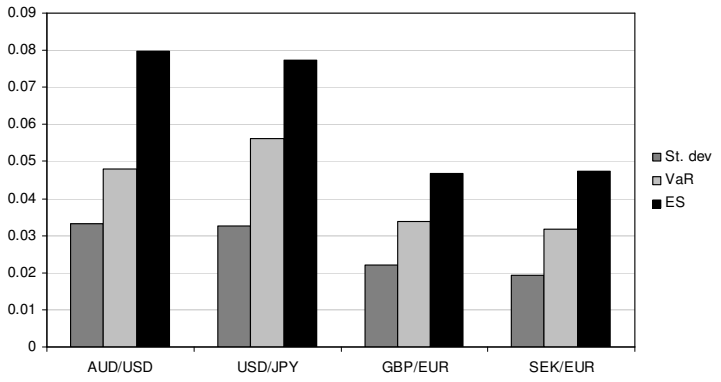

Figure 9. Example of different risk measure rankings

According to the standard deviation the SEK/EUR is the least risky, followed by the GBP/EUR, USD/JPY and the AUD/USD. The risk rankings of these currency pairs change when other risk measures are applied. The SEK/EUR has higher risk in measures of ES than GBP/EUR. Also AUD/USD and USD/JPY have changing rankings with different risk measures; in terms volatility, the riskiness of the two are close to equal, VaR is higher in the USD/JPY pair, whereas measured by ES the ranking is the contrary. The reason for the differences in the rankings is due to variation in return distribution.

5.3 Risk-adjusted performance

Previous research has shown exceptionally good results in the risk-return profiles of the currency carry trades in comparison to equity indices. Burnside et al (2007) addressed this issue and found out that Shape ratios of currency carry trade portfolios were significantly higher to the ones of the equity indices. For the reason of non-normality we extended the risk-adjusted performance by including the VaR and the ES as risk measures. The ratios for all the different currency pairs are presented in Table 5. Besides the ratio coefficients we rank the currency pairs and portfolios based on their risk-adjusted performance. The best risk-adjusted performer in our study turned out to be the SEK/USD regardless of the measure of risk. The SEK/USD currency carry trade also had the highest returns of all the currency pairs included, 6.24% p.a.. The second best risk-adjusted performer was the EUR/USD pair, with ranked 2^{nd}, 3^{rd}, 2^{nd} for Sharpe ratio, reward to VaR, and conditional Sharpe ratio, respectively. Meanwhile measured by the returns, it generated average returns of 5%, the fourth highest out of the sample. The EUR/CHF, carry trade with the lowest volatility, was surprisingly only in the mid-range of all the possible currency carry trade combinations. Ranks for the EUR/CHF were, 20^{th}, 18^{th} and 15^{th} for Sharpe ratio, reward to VaR, and conditional Sharpe ratio. The popular carry trades AUD/JPY and NZD/JPY were only above the average with the rankings of 17^{th}, 19^{th}, and 21^{st}; and 9^{th}, 9^{th}, and 11^{th}. The Hi/Lo portfolio was overall the 5^{th} best risk-adjusted performer based on Sharpe ratio and reward to VaR and 8^{th} when the measure was conditional Sharpe ratio. The lower rank in measures of the conditional Sharpe ratio is due to higher kurtosis in combination with negative skewness. The C-T-V portfolio was ranked 10^{th}, 8^{th}, and 7^{th}. An interesting finding is that Hi/Lo portfolio is higher ranked according to the first two methods, while the C-T-V performance was better by applying the conditional Sharpe ratio. To illustrate that finding: an investor that is concerned about the VaR, the worst case that can happen within a 95% confidence interval, would ceteris paribus prefer the Hi/Lo portfolio. In the other hand an investor that is concerned about the expected size of the loss that exceeds VaR, would prefer C-T-V over the Hi/Lo portfolio.

In the end of the scale we find all of the equity indices as well as the GBP/USD currency pair with negative ratios. We do not rank the negative ratios, because of interpretation difficulties. Our ratios are based on the theory of risk aversion, i.e. an investor has a preference for more return and less risk. This brings some problems when the returns are negative. A more negative risk-adjusted performance could be because of more negative return (undesirable) or lower volatility (desirable). For further discussion about the negative Sharpe ratios, see Opdyke(2007).

The advantage of the Sharpe ratio is that we can test the statistical significance by using the Jobson-Korkie test. We tested for the null hypothesis that the Sharpe ratio of the currency carry trade and the one of the best equity indices (S&P 500) are not significantly different from zero. For 37 (including Hi/Lo and C-T-V) out of our 47 portfolio we can reject the null hypothesis in a 95% confidence interval. This implies that 37 currency carry trade portfolio had a significantly better Sharpe ratio than the equity indices. By using a 99% confidence interval, 34 currency carry trade portfolio outperformed (in the Sharpe ratio environment) the equity indices significantly.

	Sharpe Ratio					Excess return on VaR		Conditional Sharpe Ratio	
Currency pair	*Coef*	*Rank*	*JK-Test*	*P-Value*	*Ho*	*Coef*	*Rank*	*Coef*	*Rank*
SEK/USD	0.166	1	8.700	0.000	rej	0.109	1	0.076	1
EUR/USD	0.144	2	7.253	0.000	rej	0.096	3	0.067	2
AUD/USD	0.140	3	7.876	0.000	rej	0.097	2	0.058	3
NOK/GBP	0.117	4	5.833	0.000	rej	0.076	4	0.056	4
H1/L1	0.113	5	6.004	0.000	rej	0.072	5	0.044	8
SEK/CAD	0.106	6	5.008	0.000	rej	0.065	7	0.050	5
SEK/GBP	0.104	7	4.729	0.000	rej	0.067	6	0.047	6
USD/JPY	0.104	8	5.004	0.000	rej	0.060	10	0.044	10
NZD/JPY	0.102	9	5.785	0.000	rej	0.064	9	0.042	11
C-T-V	0.101	10	4.518	0.000	rej	0.065	8	0.046	7
NZD/USD	0.091	11	5.112	0.000	rej	0.054	13	0.038	14
NZD/CHF	0.090	12	5.604	0.000	rej	0.054	14	0.040	12
NOK/SEK	0.088	13	3.918	0.000	rej	0.057	11	0.044	9
NZD/CAD	0.088	14	4.375	0.000	rej	0.054	12	0.040	13
NOK/USD	0.082	15	4.088	0.000	rej	0.052	15	0.037	16
NZD/AUD	0.077	16	3.424	0.000	rej	0.047	16	0.037	15
AUD/JPY	0.072	17	4.261	0.000	rej	0.043	19	0.029	21
AUD/GBP	0.072	18	3.572	0.000	rej	0.046	17	0.033	17
NZD/GBP	0.071	19	3.699	0.000	rej	0.042	20	0.031	20
GBP/EUR	0.069	20	3.442	0.000	rej	0.045	18	0.033	19
CAD/EUR	0.068	21	3.205	0.001	rej	0.042	21	0.033	18
NOK/JPY	0.067	22	3.433	0.000	rej	0.042	22	0.027	23
GBP/JPY	0.066	23	3.352	0.000	rej	0.040	23	0.026	26
CAD/CHF	0.064	24	3.763	0.000	rej	0.037	25	0.028	22
AUD/CHF	0.062	25	3.993	0.000	rej	0.037	26	0.027	25
NOK/CHF	0.060	26	3.418	0.000	rej	0.039	24	0.024	27
SEK/NZD	0.058	27	2.985	0.001	rej	0.035	27	0.027	24
SEK/EUR	0.052	28	2.663	0.004	rej	0.032	29	0.021	29
EUR/JPY	0.051	29	2.561	0.005	rej	0.031	30	0.021	30
GBP/CHF	0.050	30	2.736	0.003	rej	0.032	28	0.021	31
CAD/JPY	0.048	31	2.720	0.003	rej	0.029	31	0.019	33
SEK/AUD	0.047	32	2.512	0.006	rej	0.028	33	0.021	28
EUR/CHF	0.046	33	2.753	0.003	rej	0.029	32	0.020	32
NZD/EUR	0.041	34	2.458	0.007	rej	0.025	34	0.018	34
AUD/CAD	0.037	35	2.016	0.022	rej*	0.023	35	0.017	36
USD/CHF	0.037	36	1.869	0.031	rej*	0.022	36	0.017	35
NOK/CAD	0.034	37	1.554	0.060	not rej	0.021	37	0.016	37
SEK/JPY	0.033	38	1.874	0.030	rej*	0.020	38	0.013	38
CAD/USD	0.028	39	1.500	0.067	not rej	0.018	39	0.011	39
CAD/GBP	0.024	40	1.107	0.134	not rej	0.015	40	0.011	40
NOK/EUR	0.024	41	1.294	0.098	not rej	0.014	41	0.010	42
AUD/EUR	0.022	42	1.382	0.084	not rej	0.013	42	0.010	41
NOK/NZD	0.012	43	0.642	0.261	not rej	0.008	43	0.005	43
NOK/AUD	0.010	44	0.552	0.291	not rej	0.006	44	0.005	44
CHF/JPY	0.008	45	0.469	0.320	not rej	0.005	45	0.004	45
SEK/CHF	0.005	46	0.418	0.338	not rej	0.003	46	0.002	46
GBP/USD	-0.002	N/A	0.014	0.494	not rej	-0.001	N/A	-0.001	N/A
S&P 500	-0.002	N/A	N/A	N/A	N/A	-0.001	N/A	-0.001	N/A
MSCI WORLD	-0.014	N/A	N/A	N/A	N/A	-0.008	N/A	-0.005	N/A
FTSE 100	-0.058	N/A	N/A	N/A	N/A	-0.030	N/A	-0.021	N/A
NIKKEI 225	-0.059	N/A	N/A	N/A	N/A	-0.036	N/A	-0.025	N/A

rej = rejected at every confidence interval

rej* = rejected at a 95% confidence interval, but not at a 99%

Table 5. Risk-adjusted performance

5.4 Post-Euro returns

Since we want to take into consideration the adoption of Euro as per 1.1.1999, we analyze the returns of the post-Euro era. The index of the excess returns are presented in Figure 10, where the SEK/USD is the currency pair with the highest mean returns, the CAD/GBP with lowest mean returns. We also have the Hi/Lo and C-T-V portfolios and the equity indices.

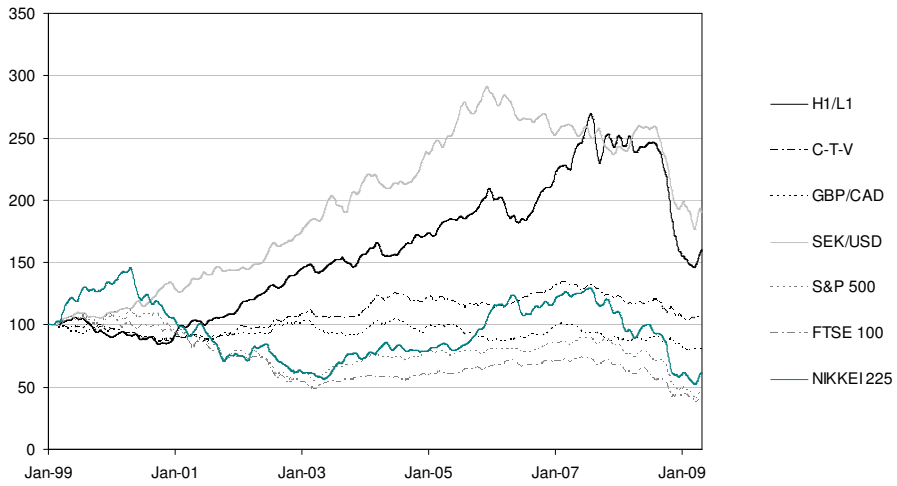

Figure 10. Returns of currency carry trades and equity indices 1999-2009.

The Hi/Lo portfolio had negative returns for the first approximately two years after 1999. Starting January 2001 until 2006 the growth of this portfolio was steadily rising. In 2006 when the stock market crashed for the previous time there was a slight drop in the returns. Furthermore, after this, the Hi/Lo demonstrated significantly underpinned performance starting late 2006. When the financial crisis initially hit, the Hi/Lo portfolio unwound and lost its value around 45% between September 2008 and March 2009. An interesting finding is the rise and fall of Hi/Lo followed the movements in the stock market. We will discuss this effect more in the correlation-part of the analysis. The C-T-V did not have such significant upward movements but had also smaller fluctuations. During the latest downturn of the economy, the C-T-V went down only 11%, which is

relatively low compared to the 45% of the Hi/Lo and the main stock indices that crashed between 40% and 55% in September 2008 - March 2009. The best performer of the series, SEK/USD went down 30% during the period. The lowest crash of the sample was experienced by the GBP/CAD, loosing only 6% of its value. Keep in mind that the GBP/CAD was also the worst performer of the carry trades in generating excess returns over the whole period of time.

The performance of the Hi/Lo reflects to the fact that during the period, it was mainly using JPY and CHF as funding currencies which both count as "safe havens" and are correlated negatively with the stock market (see Kohler, 2008 and Brunnermeier, 2007). To clarify as the stock market decreased the JPY and the CHF increased vis-à-vis the other major currencies. A currency carry trader that was short in CHF and JPY and long in other currencies, suffered simultaneously from the appreciation of the funding currencies and the depreciation of the target currencies.

The results of the post-euro era for the risk-return ratios showed somewhat mixed results. The SEK/USD which had the best risk-adjusted measures over the whole period, was placed second with Sharpe ratio of 0.151 (total period 0.18), as well as by the other risk-adjusted measures. The CAD/EUR improved from rank 12 to 1st, in terms of total vs. post-euro, with Sharpe ratio 0.17 (total 0.09) again measured by all risk-adjusted ratios. The AUD/JPY and NZD/JPY trades remained somewhat the same, while the EUR/CHF improved significantly from rank 33rd to 17th overall. The Hi/Lo portfolio debased from overall rank 5 to 15. This is because it suffered significantly more from the financial crisis than other currency carry trade combinations. The performance of the C-T-V dropped drastically in the post Euro era. This seems at the first glance rather surprising since the C-T-V as a more risk averse portfolio should have over performed the other currency carry trades during the economic crisis. By examining closer, we see that the C-T-V did over perform other currency carry trades during the recent bear market, but was one of the lowest performers during the bull market between 2001-2008. The total list and rankings of the risk-adjusted measures are found in Appendix 1.

Another notifiable change is that instead of only one pair with a negative Sharpe ratio in the total period of time, between 1999 and 2009, six currency pairs had negative returns which are again logical consequences of the recent market downturn.

5.5 Currency carry trades as an alternative asset class

Until now we have examined the returns and the risk-adjusted ratios for the different currency carry trade strategies. The most attractive strategies will be discussed as per their suitability as an alternative asset class. In addition to the sample currency pairs mentioned in the beginning of this chapter, we also include the CAD/EUR pair which has negative correlation to the equity indices. Table 6 shows the correlation of the sample currency pairs with the equity indices. The full currency correlation matrix can be found in Appendix 3. In addition to traditional correlation, we also apply the exceedence correlation method, which separates the correlation according to their different return levels of joint market upwards and downwards. The exceedance correlation is using the MSCI World as benchmark, since it is the most geographically diversified equity index within this study.

	S&P 500	*MSCI WORLD*	*FTSE 100*	*NIKKEI 225*
H1/L1	0.225	0.240	0.163	0.304
C-T-V	-0.105	-0.069	-0.234	-0.057
AUD/JPY	0.365	0.373	0.338	0.417
NZD/JPY	0.325	0.326	0.261	0.344
AUD/CHF	0.454	0.460	0.460	0.471
NZD/CHF	0.431	0.418	0.404	0.382
EUR/CHF	0.350	0.352	0.327	0.276
SEK/USD	0.215	0.236	0.155	0.184
EUR/USD	0.151	0.178	0.122	0.211
CAD/GBP	-0.209	-0.160	-0.334	-0.154
S&P 500	1.000	0.941	0.813	0.565
MSCI WORLD	0.941	1.000	0.839	0.692
FTSE 100	0.813	0.839	1.000	0.533
NIKKEI 225	0.565	0.692	0.533	1.000

Table 6. Linear correlation matrix of sample currency carry trading strategies and equity indices.

5.5.1 Hi/Lo

Especially the recent financial crisis unwound the success of the portfolio as seen in Figure 10. The correlation between the Hi/Lo portfolio and the stock market indices is in the average within the linear correlation of other single currency carry trades and equity indices. As a rule of thumb we can mention that if linear correlation is less than 30%, two variables are hardly correlated. The Hi/Lo portfolio has the most linear correlation with the NIKKEI 225, 30.04% and least with the FTSE 100, 16.3%.

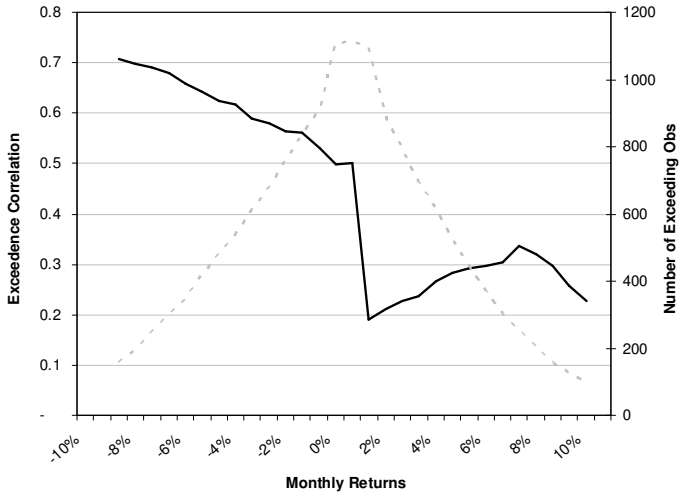

Figure 11. Exceedance correlation HiLo / MSCI World

To demonstrate the exceedance correlation, we constructed a figure with the exceedance correlation coefficients (solid line) and the number of exceeding observations (dotted line) between the currency carry trade portfolio and the MSCI World. We see that the correlation in bear market is much higher then in bull market. Especially for the high negative returns we determined an exceedance correlation of over 0.7. Another notable fact is that the total of negative returns has an exceedance correlation of 0.5, while the total of positive returns has an exceedance correlation of 0.2. Therefore the Hi/Lo portfolio is a suboptimal hedging instrument for the MSCI World.

5.5.2 Carry-to-Volatility Portfolio

The C-T-V portfolio has a negative linear correlation to the equity indices. Nevertheless it suffers from the exceedance correlation for joint market downturns (Figure 12). In market upturns the exceedance it is close to zero. This observation is in common with the investigation of the C-T-V return development in the post Euro era. It underperformed due to its low correlation during the bull market but suffered also from the recent financial crisis from its higher exceedance correlation in bear markets. However this exceedance correlation (up to 0.4) is, compared to other currency carry trade strategies, relatively low which explains its over performance during the bear markets.

Figure 12. Exceedance correlation C-T-V / MSCI World

The C-T-V portfolio is despite of the higher exceedance correlation in joint market downturns a suitable hedge for the MSCI World.

5.5.3 SEK/USD

This currency pair presented the most average returns during our sample period. The linear correlation SEK/USD is highest with the MSCI world, 0.236 and lowest with the FTSE 100, 0.155. The linear correlation of the SEK/USD with the other asset classes is relatively low.

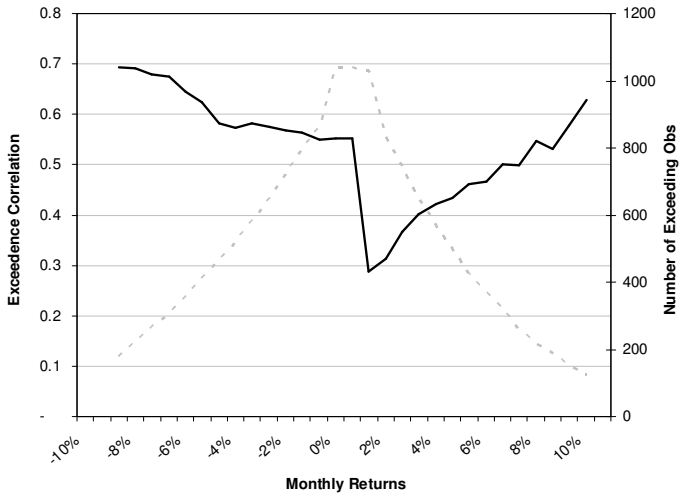

Figure 13. SEK/USD vs MSCI World

The exceedance correlation of the SEK/USD and MSCI World follows rather closely the correlation of the Hi/Lo portfolio. This leads to the same conclusion as in the Hi/Lo one: SEK/USD is neither an optimal hedge for down markets.

5.5.4 AUD/CHF, AUD/JPY, NZD/CHF, NZD/JPY

The AUD/CHF currency carry trade had the most linear correlation to the equity indices, ranging form 0.46 to 0.47. It displays also more equality among all equity indices than other currency pairs. This currency pair also has similar exceedance correlation to the MSCI World as the NZD/CHF, AUD/JPY, and NZD/JPY which are for this reason not discussed further.

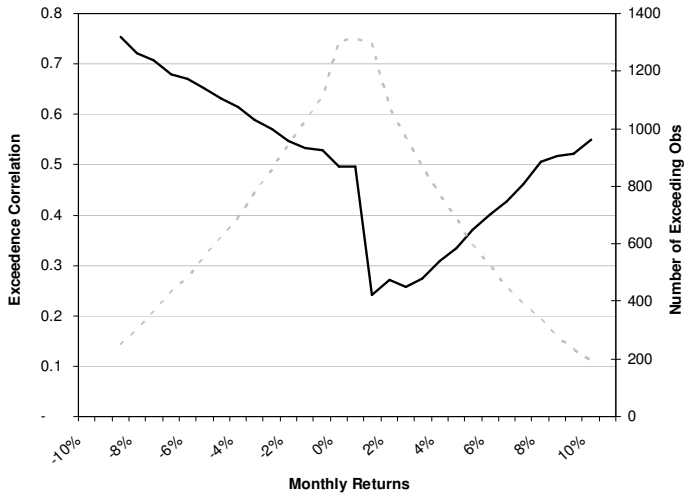

Figure 14. AUD/CHF vs MSCI World

The AUD/CHF currency carry trade is relatively highly correlated to the MSCI World. It gets even worse when we consider the bear market (exceedance correlation up to 0.8). This reflects to our earlier findings that the funding currency CHF and JPY are negatively correlated to the stock market (therefore the currency carry trade as a whole is positively correlated), especially in bear markets. Hence we conclude that those four commonly traded currency carry trades are unsuitable as a hedging instrument for the MSCI World.

5.5.5 EUR/USD

The linear correlation of the EUR/USD currency carry trade is among the least correlated pairs of our sample. With highest linear correlation to the NIKKEI 224 (0.211) and lowest with the FTSE 100 (0.122) the linear correlation is low. For the exceedance correlation, as the previous examples, the EUR/USD has also lower correlation for positive returns than for negative returns. Therefore its low linear correlation could lead to misinterpretation. As our previous example this currency carry trade is regardless of its low linear correlation not an optimal hedge for the MSCI World.

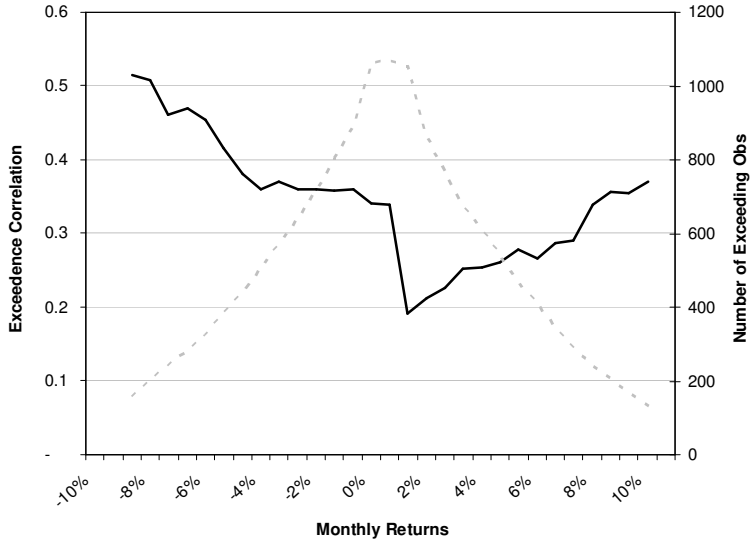

Figure 15. EUR/USD vs MSCI World

5.5.6 GBP/CAD

GBP/CAD pair had the least linear correlation out of our total sample. Negative linear correlation was shown versus to all of the equity indices. While on the event of the crash between September 2008 and March 2009 the stock market lost around 50%, the GBP/CAD decreased by only 6%. The exceedance correlation is for even high losses relatively small. Hence we can conclude that the GBP/CAD is a good hedge for the MSCI World.

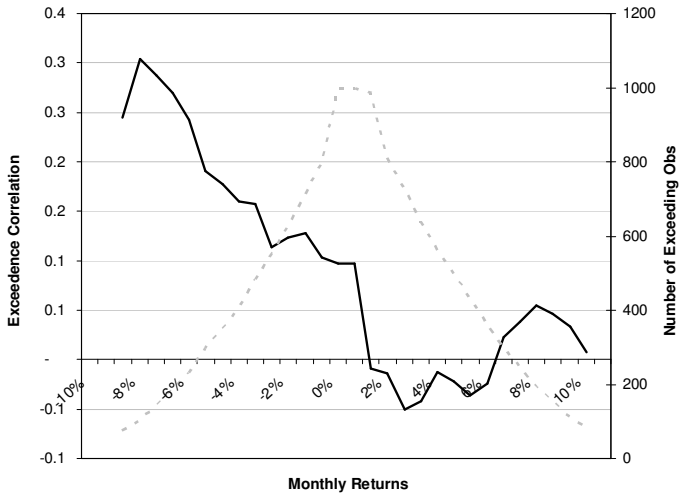

Figure 16. GBP/CAD vs MSCI World

5.6 Summary of the results

We have now discussed and analyzed the relevant results. Therefore we summarize the empirical findings before proceeding to Chapter 6, where we present conclusions and ideas for further studies.

In the beginning of Chapter 4 we presented the underlying hypotheses that we tested in the analysis part. Here we summarize the main findings. The first hypothesis required us to compare the currency carry trade pairs and portfolios with the equity indices. Out of 47 total, 46 currency carry trade strategies provided positive average returns. All of the equity indices had negative excess returns between January 1st, 1993 and April 27th 2009. The currency carry trades did in fact outperform the equity benchmarks. In the frame of the Sharpe ratio we demonstrated this outperformance with a significance test. At the confidence interval of 95% 37 of the 47 strategies did generate significantly higher Sharpe ratios. By taking VaR and ES as risk measures, the ranks of the different strategies changed slightly, nevertheless the currency carry trades outperformed the equity indices by far (taking the average as a measure). To

conclude, we have strong evidence for accepting hypothesis 1, that the risk-adjusted performance of currency carry trades is at least as good as the one of the equity indices.

The second hypothesis required a low correlation of the currency carry trades with the equity indices in joint market upwards and downwards. In form of the linear correlation the coefficients were rather low, which supported the hypothesis. But as stated earlier, the linear correlation itself is not an adequate measure. With the concept of the exceedance correlation we demonstrated that all of our currency carry trade strategies have a larger correlation in bear markets than in bull markets. For this reason, we have to reject the hypothesis of a symmetric correlation.

For the "sub"-hypotheses (3 and 4) we constructed two currency carry trading portfolios. First we ran a regression that showed that there is a statistically significant positive correlation between the size of the underlying interest rate differential and the currency carry trade return. It was not a surprise that the Hi/Lo portfolio that tries to capitalize from this relationship was one of the top performers.

By taking the exchange rate volatility into consideration, we modified the Hi/Lo portfolio. The return decreased, but as expected, so did the risk. Moreover, like the Hi/Lo portfolio, was the C-T-V portfolio among the top ten performers for every risk-adjusted performance measure. The ranks of the Hi/Lo and C-T-V portfolios change depending on the preferences of the risk-adjusted measure. All of these findings support the hypotheses 3 and 4.

As we set criteria on the validity and reliability of the research in the end of Chapter 4, we now want to refer back to them. The testing-retesting process was of great importance to get as reliable and objective results as possible. We used an intuitive currency carry trading model that followed simple rules. This mitigated the possible effect of data snooping biases tempted by searching through the entire space of trading rules for the performing strategies. (See LeBaron, 1999 for more on data snooping) No attempt of tampering the results was made.

The applied measures and methods in this thesis are used by several researchers, picking out the best, most commonly used practices. The validity of the results and analysis is in line with the hypothesis and methodology as proven.

6. Conclusions

The purpose of this thesis was to find out whether currency carry trades are prudent investments or a lottery. The motivation for the study lies within the historical fact that currency carry trades have generated excellent profits. The research was based on two criteria from which at least one had to be fulfilled.

The findings followed by the first criterion, implicated that currency carry trades outperform equity indices regardless of the risk measure. By using three different risk-adjusted measures (Sharpe ratio, reward-to-VaR, and conditional Sharpe ratio) we found higher average risk-adjusted returns for all the currency carry trade strategies in comparison to the equity indices.

The results of the second criterion, the suitability of currency carry trades as alternative investments are two-fold. The currency carry trade portfolios showed in average little (if any) linear correlation to the equity indices. In the other hand by applying exceedance correlation, we found out that currency carry trades and equity indices were higher correlated in bear markets. Through that smaller diversification effect in joint down-market, the second criterion is only partly fulfilled.

We can draw a finding that the carry trade risk/returns depend on the strategy that is chosen. This is shown with the example of constructing two portfolios using different trading strategies for different purposes. The portfolio that takes the highest interest rate spread (Hi/Lo) generated high profits whereas involving volatility as a factor in the model (C-T-V), in fact diminished the risk involved in the currency carry trade portfolio. A rational investor can choose on the personal risk preferences the investment strategy out of the two portfolios and individual currency carry trade pairs, ranging from higher risk/reward to lower.

Recent studies have dealt with carry trades and their profitability, such as Burnside et al.(2006), Brunnermeier et al. (2008) and the topic has been subject to several financial articles. One of the most important contributions of our study is that we used beside the

Sharpe ratio, also more recent risk-adjusted performance measures to take non-normality into consideration. Kohler (2008) examined the measure of exceedance correlation in currency carry trades with the "safe haven" CHF as funding currency. By applying the method to our portfolios we found out that the study is in line with Kohlers findings. Furthermore we found out that the joint down-market correlation is greater than the joint up-market correlation for all currency pairs, not only for the one using a "safe haven" as funding currency. We can state that the behavior in down-markets is also a reason for carry trade positions unwinding. We have not encountered this finding in previous studies.

The general opinion that currency carry trade implies an enormous risk is argued with the phenomenon of the unwinding of the currency carry trades. This we can support with the exceedance correlation. Nevertheless we found out that also the crash risk for the most of the currency carry trades is smaller than the one of equity indices. With our three risk-adjusted performance measure we showed that a currency carry trader gets better rewarded for its risk than an equity investor. The negative general opinion of currency carry trades is probably stemmed from a shortage in research. The few research about currency carry trade take most time only the common carry trade strategies with the CHF or JPY as funding currencies into consideration. Our research shows that these strategies imply more crash risk than others and are not necessarily better rewarded for that.

Our study has proven that we can categorize currency carry trades as prudent investments. It is fair to say that their risk-return profile is better than the general (public) image compared to stock investments. Even a risk averse investor should rethink his or her asset allocation; perhaps some of the equity in the portfolio could be substituted / complemented with some attractive currency carry trades.

Further research could be concentrated in different directions such as portfolio optimization, factor models or macroeconomic consequences. Also studies regarding more advanced portfolios would be of much interest and benefit to increase information available for investors as well as examining more in depth the different currency carry trade instruments available from several financial institutions.

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Appendix

	Sharpe Ratio		Excess return on VaR		Conditional Sharpe Ratio	
Currency pair	Coefficient	Ranking	Coefficient	Ranking	Coefficient	Ranking
SEK/CAD	0.166	1	0.101	1	0.080	1
SEK/USD	0.151	2	0.095	2	0.068	3
EUR/USD	0.147	3	0.094	3	0.067	4
CAD/EUR	0.144	4	0.090	4	0.071	2
AUD/USD	0.114	5	0.075	5	0.045	7
SEK/NZD	0.113	6	0.074	6	0.053	5
SEK/AUD	0.110	7	0.068	7	0.052	6
NZD/GBP	0.102	8	0.064	8	0.045	8
NZD/USD	0.100	9	0.058	12	0.042	9
NZD/JPY	0.093	10	0.059	11	0.037	12
NOK/JPY	0.092	11	0.062	10	0.037	11
CAD/JPY	0.091	12	0.062	9	0.036	13
AUD/JPY	0.090	13	0.058	14	0.034	15
NOK/CHF	0.088	14	0.058	13	0.034	16
H1/L1	0.087	15	0.057	15	0.033	18
NOK/GBP	0.085	16	0.054	16	0.038	10
NZD/CHF	0.083	17	0.046	19	0.035	14
EUR/CHF	0.075	18	0.050	17	0.031	20
AUD/CHF	0.075	19	0.046	18	0.030	21
AUD/GBP	0.072	20	0.046	20	0.031	19
EUR/JPY	0.069	21	0.042	22	0.028	22
NOK/SEK	0.068	22	0.046	21	0.033	17
NZD/CAD	0.062	23	0.038	24	0.028	23
CAD/CHF	0.060	24	0.035	25	0.025	24
SEK/EUR	0.054	25	0.038	23	0.020	27
USD/JPY	0.053	26	0.032	26	0.025	25
NZD/EUR	0.053	27	0.030	28	0.022	26
GBP/JPY	0.049	28	0.031	27	0.019	29
NOK/USD	0.045	29	0.028	29	0.020	28
AUD/EUR	0.038	30	0.021	30	0.016	32
NOK/AUD	0.035	31	0.021	32	0.016	31
NZD/AUD	0.034	32	0.021	31	0.017	30
AUD/CAD	0.032	33	0.019	33	0.014	33
SEK/JPY	0.027	34	0.018	34	0.011	36
NOK/NZD	0.025	35	0.016	36	0.011	34
SEK/GBP	0.025	36	0.016	35	0.011	37
NOK/CAD	0.023	37	0.014	37	0.011	35
C-T-V	0.019	38	0.012	38	0.008	38
GBP/CHF	0.012	39	0.007	39	0.004	39
GBP/EUR	0.008	40	0.005	40	0.003	40
CHF/JPY	0.001	41	0.000	41	0.000	41
USD/CHF	0.000	N/A	0.000	N/A	0.000	N/A
NOK/EUR	-0.006	N/A	-0.004	N/A	-0.003	N/A
SEK/CHF	-0.020	N/A	-0.012	N/A	-0.007	N/A
CAD/USD	-0.023	N/A	-0.015	N/A	-0.009	N/A
GBP/USD	-0.046	N/A	-0.029	N/A	-0.018	N/A
NIKKEI 225	-0.057	N/A	-0.034	N/A	-0.023	N/A
CAD/GBP	-0.061	N/A	-0.036	N/A	-0.028	N/A
MSCI WORLD	-0.102	N/A	-0.057	N/A	-0.036	N/A
S&P 500	-0.115	N/A	-0.065	N/A	-0.041	N/A
FTSE 100	-0.146	N/A	-0.073	N/A	-0.051	N/A

Appendix 1. Post-Euro Risk-adjusted ratios.

	H1/L1	C-V-T	AUD/JPY	NZD/JPY	GBP/JPY	SEK/JPY	NOK/JPY	CAD/JPY	USD/JPY	CHF/JPY	EUR/JPY	AUD/CHF	NZD/CHF	GBP/CHF	SEK/CHF	NOK/CHF	CAD/CHF	USD/CHF	EUR/CHF	AUD/USD	NZD/USD	GBP/USD	SEK/USD	NOK/USD	CAD/USD	EUR/USD
Mean	0,4568 %	0,2764 %	0,3175 %	0,4375 %	0,2470 %	0,1331 %	0,2606 %	0,1851 %	0,3385 %	0,0280 %	0,1782 %	0,2347 %	0,3134 %	0,1254 %	0,0115 %	0,1390 %	0,2132 %	0,1139 %	0,0565 %	0,4667 %	0,3103 %	-0,0042 %	0,5196 %	0,2501 %	0,0585 %	0,4164 %
Median	0,009477	0,004376	0,00782	0,008162	0,006869	0,004614	0,007545	0,005013	0,006349	0,0031	0,004624	0,005543	0,005659	0,002497	0,001912	0,002849	0,005154	0,002705	0,001493	0,006507	0,005747	0,000955	0,007038	0,002827	0,001995	0,003967
Maximum	0,138519	0,098133	0,140835	0,189282	0,119622	0,179671	0,125636	0,142559	0,121246	0,125729	0,138099	0,132315	0,142278	0,076114	0,122454	0,132119	0,100401	0,092889	0,071891	0,118668	0,16641	0,084802	0,1568	0,111958	0,121911	0,134056
Minimum	-0,358956	-0,167747	-0,443176	-0,358956	-0,295375	-0,318038	-0,333127	-0,355485	-0,156984	-0,188506	-0,283903	-0,256939	-0,172718	-0,19789	-0,131801	-0,180411	-0,169248	-0,134371	-0,097665	-0,31686	-0,232639	-0,169059	-0,191721	-0,25098	-0,229168	-0,157586
Std. Dev.	0,040375	0,02726	0,044164	0,043099	0,037285	0,039827	0,039132	0,038265	0,032665	0,033274	0,034917	0,03774	0,034803	0,024911	0,024084	0,023217	0,03311	0,030874	0,012222	0,033332	0,034155	0,024869	0,031247	0,030401	0,021006	0,028976
Skewness	-1,282348	-0,363744	-1,370925	-0,883356	-1,181512	-0,857749	-1,246042	-1,272724	-0,614564	-0,345101	-0,798695	-0,640677	-0,374701	-0,801545	-0,556555	-0,767861	-0,518122	-0,418236	-0,541875	-1,249327	-0,586294	-0,773207	-0,521745	-0,635368	-1,585256	-0,237994
Kurtosis	8,208338	4,657619	10,77939	7,236962	7,372218	6,812697	9,056095	9,308792	4,54617	4,735767	6,89186	4,837	3,780838	6,601083	5,241177	8,321335	3,56343	3,326707	7,084738	10,19494	5,66004	6,404064	5,003206	6,637695	16,08286	4,096946
Jarque-Bera	5948,836	575,5125	12008,48	3719,406	4359,58	3085,148	7569,515	8168,449	688,5965	615,8551	3123,737	885,4016	206,7365	2742,402	1105,224	5414,146	245,5564	142,3339	3152,22	10238,85	1491,563	2467,301	900,4514	2620,6	31984,15	252,3693
Probability	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	19,35209	11,64823	13,44837	18,53459	10,46497	5,637954	11,03941	7,839087	14,33865	1,184815	7,546947	9,942246	13,27627	5,313171	0,486158	5,887617	9,031507	4,824454	2,395457	19,77122	13,14319	-0,17958	22,01111	10,59609	2,477067	17,63963
Sum Sq. Dev.	6,903816	3,131453	8,260362	7,866774	5,887351	6,717592	6,485203	6,201074	4,518831	4,688731	5,163384	6,032083	5,129638	2,627981	2,456414	2,282886	4,642846	4,036813	0,632569	4,705248	4,940471	2,619236	4,134943	3,914156	1,868692	3,555771
Observations	4236	4215	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236

	AUD/EUR	C-V-T	NZD/EUR	GBP/EUR	SEK/EUR	NOK/EUR	CAD/EUR	AUD/GBP	NZD/GBP	SEK/GBP	NOK/GBP	CAD/GBP	AUD/CAD	NZD/CAD	SEK/CAD	NOK/CAD	NZD/AUD	SEK/AUD	NOK/AUD	SEK/NZD	NOK/NZD	NOK/SEK	S&P 500	MSCI WORLI	FTSE 100	NIKKEI 225
Mean	0,0713 %	0,2764 %	0,1271 %	0,1524 %	0,1002 %	0,0434 %	0,1992 %	0,2295 %	0,2179 %	0,2576 %	0,2836 %	0,0641 %	0,0968 %	0,2603 %	0,3066 %	0,0963 %	0,1616 %	0,1451 %	0,0334 %	0,1774 %	0,0390 %	0,1771 %	-0,0094 %	-0,0646 %	-0,2611 %	-0,3762 %
Median	0,0021	0,004376	0,003027	0,001784	0,001228	0,001372	0,00301	0,003303	0,003364	0,004071	0,003318	0,001425	0,002125	0,004271	0,003415	0,001053	0,002019	0,002745	0,000508	0,00285	0,000999	0,00201	0,005412	0,005775	0,003323	-0,00036
Maximum	0,117642	0,098133	0,106294	0,16009	0,073262	0,120166	0,097865	0,161566	0,121051	0,10213	0,106072	0,094075	0,07964	0,120276	0,10913	0,092165	0,128926	0,131124	0,124376	0,094776	0,118156	0,090878	0,210095	0,198806	0,162855	0,219947
Minimum	-0,179418	-0,167747	-0,126698	-0,09263	-0,100304	-0,11775	-0,125364	-0,193279	-0,130139	-0,133114	-0,119847	-0,127034	-0,131734	-0,127408	-0,11562	-0,104735	-0,070456	-0,166813	-0,141161	-0,119351	-0,168814	-0,071621	-0,35993	-0,407948	-0,306359	-0,50775
Std. Dev.	0,03272	0,02726	0,03069	0,022094	0,019299	0,018211	0,029295	0,031945	0,03082	0,024723	0,024287	0,026189	0,026058	0,029606	0,028848	0,028415	0,020957	0,03107	0,03237	0,030332	0,032542	0,020125	0,047227	0,046768	0,045366	0,063542
Skewness	-0,305288	-0,363744	-0,350788	0,238537	-0,51271	-0,305528	-0,13297	-0,174597	-0,198515	-0,436728	-0,021312	-0,128355	-0,355712	-0,256949	-0,160906	-0,110439	0,041615	-0,225455	-0,065225	-0,252633	-0,215493	0,197571	-1,145235	-1,39247	-1,067106	-0,656059
Kurtosis	3,608147	4,657619	3,465199	5,96749	5,132306	8,098586	3,131209	4,587948	4,168451	4,26146	4,202896	3,769717	3,557838	3,942353	3,308084	2,871403	3,711462	3,727246	3,486275	3,315162	4,283716	3,886851	8,510419	10,02258	6,566467	6,515055
Jarque-Bera	131,0772	575,5125	125,0715	1594,43	988,0849	4654,123	15,52143	466,5805	268,7936	415,5178	255,7089	116,2014	144,2546	203,3493	35,03159	11,52976	90,563	129,2346	44,73929	62,59055	323,6441	166,3762	6285,338	10073,29	3048,958	2484,638
Probability	0	0	0	0	0	0	0,000426	0	0	0	0	0	0	0	0	0,003136	0	0	0	0	0	0	0	0	0	0
Sum	3,021081	11,64823	5,384259	6,457495	4,243455	1,836773	8,436974	9,720023	9,230369	10,91003	12,01182	2,713714	4,099012	11,02703	12,98701	4,07734	6,845668	6,144736	1,416769	7,515745	1,653271	7,499972	-0,39669	-2,734906	-11,05861	-15,93394
Sum Sq. Dev.	4,534079	3,131453	3,988853	2,067258	1,577291	1,404463	3,63443	4,32187	4,022789	2,588503	2,498089	2,904714	2,875589	3,712147	3,524339	3,419456	1,859958	4,088274	4,437561	3,896418	4,484823	1,715297	9,44557	9,26286	8,715888	17,09923
Observations	4236	4215	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236	4236

Appendix 2. Descriptive statistics of the currency portfolios

	H1/L1	C-T-V	AUD/JPY	NZD/JPY	GBP/JPY	SKK/JPY	NOK/JPY	CAD/JPY	USD/JPY	CHF/JPY	EUR/JPY	AUD/CHF	NZD/CHF	GBP/CHF	SKK/CHF	NOK/CHF	CAD/CHF	USD/CHF	EUR/CHF	AUD/USD	NZD/USD	GBP/USD	SKK/USD	NOK/USD	CAD/USD
C-T-V	0.23	1.00																							
AUD/JPY	0.77	0.06	1.00																						
NZD/JPY	0.86	0.15	0.88	1.00																					
GBP/JPY	0.76	0.47	0.70	0.71	1.00																				
SKK/JPY	0.77	0.26	0.73	0.74	0.79	1.00																			
NOK/JPY	0.74	0.27	0.70	0.69	0.80	0.87	1.00																		
CAD/JPY	0.71	-0.04	0.81	0.74	0.76	0.72	0.73	1.00																	
USD/JPY	0.63	0.13	0.59	0.57	0.67	0.57	0.58	0.76	1.00																
CHF/JPY	0.61	0.38	0.45	0.47	0.70	0.73	0.76	0.52	0.46	1.00															
EUR/JPY	0.71	0.36	0.68	0.71	0.81	0.87	0.88	0.68	0.55	0.81	1.00														
AUD/CHF	0.39	-0.19	0.63	0.48	0.18	0.18	0.15	0.41	0.27	-0.17	0.01	1.00													
NZD/CHF	0.46	-0.16	0.56	0.65	0.16	0.15	0.09	0.36	0.24	-0.23	-0.02	0.74	1.00												
GBP/CHF	0.30	0.20	0.31	0.25	0.49	0.12	0.12	0.37	0.36	-0.10	-0.03	0.49	0.51	1.00											
SKK/CHF	0.41	-0.08	0.44	0.37	0.27	0.55	0.33	0.40	0.27	0.02	0.15	0.52	0.52	0.49	1.00										
NOK/CHF	0.35	-0.07	0.39	0.29	0.26	0.32	0.53	0.40	0.28	0.04	0.15	0.49	0.43	0.49	0.64	1.00									
CAD/CHF	0.23	-0.29	0.32	0.21	0.13	0.05	0.07	0.50	0.39	-0.19	-0.11	0.70	0.52	0.55	0.45	0.49	1.00								
USD/CHF	0.04	-0.16	0.05	-0.01	0.04	-0.14	-0.11	0.21	0.44	-0.27	-0.27	0.48	0.35	0.56	0.28	0.34	0.75	1.00							
EUR/CHF	0.34	0.03	0.43	0.36	0.27	0.33	0.34	0.37	0.25	-0.02	0.31	0.48	0.49	0.46	0.60	0.63	0.40	0.25	1.00						
AUD/USD	0.36	0.03	0.49	0.40	0.27	0.36	0.29	0.31	0.06	0.16	0.31	0.30	0.25	0.07	0.25	0.12	0.07	-0.24	0.21	1.00					
NZD/USD	0.44	0.08	0.39	0.51	0.16	0.26	0.19	0.12	-0.13	0.06	0.23	0.29	0.46	0.00	0.18	0.06	-0.04	-0.33	0.15	0.62	1.00				
GBP/USD	0.25	0.40	0.13	0.18	0.38	0.27	0.24	0.06	-0.12	0.26	0.29	-0.03	-0.04	0.20	0.06	0.00	-0.13	-0.29	0.06	0.37	0.38	1.00			
SKK/USD	0.25	0.05	0.18	0.18	0.18	0.25	0.20	0.17	0.07	0.13	0.19	0.12	0.06	0.06	0.19	0.11	0.10	-0.01	0.10	0.31	0.27	0.37	1.00		
NOK/USD	0.31	0.10	0.23	0.21	0.22	0.27	0.29	0.16	0.04	0.21	0.26	0.14	0.05	0.03	0.15	0.17	0.06	-0.08	0.13	0.23	0.15	0.29	0.55	1.00	
CAD/USD	0.11	-0.10	0.17	0.12	0.06	0.11	0.08	0.16	-0.01	0.04	0.10	0.11	0.07	0.00	0.07	0.03	0.04	-0.13	0.08	0.38	0.21	0.18	0.37	0.30	1.00
EUR/USD	0.21	0.00	0.22	0.18	0.16	0.15	0.13	0.20	0.12	-0.03	0.12	0.27	0.16	0.15	0.16	0.11	0.27	0.18	0.14	0.32	0.24	0.30	0.68	0.59	0.31
AUD/EUR	0.32	-0.17	0.51	0.39	0.13	0.10	0.09	0.30	0.17	-0.14	-0.04	0.83	0.61	0.36	0.34	0.33	0.60	0.46	0.24	0.22	0.25	-0.01	0.13	0.19	0.06
NZD/EUR	0.44	-0.11	0.42	0.57	0.12	0.09	0.04	0.24	0.14	-0.16	-0.05	0.67	0.82	0.34	0.31	0.24	0.49	0.38	0.17	0.16	0.44	0.00	0.11	0.12	0.02
GBP/EUR	0.10	0.17	0.10	0.10	0.22	-0.03	-0.08	0.13	0.18	-0.22	-0.08	0.24	0.23	0.48	0.09	0.02	0.31	0.32	0.05	0.06	0.05	0.08	0.13	0.06	-0.02
SEK/EUR	0.25	-0.12	0.18	0.14	0.16	0.32	0.15	0.25	0.21	0.06	0.00	0.19	0.18	0.25	0.55	0.27	0.24	0.20	0.04	0.02	-0.05	-0.03	0.26	0.16	0.06
NOK/EUR	0.26	-0.04	0.20	0.15	0.16	0.18	0.39	0.24	0.21	0.08	0.01	0.29	0.24	0.32	0.37	0.73	0.37	0.28	0.16	0.03	0.01	-0.01	0.07	0.13	-0.05
CAD/EUR	0.06	-0.06	0.07	0.03	0.02	-0.02	-0.04	0.14	0.11	-0.17	-0.08	0.26	0.14	0.16	0.10	0.07	0.42	0.35	0.05	0.03	0.00	0.05	0.19	0.19	-0.16
AUD/GBP	0.25	-0.04	0.24	0.22	0.16	0.25	0.21	0.24	0.13	0.16	0.26	0.17	0.04	-0.09	0.07	0.00	0.11	0.01	0.08	0.43	0.16	0.05	0.09	0.20	0.20
NZD/GBP	0.33	-0.24	0.32	0.45	-0.10	0.11	0.06	0.14	0.03	-0.04	0.12	0.32	0.48	-0.25	0.07	-0.02	0.08	-0.08	0.12	0.32	0.57	-0.18	0.05	0.08	0.12
SEK/GBP	0.06	0.12	-0.08	-0.07	0.09	-0.12	-0.16	0.00	0.08	-0.05	-0.13	0.01	0.02	0.29	-0.04	-0.10	0.11	0.19	-0.05	-0.08	-0.08	0.01	0.29	-0.02	0.01
NOK/GBP	0.12	0.03	0.10	0.10	0.03	0.06	0.02	0.02	0.02	-0.01	0.03	0.14	0.14	0.07	0.12	0.07	0.04	0.03	0.14	0.10	0.04	0.08	0.17	0.43	0.14
CAD/GBP	0.06	0.66	-0.15	-0.04	0.31	0.08	0.06	-0.33	-0.11	0.21	0.15	-0.28	-0.24	0.20	-0.14	-0.19	-0.45	-0.19	-0.12	-0.06	0.06	0.43	-0.01	0.07	-0.10
AUD/CAD	0.31	0.16	0.48	0.42	0.14	0.25	0.17	-0.01	-0.05	0.07	0.22	0.39	0.36	-0.01	0.19	0.06	-0.15	-0.21	0.19	0.42	0.49	0.14	0.09	0.12	0.09
NZD/CAD	0.36	0.26	0.25	0.49	0.11	0.17	0.09	-0.16	-0.09	0.06	0.18	0.16	0.44	-0.08	0.03	-0.10	-0.29	-0.26	0.05	0.23	0.64	0.19	0.05	0.07	-0.03
SEK/CAD	0.12	0.12	0.02	0.03	0.08	0.13	0.10	0.05	0.04	0.11	0.08	0.02	-0.05	0.00	0.09	0.04	0.08	0.07	-0.03	0.04	0.06	0.21	0.55	0.20	-0.13
NOK/CAD	0.21	0.20	0.04	0.09	0.12	0.19	0.25	-0.04	0.01	0.23	0.23	-0.05	-0.09	-0.11	0.02	0.12	-0.11	-0.09	0.06	-0.02	0.05	0.15	0.15	0.46	-0.06
NZD/AUD	0.16	0.17	-0.25	0.15	0.00	-0.04	-0.05	-0.14	-0.05	0.07	0.01	-0.30	0.10	-0.11	-0.19	-0.22	-0.20	-0.09	-0.20	-0.27	0.23	0.05	-0.04	-0.08	-0.13
SEK/AUD	0.20	-0.10	0.31	0.22	0.05	-0.03	0.00	0.14	0.02	-0.13	-0.02	0.53	0.34	0.16	0.04	0.10	0.33	0.24	0.12	0.07	0.16	0.02	0.28	0.11	0.03
NOK/AUD	0.32	0.07	0.14	0.15	0.15	0.06	0.03	0.08	0.06	0.02	0.10	0.21	0.11	0.12	-0.01	-0.06	0.13	0.12	0.06	0.14	0.18	0.14	0.15	0.33	0.07
SEK/NZD	0.36	-0.07	0.26	0.42	0.05	-0.09	-0.07	0.10	0.03	-0.19	-0.05	0.44	0.60	0.18	-0.03	0.00	0.25	0.23	0.07	0.04	0.34	0.00	0.14	0.05	0.01
NOK/NZD	0.39	0.06	0.12	0.25	0.13	-0.01	-0.12	0.06	0.05	-0.09	0.01	0.19	0.29	0.17	-0.05	-0.23	0.12	0.15	-0.02	0.10	0.36	0.12	0.07	0.11	0.02
NOK/SEK	0.14	0.03	0.07	-0.02	0.10	0.07	0.15	0.09	0.13	0.06	0.02	0.04	-0.05	0.12	0.10	0.23	0.04	0.07	0.01	-0.05	-0.13	-0.03	0.07	0.05	-0.04
S&P 500	0.22	-0.11	0.36	0.32	0.12	0.24	0.16	0.28	0.06	-0.04	0.09	0.45	0.43	0.23	0.45	0.31	0.34	0.08	0.35	0.32	0.30	0.14	0.21	0.10	0.16
MSCI WORLD	0.24	-0.07	0.37	0.33	0.11	0.25	0.16	0.22	-0.01	-0.05	0.11	0.46	0.42	0.18	0.44	0.29	0.30	-0.01	0.35	0.40	0.41	0.22	0.24	0.15	0.19
FTSE 100	0.16	-0.23	0.34	0.26	0.02	0.17	0.11	0.27	0.11	-0.09	0.03	0.46	0.40	0.15	0.41	0.31	0.39	0.18	0.33	0.26	0.20	-0.04	0.15	0.05	0.14
NIKKEI 225	0.30	-0.06	0.42	0.34	0.18	0.25	0.17	0.30	0.16	-0.01	0.14	0.47	0.38	0.21	0.36	0.23	0.35	0.14	0.28	0.29	0.31	0.08	0.18	0.14	0.14

	EUR/USD	AUD/EUR	NZD/EUR	GBP/EUR	SEK/EUR	NOK/EUR	CAD/EUR	AUD/GBP	NZD/GBP	SEK/GBP	NOK/GBP	CAD/GBP	AUD/CAD	NZD/CAD	SEK/CAD	NOK/CAD	NZD/AUD	SEK/AUD	NOK/AUD	SEK/NZD	NOK/NZD	NOK/SEK	S&P 500	MSCI WORLD	FTSE 100	NIKKEI 225
EUR/USD	1.00																									
AUD/EUR	0.34	1.00																								
NZD/EUR	0.24	0.74	1.00																							
GBP/EUR	0.36	0.31	0.31	1.00																						
SEK/EUR	0.13	0.15	0.14	0.05	1.00																					
NOK/EUR	0.07	0.28	0.22	0.02	0.26	1.00																				
CAD/EUR	0.53	0.33	0.26	0.35	0.11	0.06	1.00																			
AUD/GBP	0.21	0.27	0.14	-0.01	0.00	-0.05	0.10	1.00																		
NZD/GBP	0.06	0.29	0.50	-0.10	-0.11	-0.08	-0.01	0.34	1.00																	
SEK/GBP	0.10	0.03	0.07	0.51	0.22	-0.08	0.10	-0.07	-0.15	1.00																
NOK/GBP	0.22	0.14	0.14	0.20	0.06	0.11	0.03	0.10	0.05	0.14	1.00															
CAD/GBP	-0.05	-0.24	-0.13	0.14	-0.09	-0.11	-0.09	-0.12	-0.31	0.14	0.02	1.00														
AUD/CAD	0.08	0.36	0.32	0.00	-0.03	-0.03	-0.04	0.15	0.39	-0.09	0.12	0.23	1.00													
NZD/CAD	0.02	0.14	0.47	0.00	-0.12	-0.10	-0.10	0.06	0.53	-0.08	0.09	0.36	0.66	1.00												
SEK/CAD	0.30	0.08	0.06	0.07	0.27	0.06	0.38	0.03	-0.08	0.27	-0.02	0.01	-0.01	0.01	1.00											
NOK/CAD	0.17	-0.04	0.00	-0.11	0.02	0.20	0.22	0.12	0.03	-0.10	0.28	0.30	0.11	0.15	0.19	1.00										
NZD/AUD	-0.09	-0.24	0.23	0.00	-0.05	-0.07	-0.07	-0.10	0.26	0.07	-0.06	0.20	-0.17	0.43	0.02	0.06	1.00									
SEK/AUD	0.15	0.65	0.46	0.16	0.04	0.04	0.17	0.11	0.17	0.28	0.06	-0.17	0.28	0.11	0.25	-0.07	-0.13	1.00								
NOK/AUD	0.32	0.35	0.25	0.18	0.05	-0.03	0.25	0.31	0.16	0.12	0.29	0.10	0.19	0.12	0.05	0.27	-0.06	0.27	1.00							
SEK/NZD	0.15	0.53	0.76	0.21	-0.01	-0.02	0.17	0.10	0.40	0.24	0.07	-0.09	0.28	0.44	0.12	-0.01	0.28	0.63	0.28	1.00						
NOK/NZD	0.23	0.27	0.45	0.31	-0.02	-0.17	0.24	0.17	0.33	0.20	0.14	0.14	0.16	0.33	0.01	0.10	0.26	0.19	0.64	0.45	1.00					
NOK/SEK	0.00	0.00	-0.08	-0.01	0.32	0.37	0.02	-0.05	-0.19	0.22	0.18	0.06	-0.01	-0.14	0.14	0.11	-0.14	0.16	0.12	0.02	-0.03	1.00				
S&P 500	0.15	0.37	0.34	0.10	0.13	0.16	-0.01	0.10	0.18	-0.06	0.13	-0.21	0.20	0.11	0.01	-0.13	-0.13	0.21	-0.06	0.13	0.00	-0.11	1.00			
MSCI WORLD	0.18	0.38	0.33	0.07	0.12	0.14	0.01	0.13	0.20	-0.11	0.12	-0.16	0.29	0.17	0.03	-0.08	-0.14	0.22	-0.01	0.13	0.01	-0.10	0.94	1.00		
FTSE 100	0.12	0.37	0.29	0.02	0.16	0.17	0.02	0.10	0.22	-0.11	0.11	-0.33	0.19	0.03	0.00	-0.12	-0.19	0.22	-0.04	0.11	-0.06	-0.07	0.81	0.84	1.00	
NIKKEI 225	0.21	0.41	0.33	0.14	0.11	0.11	0.18	0.16	0.20	-0.06	0.07	-0.15	0.24	0.12	0.07	-0.01	-0.15	0.25	0.14	0.18	0.14	-0.02	0.57	0.69	0.53	1.00

Appendix 3. Linear correlation matrix