HELSINKI SCHOOL OF ECONOMICS (HSE)
Department of Accounting and Finance

CURRENCY CARRY TRADES – BETTING AGAINST THE UNCOVERED INTEREST PARITY

Finance
Master´s thesis
Jussi-Pekka Lyytinen
Spring 2007

Approved by the Council of the Department ____ / ____ 20____ and awarded the grade_____

_____

Helsinki School of Economics
Master's Thesis
Jussi-Pekka Lyytinen

Abstract
May 11, 2007

CURRENCY CARRY TRADES – BETTING AGAINST THE UNCOVERED INTEREST PARITY

OBJECTIVES OF THE STUDY

The objective of this thesis is to analyze the profitability of a specific trading strategy in the world's largest single market; the foreign exchange or FX market. The trading strategy under scrutiny, carry trade, is fundamentally based on the assumption that the uncovered interest parity (UIP), cornerstone parity condition in exchange rate economics, will not hold. The motivation of the study stems from both widely documented facts among academics that UIP is violated and evidence from market participants that a massive amount of capital is placed on this particular trading strategy.

The trading model used in the study takes leveraged positions in currencies based on their interbank interest rates. Long positions in relatively high-yielding currencies are funded with short positions in relatively low-yielding currencies. The thesis analyzes these positions from two perspectives. First, the profitability of single currency pair carry trades is examined. The second phase of the analysis combines individual positions into portfolios consisting of different number of currencies. The second phase also includes an analysis of currency investments from an alternative asset class perspective. Thus, the objective of the thesis is not merely to assess currency trading strategies but also to benchmark the results against other asset classes.

DATA AND METHODOLOGY

The study utilizes spot foreign exchange rate and one-month as well as three-month interbank interest rate data from following developed countries: Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, the U.K, and the U.S. The sample period spans from January 1993 to December 2006. Since the beginning of 1999 the common currency euro replaces the German mark.

Total returns from both the single-currency and currency portfolio carry trades are also decomposed into two components, interest rate return and exchange rate return, to highlight the basis of the total performance. Attractiveness of carry trades is analyzed risk-adjusted basis using the Sharpe ratio.

RESULTS

The main findings of the study can be summarized as follows. Violations of UIP are pervasive and widespread especially after adoption of the euro, and particularly for currency pairs with the widest interest differential. Portfolio carry trade strategies offer attractive risk-adjusted returns for prolonged periods and outperform benchmark asset classes. Moreover, currencies are virtually zero correlated with the other asset classes offering potential diversification benefits.

KEYWORDS: Foreign exchange, trading strategies, carry trade, currency investments

Helsingin Kauppakorkeakoulu **Tiivistelmä**
Rahoituksen pro gradu-tutkielma **Toukokuu 11, 2007**
Jussi-Pekka Lyytinen

CURRENCY CARRY TRADES – BETTING AGAINST THE UNCOVERED INTEREST PARITY

TUTKIMUKSEN TAVOITTEET

Tutkielma tarkastelee carry trade-strategian tuottoja valuuttamarkkinoilla. Tämä strategia ei ole puhdas arbitraasistrategia vaan perustuu olettamukseen, että kattamaton korkopariteetti ei toteudu. Tutkimuksen taustalla on lukemattomat aiemmat tulokset, joiden mukaan tämä pariteettiehto ei toteudu markkinoilla sekä tutkimukset, jotka osoittavat kyseisen trading-strategian olevan erittäin yleisesti käytetty.

Tutkielma käsittelee valuuttaspekuloinnin tuottoja sekä yksittäisten valuuttaparien osalta että portfolioista, jotka on muodostettu näistä yksittäisistä valuuttapareista. Valuuttaparit valitaan korkoeron mukaan siten, että suhteellisesti matalan koron valuuttaa lainataan ja sijoitetaan suhteellisesti korkean koron valuuttaan. Valuuttasijoituksia analysoidaan myös vertaamalla niitä muihin instrumentteihin.

AINEISTO JA MENETELMÄT

Tutkimuksen empiirisessä osiossa käytetään sekä spot-valuuttakursseja että yhden ja kolmen kuukauden interbank-korkoja seuraavista maista: Australia, Iso-Britannia, Japani, Kanada, Norja, Ruotsi, Saksa, Sveitsi, Uusi-Seelanti sekä Yhdysvallat. Tutkimusperiodi kattaa ajanjakson vuoden 1993 alusta vuoden 2006 loppuun. Yhteisvaluutta euro ja euro interbank-korot korvaavat Saksan datan vuodesta 1999 alkaen.

Empiirisessä osiossa analysoidaan sekä trading-strategian kokonaistuottoja että kahta komponenttia, joista tämä tuotto muodostuu: korkoero sekä valuuttakurssin muutos. Kokonaistuottoja tarkastellaan myös riskikorjattuna käyttäen mittarina Sharpen lukua.

TULOKSET

Tulokset antavat tukea tutkimushypoteesille, jonka mukaan kattamaton korkopariteetti ei päde valuuttamarkkinoilla. Tulokset ovat erityisen vahvat aikajaksolla euron käyttöönoton jälkeen varsinkin korkean korkoeron valuuttapareille. Valuuttaportfoliot ovat erityisen tuottoisia myös riskikorjattuina ja verrattuna muihin sijoituskohteisiin.

ASIASANAT: Valuuttaspekulointi, carry trade, kattamaton korkopariteetti

ACKNOWLEDGEMENTS

I am truly thankful to Professor Matti Suominen for his guidance and assistance during the research process. I would also like to thank Huhtamaki Plc's Group Treasury for their flexibility over the last weeks. Finally, I would like to express my gratitude to my friends and family for their support. Most of all, thank you Anja.

TABLE OF CONTENTS

List of tables and figures

Tables:

Figures:

1. Introduction

Anyone who has been following the major financial market news has been exposed with a high probability to foreign exchange market related citations like these:

> *"Yen carry trade a significant factor behind the high volatility of USD/JPY"*
>
> BIS Quarterly Review, March 1999

> *"Barclays launches an automated FX fund"*
>
> Financial Times, Jan 08, 2007

> *"No end to yen carry trade unwinding"*
>
> Bloomberg, Mar 06, 2007

> "*Merrill Lynch creates "ML FX Clone" model to replicate hedge fund foreign exchange strategies"*
>
> The Wall Street Journal, Mar 22, 2007

These examples show that the phenomenon called carry trade has attracted a lot of attention lately, but is not a new invention as can be concluded based on the date of the first citation. Moreover, it also seems that banks are adopting foreign currency trading strategies similar to those used by a large number of hedge funds. Actually, it is nowadays possible to almost anyone, you and me, to become a foreign exchange trader and engage in these carry trades. The following study will explore the foreign exchange market, the participants in the market, trading strategies they use, and most importantly, the profitability of one of these strategies, namely carry trade.

1.1. Motivation of the study

The fundamental motivation of this study can be divided into theoretical and practical part. The theoretical motivation stems from the routinely documented fact among academics that the uncovered interest parity, the cornerstone parity condition in exchange rate economics, is severely violated. This evidence is further supported with the results from several surveys among foreign exchange market participants that indicate a widespread use of trading strategies utilizing violations of the uncovered interest parity. This is the practical motivation of the study. Furthermore, the violation of the uncovered interest parity is not the only "puzzle" prevailing in the foreign exchange market. This study addresses probably the two most often documented puzzles in academic literature about exchange rate economics and their practical implications.

Foreign exchange market has evolved rapidly, and mainly due to technological change it has become available not only to a wider array of institutional investors but to private investors as well. Should there be any anomalies present in the market, more and more market participants are ready to reap the profits. On the other hand, this could be assumed to increase the market efficiency, when greater number of agents is processing the information in the market.

Moreover, despite the numerous papers studying the foreign exchange market, trading strategies utilizing the possible anomaly has attracted a lot less interest considering the total amount of research. In addition, the current research concentrates on a rather limited set of U.S dollar-based exchange rates. This thesis studies the profitability of a widely used currency trading strategy, which is based on the prevailing interest rate differentials between countries, using an extensive set of exchange rate data.

1.2. Objectives and contribution of the study

To date the usual source of analysis of currency markets has been the research conducted by the Bank for International Settlements (BIS), the Federal Reserve, or some other central banks. Although the earliest findings of puzzles in the foreign exchange market date back to early 1980s and to seminal papers by Meese and Rogoff (1983) and Fama

(1984), the academic research since then has reviewed profit opportunities arising from the currency fluctuations mostly in the spirit of technical analysis. Only very recently papers by, for instance, Baz et al. (2001) and Burnside et al. (2006) have tackled the issue of profitability of currency trading strategies from a different point of view, namely carry trade strategies. A worth of noting are also the important contributions by Lyons (2001) in the strand of exchange rate modeling using the microstructure approach as opposed to the traditional fundamentals-based research.

The main objective of this paper is to examine whether simple carry trade strategies are able to generate high risk-adjusted returns. Two alternative strategies are analyzed in-depth: single-currency strategy as well as currency portfolio strategy. These both have been massively exploited by institutional investors as documented in numerous surveys by BIS. This study contributes to the currently small number of papers addressing the profitability of carry trades. The main limitation of existing research is a rather narrow use of possible exchange rates. Usually these studies have utilized only U.S. dollar based exchange rates. To meet this shortcoming, this study contributes to the existing literature utilizing an extensive set of cross-exchange rates instead of relying only on exchange rates against U.S. dollar, for instance. To my knowledge, this is the first paper using such a wide exchange rate data set.

The second objective of the study is to analyze currencies also from an alternative asset class perspective. Managed currency investments are actually quite new alternatives available to investors and thus still relatively rarely studied. As Middleton (2005) notes the total number of pure currency investment programs is still quite small. The attractiveness of these investments is often rationalized by excellent diversification benefits, since currency returns have been practically uncorrelated with other asset classes. This study contributes to the small number of existing literature by offering an incremental piece of research of currencies as an additional source to traditional portfolio returns.

1.3. Limitations of the study

Although the study utilizes a wider set of exchange rates than the earlier literature, the potential limitations of the study can be considered as data related. As is evidenced for instance by several BIS reports, especially recently carry trades have targeted several emerging market currencies. This study, on the other hand, utilizes only the most actively traded currencies. This choice is motivated by the availability and quality of data. The sample period does not cover the whole free-floating era in the foreign exchange market, which someone could argue as a limitation. However, not all the currencies included in the data started to float freely in the beginning of the 1970s. The choice of the sample period was thus also a data availability but also a quality issue. Chapter 5 discusses in more detail the data selection process and motivates the choices I have made.

1.4. Structure of the study

The remainder of the paper is organized as follows. The next chapter offers a detailed description of characteristics of carry trades. Chapter 3 provides theoretical and empirical backgrounds to foreign exchange markets. First, the essentials of the exchange rate economics to carry trades are discussed. Second, an alternative approach to traditional exchange rate models is presented. Third, foreign exchange market statistics are reviewed to give a perspective of the currency market. Chapter 4 presents the research hypotheses. The trading model used in the empirical part of the study as well as the data used are discussed in Chapter 5. Empirical results are presented and analyzed in Chapter 6, and Chapter 7 is devoted to concluding remarks and some ideas for future research.

2. Characteristics of carry trades

I devote this chapter to a definition as exhaustive as possible of the phenomenon called carry trade. Although the intuition behind carry trades is very simple, it can take many, often quite complex forms. Let us start with a broad definition and then see what this implies to the topic of this study, namely currency carry trades. At the end of this chapter I will also offer practical examples of components of currency carry trades in its most observed form – so called "yen carry trade", which then can be generalized to other currencies as well. This chapter focuses on current issues based on the most recent evidence, whereas the empirical part in Chapter 6 will examine the persistence of this phenomenon.[1]

No matter how investors engage in carry trades the underlying motivation is the same: to exploit profit opportunities presented by a persistently low cost of funds in one market segment combined with high returns in another. While the term "carry" generally stands for the difference between the income from a security (or portfolio) and the corresponding financing cost, it is convenient to explain the nature of carry trades in the context of futures contracts. The theoretical price of the contracts is achieved by reference to an arbitrage portfolio that combines a long position on the underlying security with financing at the risk-free rate. In practice, however, the relevant financing rate for arbitrageurs is the repo rate, which is slightly higher than the risk-free rate on government paper. A positive (negative) "carry" implies that the futures price is lower (higher) than the current spot rate of the underlying security. While spot and futures price always converge towards the maturity of the contract, there are instances when the latter tend to persistently over or under-predict the future spot rate that will prevail at the maturity. In case of a currency futures contract this would amount to a persistent deviation from the uncovered interest parity condition[2]. Carry trade strategies are designed to profit from such persistent one-sided biases by taking the appropriate positions on both sides of the arbitrage portfolio. It should be stressed that carry trades

[1] For additional evidence among voluminous recent discussion, see BIS (2007).
[2] Uncovered interest parity (UIP) states that expected exchange rate change equals interest rate differential between two countries. The parity condition is examined in the next chapter.

are not, however, pure arbitrage strategies as the funding is in short-term liabilities and the investor assumes duration risk, and in the case of currency carry trade, is willing to bear the exchange rate risk as well.

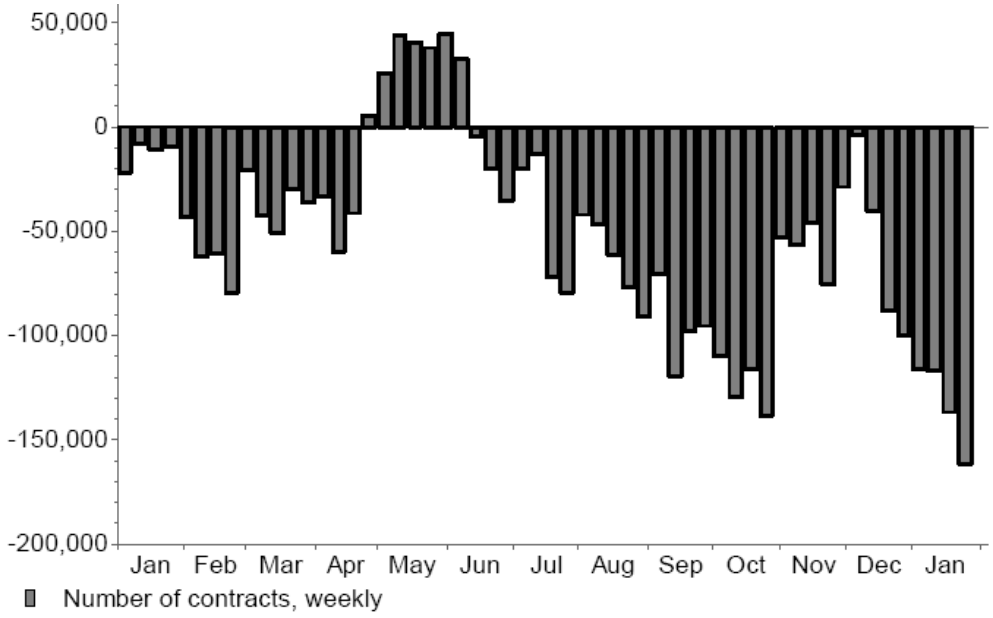
A currency carry trade involves borrowing funds in a low-interest rate currency and investing them in a high-interest currency. In its simplest form, borrowed funds are converted in the spot market and invested in securities denominated in high-yielding currency. At the end of holding period, the equivalent of borrowed amount is converted in the spot market back to funding currency to repay the loan. Thus, profitability of carry trade depends crucially on the exchange rate change between the two currencies. However, markets offer several alternatives to outright borrowing in the money market for the practical implementation of carry trades. Abovementioned transactions can be also conducted using forward contracts. In this case a speculator will sell forward a currency, which is said to be trading on forward premium (i.e. its forward rate exceeds the current spot rate) and buy forward a currency, which is selling at forward discount (current spot rate exceeds the forward rate). Alternatively, a synthetic forward contract transaction can be implemented through a combination of sale of currency in the spot market and a swap of the proceeds for the currency of denomination of the assets to be purchased. This alternative takes advantage of the greater liquidity of the swap markets. Finally, the long position can be financed by sales of borrowed securities denominated in the relevant currency. In this case, of course, the additional risk implied by the exposure to other market factors beyond short-term interest rates will have to be hedged.

Now the reader should be familiar with carry trade concept and we can turn into a more detailed analysis of currency carry trades. The most often cited example is “yen carry trade”, which stems from the widespread use of the Japanese yen as a funding currency due to ultra-low level of interest rates in Japan since mid 1995. I will analyze several components, which include investments funded by yen borrowings, supported by evidence from various sources. It should be noted, however, that evaluating the volume of carry trades on the basis of publicly available data is problematic because of loose data disclosure requirements some market actively involved in such trades face. Additionally, as was discussed, it is possible to engage in carry trades using several different

instruments, some of which are so called off-balance sheet items (e.g. currency swaps) and do not come up in any records. Following information is thus at its very best only an approximation.

At least three major components constituting to the yen carry trade can be identified. First component to be separated are speculative positions via international money market (IMM) instruments. Possible carry trade activity via IMM, which is part of the Chicago Mercantile Exchange (CME), can be assessed with net open-interest data of currency futures contracts. The most recent evidence is presented in Figure 1, which shows the net speculative yen positions indicating that investors in total have been short in the yen most of the time in 2006.

Figure 1: IMM Japanese yen net open interest in 2006
Figure 1 presents the net open interest in the Japanese yen futures contracts from January 2006 to January 2007. Data source: Foreign exchange contact group (FXCG) of the European Central Bank.



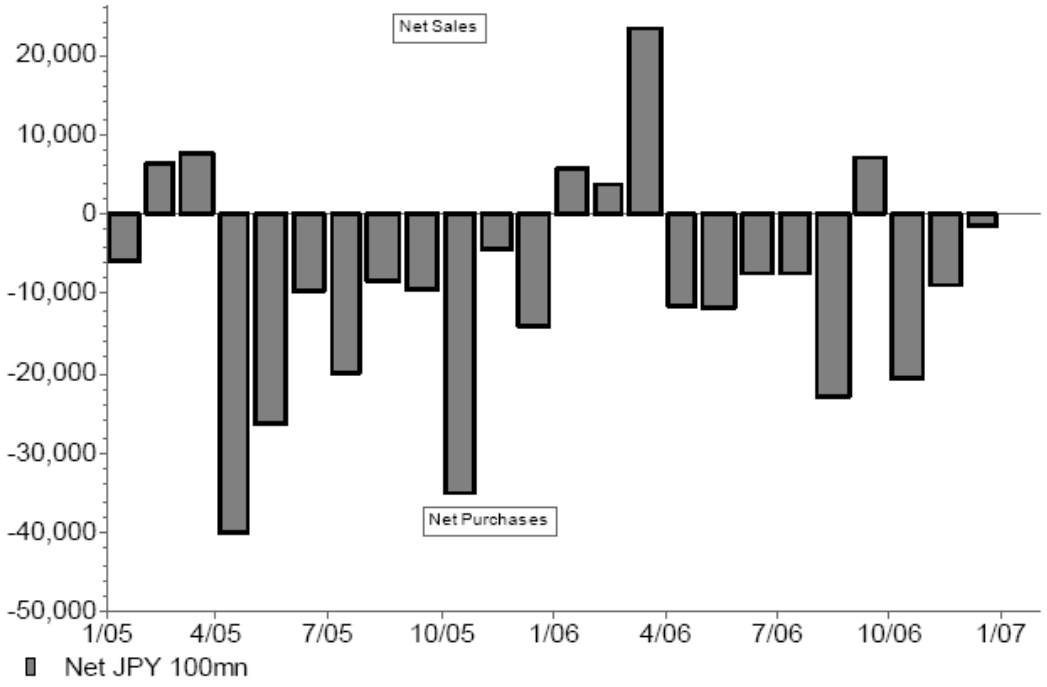
The second factor, which has an increasing importance on the strength or weakness of the yen, is margin FX trading. Earlier only institutional investor had access to foreign exchange market, but due to technological change several electronic trading platforms are

available to retail investors as well. In addition, with currency-only hedge funds foreign exchange has become more like an alternative asset class. Middleton (2005) presents evidence for rapid growth in currency fund sector. More evidence can be obtained from a recent article about foreign-exchange trading in Japan. The following data has been largely unmeasured before 2005, when many foreign-currency retail intermediaries joined the Financial Futures Association of Japan (FFAJ). In the three months to December 2005, trading involving its members amounted to $280 billion, or almost $10 billion a day, which is approximated to be around 20 % of the total size of Japan's foreign-currency market. Total inflows during 2005 to foreign-currency investment trusts came to $170 billion, a sixfold rise from 2000. All in all, individuals are becoming more powerful in FX market. FFAJ estimates that they held a net long position in foreign currencies of $130 billion at the end of 2005. To put the figure in perspective, it is almost as big as Japan's current-account surplus and more than foreigners have in Japanese stocks.

The reader should bear in mind that buying (selling) foreign currency in FX market involves a simultaneous sale (purchase) of respective counter-currency. When an (institutional or retail) investor engages in spot FX transaction, the brokerage pays the relevant interest rate in currency, where investor has a long position and charges interest rate according to a short position. Moreover, online retail brokerages offer leverage up to 400 times the required initial deposit. Although it usually takes a mere $1.000 to open an account, to be able to trade at the thinnest spread, some service providers require an initial deposit of $10.000. Even the retail market has become so highly competed that main brokerages do not charge any commissions, the spread being the only expense to the investor. This means that individual investor is able to make a bet of $4.000.000. Thus anyone with trading account can get involved in (leveraged) currency carry trades, and as the data above demonstrates, it is not only the foreign investors who have been participating in yen carry trades. Their Japanese counterparts are also very active in their search for yield.

The third important factor is the foreign-currency denominated bonds issued in Japan and purchased by Japanese investors. These so called Uridashi-bonds are favored by Japanese investors because of the relatively high yield they offer, although investors are at the same time exposed to currency movements. Not surprisingly, according to report by Reserve Bank of New Zealand[3] most of the issues in recent years have been denominated in the Australian, New Zealand and U.S. dollars. The first two of these especially are considered high yielding currencies and are major recipients of carry trade money. Figure 2 sheds light on the volume of foreign bond purchases by Japanese investors. Since the investors are required to sell the yen to buy the foreign-currency denominated bond, the yen will be under pressure to depreciate. At the maturity, vice versa, investors would sell the foreign-currency proceeds to buy the yen. However, RBNZ report states that so far the proceeds from Uridashi bonds have been mostly rolled over into new issues.

Figure 2: Japanese monthly foreign bond purchases
Figure 2 presents monthly amount of foreign bonds purchased by Japanese investors. Data source: Foreign exchange contact group (FXCG) of the European Central Bank.



[3] RBNZ Uridashi bond flow memorandum, published February 8th, 2006.

I have now outlined the main characteristics of carry trades and more specifically currency carry trades. From now on throughout the text the terms “carry trade” and “currency carry trade” are used interchangeably if not specifically otherwise mentioned. Essential for the reader to understand at this point is the fact that these trading strategies should on average yield zero returns if we assume the uncovered interest parity, which will be presented throughout in the next chapter, is not violated. As was mentioned in the opening paragraph of this chapter, investors have engaged in carry trades not only in the yen but also in several other currencies simultaneously. The empirical part in Chapter 6 will examine the profitability of these strategies in a more broad perspective. However, let us first turn to exchange rate related theory and empirical evidence.

3. Foreign exchange: theory and research

The review of underlying theory, related earlier research and foreign exchange market statistics in this chapter will concentrate on topics that are relevant in implementing and analyzing carry trades. The focus is kept on fairly recent research, although some groundbreaking papers are included in discussion. Voluminous number of existing literature on foreign exchange requires sharp focus and thus topics of this study are strictly limited. For that reason, for instance, the role of central banks and related research are set aside. For a great discussion on official intervention in the foreign exchange market, see Sarno and Taylor (2002). This chapter includes topics and is structured as follows: the first part of the chapter discusses fundamentals of exchange rate economics and three major puzzles, or anomalies, documented in a vast body of literature. The second part introduces an alternative field of empirical research, which has gained ground since the beginning of the nineties, namely microstructure approach. Third, I review the characteristics of the foreign exchange market, which differs greatly from other asset markets. This final part also presents the still relatively marginal volume of research on carry trades.

3.1. Exchange rate economics and puzzles

Exchange rate economics is characterized by a number of puzzles, which academics struggle to explain on the basis of either sound economic theory or practical thinking. Put another way, the international finance profession has not yet been able to produce theories and empirical models to explain the behaviour of exchange rates with a reasonable degree of accuracy. The first puzzle to be analyzed is the "forward bias puzzle", relating to the fact that the foreign exchange market is not only inefficient, but it appears to be so inefficient that the forward market, which captures market expectations of future exchange rates, may systematically predict future exchange rate movements in the wrong direction. The second puzzle, which in a way interconnects the first one and the purchasing power parity (PPP) puzzle, is the missing link between nominal exchange rates and a variety of economic or financial fundamentals that international economics theory suggest should drive exchange rates. This puzzle is called the "exchange rate

forecasting puzzle". PPP puzzle can be stated shortly as the lack of any strong tendency of exchange rates to move in sync with relative prices, which should happen if purchasing power is expected to remain constant across countries over long periods of time in a world with international arbitrage in goods markets. However, PPP puzzle is out of the scope of this study. See e.g. Cheung and Chinn (2001) for practitioners' opinion about PPP.

3.1.1. Interest rate parities and the forward bias puzzle

In an efficient speculative market, prices should fully reflect information available to market participants and it should be impossible for an investor to earn excess returns to speculation. The uncovered interest parity (UIP) is the cornerstone parity condition for foreign exchange market efficiency:

$$E_t\,(s_{t+k}) - s_t = i_{t,k} - i^*_{t,k}, \tag{1}$$

where $E_t\,(s_{t+k})$ denotes the logarithm of expected spot exchange rate at time $t+k$, when the expectation is made at time t; s_t denotes the logarithm of the spot exchange rate at time t; $i_{t,k}$ and $i^*_{t,}$ are the nominal interest rates available on similar domestic and foreign securities respectively with k periods to maturity. Thus assuming the agents in the foreign exchange market are risk-neutral and they have rational expectations, the interest rate differential must be offset by expected exchange rate return.

Most often, analyses of foreign exchange market efficiency have taken place in the context of the relationship between spot and forward exchange rates under the assumption of the covered interest parity (CIP):

$$f_t^k - s_t = i_{t,k} - i^*_{t,k}, \tag{2}$$

where the first term, f_t^k, is the logarithm of the k-period forward rate at time t. Left-hand side part of the equation is called the forward spread, and furthermore, forward premium when forward rate exceeds the current spot rate positive and forward discount when the

spot rate exceeds the forward rate. Traders in foreign exchange markets, in fact, use this condition to set forward exchange rates and, thereby, forward spread. This implies that currencies with a low interest rate are typically at a forward premium, whereas currencies with a high interest rate are typically at a forward discount. Therefore, borrowing in currencies with low interest rates and lending in currencies with high interest rates is equivalent to selling currencies that are at a forward premium and buying currencies that are at a forward discount. Thus an assumption that CIP holds is reasonably mild. For instance, Sarno and Taylor (2002) provide a survey of extensive empirical evidence supporting this assumption.

A number of researchers, since Fama (1984) in his seminal paper, have tested UIP replacing the interest rate differential with the forward spread and by estimating a regression of the form:

$$E_t\,(s_{t+1}) - s_t = \alpha + \beta(f_t^1 - s_t) + \acute{\varepsilon}_{t+1}\,, \qquad (3)$$

where k have been assumed equal to 1, and $\acute{\varepsilon}_{t+1}$ is a disturbance term. Under UIP, $\alpha = 0$, the slope parameter β must equal unity, and the disturbance term must be uncorrelated with information at time t. Empirical evidence based on the estimation of equation (3) generally rejects the UIP and the simple, risk-neutral efficient market hypothesis (EMH). For example, the dollar sold at a forward discount from late 1980 until early 1985, implying that value of the dollar should fall in order to offset the positive interest differential on dollar. Instead, the "dazzling dollar", as it was referred to, appreciated at a rate of about 13 % per year.

Indeed, a common finding is that estimates of β, using exchange rates against the dollar, are often statistically insignificantly different from zero and generally closer to minus unity than plus unity as documented by Froot and Thaler (1990), for instance. Extensive surveys of evidence for rejection of EMH include also Hodrick (1987), Lewis (1995) and Engel (1996), among others. This strand of research is concentrated on an explanation already offered by Fama (1984) that the rejection of the risk-neutral EMH may be due to a risk premium required by risk-averse market participants. The results from empirical

analysis of risk-premium models indicate that it is hard to explain the excess returns in forward foreign exchange by an appeal to risk premium alone. Risk premium is not the only explanation offered for the rejection of the simple efficient market hypothesis. The other field of research has concentrated on the expectations component of the joint hypothesis. Speculative bubbles, learning, and peso problems[4] all imply deviations from rational expectations that generate potentially predictable excess returns even when market participants are risk-neutral.

The availability of survey data on exchange rate expectations, for instance from the American Express Bank, the Economist and Money Market Services, has allowed researchers to conduct tests of each component of the joint hypothesis in an attempt to remove all the assumptions regarding the expectation formation mechanisms of agents. Important contributions in this area include the work by Frankel and Froot (1987) and Froot and Frankel (1989). The results from this line of research imply that both the risk aversion and departures from rational expectations are responsible for the rejection of the simple efficient market hypothesis.

Some support from recent studies in favour of UIP, however, can also be presented. Bansal and Dahlquist (2000) confine the forward bias largely to developed economies and to countries where the U.S interest rate exceeds foreign interest rates. Flood and Rose (2002) report that the failure of UIP is less severe during the 1990s and for countries which have faced currency crises over the sample period investigated. Chinn and Meredith (2005) test UIP at short and long horizons and argue that for instruments with maturities of five years, all of the coefficients on interest rate differentials in the unbiasedness regressions are of correct sign and findings give statistical support on the null hypothesis.

Not only central to foreign exchange economics, UIP, or its violation, is a cornerstone of this study as well. According to these two parity conditions the expected exchange rate change can be thus estimated either by interest rate differential or forward spread. The

[4] The term “peso problem” stems from the behaviour of the Mexican peso which, although it had been fixed for a decade, traded at forward discount to the U.S. dollar during the early 1970s. However, the anticipated devaluation did not occur until 1976

abovementioned findings indicate that the more domestic interest rate exceeds foreign interest rate, the more the domestic currency tends on average to appreciate over the holding period, not to depreciate so as to offset the interest differential. Furthermore, this implies that UIP is violated. As was mentioned in previous chapter, carry trades are all about violations of UIP. Note that, unlike CIP, UIP is not an arbitrage condition since the expected exchange rate component in the equation (1) is unknown at time *t*, and therefore deviations from UIP do not necessarily imply arbitrage profits due to the foreign exchange risk. Investors engaged in carry trades are in essence betting that the parity will not hold.

3.1.2. Exchange rate forecasting puzzle

Since 1970s the foreign exchange market has been studied extensively. Numerous studies have been conducted in order to find a model for predicting exchange rates. These attempts have, however, all somewhat failed. Consensus is that exchange rates adjust to a long-term fundamental value but the short-run fluctuations cannot be predicted from the fundamentals very well.

A logical way of examining the empirical ability of exchange rate models is to examine their out-of-sample forecasting performance. Meese and Rogoff (1983) study in their seminal and often cited paper forecasting accuracy of structural and time series exchange rate models of the seventies. The structural models they use include flexible-price monetary (Frenkel-Bilson) model, the sticky-price monetary (Dornbusch-Frankel) model, and the Hooper-Merton model, a sticky-price model which incorporates the effects of the current account. The time series models involve several univariate models and a multivariate model. The exchange rate data consist of three currency pairs: the dollar/mark, dollar/pound, and dollar/yen spot exchange rates over the period March 1973 to June 1981 are used. They use also trade-weighted dollar data. The major finding of their research is that none of these models have performed significantly better than the simple random walk model at one to twelve month horizons.

20 years and dozens of papers later, Cheung et al. (2005) re-assess exchange rate models developed during the 1990s. The authors stress that none of these models have been studied as rigorously as Meese and Rogoff (1983) did when studying exchange rate models of the seventies. The models Cheung et al. test against random walk are the purchasing power parity (PPP), the Dornbusch-Frankel model, a generic exchange rate model incorporating productivity differential, and a composite model incorporating a number of relationships identified in differing theoretical models, e.g. net foreign assets and ratio of government debt to GDP. In addition, they test uncovered interest rate parity. After estimating two specifications of the models and evaluating the models at different horizons using several criteria, the results can be summarized concluding that none of these models point out as being very successful.

A general finding in the literature of exchange rate modelling is that researchers have found that one key to improving forecasting performance based on economics fundamentals lies in the introduction of equation dynamics. However, it remains true that while many studies claim to have beaten the random walk in out-of-sample forecasting, the results turn out to be fragile when the superior forecasting performance should be replicated for alternative periods and alternative currencies. Early findings by Meese and Rogoff are therefore extremely robust.

Prior research on the ability of models based on monetary fundamentals to forecast exchange rates relies on statistical measures of forecast accuracy. Surprisingly little attention has been directed to assessing whether there is any economic value to exchange rate predictability. A recent paper by Abhyankar, Sarno and Valente (2005) investigates the ability of monetary fundamentals to predict exchange rates by measuring the economic or utility-based value to an investor who allocates her wealth according to the model between two assets identical in all respects except the currency of denomination. They focus on two questions. First, they ask how exchange rate predictability affects optimal portfolio choice for investors with a range of horizons up to ten years. Second, whether there is any economic value added to a utility maximizing investor who uses exchange rate forecasts from monetary fundamentals relative to an investor who uses forecasts from random walk model.

The results using three major U.S. dollar exchange rates and forecast horizons from one to ten years are as follows. They find that exchange rate predictability substantially affects the choice between domestic and foreign assets for all currencies and across different levels of risk aversion. Particularly, predictability of exchange rates can generate substantially different optimal weights to the foreign asset compared to optimal weights generated under a random walk model. The main result is, however, evidence of economic value to exchange rate predictability across all exchange rates examined. Specifically, the realized end-of-period wealth achieved by a U.S. investor over a ten-year horizon is higher using a fundamental-based exchange rate model for forecasting than the corresponding wealth obtained using a random walk model.

Argument by Huttman and Harris (2006) further clarifies the exchange rate forecasting puzzle. They note that factors affecting currencies move in fashion. Monetary variables have been more important factors 20 years ago. After that, the pertinent issue was the U.S. trade balance. By 1993-1994 differences in monetary policies between the Bundesbank and the Federal Reserve had become one of the main drivers, and in 1996-1997 expected growth differentials were driving the U.S. dollar higher. To date, among the most important factors are interest rate differentials and trade deficits. Set against this failure of exchange rate models, we move now into other strand of research, which has searched the solution to the exchange rate puzzles from a different approach.

3.2. Microstructure approach to foreign exchange

The frustration to the poor performance of traditional macro fundamental-based exchange rate models discussed above has led, at least partially, to emergence of microstructure research on foreign exchange. The literature on foreign exchange market microstructure reflects an attempt by researchers to understand the mechanisms generating deviations from macroeconomic fundamentals which appear to characterize exchange rate movements. Compared to the conventional macroeconomic approach the microstructure research differs both in its assumptions and its methods. The microstructure approach has relaxed some of the most controversial assumptions underlying traditional exchange rate models and has given emphasis to the role of heterogeneity of agents, to the fact public

information is not the only source of information in exchange rate determination, and to the importance of the institutional details of the foreign exchange trading (Lyons, 2001). With respect to methodology the microstructure literature is concerned with the details and importance of the mechanics of foreign exchange trading, whereas standard macro approach, taking these for granted and implicitly dismissing them, uses a set of macroeconomic relationships to solve for the exchange rate (Sarno and Taylor, 2002).

Considerations of distinguishing features of the foreign exchange market highlight following important aspects relative to other financial markets. Foreign exchange trading occurs in a highly decentralised multiple-dealer market where mainly high-volume inter-dealer transactions are carried out. Furthermore, the transparency of these transactions is low compared to other markets. Although electronic dealing and broking systems as the Reuters 3000 Dealing System and the Electronic Broking System (EBS) Spot Dealing System are driving the market towards virtual centralisation, some degree of fragmentation occurs. One important implication of this is that not all dealer quotes are observable and, therefore, trading may occur at the same time at different prices.

If the underlying assumption in the traditional exchange rate models was that expectations are rational, the microstructure literature has been trying to employ direct measures of expectations using data from surveys of market participants conducted by financial service companies. According to Sarno and Taylor (2002) surveys have often been used for examining, in spot-forward regressions, the foreign exchange market risk premium. The results of these surveys generally indicate the presence of a non-zero risk premium, which appears to be stable and uncorrelated with the forward spread.

Two variables that play no role in the macro approach are hallmarks of the micro approach helping to define the microstructure. These variables are order flow and bid-ask spreads. Understanding implication of the variables, especially order flow, is essential for appreciating how the microstructure approach departs from traditional macro approach. The most important fact to recognize is that order flow and transaction volume are not the same. As Lyons (2001) defines order flow is transaction volume that is signed from initiator perspective. For example, if an investor decides to sell the dealer 10 units (shares,

euros, etc.) the transaction volume is 10, but order flow is -10. Over time, order flow can be measured as the sum of the buyer-initiated and seller-initiated orders. A negative sum means net selling pressure and positive sum net buying pressure over the period.

Lyons (2001) lists three reasons why spreads are the other hallmark theme of micro research; scientific, practical, and historical reason. Scientific reason is data-related. They are a core element of most micro research data sets, and thus ready for hypothesis testing in contrast to other important but not as readily measurable features of the trading environment. Practitioners in the market are concerned with trading costs. This concern and the resources devoted to manage the costs have influenced the course within microstructure. Thus spreads receive attention purely from practical reasons. The third reason stems from the origin of the microstructure research when it sought to separate from the literature on trading models under rational expectations. These models abstract completely from trading mechanisms, due to an assumption that these mechanisms have little effect on the relationship between the fundamentals and price. To distinguish from earlier models, microstructure research focused on the determination of real-world transaction prices – spreads. For an interesting evidence of bid-ask spread related issues from the market; see a survey by Cheung and Chinn (2001) among U.S foreign exchange traders.

Microstructure literature has studied the power of order flow in explaining exchange rate behaviour. The findings indicate that order flow has more explanatory power than macro variables, especially in the short run. An important paper in this literature is by Evans and Lyons (2002). The main determinant of exchange rate in their model is order flow. Using data from the Reuters dealing system, they provide is a significant determinant of the Deutsche mark/dollar and the yen/dollar exchange rates obtaining coefficients of determination over 60 percent and 40 percent, respectively. These are significantly larger than the ones usually obtained using standard macro models.

Using a time-aggregated order flow data from a top-tier investment bank with a remarkable market share in major-currency customer business Lyons (2001) studies the remarkable drop in the dollar/yen exchange rate in October 1998 at the time of LTCM

crisis. The data are split into three customer categories: non-financial institutions (e.g. corporations), unleveraged financial institutions (e.g. mutual funds), and leveraged financial institutions (e.g. hedge funds). The results are very interesting and imply that these three types of customers have behaved in a notably different way prior to, during, and after the crash of the dollar. Non-financial companies have been buying the dollar before the crash and during the crash, after a short period of selling. However, non-financial institution order flow amounted at the maximum to only half of order flows of either financial institution. The leveraged financial institutions have been selling the dollar almost constantly already a month before the collapse. At the time of the crash, they have been actually buying the dollar thus renewing their positions. However, these are quickly reverted in two weeks time. A bit surprisingly, it seems that unleveraged financial companies have been selling most aggressively just prior to the crash. Furthermore, their order flow ceased almost immediately after the collapse in contrast to leveraged institutions flow.

Other important research in the field of microstructure includes a paper by Froot and Ramadorai (2005). They explore interactions between currency returns and institutional investor currency flows. The findings indicate that flows are related to short-term currency returns, while fundamentals better explain long-term returns. Cheung and Chinn (2001) document survey evidence from practitioners on order flow information. In addition to findings related to order flow, Wei and Kim (1997) and Cai et. al (2001) find that large-trader positions explain currency volatility better than do news announcements or traditional fundamentals.

However, as Sarno and Taylor emphasize, the high explanatory power of order flow in the abovementioned studies does not necessarily imply that order flow is the underlying driver of exchange rates. Macroeconomic fundamentals may still be the driving force but the measures of these fundamentals are so imprecise that order flow performs as a better proxy for these variables in estimation. Future research on either the traditional macro approach or the microstructure approach should not be viewed thus in isolation but more like a hybrid view combining these both.

3.3. Foreign exchange market

Until the early 1970s exchange rates were defined according to the Bretton Woods system of the fixed exchange rates. Value of the U.S dollar was linked to gold and other currencies were pegged to the U.S dollar. The system collapsed in 1971 and the era of floating exchange rates began. Since then the foreign exchange market has evolved into the world's largest single market. One of the special features of the foreign exchange market, which has also inspired a lot of research, is that not all market participants are profit maximizers. This group includes for instance corporate treasurers, and it is argued that due to these non-profit maximizing agents, profit opportunities for speculators exist. The other distinguishing features of FX market compared to other financial markets were discussed above in conjunction with microstructure approach and thereby this part focuses first on market statistics and then presents foreign currency speculation related research. As was mentioned in the opening paragraph of this chapter central banks are not included in the discussion. However, several papers have studied the possibility of profitable trading opportunities as a result of central bank intervention. See Sweeney (1997), Szakmary and Mathur (1997), and Neely (2000), among others.

3.3.1. Market characteristics

Although marketwide volume in FX is not generally available, because FX trades are not reported in most countries, Bank for International Settlements (BIS) conducts a study every three years to survey foreign exchange (and derivatives) trading activity. The latest Triennial Central Bank Survey (BIS 2005) conducted in April 2004 shows a surge in FX trading compared to previous survey in April 2001. Average daily turnover rose 57 % at current exchange rates amounting to $1.9 trillion, which more than reversed the fall in global trading volumes between 1998 and 2001. Turnover rose particularly in spot and forward markets. Noteworthy are also the changes in share of total trading between different counterparties. Share of interbank activity has been falling since 1998, amounting to 53 % of total turnover in 2004, although the dollar amount of interbank trading increased approximately 36 % during the latest survey period. Meanwhile, trading between banks and financial customers increased markedly. Share in total turnover rose from 28 % to 33 % in tandem with absolute dollar value which surged 78 % since 2001.

According to Galati and Melvin (2004) the surge in market activity seems to reflect both structural and conjunctural factors. In the context of a global search for yield especially pension funds, insurance companies, mutual funds and other institutional investors became increasingly interested in foreign exchange as an asset class alternative to equity and fixed income. In some countries, for example Australia, investment funds have increased rapidly the proportion of their offshore assets. This may partly explain the 98 % increase in turnover in Australian dollars. In Sweden, for instance, restrictions on foreign exchange exposures for pension funds have been relaxed. Also hedge funds have grown markedly between 2001 and 2004. This contrasts to previous three-year period, when the number and activity of hedge funds in FX markets decreased, following the collapse of LTCM and the withdrawal of Tiger and Quantum from the market. Finally, two additional parties which have been seen to contribute to the fast growth in trading between banks and financial customers are commodity trading advisors (CTAs) and currency overlay managers (COMs). In addition to these factors relating to profit opportunities, also hedging activity increased during the three year period contributing to higher turnover. Multinational companies faced even greater incentives to hedge due to long swings in currencies.

Abovementioned investors followed mainly two strategies that targeted the same currencies: carry trades and momentum trading. In carry trade strategy investor exploits the forward bias by taking a short position in a low interest rate currency and a long position in a higher interest rate currency, essentially betting that the exchange rate will not change so as to offset the interest rate differential. In the second strategy, investors take large positions in currencies to exploit longer-persisting trends or “runs” in exchange rates. This strategy further supports the ongoing trends.

The 2001 – 2004 period was not, however, the first one when carry trades were seen as one of the main drivers of foreign exchange market turnover. BIS (1999) documents extensive evidence for yen carry trade as a significant factor behind the high volatility of yen/dollar exchange since the yen started to decline in the spring 1995. This falling trend continued essentially all the way to the latter half of 1998. During that period the yen was

borrowed to fund a wide array of assets ranging from US Treasuries to high-yielding emerging market securities. Since July 1998 the yen appreciated sharply against dollar: in the period between August 31st and September 7th the dollar fell by about 9 %, and it depreciated dramatically further on 7th and 8th October by 12 %. According to market commentary these movements were to a high extent due to the unwinding of yen carry trades by hedge funds and other institutional investors. The BIS report gives an example of magnitude of these transactions: the Jaguar Fund, macro hedge fund of the Tiger Management Company, began unwinding an estimated $35 billion long dollar/yen position following the first rapid yen appreciation in early September. About $10 billion was offloaded in the market overnight.

Finally, the among the most recent evidence for carry trades being a major driving force in the foreign exchange market is documentation in BIS (2006). It highlights that carry trades were used by different types of international investors in their search for yield. The report also documents the extreme effect which reversal of these positions can cause to the market:

> "The unwinding of positions involving the [Icelandic] króna caused a 10% depreciation of the currency within two days. While such an event would not normally influence other foreign exchange markets, it spilled over within hours to the high-yielding currencies of Australia, Brazil, Hungary, New Zealand and South Africa, all affected by carry trades."

3.3.2. Research on currency investments and speculation

Although speculation in foreign exchange market seems widespread among institutional investors, very few research papers have been dedicated to study different speculation strategies and their success as well as attractiveness of currency investments generally. Only recently this area has aroused more interest, which may partly reflect the fact highlighted in Chapter 2 that possibility into pure currency investments is still relatively small, though rapidly growing, compared to other asset classes.

Among the earlier research Backus et al. (1993) study predictability of currency returns on forward contracts and find that returns from currency speculation are close to zero on average, but they vary on a highly predictable way. The authors construct a simple investment strategy using forward spread to predict returns. This speculation strategy produces high monthly Sharpe ratios ranging from 0.17 to 0.29. To model these returns Backus et al. work with a representative agent theory of asset pricing featuring habit persistence. Although the results from their study indicate that with the habit persistence the model is more successful in explaining the standard deviation of both the equilibrium price measure and the expected currency speculation returns, at the same time they find that theory has features totally contradictory to the data. These include e.g. the autocorrelation of the forward premium. They conclude that this limited success should direct the future work in new directions.

Baz et al. (2001) assess the risk-return performance of currency trading strategy that seeks to take advantage of positive interest differential and violation of UIP. Assuming that exchange rates follow a random walk, they construct an optimal portfolio of currencies. Using four major currencies against the U.S. dollar the authors find a portfolio, which generate positive excess return, and depending on the holding period, an annual Sharpe ratio between 0.50 and 0.79. They also find that portfolio weights are reasonably stable over time, and that the returns are uncorrelated with major fixed-income and equity indexes.

One recent example in the area of profitability of currency trading strategies is a paper by Burnside et al. (2006), which documents the forward discount anomaly and measures returns from two currency speculation strategies. The first one is the carry trade strategy and the other one the regression used to forecast the payoff to selling currencies forward used previously by Backus et al. (1993). Burnside et al. study the returns from the two speculation strategies for nine individual currencies against the pound sterling as well as for equally-weighted and optimally-weighted portfolios of currencies. They report the average return, standard deviation and Sharpe ratio of the monthly payoffs with and without transaction costs. Of these two strategies, the carry trade strategy generates somewhat higher Sharpe ratios than the regression-based strategy. The portfolios of

currencies produce clearly higher Sharpe ratios with carry trade strategy. They also highlight the fact that rolling Sharpe ratios for the optimally-weighted carry trade strategy are consistently positive between the 1979 and 2005 period with an exception of short period just before 1995, after which the Sharpe ratio peaks to its highest level around 1997.

To find an explanation behind these Sharpe ratios the authors first study and close out the possibility of non-normality of payoff distributions to account for the high Sharpe ratios. Next they analyze the possible correlation between the payoffs and a variety of risk factors. These include inter alia U.S. and UK per-capita consumption growth, the returns to the S&P 500 and the FTSE 100, and the slope of the U.S yield curve. The possible effects of these variables to speculation profits are examined using both a time-series risk-factor analysis as well as a panel risk-factor analysis. However, neither analysis provides supporting evidence that speculation profits are due to abovementioned risk variables. Further, motivated by existing literature, Burnside et al. investigate the possibility that monetary policy variables could generate time-varying risk premiums. Real excess returns to the currency speculation strategies are regressed on the Fed Funds rate, the rate of inflation, and the growth rates of four different measures of money (M1, M2, M3, and MZM). They find positive and statistically significant relationship between the returns and inflation as well as Fed Funds rate. Yet, none of the monetary variables enter the regression significantly.

Finally, they turn to microstructure approach to find an explanation behind the returns to currency speculation strategies. To my knowledge, this is the first paper investigating foreign exchange speculation strategies and applying microstructural methods. Their argument is that, while the average Sharpe ratio of the currency speculation strategies is positive, the marginal Sharpe ratio is zero. As I discussed above, the microstructure approach to foreign exchange takes into account the special features of that market. Due to bilateral trade, asymmetric information problems arise between customers and dealers and between dealers themselves. According to microstructure literature asymmetric information generates price pressure, which means that the transaction price depends on the transaction quantity.

As Burnside et al. emphasize a major limitation to price pressure study is the difficulty to obtain data on FX trading volume. They use estimates by Evans and Lyons (2002) and Berger et al. (2006) to study the implications of price pressure for the average and marginal profits to currency speculation strategies. The results by Burnside et al. imply that the presence of price pressure drives the marginal Sharpe ratio to zero and thus limits the transaction amount speculators would place on the strategies.

Finally, before moving forward I present a paper, which discusses a possible source of alpha from active currency investment strategies. Huttman and Harris (2006) argue that active currency management as an asset class has come to be regarded in a similar manner to its counterparts in equity and bond management. As the authors note, currency volatility plays an important role in the overall variability of international portfolios. They present evidence that about 20 % of the volatility in international equity portfolio is attributable to currency risk. What comes to bond portfolios, the FX risk often exceeds the interest rate risk.

International investors have thus two options to manage the currency risk. They can simply negate the risk completely by hedging it out, or alternatively, they can seek to manage the currency exposure actively. If choosing the latter option, there are typically two objectives. The first is to protect the value of foreign assets in periods of expected base currency appreciation. The second is to add value by optimizing other opportunities that exist in currency markets, which is done by seeking diversified exposures within the universe of currencies.

Returns to active currency investments stem broadly from three distinct types of trades that currency managers transact. First, in directional trades currency managers buy and sell currency pairs based on expectation on market direction. Second type is yield-enhancing trades, which are comparable with spread trading in the bond market. Managers look for a yield pick-up by selling a low-yielding currency and simultaneously buying a relatively high-yielding currency. Third, managers can engage in two-types of non-directional trades. These include trading the volatility using a option strategy, and

arbitraging the OTC cash currency market and the exchange-traded currency futures markets.

How the currency investment programs have performed? Historically, absolute return currency funds have offered an annual net return between 8 % and 12 % on average, with about 8 % to 10 % annualized risk. Furthermore, the managed currency returns show virtually no correlation with traditional asset classes and therefore provide a strong diversification benefit when added to traditional portfolios.

This chapter has offered the reader a ground for the theoretical understanding of evolution and current state of the exchange rate economics and research. Based on this knowledge we can now move towards the empirical part of the study. Before the hands-on part the research hypotheses of this paper are presented in the next chapter.

4. Hypotheses

This chapter presents the hypotheses examined in the study. Previous chapter laid the theoretical foundations for the two hypotheses to be analyzed, and additional motivation is provided below. Based on the extensive evidence from earlier literature, the first hypothesis concentrates on profit opportunities from violations of UIP. According to the two parity conditions yield spread (forward spread equivalently) should equal the expected change in the spot exchange rate.

H1: *Violations of UIP are pervasive and widespread offering therefore a source of anomaly profit opportunities for single trading strategies based on interest rate differentials.*

The first hypothesis is tested using a simple trading model to engage in carry trades. The analysis is conducted both on currency pair and currency portfolio level. Rejection of the null hypothesis implies that violations of UIP are only transitory.

The second hypothesis scrutinizes the presumed returns. It assumes that the returns are also attractive after taking the risk into account. Furthermore, the hypothetical returns are benchmarked to other asset classes.

H2: *Returns to carry trade strategies are attractive also risk-adjusted basis and against other asset classes. Additionally, currency investment strategy offers a way for diversification.*

Statistical significance of absolute returns is measured and reported. In order to find out, whether the risk-adjusted returns are attractive, Sharpe ratios for each strategy are calculated. The correlation of returns with alternative investments is also calculated.

5. Data and methods

This chapter presents both the raw data and the methods used in this study. Empirically the study concentrates on profitability of leveraged currency investments. The first section presents the data in detail including summary statistics for the base data set. Issues such as data collection and coverage will be discussed and rationalized also in the first part of the chapter. In the second part the construction of a simple trading model, which is used in the study to scrutinize the possible profit opportunities arising from violation of UIP, is under review.

5.1. Data set and notations

The empirical part in this study utilizes two separate data sets: spot foreign exchange rates and interbank interest rates collected from the Datastream database at both monthly and quarterly intervals. The analysis is centered on the following developed countries: Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States. In addition, the common currency euro is included to data set. The full sample period spans 14 years, from January 1993 through December 2006, except for Germany where the data end in December 1998 due to introduction of euro. Thus the euro data spans from January 1st 1999 to the end of 2006. These countries were selected on the basis of data quality; they comprise the world's most heavily-traded free-floating currencies[5], and carry trades could be easily implemented in these exchange rates without any impeding institutional constraints, such as capital controls. Moreover, although the collapse of Bretton Woods system in the beginning of the 1970s started the era of free-floating exchange rates, some currencies were not allowed to float freely until mid 1980s, Australian and New Zealand dollars, for instance.

[5] See BIS (2005) for decomposition of total FX market volume by currency basis.

Additional and the more important reason for this particular time span to be selected is that in the beginning of the 1990's electronic brokerage services, such as EBS and Reuters Dealing, were launched and the number of traditional voice-based brokerage services started to diminish rapidly. To date, electronic brokers have in practice absorbed the total market volume. During the last years several electronic trading platforms have become available to retail investors as well. This so called virtual centralization has caused altogether the convergence of bid-ask spreads, smaller transaction costs and thus more effective pricing in the market. Taking into account this revolutionary change I decide to focus on this "electronic trading era", and consider earlier data inappropriate.

5.1.1. Exchange rate data

Table 1 presents the international ISO codes for every currency used in this study. These abbreviations will be used throughout the next from now on, and thus it will be easier for the reader to be familiar with them.

Table 1: Currency ISO codes

ISO code	Country
AUD	Australian dollar
CAD	Canadian dollar
CHF	Swiss franc
DEM	German mark
EUR	euro
GBP	British pound
JPY	Japanese yen
NOK	Norwegian krona
NZD	New Zealand dollar
SEK	Swedish krona
USD	U.S. dollar

This study contributes to existing literature by adopting a more comprehensive approach analyzing a larger number of exchange rates. Unlike the majority of earlier studies which tend to focus exclusively on U.S dollar exchange rates, often only a few one, this paper utilizes the whole range of possible cross exchange rates given the data set. Eventually, as opposed to most of the earlier research, it is possible to include data extensive enough for the euro as well. All in all, it is possible to generate 45 different cross exchange rates from the base data set. Table 2 reveals summary statistics of returns of all 11 currencies, each of them used as a base currency. The base currency is highlighted at the leftmost column and the results are presented from the base currency perspective. In this study all returns are calculated as logarithmic returns unless otherwise mentioned.

Table 2 reports the average of monthly returns in percentages, standard deviations of returns, p-values for statistical significance, as well as skewness and kurtosis of return distributions for each base currency. Overall, it can be noted that monthly returns are small from both economical and statistical point of view. Due to small returns and high standard deviations of returns none of the returns is statistically significantly different from zero at any meaningful significance levels. Despite of that, interesting findings can be made based on the summary information. For example, NZD is the only currency, which has appreciated against every other currency on average. On the other hand, USD has depreciated against every currency, except DEM. GBP posts positive returns against every other currency but NZD. The second worse performer is SEK, which has lost against eight currencies, appreciating only against EUR and USD. Although EUR has not performed particularly well, it posts the highest average return of the whole sample, namely against JPY.

Table 2: Monthly cross exchange rate returns statistics

Table 2 presents monthly return statistics for all 45 cross exchange rates used in the study. Returns are calculated in respect of a currency in the *Base currency* column. *Mean* stands for the average monthly return, *St.Dev* is the standard deviation of the returns, *p-value* is a measure of statistical significance, *Skew* and *Kurt* stand for skewness and kurtosis, respectively, and are distributional measures.

	AUD	CAD	CHF	DEM	EUR	GBP	JPY	NOK	NZD	SEK	USD
Base currency											
AUD											
Mean	N/A	0.026	-0.036	-0.078	0.115	-0.055	0.042	0.013	-0.091	0.055	0.093
St. Dev	N/A	2.434	3.802	4.112	3.069	3.068	3.891	3.495	2.002	3.171	2.888
p-value	N/A	0.891	0.904	0.873	0.715	0.817	0.890	0.961	0.558	0.824	0.679
Skew	N/A	-0.202	-0.374	-0.200	-0.324	-0.181	-0.232	0.117	0.144	0.020	0.003
Kurt	N/A	-0.215	0.024	-0.170	0.248	0.350	0.444	-0.093	-0.201	-0.408	-0.509
CAD											
Mean	-0.026	N/A	-0.062	-0.212	0.170	-0.081	0.016	-0.012	-0.117	0.029	0.067
St. Dev	2.434	N/A	3.410	3.337	3.036	2.591	3.650	3.006	2.859	2.972	1.778
p-value	0.891	N/A	0.816	0.594	0.587	0.687	0.956	0.957	0.598	0.901	0.628
Skew	0.202	N/A	-0.328	-0.164	-0.311	-0.037	-0.305	-0.179	0.162	-0.085	0.165
Kurt	-0.215	N/A	-0.338	0.222	-0.292	0.192	0.034	-0.340	-0.284	-0.114	0.621
CHF											
Mean	0.036	0.062	N/A	0.150	0.016	-0.019	0.077	0.049	-0.055	0.090	0.128
St. Dev	3.802	3.410	N/A	1.188	0.938	2.321	3.476	1.821	3.526	2.226	3.084
p-value	0.904	0.816	N/A	0.291	0.870	0.915	0.774	0.728	0.840	0.601	0.592
Skew	0.374	0.328	N/A	0.416	0.175	0.255	-0.310	0.342	0.344	0.633	0.318
Kurt	0.024	-0.338	N/A	0.077	-0.363	0.984	1.738	0.373	0.083	1.239	-0.669
DEM											
Mean	0.078	0.212	-0.150	N/A	N/A	-0.151	-0.115	0.049	-0.084	0.113	-0.044
St. Dev	4.112	3.337	1.188	N/A	N/A	2.352	3.937	1.395	3.421	2.530	2.755
p-value	0.806	0.413	0.105	N/A	N/A	0.409	0.707	0.648	0.753	0.563	0.838
Skew	0.200	0.164	-0.416	N/A	N/A	0.513	-0.835	-0.264	0.156	0.345	0.194
Kurt	-0.170	0.222	0.077	N/A	N/A	0.346	1.801	3.118	0.257	0.296	-0.083
EUR											
Mean	-0.115	-0.170	-0.016	N/A	N/A	-0.053	0.220	-0.244	-0.049	0.088	0.131
St. Dev	3.069	3.036	0.938	N/A	N/A	1.956	2.754	3.054	3.520	3.079	3.056
p-value	0.628	0.471	0.828	N/A	N/A	0.724	0.304	0.302	0.858	0.712	0.580
Skew	0.324	0.311	-0.175	N/A	N/A	0.471	0.183	-0.220	0.095	-0.598	0.149
Kurt	0.248	-0.292	-0.363	N/A	N/A	0.354	0.967	0.389	0.567	1.482	-0.340
GBP											
Mean	0.055	0.081	0.019	0.151	0.053	N/A	0.097	0.068	-0.036	0.110	0.148
St. Dev	3.068	2.591	2.321	2.352	1.956	N/A	3.509	2.281	2.953	2.455	2.207
p-value	0.817	0.687	0.915	0.591	0.790	N/A	0.722	0.699	0.875	0.565	0.389
Skew	0.181	0.037	-0.255	-0.513	-0.471	N/A	-0.604	-0.080	-0.074	-0.109	0.145
Kurt	0.350	0.192	0.984	0.346	0.354	N/A	1.860	0.596	1.079	-0.425	-0.022
JPY											
Mean	-0.042	-0.016	-0.077	0.115	-0.220	-0.097	N/A	-0.028	-0.133	0.013	0.051
St. Dev	3.891	3.650	3.476	3.937	2.754	3.509	N/A	3.627	3.711	3.733	3.426
p-value	0.890	0.956	0.774	0.807	0.304	0.722	N/A	0.920	0.645	0.964	0.848
Skew	0.232	0.305	0.310	0.835	0.183	0.604	N/A	0.422	0.182	0.236	0.539
Kurt	0.444	0.034	1.738	1.801	0.967	1.860	N/A	0.560	0.552	0.447	0.967
NOK											
Mean	-0.013	0.012	-0.049	-0.049	0.078	-0.068	0.028	N/A	-0.104	0.041	0.079
St. Dev	3.495	3.006	1.821	1.395	1.672	2.281	3.627	N/A	3.351	1.997	2.810
p-value	0.961	0.957	0.728	0.767	0.649	0.699	0.920	N/A	0.688	0.790	0.716
Skew	-0.117	0.179	-0.342	0.264	-0.769	0.080	-0.422	N/A	-0.008	0.146	0.062
Kurt	-0.093	-0.340	0.373	3.118	0.224	0.596	0.560	N/A	0.417	-0.187	-0.214
NZD											
Mean	0.091	0.117	0.055	0.084	0.127	0.036	0.133	0.104	N/A	0.146	0.184
St. Dev	2.002	2.859	3.526	3.421	3.204	2.953	3.711	3.351	N/A	3.081	3.059
p-value	0.558	0.598	0.840	0.838	0.699	0.875	0.645	0.688	N/A	0.543	0.439
Skew	-0.144	-0.162	-0.344	-0.156	-0.714	0.074	-0.182	0.008	N/A	-0.208	-0.203
Kurt	-0.201	-0.284	0.083	0.257	1.186	1.079	0.552	0.417	N/A	0.667	-0.050
SEK											
Mean	-0.055	-0.029	-0.090	-0.113	0.039	-0.110	-0.013	-0.041	-0.146	N/A	0.038
St. Dev	3.171	2.972	2.226	2.530	1.470	2.455	3.733	1.997	3.081	N/A	2.947
p-value	0.824	0.901	0.601	0.707	0.795	0.565	0.964	0.790	0.543	N/A	0.868
Skew	-0.020	0.085	-0.633	-0.345	0.113	0.109	-0.236	-0.146	0.208	N/A	0.008
Kurt	-0.408	-0.114	1.239	0.296	1.924	-0.425	0.447	-0.187	0.667	N/A	-0.698
USD											
Mean	-0.093	-0.067	-0.128	0.044	-0.131	-0.148	-0.051	-0.079	-0.184	-0.038	N/A
St. Dev	2.888	1.778	3.084	2.755	3.056	2.207	3.426	2.810	3.059	2.947	N/A
p-value	0.679	0.628	0.592	0.894	0.677	0.389	0.848	0.716	0.439	0.868	N/A
Skew	-0.003	-0.165	-0.318	-0.194	-0.149	-0.145	-0.539	-0.062	0.203	-0.008	N/A
Kurt	-0.509	0.621	-0.669	-0.083	-0.340	-0.022	0.967	-0.214	-0.050	-0.698	N/A

5.1.2. Interest rate data

The empirical part utilizes both one-month and three-month interbank interest rates but in this section the summary statistics will be presented only for one-month interest rate data. The statistics are divided into pre-euro and post-euro periods and reported in Table 3. The figures indicate several interesting features of interest rate behavior over the sample period. First, it can be observed that the average one-month interest rate is lower in every currency during the latter half of the sample period. Also the standard deviation is largely lower over the post-euro era. The exceptions are GBP, NOK and USD. Second, ranking of the countries based on their interest rate level has somewhat changed. This is an extremely important indicator in this study as will become clear in the next section where the trading model is presented. NZD is the highest-yielding currency on average over the whole sample. Other currencies among top-five during both pre- and post-euro are AUD, GBP and NOK. SEK, which is the second highest-yielding currency before the euro, ranks only seventh after adoption of the common currency. Notable fact is also that the three lowest-yielding currencies are the same over the both subperiods, namely DEM/EUR, CHF and JPY. A striking result as such is the interest rate trend in Japan. Already in the pre-euro era, one-month JPY interest rate drops below 1 %, and in the post-euro era even the maximum observation is below that level. The post-euro average is only 0.125, the lowest monthly rate being virtually zero.

Table 3: One-month interbank interest rate statistics

Table 3 presents summary statistics for one-month interest data used in the study. The figures are in percentage points.

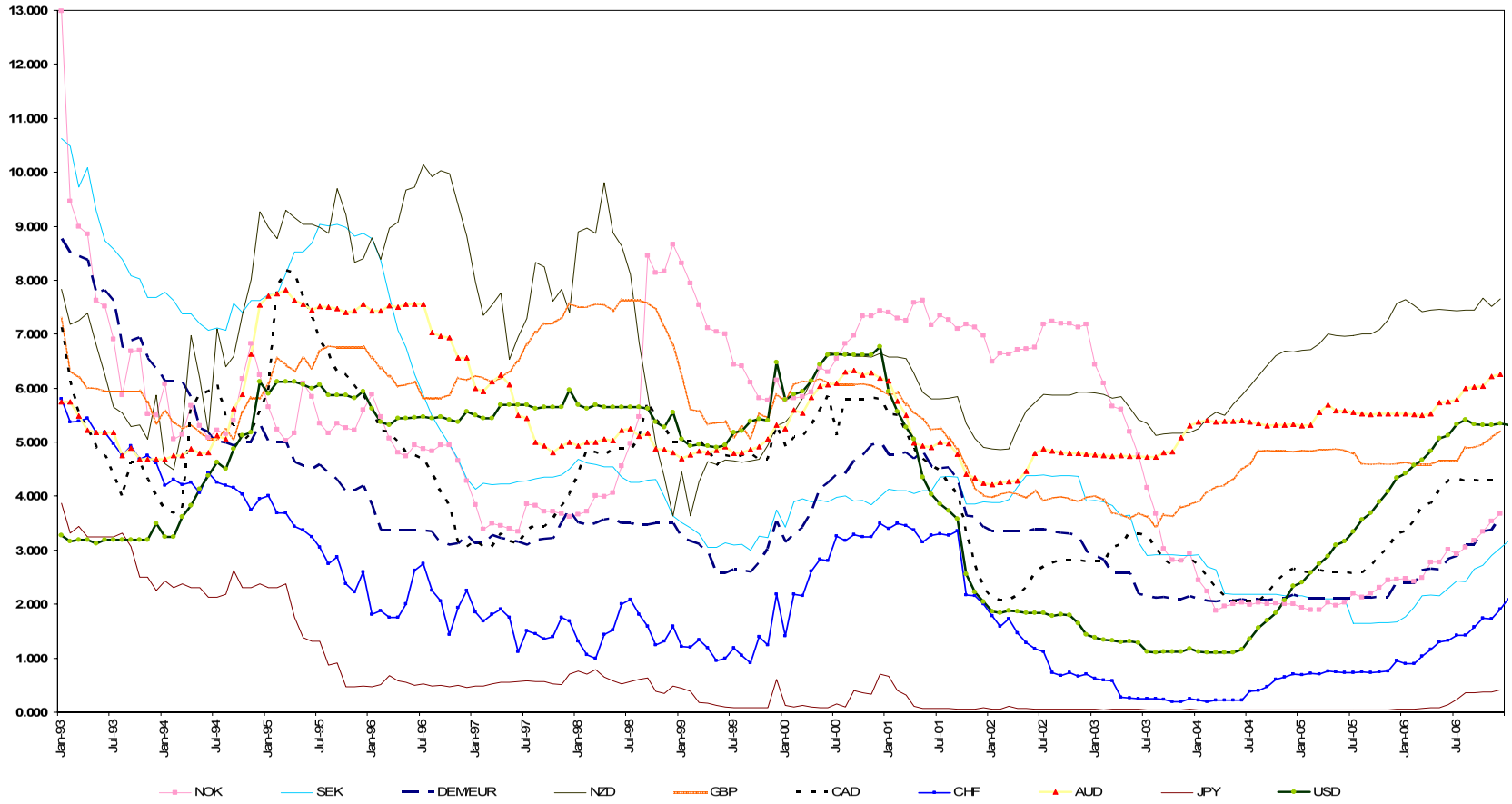
Currency	AUD	CAD	CHF	DEM/EUR	GBP	JPY	NOK	NZD	SEK	USD
Pre-euro										
Max	7.813	8.180	5.797	8.773	7.625	3.875	12.980	10.140	10.630	6.125
Min	4.688	3.063	1.000	3.094	5.063	0.345	3.350	3.640	3.627	3.125
Mean	5.969	4.974	2.916	4.601	6.371	1.402	5.494	7.669	6.644	5.047
St.Dev	1.135	1.272	1.395	1.597	0.736	1.058	1.717	1.630	2.014	1.023
Post-euro										
Max	6.323	5.863	3.492	5.000	6.250	0.706	8.320	7.670	4.400	6.769
Min	4.212	2.060	0.197	2.045	3.443	0.038	1.880	3.640	1.642	1.099
Mean	5.248	3.652	1.380	3.031	4.798	0.125	4.891	6.038	3.165	3.562
St.Dev	0.546	1.195	1.033	0.895	0.775	0.145	2.216	0.946	0.874	1.908

Behavior of the interest rates over the full sample period can be seen in Figure 3. It further strengthens the observations based on the information in Table 3. The overall interest rate level has been the highest in the beginning of 1993. It can be seen how the interest rate in New Zealand starts to rise in 1994, while the declining trend in Canadian, Japanese, and Swiss rates is almost uninterrupted. The pre-euro era is characterized by large swings in interest rates in several countries, whereas during the post-euro era rate behavior is less volatile, and the rates move more in conjunction with each other.

The base data set are now reviewed and I will turn next to describing the trading experiment, which is the foundation of my study. The last page of this chapter discusses also the statistical measures used in evaluation of the results from the trading model.

Figure 3: One-month interest rates in data set countries 1993-2006

Figure 3 shows the development of one-month interbank interest rates in analyzed countries. German mark and euro interest rate curves are combined into one single curve. Countries are listed below the graph in descending order according to the first interest rate observation.



5.2. Trading strategies

The empirical foundation of the study in hand is presented in this section. Empirical findings discussed in Chapter 2 highlight that violations of unbiasedness hypothesis are pervasive, and market participants have massively exploited trading strategies targeted on anomalous behaviour of exchange rates. The purpose of the study is to examine possible abnormal returns, which are not compensation for risk, constructing a simple trading experiment replicating the most common methods used by practitioners.

Before describing the trading model, two caveats relating to the issue of data snooping are appropriate at this point. First, only very basic approach to trading the violations of uncovered interest parity is utilized in this study, as the application of simple trading rules mitigates the potential impact of data snooping biases induced by searching the entire space of trading rules for the best performing strategies (LeBaron, 1999). Furthermore, the selection of trading strategy is motivated by the fact that it tries to mimic the performance of several market participants. Second, as mentioned already, particular attention is paid to quality of data as well as performance of this trading strategy over the whole sample period. This is also in effort to reduce the potential for biases from reporting only the most favourable results in certain subperiods. The reader should bear in mind that the aim of this study is merely to assess whether violations of UIP detected earlier have been sufficient to generate attractive returns for a simple trading approach. No attempt was made to optimize the trading results.

5.2.1. Single-currency carry trades

Set against this backdrop, the trading procedure is as follows. Industrialized countries are ranked from highest to lowest on the basis of their one-month (three-month) interbank interest rates, and these rankings are adjusted monthly (quarterly). At the beginning of the month (quarter), funds are borrowed from the country with the lowest interbank interest rate. This borrowing is then converted into the currency of the country with the highest interest rate, and invested at the prevailing interest rate for one month (quarter). This is repeated for the countries with the second, third, fourth and fifth largest interest rate

differentials respectively (for example a long position in the second highest yielding currency is funded with a short position in the second lowest yielding currency, and so on). In effect, borrowing is undertaken in relatively low yielding currencies to fund investing in relatively high yielding currencies. Two fundamental assumptions have been made when constructing the trading model. First, it is assumed that "limited exposure" mandates would preclude a trader to take every leveraged position in just one currency. Hence, it would not be possible to fund a large long position only in the highest yielding currency with smaller short positions in the lowest, second lowest, third lowest, fourth lowest and fifth lowest yielding currencies. The same mandate would prevent a large short position in the lowest yielding currency funding long positions in all five highest yielding currencies. Second, it is assumed that there are no stop-loss triggers used by traders. This implies that the positions taken for the prespecified investment period will be held until maturity regardless of the losses these positions have generated. Of course, rationality of the second assumption in real world can be questioned but since this paper is only interested in profitability of these strategies and not the optimal strategy per se, the second assumption is justified. It also makes the trading model much simpler to construct.

The success of this trading strategy is dependent on consistent violations of UIP. The total return consists of two components: the interest rate differential, which is guaranteed to be positive at the beginning of the investment period (a month or a quarter in this case), and the uncovered foreign exchange position, which is risky and not realized until the end of the holding period. As long as the interest rate returns from funding relatively high yielding investments with relatively low cost borrowing are not erased by a depreciation the size of the interest rate differential (or equivalently forward spread) of the high yielding currency, carry trade will offer positive returns. The strategy will be particularly attractive in situations where the high yielding currency appreciates as interest gains will be enhanced with positive returns on the uncovered foreign exchange position.

Although transaction costs in foreign exchange market are small compared for instance to stock market, they are incorporated into the analysis to improve the quality and comparability of results. A roundtrip cost of 0.1 percent is incurred for each trade[6]. This consists of 0.05 percent cost when borrowed funds are converted into the high yielding currency at the beginning of the investment period, and 0.05 percent when the positions are closed and currency rankings adjusted. Additional cost of 0.05 percent is incurred at the end of each holding period, because profits are assumed to be repatriated to the US. When carry trade results in a loss, the shortfall is met by converting additional U.S dollars into the borrowed currency. This incurs also a cost of 0.05 percent. The only exceptions occur when a position is taken in the U.S dollar as one leg of the currency transaction is avoided, or when currency ranking remains the same at the end of holding period and borrowing and lending positions are simply rolled over for another period.

5.2.2. Currency portfolio carry trades

The next phase of the analysis is to construct currency portfolios from currency pairs according to the same selection process as was described above. Altogether four portfolios are formed, in which the first one consists of long position in the highest and second highest yielding currencies funded with short position in the lowest and second lowest yielding currencies. The second portfolio is obtained from the first one after adding a short position in the third lowest yielding currency used to fund a long position in the third highest yielding currency. The positions in the fourth highest and lowest yielding currencies are added to the second portfolio to obtain the third one. The fourth portfolio includes all currency pairs and therefore short positions in the five lowest yielding currencies are used to fund investments in the five highest yielding currencies.

The currency portfolio analysis is conducted, firstly, in order to detect possible gains from diversification. Secondly, since the portfolios are combinations of single-currency carry strategies, it can be reasonably assumed that currency portfolios incur lower transaction costs. To see the intuition behind this assumption, a short example is offered.

[6] Transaction cost of this magnitude is considered a conservative upper bound for large traders encountering in foreign exchange markets, and is often employed in foreign exchange trading experiments (see Bilson and Hsieh (1987), and LeBaron (1999), among others).

When the currencies are ranked according to the periodically interest rates, it might be the case that the ranking of currency pairs changes whereas the currency pair itself remains the same. For instance, when the highest yielding – lowest yielding currencies become the second highest yielding – second lowest yielding and vice versa, the ranking of currency pairs has changed without changing the mutual order between two currencies. This leads to readjusting the positions in both, the first and the second single currency carry trade strategy (the highest – the lowest and the second highest – the second lowest). However, there will be no need to adjust the position in the first carry portfolio strategy, which combines the two single strategies.

The return characteristics of the abovementioned strategies are analyzed in the next chapter. The statistical significance of the returns is measured using a standard t-test. The test statistic is calculated according to Equation 4.

$$t = \frac{\overline{X} - \mu}{S / \sqrt{n}} \sim t(n\text{-}1) \tag{4}$$

where $\overline{X}$ is the sample mean, μ is the population mean, S is the sample standard deviation, and n is the sample size. The test statistic follows a t-distribution having $n\text{-}1$ degrees of freedom.

The Sharpe ratio, commonly used in the academic research as well as by practitioners, is the measure for risk-adjusted returns and defined in Equation 5.

$$Sharpe\ ratio = \frac{E(r_i) - r_f}{\sigma_i} = \frac{Excess\ return}{\sigma_i} \tag{5}$$

where $E(r_i)$ is the expected return of i, r_f is the risk-free rate, and σ_i is the standard deviation of i. Sharpe ratio was first presented in Sharpe (1966). See also Sharpe (1994) for a discussion of potential wider use of the measure.

6. Analysis and results

This chapter presents and analyzes the empirical results of the study. The chapter consists of two parts reporting the results. The first one concentrates on profitability of single-currency carry trades analyzing individual cross currency rates more like a stand-alone instrument or investment strategy. The second part focuses on profitability of currency portfolio strategies and views the results also from an alternative asset class viewpoint. Finally, a separate section at the end of this chapter is devoted to summarize the most important empirical findings of this study. Both monthly and quarterly interest rate and exchange rate data are examined in this study, but since the differences in results between one-month and three-month investment periods are relatively small, I present only one-month results in this chapter. For a full comparison, both the three-month single-currency carry trade and carry portfolio results are reported in Appendixes1 and 2, respectively**.**

6.1. Single-currency carry trades

The figures in Table 4 highlight the characteristics of annualized monthly returns from single-currency trading strategies. The strategies consist of long positions in relatively high-yielding currencies funded with short positions in relatively low-yielding currencies. The numbers in column headings indicate the relative position of each currency, i.e. 1H is the highest, 1L the lowest etc. Total carry trade return consist of two components, exchange rate return and interest rate return, and is decomposed into these two to highlight the performance of both components. The sample period is analyzed also over two subperiods: before the euro and after adoption of the common currency. All results are reported in Table 2 for transparent comparison, but since there are major differences in findings between these two periods, a detailed analysis below is divided into two separate sections.

The results are quite interesting although mixed. Total returns of the one-month single-currency carry trades are positive and statistically significant at the 5 % level in four out of the five positions over the full sample, and three of these are statistically significant at the 1 % level. Over the 14 year sample period statistically significant average total returns

from carry trade strategies vary between 1.80 % and 8.77 %. The only strategy which yields negative return, though both statistically and economically insignificant, is 4H4L. Positive total returns indicate that exchange rate changes only partly offset the positive interest rate returns. Average interest differentials, a non-random component of total return, range from 0.42 % to 6.85 %. Foreign exchange returns are statistically significant at least at the 10 % level also in four cases and vary in the range of -1.39 % and 6.21 %.

Table 4: Single-currency carry trade profitability

Table 4 presents the results of the one-month single-currency carry trade strategies over the full sample as well as during two subperiods. *Mean* is the average annualized monthly return. Figures denoted with ***, ** and * are statistically significantly different from zero at the 1, 5 and 10 percent levels respectively. *St. Dev* is the annualized standard deviation of monthly returns. *Skew* and *Kurt* stand for skewness and kurtosis, respectively, and exhibit characteristics of distribution of the returns. *Sharpe* is the annual Sharpe ratio. Columns refer to particular carry trade strategies where long position in relatively high-yielding currency is financed with short position in relatively low-yielding one. *FX* and *Int* refer to exchange rate and interest rate return components, respectively. *Total* is the total return from particular positions.

Carry trade strategy	1H1L FX	1H1L Int	1H1L Total	2H2L FX	2H2L Int	2H2L Total	3H3L FX	3H3L Int	3H3L Total	4H4L FX	4H4L Int	4H4L Total	5H5L FX	5H5L Int	5H5L Total
Pre Euro															
Mean	-0.34	7.18	6,84 ***	-2.43 *	4.85	2,42 *	2.41 *	2.50	4,91 ***	-2.31 **	1.37	-0.94	0.35	0.40	0.75
St. Dev	12.88	0.41	12.95	11.09	0.37	11.10	10.85	0.21	10.87	9.20	0.17	9.21	8.80	0.08	8.81
Skew	-0.605	-0.148	-0.599	-0.476	-0.633	-0.468	-0.491	-0.259	-0.482	0.683	0.445	0.673	-0.133	0.457	-0.132
Kurt	1.121	-1.048	1.063	-0.199	-0.417	-0.219	0.363	0.056	0.357	2.223	-0.099	2.191	1.363	-0.291	1.368
Sharpe			0.53			0.22			0.45			-0.10			0.08
Post Euro															
Mean	3.49 ***	6.59	10,08 ***	0.84	4.27	5,11 ***	9.04 ***	2.63	11,67 ***	-0.69	1.33	0.64	2.14 **	0.44	2,58 ***
St. Dev	11.27	0.20	11.29	10.88	0.22	10.90	8.40	0.15	8.38	9.01	0.16	9.02	9.40	0.11	9.39
Skew	-0.359	-0.626	-0.356	-0.610	-0.756	-0.620	-0.288	-0.851	-0.278	-0.153	-0.563	-0.151	-0.217	0.837	-0.222
Kurt	1.354	-0.610	1.364	0.543	-0.480	0.550	-0.155	0.562	-0.136	0.016	-0.881	-0.004	0.063	-0.138	0.066
Sharpe			0.89			0.47			1.39			0.07			0.27
Full sample															
Mean	1.85 **	6.85	8,70 ***	-0.56	4.52	3,96 ***	6.21 ***	2.57	8,77 ***	-1.39 **	1.35	-0.04	1.38 *	0.42	1,80 **
St. Dev	11.96	0.32	12.00	10.95	0.31	10.96	9.54	0.18	9.55	9.07	0.16	9.08	9.12	0.09	9.12
Skew	-0.503	0.277	-0.498	-0.547	-0.255	-0.549	-0.489	-0.562	-0.483	0.212	-0.114	0.209	-0.178	0.823	-0.181
Kurt	1.256	-0.124	1.227	0.164	-0.237	0.160	0.456	0.453	0.465	0.884	-0.490	0.861	0.488	0.181	0.493
Sharpe			0.72			0.36			0.92			0.00			0.20

According to the hypothesis of the study, three strategies (1H1L, 3H3L and 5H5L) achieve additional returns over the interest rate differential from favorable currency movements. These exchange rate returns amount to 1.85 %, 6.21% and 1.38 %, respectively. Couple of interesting findings should also be addressed. First, currency returns from 1H1L and 5H5L are quite similar in magnitude although according to the trading strategy set-up the interest rate differential is much higher in the first strategy. Second, total returns from 3H3L and 5H5L strategies are mostly attributable to currency

returns, which add up to 71 % and 77 % of total return, respectively. Third, whereas the four other strategies support the hypothesis of the study, 4H4L strategy actually shows strong evidence in favor of UIP. Fourth, while 1H1L and 3H3L strategies provide almost identical total return, the component returns are totally opposite.

When evaluating attractiveness of returns from an investment strategy it is crucial to incorporate a measure of risk into the analysis. I follow the established practice among both academics as well as practitioners measuring risk-adjusted returns by Sharpe ratio. These are documented in Table 4 as well. Full sample average Sharpe ratio of 0.44 is somewhat lower to that of historical buy-and-hold equity strategy, and in line with findings by Lyons (2001) for U.S. dollar denominated carry trades and Burnside et al. (2006) for pound sterling carry trade strategies. However, as is observable in Table 4 there are extreme variations in Sharpe ratios between strategies. As UIP seems to hold with 4H4L strategy, its Sharpe ratio is naturally zero. Sharpe ratios of 2H2L and 5H5L strategies are also quite small, whereas 1H1L and 3H3L show totally opposite figures, 0.72 and 0.92, respectively. A much lower currency returns volatility in 3H3L strategy contributes to the higher ratio. These both exceed clearly the abovementioned examples from earlier studies, as well as the Sharpe ratio of 0.60 find by Baz et al. (2001) over one-month holding period, even though they use optimized currency portfolio. To conclude, these are extremely attractive Sharpe ratios from strategies which should yield zero return on average.

6.1.1. Performance during pre-euro period

Interest rate differentials range from 0.4 % to 7.2 % during pre-euro era. Although the average foreign exchange returns from 1H1L, 2H2L and 4H4L strategies are negative at the same time (-0.34, -2.34 % and -2.31 %, respectively) , the two most high-yielding currencies have not depreciated enough to offset the interest rate return showing evidence for violation of UIP, and supporting the hypothesis of the study. For further evidence, 3H3L and 5H5L strategies yield positive FX returns (2.41 % and 0.35 %, respectively) similar in magnitude with their interest rate returns, thus almost doubling the total return.

On the other hand, 4H4L strategy posts negative total returns due to more than offsetting exchange rate return.

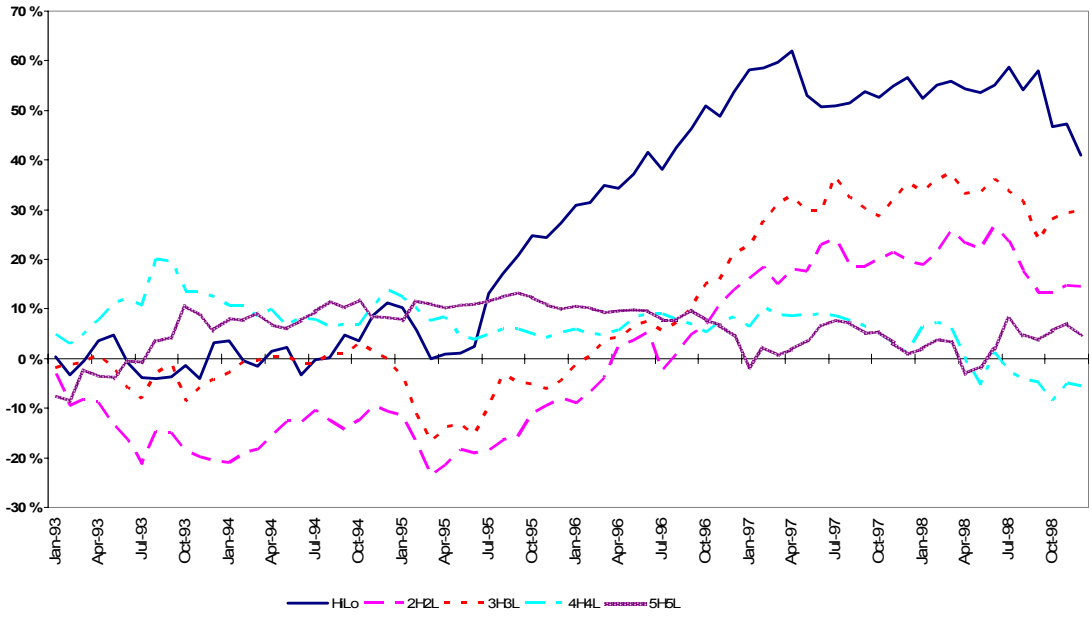
Although some evidence for violations of UIP might be observed over the first subperiod, a risk-adjusted performance of these strategies is poor. Average Sharpe ratio over pre-euro period is only 0.24. The 4H4L strategy even posts a negative Sharpe ratio, which can not be interpreted in reasonable manner. Sharpe ratios of 2H2L and 5H5L, which is virtually zero, are also unattractive. Due to the high exchange rate return volatility even the two best performers, 1H1L and 3H3L, offer Sharpe ratios similar to that of buy-and-hold equity strategy.

A more detailed performance analysis of each of the carry trade strategies could allow us to get a better picture of foundations of results presented above. Figure 4 presents cumulative returns for one-month single currency trading strategies. In the figure an upward sloping curve indicates a period when UIP is violated, a flat line a period when negative currency returns offset interest rate differential, and a downward sloping curve currency returns which more than offset the positive interest rate differential.

1H1L strategy consist of a long position in the highest yielding currency and a short position in the lowest yielding currency. In the beginning of sample period in 1993 this strategy was long in SEK, where interest rate was over 9 % on average during the first nine months, and short in USD, where interest rate level was just above 3 %. Since September 1993 this portfolio has been short in JPY, where interest rate decreased from 3.9 % in January 1993 to around 3 % in September 1993 and further to 0.9 % in August 1995 and remained below 1 % the whole pre-euro period. SEK was the highest yielding currency until November 1994, after which interest rate was sharply decreased in Sweden. Since then NZD was the highest yielding currency until August 1998, except for five single months. Despite of wide interest rate differential this strategy seems to provide zero return, and against the hypothesis, give support for UIP until mid 1995, after which a sharp upturn occurs and the returns skyrocket for two consecutive years. During this period the average interest rate in New Zealand was almost 9 % while in Japan only 0.6 % offering an average interest differential over 800 basis points per annum. During the

same time NZD appreciated against JPY about 35 %. This trend reversed in May 1997 when NZD started to depreciate against JPY. It is also evident from Figure 3 that interest rate dramatically decreased in New Zealand while rising in Norway during the last four months in pre-euro period, and 1H1L strategy thus being long in NOK and short in JPY yielded a massive 20 % loss.

Figure 4: Performance of one-month single-currency strategies 1993 - 1998
The figure presents the cumulative returns for each one-month single-currency carry trade strategy during the pre-euro period.



2H2L and 3H3L strategies post negative returns until 1996 although the interest rate differentials were on average 400 and 250 basis points, respectively. Especially for 2H2L negative exchange rate returns more than offset the interest rate differential. This strategy was first short in JPY, then in USD, and since July 1994 to the end of 1998 CHF. The long position was not as concentrated as in 1H1L strategy before April 1996, when first AUD and then GBP was the second highest yielding currency for a prolonged period. Thus, transaction costs from readjusting the positions almost monthly reduce the total return further. For 3H3L, CAD and DEM have been most often the funding currencies whereas AUD and USD the high-yielding currencies. There is no, however, similar

concentration as in 1H1L and thus transaction costs also diminish the returns from this strategy. What 2H2L and 3H3L have in common with 1H1L is the upturn after mid 1995, although it takes about a year before these two strategies provide positive cumulative returns.

4H4L and 5H5L show quite different pattern and it seems that UIP holds actually rather well. The positions change almost month-by-month especially before late 1996. Only in the very beginning of the sample period these two strategies, where interest differentials are the lowest, have gained additive returns from positive exchange rate changes.

6.1.2. Performance after adoption of the euro

Post-euro period exhibits much more striking results with positive total returns from every currency pair strategy. Furthermore, the total returns are statistically significantly different from zero at 1 % level in all but 4H4L strategy. Examining of the components of total return reveals that average interest rate differentials are basically in the same magnitude (from 0.44 % to 6.59 %) during the latter half of the sample period as they were before the euro. However, exchange rate returns supplement interest rate returns in all but one strategy (4H4L), which posts both statistically and economically insignificantly negative currency return (-0.69 %). FX return from 2H2L strategy is also insignificant, though positive (0.84 %). Positive and significant currency returns vary between approximately 2 % and 9 %, indicating that the violations of UIP are pervasive particularly in the post-euro era. For 3H3L and 5H5L strategies this is especially true, since approximately 77 % and 83 %, respectively, of their total return is attributable to appreciation of higher-yielding currency.

This totally reversed behavior of exchange rates is directly reflected into risk-adjusted performance of the carry trade strategies. The average Sharpe ratio during the latter half of the sample period is 0.62 (vs. 0.24 pre-euro). Although Sharpe ratio is still negligible from 4H4L strategy (0.07), relatively small from 5H5L strategy (0.27), and at the same magnitude with passive equity strategy from 2H2L carry trade (0.47), 1H1L and 3H3L strategies post impressive figures (0.89 and 1.39, respectively) resulting also high full

sample Sharpe ratios, as was mentioned. In addition to positive returns, the volatility of exchange rate changes has diminished in all strategies, except 5H5L, thus contributing to these positive risk-adjusted results.

Figure 5: Performance of one-month single-currency strategies 1999 - 2006
The figure presents the cumulative returns for each one-month single-currency carry trade strategy during the post-euro period.

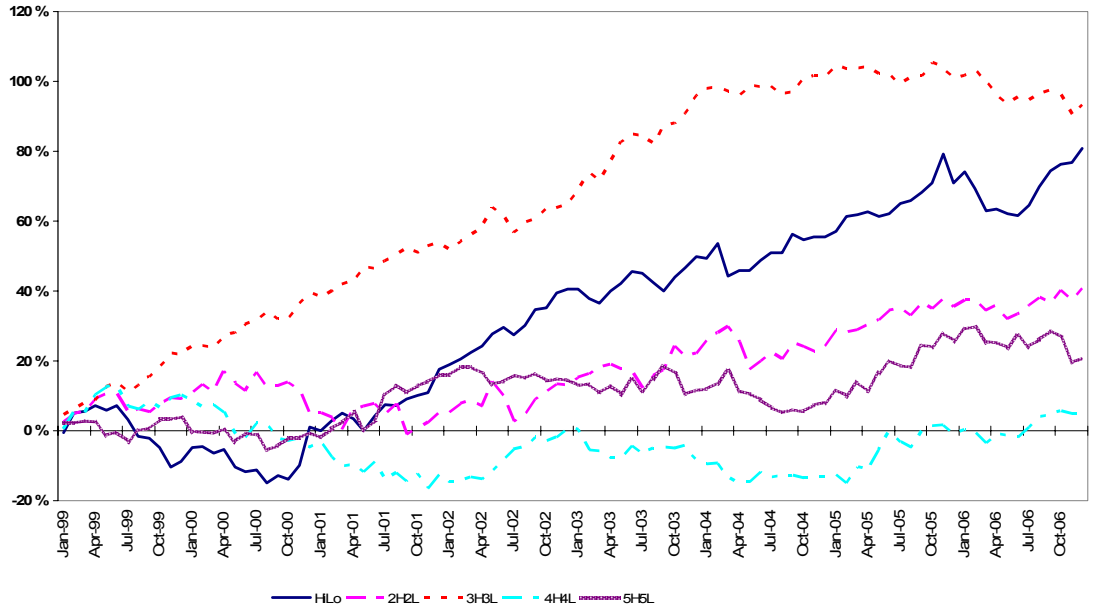


Figure 5 exhibits post-euro cumulative returns. The strategy based on the highest interest rate differential, 1H1L, produces negative returns in practice for two years after adoption of the euro. Since late 1998 it has been long in NOK and short in JPY over the whole year 1999, after which interest rates in New Zealand, U.K and U.S rose above the Norwegian rate for a short period of time. Interestingly, since October 2000, when 1H1L starts to post positive returns, positions reverts to long in NOK short in JPY and remain unchanged for the next two and a half years. Since the first quarter of 2003 for the next almost four years until the end of sample period 1H1L strategy consist of short position still in JPY, and long position in NZD, except for two single months when interest rate in Australia exceeds the rate in New Zealand only by negligible 10 basis points. Thus, this strategy has been short in JPY since September 1993, or more than 13 years.

2H2L strategy does not generate positive returns until after the latter half of 2002. For about two years, between January 2001 and March 2003, the strategy was long in NZD and short in CHF. Since July 2003 until the end of sample period 2H2L is short in CHF and long in AUD, except for those two abovementioned months when interest rates were highest in Australia. In this strategy long positions are financed with CHF for the last 12.5 years.

The most striking result is, however, the performance of 3H3L strategy. It posts sharply rising returns in practice for the first six years. During this period currency returns add up to 87 % of total return of 96 %. Especially interesting is the 1999-2001 period, when returns from other strategies have more or less tumbled. Characteristic for 3H3L strategy is prolonged periods particularly in funding currencies. For the first one and half year strategy is short in EUR, the next twelve months in SEK, and the next three and half years in USD. Since 2002 also long positions remain unchanged for long periods in AUD and GBP.

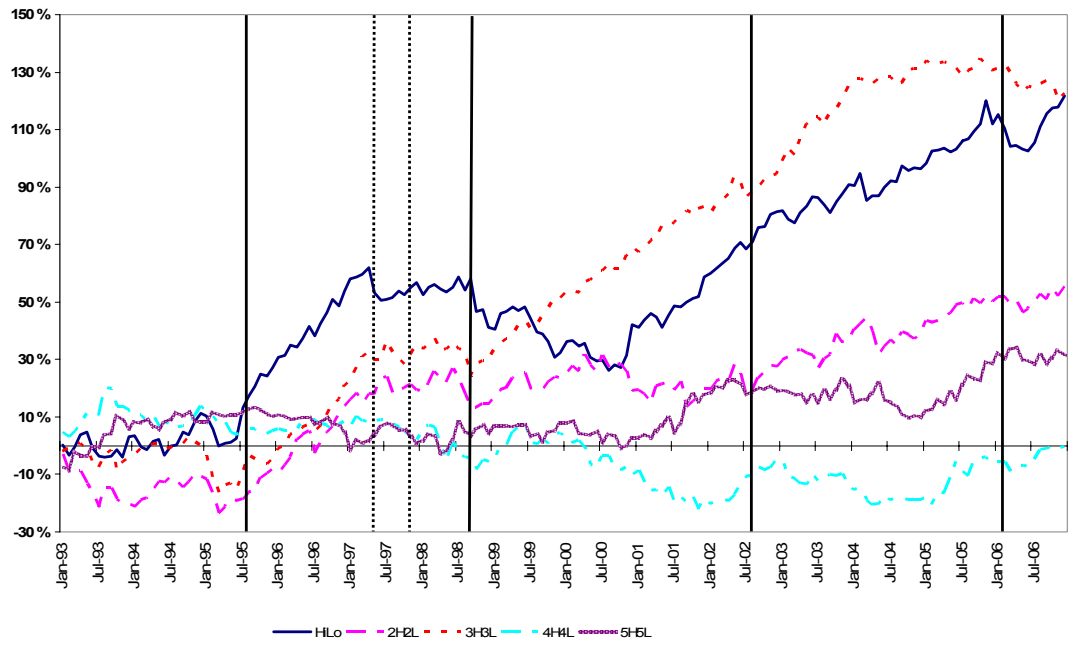
The two strategies with the narrowest interest rate differential, 4H4L and 5H5L, perform clearly more moderately. Half of the rather small interest differential in 4H4L is lost with negative currency returns, on average, yielding insignificant result both economically and statistically. A bit surprisingly, a virtually zero interest rate returns in 5H5L are supplemented with positive currency returns, and this strategy generates positive return since 2001. However, it can be argued that UIP holds well for these strategies and especially for 4H4L.

All in all, what can be observed is that, while interest rate differentials have remained quite stable before and after the euro, exchange rate returns from every strategy are higher during the post-euro era than before adoption of the common currency and moreover statistically significantly positive in four of the five carry trade strategies. Interestingly, currency returns between 1H1L and 5H5L strategies are quite similar, whereas 3H3L strategy posts much higher FX returns than any other position.

6.1.3. Effects of global financial market events

What has then actually happened in financial markets globally since 1993? Performance of these all five strategies over the whole sample period is presented in Figure 6. Return patterns from single-currency carry trades are analyzed in conjunction with major events in global financial markets. All these events are marked with vertical lines in the figure.

Figure 6: Carry trade performance and major global financial markets events 1993 - 2006
The figure presents the cumulative returns for each one-month single-currency carry trade strategy together with major financial market events over the whole sample period. The area between the two dashed lines refers to Asian currency crisis. The first solid line stands for the beginning of near-zero interest rate era in Japan. The second solid line marks the time of Russian default and recapitalization of LTCM. The third line stands for the beginning of below one interest rate era in Switzerland. The last line represents first signals of global reduction in risk appetite and emerging markets sell-off.



The first solid line in the figure stands for the beginning of ultra-low interest rate era in Japan, the main source of funding of carry trades. Short-term interbank interest rate used in this study dipped below 1 %, where they have remained up to the present. Two dashed lines represent the time period when Asian currency crisis took place. This episode was followed by a turbulent period in global financial markets culminating in Russian sovereign debt default and recapitalization of LTCM, a hedge fund actively involved in carry trades. As is discussed in Chapter 2, hedge funds unwound massive short JPY positions during the latter half of 1998. This is highlighted with the second solid line and

effects for 1H1L strategy, which is short in JPY, can be clearly seen. Interestingly, at the same time 3H3L strategy shows totally opposite pattern, working as a good hedge against 1H1L losses.

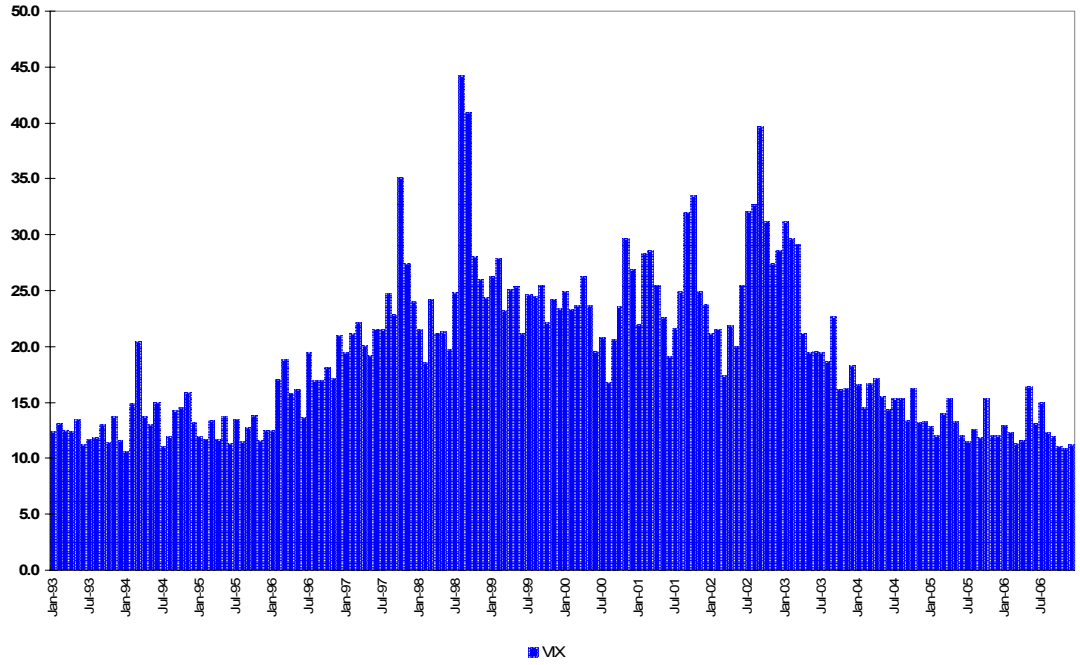
As in Japan since 1995, interest rates have been remarkably low in Switzerland as well. One-month Swiss interbank rate dropped below one in August 2002, which is represented with the third line in the figure, and remained below one for the next three and a half years. As shown this coincides with increasing returns from 2H2L strategy, in which short position is denominated in CHF. Currency returns from short CHF positions since August 2002 until the end of sample add up to almost 18 %, or approximately 4 % annually on average.

The last line represents events in spring 2006. The potential for negative developments in one market to spill over to other markets was starkly illustrated in February, when Icelandic krona depreciated sharply in two days following rating agency Fitch's announcement of a negative outlook on Iceland's sovereign rating. Within hours the unwinding of positions led to sharp falls in other high-yielding currencies[7] like those of Australia, Brazil, Hungary, New Zealand and South Africa. During the spring risk-appetite of institutional investors was reduced sharply, which triggered a major sell-off globally in emerging markets.

It is also interesting to view events in global markets from a bit different angle and compare those findings with carry trade returns. The Chicago Board Options Exchange's (CBOE) Volatility Index (VIX) is a key measure of market expectations of near-term volatility conveyed by S&P 500 stock index option prices, and has been considered to be the world's premier investor sentiment and market volatility barometer. Additional attractiveness to compare the interaction between VIX and carry trade returns is that VIX was introduced in 1993, and thus the sample period for these two is exactly equal. Figure 7 presents monthly values of VIX.

[7] One-month interbank interest rate in Iceland was at that time over 10 %.

Figure 7: Volatility Index (VIX)
Figure 7 presents monthly values of the Volatility Index. Data source: CBOE.



Markets seem to have been quite calm except one spike in 1994. This could be due to Mexican financial crisis at that time. When compared to Figure 6 no any strong relation between that hike and carry trade returns can be observed. In addition, UIP has hold well back then and thus carry trades have not been particularly attractive. Market volatility starts to rise in 1995, in conjunction with carry trade returns, and the second spike takes place during the Asian currency crisis, which is also highlighted in Figure 6. After that, VIX drops just to hit the record high October 1998 at the time of Russian debt moratorium and near collapse of LTCM. This moment is also a turning point for the yen carry trade in Figure 6 above. Since 1999 market volatility remains higher than prior to the two crises. Interestingly, volatility spikes in the beginning of the new millennium due to 9/11 terrorist attacks and burst of internet bubble, among others, and the uncertainty in the stock market, which prevailed until mid 2003 do not seem to affect carry trade returns in any remarkable way. During the last two years market volatility has been at similar levels as during the first two years. The highest recent spike can be traced back to May 2006, when global investors retreated from emerging markets. This volatility spike

coincides also with carry trade return downturn. However, the panic was short-lived, which can be observed in both, market volatility and yen carry trade.

To summarize the findings from the first part of the chapter, the results of the trading experiment show so far strong evidence for the hypothesis that the high-yielding currencies post positive returns for prolonged periods thus violating UIP. On the other hand, there are periods when UIP seems to hold, particularly for lower-yielding currencies. A controversial issue in existing research is exactly the time span in which UIP should hold, as academics often argue that UIP should hold on the long-run. The results above indicate that at least over the last 14 years, which could be thought of a long-run period, UIP is severely violated. As noted in BIS (2005) trading strategies trying to capture the profits from violations of UIP target several currencies simultaneously and therefore it will be interesting to explore not only single currency pair returns but returns to portfolios of currencies. I will turn to this next.

6.2. Currency portfolio carry trades

In this section I further analyze carry trade returns. Separate currency pairs under scrutiny in previous section are now combined into portfolios to find out possible gains from diversification. More emphasis on currencies as an alternative investment is put in the latter part of this section, where the performance of a carry trade portfolio is analyzed against traditional asset classes. These findings are also compared to results from other currency investment analysis. To begin with, Table 4 presents the return characteristics of currency portfolios.

6.2.1. Performance of currency portfolios

The results in Table 4 are reported in similar fashion as in the first section of this chapter in Table 2, thus consisting of monthly annualized returns. Instead of one currency pair only, here column headings refer to portfolio, which contains X number of individual high-yielding and funding currencies. The leftmost column shows details for portfolio, which invests in the two highest-yielding currencies, funded with short positions in the

two lowest-yielding ones. Similarly, in the rightmost column is the portfolio which has long and short positions in all five highest- and lowest-yielding currencies used in this study.

Table 5: Currency portfolio carry trade profitability

Table 5 presents the results of the one-month currency portfolio carry trade strategies over the full sample as well as during two subperiods. *Mean* is the average annualized monthly return. Figures denoted with ***, ** and * are statistically significantly different from zero at the 1, 5 and 10 percent levels respectively. *St. Dev* is the annualized standard deviation of monthly returns. *Skew* and *Kurt* stand for skewness and kurtosis, respectively, and exhibit the distribution characteristics of the returns. *Sharpe* is the annual Sharpe ratio. Columns refer to particular carry trade strategies, which are combinations of single-currency carry trades and include X highest and X lowest yielding currencies. *FX* and *Int* refer to exchange rate and interest rate return components, respectively. *Total* is the total return from particular positions.

Carry trade strategy	2 Highest / 2 Lowest			3 Highest / 3 Lowest			4 Highest / 4 Lowest			5 Highest / 5 Lowest		
	FX	Int	Total	FX	Int	Total	FX	Int	Total	FX	Int	Total
Pre Euro												
Mean	-2.77	12.04	9,27***	-0.35	14.54	14,19***	-2.66	15.90	13,24***	-2.31	16.30	13,99***
St. Dev	19.35	0.74	19.44	26.63	0.89	26.75	30.67	0.97	30.77	32.16	0.98	32.21
Skew	-0.709	-0.576	-0.688	-0.591	-0.703	-0.572	-0.436	-0.894	-0.423	-0.254	-0.987	-0.236
Kurt	-0.247	-0.837	-0.287	-0.329	-0.489	-0.337	-0.177	-0.225	-0.229	0.196	-0.057	0.132
Sharpe			0.48			0.53			0.43			0.43
Post Euro												
Mean	4.33 **	10.87	15,20***	13.37 ***	13.50	26,87***	12.68 ***	14.83	27,51***	14.82 ***	15.26	30,08***
St. Dev	16.76	0.26	16.78	20.30	0.35	20.30	24.38	0.39	24.40	28.53	0.47	28.54
Skew	-0.397	0.129	-0.390	-0.648	-0.275	-0.636	-0.628	-0.304	-0.613	-0.767	-0.099	-0.753
Kurt	0.046	-1.258	0.029	0.665	-0.991	0.628	0.644	-0.357	0.613	0.568	-0.600	0.543
Sharpe			0.91			1.32			1.13			1.05
Full sample												
Mean	1.29	11.37	12,66***	7.49 ***	13.94	21,43***	6.11 ***	15.29	21,40***	7.48 **	15.71	23,19***
St. Dev	17.89	0.54	17.93	23.23	0.65	23.28	27.26	0.71	27.30	30.15	0.74	30.16
Skew	-0.584	0.152	-0.568	-0.685	-0.227	-0.666	-0.569	-0.463	-0.552	-0.524	-0.550	-0.507
Kurt	-0.030	-0.098	-0.071	0.241	0.287	0.219	0.258	0.459	0.213	0.304	0.261	0.263
Sharpe			0.71			0.92			0.78			0.77

Total returns are statistically significantly different from zero at 1 % level in all portfolios over the full sample as well as during the both subperiods. As can be seen, currency returns are negative (from -0.35 % to -2.77 %) and highly volatile in every portfolio during the pre-euro period reducing the total return. Due to the high volatility currency returns are not statistically significantly different from zero. Since exchange rate changes do not offset interest rate returns, which range from about 12 % to 16.30 %, average total returns vary between 9.27 % and 14.19 %. Considering risk-adjusted returns, these portfolios offer an average Sharpe ratio of 0.47, which exceeds clearly the average of 0.24 of individual currency pairs reported in Table 2. The highest Sharpe ratio (0.53) is

obtained from portfolio, which has long positions in three highest-yielding currencies and short positions in three lowest-yielding ones. This Sharpe ratio is actually equal to that from 1H1L single-currency strategy.

Currency returns are totally reversed during the post-euro period. Findings are positive ranging from 4.33% to 14.82 % and statistically very significant. In portfolios, which contain positions in six or more currencies, exchange rate returns (13.37 %, 12.68 % and 14.82 %) form approximately half of the total return. Even in the first portfolio, which has positions in four currencies, exchange rate return adds up to almost 30 % of the total return. Although interest rate differentials have somewhat converged, ranging from 10.87 % to 15.26 %, impressive currency returns and their diminished volatility combined offer attractive risk-return profiles for portfolios. Post-euro Sharpe ratios vary between 0.91 and 1.32 averaging to 1.10. Although the portfolio including all the ten currencies offers the highest currency return, its Sharpe ratio is somewhat lower than those obtained from portfolios with eight and six currencies due to clearly higher currency return volatility.

Figure 8 presents the portfolio performance during the pre-euro era. As can be seen, even if combining up to ten currencies, portfolios are not generating positive returns until in the latter half of 1995. This indicates strong evidence for UIP, against the first hypothesis of the study. However, the picture changes for the next two years. The main driver is the first portfolio, which contains long positions in the two highest-yielding currencies funded with the two lowest-yielding ones. The return spread between this and the portfolio containing all five currency pairs widens substantially not until in 1997. On the other hand, the downturn in 1998 seems to be stronger the more currencies are included in carry trade portfolio.

When turning into the post-euro era, currency returns really start to boost total portfolio returns, which can be observed in Figure 9. For the portfolio with positions altogether in four currencies UIP seems to hold well still in the latter half of 2001. However, adding one more currency pair improves remarkably the total portfolio performance. Since 2002 all portfolios show positive performance and due to positive interest differential combined with supplementing currency returns, the gap between the first portfolio and

other portfolios widens. True value added from including all ten currency pairs is, however, present only during the last two years.

Figure 8: Performance of currency portfolio strategies 1993 - 1998
The figure presents the cumulative returns for each currency portfolio carry trade strategy during the pre-euro period.

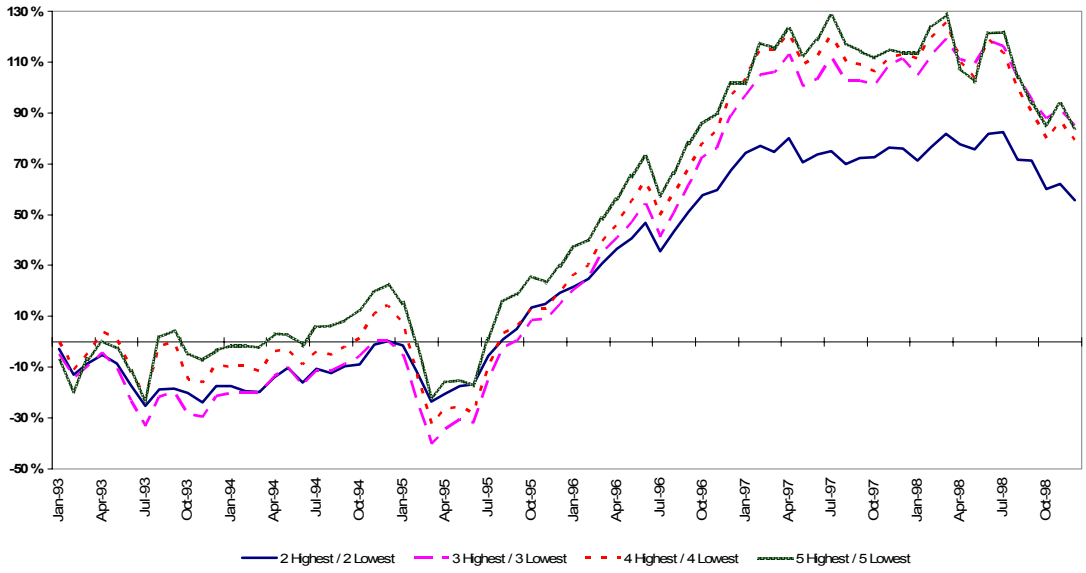
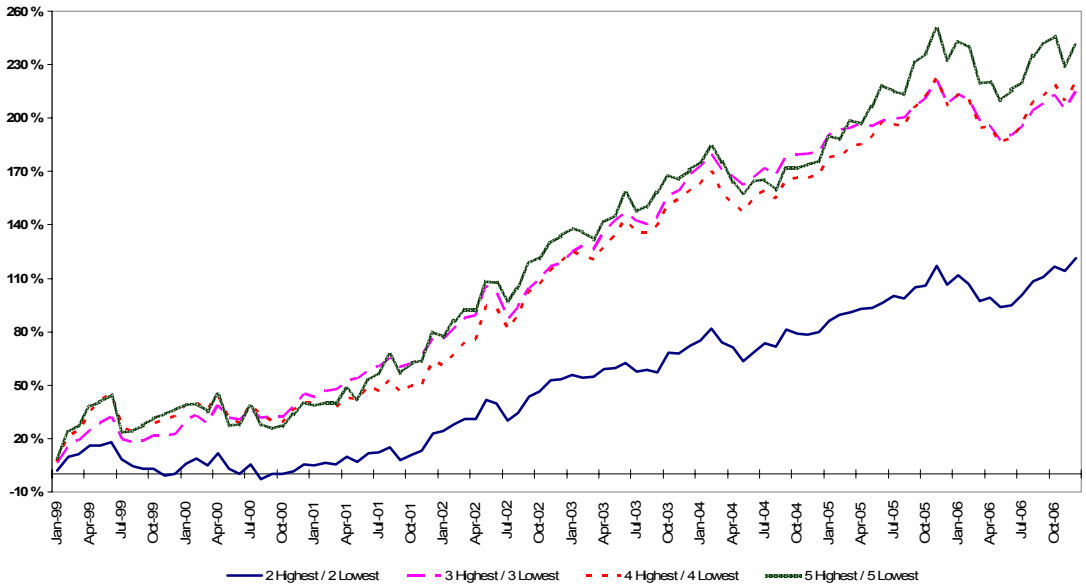
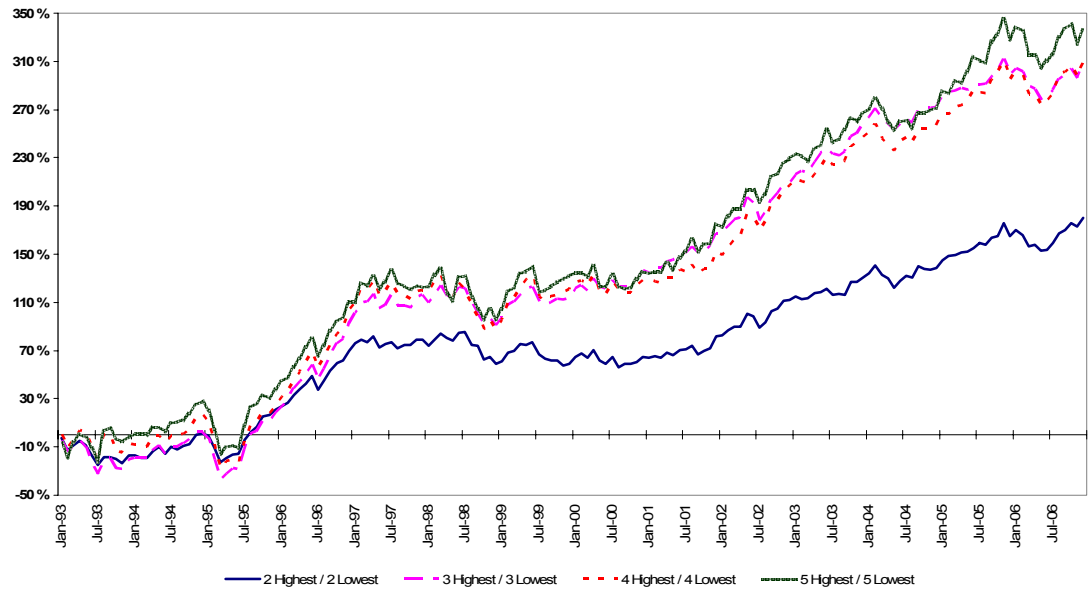


Figure 9: Performance of currency portfolio strategies 1999 - 2006
The figure presents the cumulative returns for each currency portfolio carry trade strategy during the post-euro period.



To summarize the results so far, I present the performance of the portfolios over the full sample in Figure 10. During this 14-year period, there has clearly been two distinct subperiods when UIP has hold well. However, to date the performance of carry trade portfolios indicate severe violation of UIP. More importantly, if the return patterns in Figure 10 are compared with those in Figure 6, it can be seen that during the turbulent period between the late 1997 and early 1999, despite of the dip in total portfolio returns, currency portfolio performance is clearly smoother and quickly reversed in the beginning of 1999, indicating diversification benefits from different currency pairs.

Figure 10: Performance of currency portfolio strategies 1993 - 2006
The figure presents the cumulative returns for each currency portfolio carry trade strategy over the whole sample.

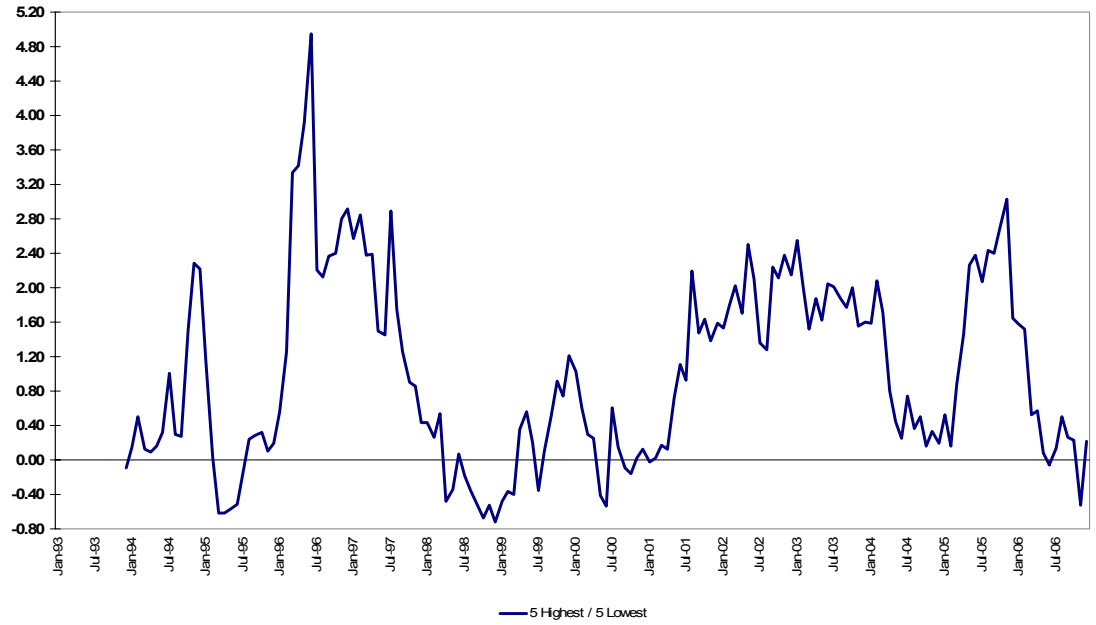


Next I will turn to analyze risk-adjusted performance of a carry trade portfolio. Although the portfolio, which includes three highest- and lowest-yielding currencies, provides the highest Sharpe ratio as was evident in Table 4, I will use the portfolio including all ten currency pairs. The reason is that I believe this offers the most extensive view of the overall risk-adjusted performance of carry trade strategies. For a reminder, this portfolio offers an average annual full-sample Sharpe ratio of 0.77. Figure 10 shows one-year rolling annual Sharpe ratio of the 5 Highest / 5 Lowest- portfolio. It can be seen that

Sharpe ratio peaks around mid 1996, after which it sharply reduces, still being at very attractive levels. The collapse of carry trade returns drives the Sharpe ratio negative and it touches the bottom in the beginning of 1999. After bouncing back and forth the Sharpe ratio rises sharply and remains positive until very recent observations. Especially attractive is the three-year period in 2001 – 2004, when annual Sharpe ratio varies between about 1 and 2.4. The events in spring 2006, which were discussed in conjunction with market volatility analysis, can be seen also in Figure 11. Sharpe ratio plummets and even turns into negative for the first time in five years.

Figure 11: One-year rolling Sharpe ratios 1993 - 2006

The figure presents annual Sharpe ratios of currency portfolio, which includes all ten currency pairs, using one-year rolling window.



6.2.2. Currency investments as an alternative asset class

The final part of this chapter is devoted to an analysis of these currency portfolios as an alternative asset class. As can be recalled from Chapter 3, active currency investments are not only carry trade orientated, rather yield-enhancing trades are just one source of possible excess returns. Thus, carry trade strategies presented in this study should not be interpreted as an optimal active currency investment, but more like a one possible option in a universe of managed currency programs. For this reason, I also present findings by Huttman and Harris (2006) to offer a comparison not only between asset classes but also between different currency strategies.

First, I compare the performance of carry trade portfolio, which includes all ten currency pairs, with equities, bonds, and commodities. Morgan Stanley Capital International World- Index (MSCI World) and Standard & Poor's 500 Composite Index (S&P 500) represent the stock market benchmarks, Lehman Brothers U.S. Treasury index (LBUS) is the bond benchmark, and Goldman Sachs Commodity Index (GSCI) represents the benchmark for commodity markets. These all are pictured in Figure 12, which shows the performance over the whole sample period 1993 – 2006. As can be observed, carry trade portfolio does not stand out in the beginning of the sample period, and is actually the worst performer in mid 1995. However, the next two years are totally opposite, and carry portfolio performs better than any of the benchmarks. After the following tranquil period, which has been already identified as the second subperiod when UIP holds, carry trade does not seem any more attractive than equity indexes. The downturn in equity markets in the beginning of the new millennium, which was also discussed with VIX, does not affect negatively to carry portfolio and its performance becomes superior to any other alternative.

These five investment alternatives are further analyzed in Table 6, which shows correlations between the abovementioned asset classes. As was discussed in Chapter 3, currencies as an alternative investment have attracted investors' interest partly because of the low correlation with other asset classes offering strong diversification benefits when added to traditional portfolios. Statistical significance of correlation between the five asset classes is tested and possible significant findings are indicated with asterisks in

Table 6. Carry portfolio has the highest correlation with MSCI (0.24), which is the only statistically significant correlation between currency portfolio and the other asset classes. The correlation between carry portfolio and S&P 500 is only about half of that recorded with MSCI, and even lower with GSCI (0.06). Correlation with U.S. Treasury Index is even negative. What comes to mutual findings with other investment options, the correlation between MSCI and S&P 500 is the highest (0.78), not surprisingly. However, other figures indicate low correlation from both economical and statistical perspective.

Figure 12: Performances of carry trade portfolio and other asset classes 1993 -2006
Figure 12 presents the performance of carry trade portfolio benchmarked with equity (MSCI and S&P 500), bond (LBUS), and commodity (GSCI) indexes over the whole sample period.

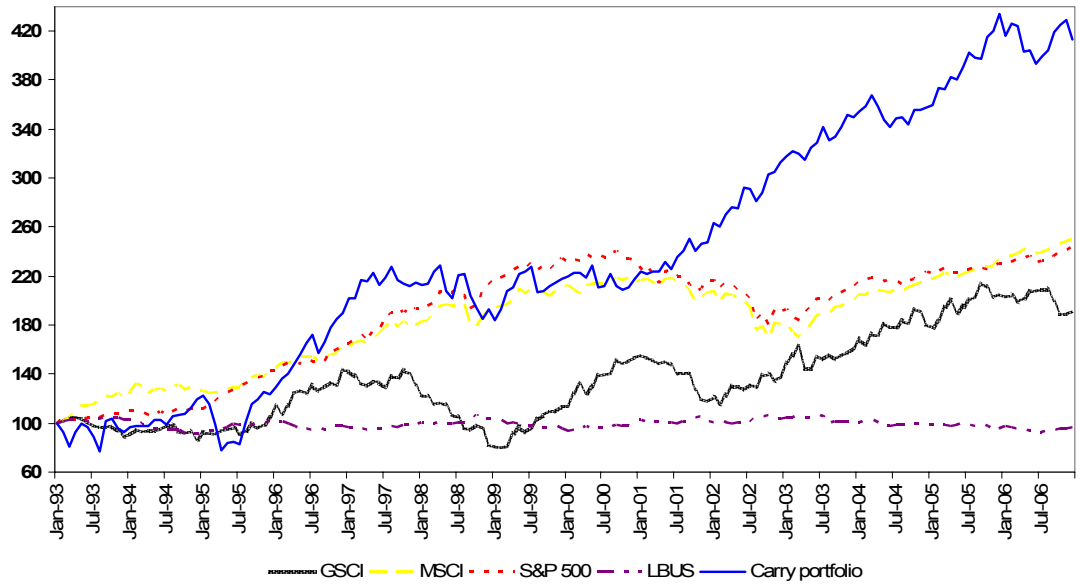


Table 6: Correlation coefficients between carry portfolio and other asset classes
Table 6 presents the correlation between different asset class returns. Carry portfolio represents currency investments, MSCI and S&P 500 equities, GCSI commodities, and LBUS bonds. Correlation coefficients denoted with ***, ** and * are statistically significantly different from zero at the 1, 5 and 10 percent levels respectively.

Correlations	Carry portfolio	MSCI	S&P 500	GSCI	LBUS
Carry portfolio	1				
MSCI	0.24 ***	1			
S&P 500	0.13	0.78 ***	1		
GSCI	0.06	0.08	0.01	1	
LBUS	-0.10	-0.11	-0.02	0.03	1

To give these findings additional perspective, I present correlation coefficients reported by Huttman and Harris (2006) in Table 7. This analysis includes a wider array of assets, especially stock market benchmarks. The authors include two currency investment alternatives, Millennium Global Currency fund (MGC) and Parker FX Index. The Parker FX Index tracks the performance of currency managers, is equally weighted and includes 66 currency investment programs managed by 45 firms located in the United States, Canada, the United Kingdom, Ireland, and Switzerland. The programs manage over $15.7 billion in currency assets.

In addition to S&P 500, equity indexes analyzed include Japanese Nikkei 225, British FTSE 100, German DAX, and Swiss SMI. Correlation with commodities and global bonds is also reported. First, it can be noticed that MGC currency fund correlates closely (0.64) with the Parker FX Index. However, correlation of these both currency investments with other asset classes is extremely low. The only exception is global bond benchmark, which has somewhat higher correlation with MGC (0.18) and Parker Index (0.29). As is present also in Table 6 above, equity indexes strongly correlate with each other. In Table 7, the highest equity index correlation (0.72) is between FTSE 100 and DAX, as well as FTSE 100 and SMI. Except the Nikkei 225, all equity benchmarks have correlation above 0.60 with each other. As in Table 6, also Table 7 shows low correlation between commodities and other asset classes, except Nikkei 225, which has a correlation coefficient of 0.26 with GSCI.

Table 7: Correlation coefficients between managed currency investments and other asset classes
Table 7 presents correlation coefficients of two currency investment alternatives, MGC and Parker FX Index, with equity, bond, and commodity benchmarks.

Correlations	MGC	Parker FX Index	S&P 500	Nikkei 225	FTSE 100	DAX	SMI	GSCI	World Bonds
MGC	1								
Parker FX Index	0.64	1							
S&P 500	0.03	0.00	1						
Nikkei 225	0.01	-0.02	0.35	1					
FTSE 100	-0.04	-0.10	0.69	0.30	1				
DAX	0.06	-0.04	0.65	0.65	0.72	1			
SMI	0.03	-0.09	0.63	0.31	0.72	0.69	1		
GSCI	-0.07	-0.08	-0.02	0.26	-0.02	-0.06	-0.09	1	
World Bonds	0.18	0.29	0.00	-0.14	-0.15	-0.31	-0.20	0.10	1

The empirical findings of this study are now presented and analyzed. Before the concluding remarks, the last section of this chapter summarizes the most important features and results of the empirical part.

6.3. Main findings of the study

This study has put under scrutiny the cornerstone parity condition of exchange rate economics, the uncovered interest parity. The violation of UIP is widely documented by academics and massively exploited by practitioners. The trading model in this study is used to gauge the attractiveness of trading strategies based on interest differentials. The first section of this chapter analyzed currencies on a pair-by-pair basis. The results in Table 4 indicate that UIP is violated but the evidence is somewhat mixed. Some strategies offer attractive returns even on the risk-adjusted basis, whereas the others generate virtually zero returns. Moreover, it seems that the violations of UIP are more severe during the post-euro era. This is confirmed also in Figures 4 and 5, which show that UIP has hold until 1995 for every single strategy, after which the yen carry trade has been especially attractive for couple of years. The whole post-euro period is highlighted with pervasive violations of UIP, especially for the higher-yielding currencies. It was also found that during the sample period global financial crises have had a major impact to the performance carry trade strategies.

The second section of this chapter analyzed carry trade strategies from a portfolio perspective, motivated by research among market participants. The results in Table 5 give even stronger supporting evidence for the main hypotheses of the study. Returns from currency portfolios are very attractive also after adjusting to risk. The pre-euro period offers on average a Sharpe ratio similar to a passive buy-and-hold equity strategy, but the post-euro period shows twice as high Sharpe ratio. Figures 8 and 9 show the effect of including additional currency pairs into the portfolio. Since Asian currency crisis in 1997, particularly, the positive impact of including at least six currencies into the portfolio is visible. Continuity of high risk-adjusted returns was also analyzed and as the Figure 11 shows, there are two distinct subperiods, in 1995-1998 and 2001-2004, when the annual rolling Sharpe ratio has remained at very high levels.

Finally, currency investments were scrutinized as an alternative asset class. The motivation behind adding currencies into traditional portfolios is the low correlation between currency strategies and other asset classes. The performance of carry trade portfolio, which consists of long positions in the five highest-yielding currencies and short positions in the five lowest-yielding ones, was analyzed against equity, bond, and commodity benchmarks. As is evident in Figure 12, carry trade portfolio was the worst performer among the MSCI, S&P 500, GSCI, and Lehman Brothers U.S. Treasury Index for the first two years of the sample. A sharp upturn in carry portfolio returns change the picture, however, and before the Asian crisis, Russian default, and near collapse of the LTCM, the portfolio became the best performer. The major events and increased uncertainty in the global financial markets led the carry trade returns to dry up, and when approaching the advent of the new millennium carry trade was not any more attractive investment strategy than a passive investment into equity index. The last four years of the sample period have been the era of prosperity of carry trades and returns have soared well above of those obtained from the other alternatives.

Correlations of carry trade portfolio with the alternative asset classes were statistically insignificantly different from zero in every case, except the MSCI. This indicates that the performance of traditional portfolios could indeed enhanced by diversifying into currencies. This finding was further supported by the results from other study with broader coverage of asset classes.

7. Conclusions and future research

This study has examined the profitability of trading strategies in foreign exchange market, the world's largest single market. The main motivation of the research stems both from academic and practical evidence that currency trading strategies based on interest rate differentials could be profitable and attractive also from risk-adjusted basis. The academic documentation dates back to the seminal paper by Fama (1984). Since then violations of the uncovered interest parity, the cornerstone parity condition of exchange rate economics, have been routinely documented. Despite of voluminous number of foreign exchange market research, carry trades have only recently been scrutinized, by Burnside et al. (2006), for instance.

Following a discussion on the characteristics of carry trades, theoretical foundation and earlier research on exchange rates with up-to-date market statistics were presented. Based on the existing evidence, two research hypothesis concerning carry trades were established for the empirical part of the study. After constructing the trading model, hypothesis were tested.

The findings of the study implicate violations of the uncovered interest parity especially since the common currency euro was launched. It seems that for the higher-yielding currencies particularly the parity has held only in the beginning of the sample period, and during extremely turbulent periods in the markets. Based on the evidence, that carry traders have targeted several currencies simultaneously, the empirical part examined carry trade strategy profitability also from currency portfolio perspective. The results were even more striking. Including additional currency pairs into portfolios presented evidence for diversification benefits, and currency portfolios offered extremely attractive risk-adjusted returns for prolonged periods.

It was also highlighted that during the recent years currencies have increased their interest as an alternative asset class among investors. This strand of research is still relatively exiguous and additional purpose of this study was to supplement this research. The

performance of a carry trade portfolio was first investigated against other asset classes, and over the full sample it outperformed equity, bond, as well as commodity benchmarks despite of the poor performance over the first years. Additionally, the results indicate that due to low correlation with traditional asset classes managed currency investments can offer diversification benefits when included to traditional portfolios.

This study has contributed to the existing literature by examining commonly used trading strategies utilizing a wider set of exchange rate data than the previous studies. The future course of research can be concentrated into various directions. First, considering the poor performance of traditional exchange rate models noted already by Meese and Rogoff (1983), and some prominent results from the microstructure approach to exchange rates, a hybrid model combining these two views could offer a breakthrough solution. Second, as this study concentrated purely on the profitability of carry trade strategies, it would be interesting for future researchers to find possible triggers for accumulation and unwinding carry trade positions. Of course, as was mentioned, the availability of proper data has been the major drawback in both microstructure research and the extensive carry trade analysis. Third future research topic could be the currency investment programs, which are becoming a mainstream instruments and still their attractiveness is mostly unexplored.

The last two years have seen the prosperity of carry trades. It has been an extremely well covered topic in financial news as is evident from the citations in the first chapter. However, at the time of finishing the study, uncertainty, which started in Asian stock markets and spilled over to exchanges in other continents, and the following reactions in the foreign exchange market, has aroused speculation about massive unwinding of global carry trade positions.

References

Backus, D. K., A.W. Gregory and C.I. Telmer, (1993), 'Accounting for Forward Rates in Markets for Foreign Currency', *Journal of Finance*, 48, 1887-1908.

Bank for International Settlements, 1999, International Banking and Financial Market Developments, *BIS Quarterly Review*, March.

Bank for International Settlements, 2005, Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2004, www.bis.org.

Bank for International Settlements, 2006, *76th Annual Report*, June.

Bank for International Settlements, 2007, International Banking and Financial Market Developments, *BIS Quarterly Review*, March.

Bansal, R. and M. Dahlquist, (2000), 'The Forward Premium Puzzle: Different Tales from Developed and Emerging Economies', *Journal of International Economics*, 51, 115-144.

Baz, J., F. Breedon, V. Naik and J. Peress, (2001), 'Optimal Portfolios of Foreign Currencies', *Journal of Portfolio Management*, 28, 102-111.

Berger, D.W., A.P. Chaboud, S.V. Chernenko, E. Howorka and J.H. Wright, (2006), 'Order Flow and Exchange Rate Dynamics in Electronic Brokerage System Data', mimeo, Board of Governors of the Federal Reserve System.

Bilson, J.F.O. and D.A. Hsieh, (1987), 'The Profitability of Currency Speculation', *International Journal of Forecasting*, 3, 115-130.

Burnside, C., M. Eichenbaum, I. Kleshchelski and S. Rebelo, (2006), 'The Returns to Currency Speculation', Working Paper No. 12489, National Bureau of Economic Research.

Cai, J., Y.-L. Cheung, R.S.K. Lee and M. Melvin, (2001), 'Once-in-a-Generation Yen Volatility in 1998: Fundamentals, Intervention, and Order Flow', *Journal of International Money and Finance*, 20, 327-347.

Cheung, Y.-W. and M.D. Chinn, (2001), 'Currency Traders and Exchange Rate Dynamics: a Survey of the US Market', *Journal of International Money and Finance*, 20, 439-471.

Cheung, Y.-W., M.D. Chinn and A.G. Pascual, (2005), 'Empirical Exchange Rate Models of the Nineties: Are Any Fit to Survive?', *Journal of International Money and Finance*, 24, 1150-1175.

Chinn, M.D. and G. Meredith, (2005), 'Testing Uncovered Interest Parity at Short and Long Horizons During the Post-Bretton Woods Era', Working Paper No. 11077, National Bureau of Economic Research.

Engel, C., (1996), 'The Forward Discount Anomaly and the Risk Premium: A Survey of Recent Evidence', *Journal of Empirical Finance*, 3, 123-192.

Evans, M.D.D. and R.K. Lyons, (2002), 'Order Flow and Exchange Rate Dynamics', *Journal of Political Economy*, 110, 171-180.

Fama, E.F., (1984), 'Forward and Spot Exchange Rates', *Journal of Monetary Economics*, 14, 319-338.

Frankel, J.A. and K. Froot, (1987), 'Using Survey Data to Test Standard Propositions Regarding Exchange Rate Expectations', *American Economic Review*, 77, 133-153.

Frankel, J.A. and A.K. Rose, (1995), 'An Empirical Characterization of Nominal Exchange Rates', in G.A. Grossman and K. Rogoff (eds.) *Handbook of International Economics*, vol. III, (North-Holland, Amsterdam).

Flood, R.B. and A.K. Rose, (2002), 'Uncovered Interest Parity in Crisis,' *International Monetary Fund Staff Papers*, 49, 252-266.

Froot, K. and J.A. Frankel, (1989), 'Forward Discount Bias: Is It an Exchange Risk Premium?', *Quarterly Journal of Economics*, 104, 139-161.

Froot, K. and R.H. Thaler, (1990), 'Anomalies: Foreign Exchange', *Journal of Economic Perspectives*, 4, 179-192.

Froot, K.A. and T. Ramadorai, (2005), 'Currency Returns, Intrinsic Value, and Institutional-Investor Flows', *Journal of Finance*, 60, 1535-1566.

Galati, G. and M. Melvin, (2004), 'Why has FX Trading Surged? Explaining the 2004 Triennial Survey', *BIS Quarterly Review*, December.

Hansen, L.P. and R.J. Hodrick, (1980), 'Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis', *Journal of Political Economy*, 88, 829-853.

Hodrick, R.J., (1987), *The Empirical Evidence on the Efficiency of Forward and Futures Foreign Exchange Markets*, (Harwood, Chur).

Huttman, M. and L. Harris, (2006), 'Generating Alpha from Currency Programs', *Journal of Alternative Investments*, 8, 48-54.

LeBaron, B., (1999). 'Technical Trading Rule Profitability and Foreign Exchange Intervention', *Journal of International Economics*, 49, 125-143.

Lewis, K., (1995), 'Puzzles in International Financial Markets', in G.A. Grossman and K. Rogoff (eds.) *Handbook of International Economics*, vol. III, (North-Holland, Amsterdam).

Lyons, R.K., (2001) *The Microstructure Approach to Exchange Rates*, (MIT Press, Cambridge, MA).

Meese, R.A. and K. Rogoff, (1983), 'Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?', *Journal of International Economics*, 14, 3-24.

Middleton, A. (2005), 'Trading Style Analysis: A Quantitative Assessment of the Currency Industry', *Journal of Alternative Investments*, 1, 14-28.

Neely, C.J., (2000), 'The Temporal Pattern of Trading Rule Returns and Central Bank Intervention: Intervention Does Not Generate Technical Trading Rule Profits', Working Paper, St. Louis Federal Reserve Bank.

Sarno L. and M.P. Taylor, (2002), *The Economics of Exchange Rates*, (Cambridge University Press, Cambridge).

Sharpe, W. F. (1966), 'Mutual Fund Performance', *Journal of Business*, 39, 119-138.

Sharpe, W. F. (1994), 'The Sharpe Ratio', *Journal of Portfolio Management*, 21, 49-57.

Sweeney, R.J., (1997), 'Do Central Banks Lose on Foreign Exchange Intervention? A Review Article', *Journal of Banking and Finance*, 21, 1667-1684.

Szakmary, A. C. and I. Mathur, (1997), 'Central Bank Intervention and Trading Rule Profits in Foreign Exchange Markets', *Journal of International Money and Finance*, 16, 513-535.

Wei S.-J. and J. Kim, (1997), 'The Big Players in the Foreign Exchange Market: Do They Trade on Information or Noise?', Working Paper No. 6256, National Bureau of Economic Research.

Appendix 1

Table 8: Three-month single currency carry trade profitability

Table 8 presents the results of the three-month single-currency carry trade strategies over the full sample as well as during two subperiods. *Mean* is the average annualized monthly return. Figures denoted with ***, ** and * are statistically significantly different from zero at the 1, 5 and 10 percent levels respectively. *St. Dev* is the annualized standard deviation of monthly returns. *Skew* and *Kurt* stand for skewness and kurtosis, respectively, and exhibit characteristics of distribution of the returns. *Sharpe* is the annual Sharpe ratio. Columns refer to particular carry trade strategies where long position in relatively high-yielding currency is financed with short position in relatively low-yielding one. *FX* and *Int* refer to exchange rate and interest rate return components, respectively. *Total* is the total return from particular positions.

Carry trade strategy	1H1L			2H2L			3H3L			4H4L			5H5L		
	FX	Int	Total	FX	Int	Total	FX	Int	Total	FX	Int	Total	FX	Int	Total
Pre Euro															
Mean	-1.66	7.25	5,59*	-2.35	5.00	2.66	2.80	2.54	5,34**	-1.73	1.35	-0.38	2.92	0.37	3,29**
St. Dev	15.59	3.62	15.72	14.11	2.50	14.10	10.97	1.27	11.02	9.90	0.67	9.96	6.19	0.18	6.18
Skew	-0.004	-0.237	0.024	-1.016	-0.688	-1.008	-0.543	0.218	-0.522	-0.100	0.407	-0.094	1.259	0.448	1.245
Kurt	1.763	-0.861	1.676	0.409	-0.569	0.427	0.339	-1.078	0.327	-1.047	0.618	-1.021	2.301	-0.781	2.242
Sharpe			0.36			0.19			0.48			-0.04			0.53
Post Euro															
Mean	3.69	6.59	10,28***	-0.51	4.26	3,75**	7.26	2.62	9,88***	4.94	1.33	6,27***	0.90	0.43	1.33
St. Dev	11.69	0.59	11.73	9.54	0.39	9.62	9.14	0.26	9.13	9.54	0.29	9.54	8.16	0.18	8.12
Skew	-0.169	-0.637	-0.174	-0.737	-0.654	-0.773	0.390	-0.645	0.388	-0.234	-0.594	-0.282	-0.649	0.868	-0.670
Kurt	-0.567	-0.468	-0.575	-0.410	-0.646	-0.435	-0.381	0.066	-0.274	1.019	-0.817	1.036	-0.259	0.169	-0.205
Sharpe			0.88			0.39			1.08			0.66			0.16
Full sample															
Mean	1.40	6.87	8,27***	-1.30	4.58	3,28**	5.35	2.59	7,94***	2.08	1.34	3,42**	1.77	0.41	2,18**
St. Dev	13.43	0.54	13.50	11.61	0.53	11.63	9.93	0.28	9.95	9.75	0.29	9.78	7.33	0.15	7.31
Skew	-0.150	0.276	-0.124	-0.997	-0.123	-0.979	-0.186	-0.203	-0.181	-0.179	-0.139	-0.203	-0.244	0.930	-0.258
Kurt	1.080	-0.024	1.040	0.649	-0.572	0.583	0.250	-0.687	0.290	-0.054	-0.233	-0.061	0.551	0.652	0.580
Sharpe			0.61			0.28			0.80			0.35			0.30

Appendix 2

Table 9: Three-month currency portfolio carry trade profitability

Table 8 presents the results of the three-month currency portfolio carry trade strategies over the full sample as well as during two subperiods. *Mean* is the average annualized monthly return. Figures denoted with ***, ** and * are statistically significantly different from zero at the 1, 5 and 10 percent levels respectively. *St. Dev* is the annualized standard deviation of monthly returns. *Skew* and *Kurt* stand for skewness and kurtosis, respectively, and exhibit the distribution characteristics of the returns. *Sharpe* is the annual Sharpe ratio. Columns refer to particular carry trade strategies, which are combinations of single-currency carry trades and include X highest and X lowest yielding currencies. *FX* and *Int* refer to exchange rate and interest rate return components, respectively. *Total* is the total return from particular positions.

Carry trade strategy	2 Highest/Lowest			3 Highest/Lowest			4 Highest/Lowest			5 Highest/Lowest		
	FX	Int	Total	FX	Int	Total	FX	Int	Total	FX	Int	Total
Pre Euro												
Mean	-4.01	12.25	8,24*	-1.21	14.80	13,59**	-2.94	16.15	13,21*	-0.02	16.51	16,49**
St. Dev	22.89	1.23	23.08	31.63	1.43	31.90	35.16	1.56	35.50	33.68	1.56	34.00
Skew	-0.787	-0.727	-0.724	-0.757	-0.714	-0.691	-0.921	-0.838	-0.870	-0.567	-0.869	-0.517
Kurt	0.745	-0.801	0.735	1.043	-0.749	0.988	1.840	-0.614	1.753	1.837	-0.525	1.816
Sharpe			0.36			0.43			0.37			0.49
Post Euro												
Mean	3.17	10.85	14,02***	10.43	13.46	23,89***	15.37	14.79	30,16***	16.27	15.23	31,50***
St. Dev	15.69	0.45	15.77	18.95	0.61	18.96	23.29	0.69	23.29	24.82	0.81	24.79
Skew	-0.432	0.111	-0.444	-0.147	-0.169	-0.152	-0.156	-0.291	-0.167	-0.099	-0.107	-0.102
Kurt	-0.610	-1.330	-0.613	-0.695	-1.372	-0.697	-0.819	-0.399	-0.825	-1.170	-0.603	-1.182
Sharpe			0.89			1.26			1.30			1.27
Full sample												
Mean	0.10	11.45	11,56***	5.44	14.04	19,48***	7.52	15.37	22,89***	9.29	15.78	25,07***
St. Dev	19.00	0.93	19.10	25.08	1.09	25.20	29.04	1.18	29.16	28.95	1.22	29.05
Skew	-0.787	0.202	-0.731	-0.813	-0.012	-0.750	-0.886	-0.194	-0.852	-0.517	-0.267	-0.487
Kurt	0.913	-0.471	0.861	1.764	-0.434	1.691	2.087	-0.361	2.017	1.262	-0.524	1.265
Sharpe			0.60			0.77			0.79			0.86