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THE PROFITABILITY OF SELECTED MOMENTUM STRATEGIES IN THE FOREIGN EXCHANGE MARKET

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Abstract
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PURPOSE OF THE STUDY

The purpose of this thesis is two-folded. First, I aim at updating the existing foreign exchange momentum literature with more recent data. Secondly, I study the momentum trading strategies in markets which have not been studied previously in the academic literature. The goal is to empirically test wheter or not different momentum trading strategies are significantly profitable.

DATA

The data consists of the foreign exchange rates and one month interest rates spanning from January 1993 to March 2008. The markets of which the abovementioned data are gathered are: US, UK, Switzerland, Norway, Sweden, Iceland, Japan and euro-area.

RESULTS

The results of this study indicate that momentum still exists in most of the studied foreign exchange markets. The majority of the average monthly momentum returns are positive and higher than those generated by applying an equal weighted currency portfolio. In the Japanese and US based market momentum was found very weak while the rest of the studied markets indicated signs of profitability while using momentum trading strategies. The Nordic markets indicated the largest and most significant momentum returns.

KEYWORDS

Momentum, foreign exchange, market efficiency hypothesis

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THE PROFITABILITY OF SELECTED MOMENTUM STRATEGIES IN THE FOREIGN EXCHANGE MARKET

TUTKIELMAN TARKOITUS

Tällä tutkielmalla on kaksi päätavoitetta. Ensiksi, pyrin laajentamaan olemassa olevaa valuuttakurssimomenttia käsittelevää kirjallisuutta uudemmalla lähdeaineistolla. Toiseksi, tutkin momenttikaupankäyntistrategioita markkinoilla, joita ei aikaisemmin ole tarkasteltu akateemisessa kirjallisuudessa. Tarkoituksena on empiirisesti testata ovatko erilaiset momenttikaupankäyntistrategiat tuottavia tilastollisesti merkitsevällä tasolla.

TUTKIELMAN AINEISTO

Lähdeaineisto koostuu valuuttakursseista ja yhden kuukauden koroista aikajaksolta, joka ulottuu tammikuusta 1993 maaliskuuhun 2008. Markkinat, joista lähdeaineiston tiedot on kerätty ovat seuraavat: Yhdysvallat, Iso-Britannia, Sveitsi, Norja, Ruotsi, Islanti, Japani ja euro-alue.

TULOKSET

Tämän tutkielman tulokset osoittavat, että valuuttakurssimarkkinoilla on edelleen mahdollista saavuttaa momenttituottoja. Suurin osa keskimääräisistä kuukausittaisista momenttituotoista on positiivisia ja suurempia kuin yhtä suurilla painoilla painotetun valuuttaportfolion tuotot. Japanin ja Yhdysvaltojen valuuttamarkkinoilla vaikutti siltä, että momentti on heikkoa kun taas muilla tutkituilla markkinoilla oli selviä merkkejä tuottavuudesta kun käytettiin momenttikaupankäyntistrategioita. Pohjoismaiden markkinat vaikuttivat tuottavan suurimmat ja kaikkein tilastollisesti merkitsevimmät momenttituotot.

AVAINSANAT

Momentti, valuuttakurssit, markkinoiden tehokkuus -hypoteesi

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1. Introduction

Since the launch of floating foreign exchange currencies, the foreign exchange market efficiency has been a theme of debates. The academic belief has been that price behaviour can be explained entirely with market fundamentals. Investors, however, have disagreed with this belief and argued that profitable opportunities exist due to market inefficiencies at least in the short-term. This thesis aims at finding out whether momentum trading strategies have remained profitable since 1993 to this day. I am studying more locally traded currencies, i.e. Nordic currencies, which have gained less research interest among the previous studies. To enable the comparison with the earlier academic literature, I have also included significant main currencies i.e. some of the most liquid and traded currencies. Changes after transfer to single European currency unit, euro, are also a certain point of interest, for euro has earned its place among the most significant currencies in the world.

Momentum can be defined as an empirical phenomenon contradicting market efficiency. A vast amount of literature discusses both the foreign exchange market and other financial market inefficiencies. Momentum literature was first introduced in the equity markets literature (Jegadeesh and Titman, 1993). They found that in the equity markets trading strategies buying past winners and selling short past losers generate significant abnormal returns. They applied a simple method of ranking shares based on their past performance and forming long portfolios of shares generating highest returns in the past and short portfolios of the poorest performing shares. This approach also forms the base for my study.

Recent studies have, in addition to the momentum based research, examined the profitability of different technical trading rules, excess returns from carry trading and the role of central bank interventions in the momentum profits.[1] These studies show clear empirical evidence supporting the profitability of momentum strategies. Their time range spans from the 1970s to the beginning of the 21st century and it seems apparent that momentum strategies have remained profitable throughout the period of fluctuating foreign exchange rates.

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[1] For example, about technical trading rules, see Dueker and Neely, 2007; Okunev and White, 2003; Bianchi et al., 2005; Kearns and Manners, 2004; and Kho, 1996. About carry trading, see Brunnermeier et al., 2008; Jylhä et al., 2008; and Roll and Yan, 2000. About central bank intervention, see Dominguez, 2003; and LeBaron, 1999.

Despite the vast amount of literature studying momentum based strategies, there is a lack of empirical evidence testing the momentum with more locally traded currencies. Previous studies have, almost with no exception, examined the world's leading currencies and inefficiencies in those markets. Therefore, in this thesis, I have two objectives: First, I try to find out, whether momentum still exists in foreign exchange market since 1993 and second, my objective is to expand the literature to unexamined foreign exchange markets by adding Nordic currencies to the data set.

My empirical findings indicate that momentum strategies have remained profitable also during the period of my data set. Similar statistically significant findings throughout the set of eight different currencies show that the profitability of these strategies is not random but systematically generates excess profits that can not be explained by reasoning developed in the academic literature.

A limitation of my thesis is that the data period spans only since 1993 to this date. The reason for this is that euro is one of the studied currencies and proper currency and interest rate data is not available for that prior to 1993. One could also expand the perspective of this study by applying daily or weekly observations alongside the monthly observations like some previous studies have done.

The remainder of this thesis has seven major sections. The second chapter presents the structure of the foreign exchange market and discusses its characteristics. The third chapter presents and discusses the existing academic literature in the field of foreign exchange market efficiency. Chapter 4 shows the theoretical background of the efficient market hypothesis and chapter 5 forms and presents the hypotheses for the empirical study. The sixth chapter presents the data set used as well as the methods applied in this thesis. The seventh chapter discusses my empirical findings and their position in the context of the existing academic literature and finally, chapter 8 concludes.

2. Structure of the foreign exchange market

This chapter discusses the decentralization of the foreign exchange market, the market participants, structure of the market and trading procedures in the foreign exchange market.

2.1. Decentralization

The foreign exchange market is a decentralized market, because market players are usually separated from each other and transactions are carried out with the aid of electronic media. This is resulted in two implications: fragmentation and lack of transparency (Sager and Taylor, 2006). Fragmentation can be seen in simultaneous or nearly simultaneous transactions closed at different prices (Sarno and Taylor, 2002). The foreign exchange market lacks transparency in the sense that the absence of a material market place makes price-information formation process difficult to examine and understand (Dominguez, 2003). Liquidity is also one of the characteristics of the foreign exchange market. It is the most liquid financial exchange in the world, with an estimated daily market turnover of $3.2 trillion including both spot and swap transactions, which indicated a considerable growth of 69% since April 2004. This increase was significantly stronger than the change during 2001-2004 (BIS, 2007).

As stated in the previous paragraph the foreign exchange market is much decentralized. It, however, has several physical trading centres around the world where the majority of important market participants gather. If, for example, a foreign exchange transaction is booked in the London office of a global bank, it would be counted to having been taken place in London, although it was done via electronic media and the customer was located somewhere else. Therefore, London has strengthened its position as the most important trading centre in the foreign exchange market, with a share of 34% of the total daily market volume in the world (BIS, 2007). Other large market centres include New York and Tokyo; smaller ones are Auckland, Sydney, Singapore, Hong Kong, Frankfurt and San Francisco (Sager and Taylor, 2006).

The most traded currency is US dollar. It is on one side of the transaction in approximately 86% of all transactions. At the second position is euro, with a share of 37%, followed by yen and sterling, with slightly over 15% share each (BIS, 2007). Euro-dollar is apparently the

most liquid exchange rate, followed by yen-dollar and sterling-dollar. There have been only moderate changes in the rankings during the last 15 years. However, sterling-dollar has somewhat increased its significance at a cost of yen-dollar (Sager and Taylor, 2006).

2.2. Market participants

In the foreign exchange market, there are two types of market participants: dealers and customers. Dealers have historically been responsible for the majority of total market liquidity, but the dominance is no longer evident. Some 43% of the total daily market volume takes place within the interdealer market compared to 59% in 2002 (BIS, 2007, 2002). Turnover between reporting dealers and non-financial customers, however, has doubled since 2004 (BIS 2007, 2004). Financial institutions are still the largest customer subsegment, with a share of 40% of the total daily market, but non-financial customers have gained share and currently hold approximately 17% of the total daily volume (BIS, 2007). Although a breakdown of the financial customer segment is not publicly available, Sager and Taylor (2006) comment that asset management companies and hedge funds both hold approximately 25% of the customer flow, with commodity trading advisors (CTAs), central banks and individuals accounting for the rest.

The interdealer market consists of market-makers, leverage traders, designated proprietary traders and senior risk takers. Market-makers' core responsibility in the foreign exchange market is to provide customers an access to interdealer liquidity and execute customer trades. In addition to this, their role has expanded over the past years. First, market-makers are usually allocated a book exchange rate, on which they mainly concentrate. Few years ago, market-makers traded in a range of exchange rates. Second, there is evidence that market-makers today often focus on one side of the market (Danielsson and Payne, 2001). Therefore, market-makers are no more the foreign exchange market price discoverers or do not strive for generating excess profits but rather mainly facilitate customer trades. Similarly, the ratio of sales people to market-makers has increased significantly in a number of banks.

Proprietary traders can be characterised as intra-day traders (Bjonnes and Rime, 2005). Their investment horizon varies from minutes to hours, but they do not have the capacity to hold overnight positions. Another market participant group, similar to this description, is leverage

traders, i.e. spot traders. They trade according to order flow executed by the trading desk of the bank and have investment horizon varying from few hours to days at a maximum. Activities of these traders are very short term in nature, which leads them to represent a significant source of the total market volatility, with fixed stop-loss spots usually defined around every position. Actually, proprietary traders are often encouraged by senior management to focus a more significant portion of their total risk budget on longer investment horizon than leverage traders and to avoid excess trading. Proprietary desk risk budgets are generally reduced overnight but remain positive, reflecting the complexity of monitoring positions outside of business hours.

Finally, there is another group of market participants, which consists of senior risk-takers working for large investment banks (Sager and Taylor, 2006). These market participants have similar targets as designated proprietary traders, but they trade with a considerably larger risk budget, which reflects their senior position, experience and historical performance within the market. Like the proprietary traders', senior risk-takers' risk budgets are also normally reduced overnight. These market participants are also motivated to focus larger portions of their risk budgets on longer horizon investments (Sager and Taylor, 2006).

2.3. *Trading in the interdealer market*

A number of fundamental trends can be identified in the interdealer market. Industry consolidation has drastically decreased the number of banks that hold the majority of the interdealer market (BIS, 2007). Second, the overall risk aversion within the interdealer market has increased after the 1998 Long-Term Capital Management crisis, which led to the decline in the amount of risk capital of individual traders (Sager and Taylor, 2006). Another trend, which is also related to the previous point, is the fact that the accuracy and efficiency of risk management tools and infrastructure associated with dealer activity has improved considerably in recent years (Geithner, 2004). Amount of risk capital allocated to an individual trader is in many banks a function of historical performance, rewarding a trader with a larger risk capital allocation from positive past performance and penalizing from bad performance. A normal approach is that bad performance is carried by the individual trader alone, i.e. losses decrease the next month's risk capital portfolio. Profits, however, are

generally shared with the bank, i.e. the risk capital available to a trader in the next month increases by a certain percentage of the last month's reported profits.

Trading risk is also controlled with a number of other methods, for example daily maximum drawdown or capital loss, and Daily Value at Risk limits. The deviation from daily directive levels of these methods, however, does not automatically lead to a decrease in trader's risk portfolio, but instead acts as a signal to senior management and triggers a notification that a detailed explanation is needed (Sager and Taylor, 2006).

Most interbank trading is conducted electronically. The functionality of electrical trading systems is essentially equivalent, offering ex ante anonymous limit order bid-ask pricing to market participants. Electronic Brokerage System (EBS) and Reuters, together, account for approximately 85% of total interbank activity (Sager and Taylor, 2006).

Customers operate with dealers to gain access to the interbank liquidity. Voice trading continues to be a significant part of the customer foreign exchange market but electronic systems are rapidly gaining market in customer-dealer space. The emergence of these systems is not likely to increase the amount of order flow data and therefore has limited opportunities improve the transparency of customer foreign exchange market (Sager and Taylor, 2006).

Activities in the customer foreign exchange market are related to hedging of the translation risk of international sales and costs. The other and probably more important source of activity is the management of currency exposure in investment portfolios. Order flow is regarded as the most important source of private information in the foreign exchange market, and the sign of trades is considered to be more informative than the associated nominal value of these trades (e.g. Lyons, 1995). This position as the most important source of information can be explained by the heterogeneity evident within this segment of the foreign exchange market: informational asymmetries, different reaction paces to new data discoveries, varied opportunity sets and risk-return anticipations (Sager and Taylor, 2006). Customers can be divided into groups in several different ways, which are presented in the following paragraphs.

2.4. Customer classification

Customers can be classified according to their activeness in the foreign exchange market. It is anticipated that only a narrow fraction of daily customer flows are conducted by rational investors maximizing profits. Majority of the flows represent the non-price-level hedging activity. Passive customers get their foreign exchange exposure from the acquisition and divestment of underlying assets, like international securities, or from the international sales and costs by companies.

Passive customers can react to this abovementioned exposure in one of two ways. It can be left unhedged, which means that the customer is willing to neglect the currency exposure, probably assuming that profits from active currency management average to zero over the long term (Sager and Taylor, 2006). Another way that assumed currency exposure can be addressed by passive clients is by the use of hedges that return exposure back to an underlying strategic benchmark position. These hedges are usually used without strategic consideration of the underlying exchange rate. Both hedging strategies seem to contradict at least to some extent the efficient market hypothesis (EMH), which assumes risk-neutrality of investors, because passive customers seem to be willing to pay premium to other, active market participants, to make them assume their short-term foreign exchange risk exposure (Kearns and Manners, 2004).

Active customers introduce the foreign currency exposure of their portfolios as a part of their active trading strategy. This strategy is closest to the efficient market hypothesis, but can be still questioned from the risk-neutrality perspective. According to active currency strategies, investors grant currency managers the power of decision to add value to underlying portfolios by using suitable hedges within certain limits that make sure that the risk of these hedges is in line with ex ante investor expectations. Strategic currency benchmarks have usually been defined in relation to a set of assets or liabilities to which the investor has a long-term exposure. Recently, investor interest has increased in currency programmes conducted on the basis of an underlying theoretical capital value separate to this underlying exposure with a point of reference interest rate equal to zero or risk-free rate (Sager and Taylor, 2006).

Another way to classify customers is to group them according to their level of sophistication into two groups: informed and uniformed customers. This classification reflects the ability of

a specific customer to understand the effects of new data discoveries concerning future exchange rate returns. Probably the clearest example of an informed customer is a central bank, which has access to order flow data and studies the innovations in fundamentals relevant to currency rate formation. Central bank foreign exchange activity is one of the most important sources of private information, which reflects both the sophistication of the actions and the volume of associated flows. Customer differences and breakage of the EMH conditions can also be observed in the investment styles of actively trading informed customer groups. These groups have various information sources and exploit it in various ways, which results in differences in exchange rate expectations (Sager and Taylor, 2006).

Many commodity trading advisors use solely technical analysis. Their investment procedure usually consists of a range of optimized technical or chartist trading rules that have no theoretical interpretation. News to this customer group is historical price performance over any time period ranging from minutes to years with detailed trading rules exploiting key support and resistance levels, moving average levels, over-bought and over-sold methods and a range of other technical rules. In the contrary, publicly disclosed economic news is used only indirectly; to the extent they form a historical price pattern (Sager and Taylor, 2006). This way of trading in the foreign exchange market has been confirmed by Taylor and Allen (1992), for example. From a theoretical perspective, assuming EMH holds, these traders are acting irrationally. However, if these methods can generate continuing excess returns, these market participants are actually acting rationally and taking advantage of the proven characteristics of the foreign exchange market (Taylor et al., 2001).

Hedge funds and currency overlay managers initiate order flow principally according to publicly available information, with an expected payoff horizon ranging from approximately one to three months. The investment procedure is usually very strictly defined using pre-specified trading rules, which are based on theoretical relations with economic variables and exchange rates. Most hedge funds and currency overlay managers also use similar technical analysis as CTAs. Risk control currency managers employ option replication processes into client portfolios to minimize and shrink the downsize risk related to foreign exchange exposure. As a result, these managers react to price and data discoveries indirectly if they have an impact on the downsize risk profile of their customer portfolios (Sager and Taylor, 2006).

Final customer classification method used by Sager and Taylor (2006) is the customer's reaction speed to new data innovations. Hedge funds are usually among the most rapid to respond to significant new information by instantly trading to achieve the optimal portfolio in the light of this information. Currency overlay companies, in the contrary, usually employ investment strategies that increase or reduce active hedges progressively during following several trading sessions when they react to new data innovations. Variation in customers' reaction speed to new data discoveries can provide dealers with useful information about the sign and size of customer trades, and the likely persistence of this trading. As long as a dealer sees order flow from active, informed customer it makes sense to suppose that this is only a small part of the total trade and the remaining parts are likely to come into the market throughout the current trading session (hedge funds) or several trading sessions (currency overlay managers).

3. Related studies on market efficiency

Foreign exchange market efficiency research began in the 1960s and studies tested for the randomness of exchange rate changes. For example Poole (1967) studied ten different flexible exchange rate time series during 1950-1962 and found significant evidence against the random walk hypothesis. Logical extension to the early research of randomness of exchange rates was to test for the randomness of deviations of interest rate parity and Fisher hypothesis (Cumby and Obstfeld, 1981). Fisher hypothesis suggests that nominal interest differentials between similar assets only denominated in different currencies can be wholly explained by the expected exchange rate change during the holding period. The data consisted of seven currency nominated deposits and exchange rates during 1974-1980. The authors rejected Fisher hypothesis in all cases when assuming a 5% confidentiality level and in three cases when a 1% confidentiality level was used.

3.1. Momentum strategies research

Momentum is an empirical phenomenon contradicting market efficiency. If the market is efficient, there should not be any excess profit potential when using simple trading rules. Fama and French (1996), who, in general, support the Efficient Market Hypothesis, report

that the momentum profits could be attributable to market inefficiency. There are, however, many other theories, which try to explain momentum.

There is a great amount of momentum literature studying equity markets. For example, Jegadeesh and Titman (1993, 2001) have studied the profitability of momentum based strategies in equity markets. They found that momentum strategies are profitable throughout the 1990s. This study suggests that the original results are not attributable to data snooping. They apply strategies that invest in the equities that have performed well in the past and sell short the equities that have performed poorly. Jegadeesh and Titman (1993, 2001) also state that the findings can not be explained by systematic risk or a delay in share price adjustment as a reaction to common factors. This study has been replicated in several national markets and the results have been in line with those of Jegadeesh and Titman (1993, 2001). For example Rouwenhorst (1998) found momentum profits significantly positive in the sample of 12 countries.

One possible source of momentum profits is the relative importance of common market-wide factors and company-specific information. Chordia and Shivakumar (2002) test the relation between momentum profits and common macroeconomic variables relating to the business cycle. They report that momentum strategies are profitable only during expansionary periods, and can generate negative, yet insignificant, returns during recessions. The study estimates returns one month ahead with lagged macroeconomic variables, like dividend yield, default spread, T-bill yield and term structure spread. Chordia and Shivakumar (2002) found that the estimated element of the returns is the major reason to the discovered momentum profits.

Behavioural bias is one of the most commonly used explanations for momentum regardless of the asset type. Two basic behavioural biases that can cause momentum in the market are underreaction and overreaction to newly discovered information. When underreaction is concerned, investors can not interpret new information in timely fashion and therefore prices adjust to reflect new information with a lag. The overreaction reflects an investors' cognitive bias, which extrapolates old information into the future. Jegadeesh and Titman (1993) initially assumed that individual share momentum could be a result of investor underreaction to company-specific information. Hong et al. (2000) found that momentum strategies are more profitable among shares with scarce analyst coverage. This is in line with the hypothesis that company-specific information is distributed only gradually among the investors. Daniel et al.

(1998) and Barberis et al. (1998) assume that the momentum profits are attributable to investors' cognitive bias. There is also evidence that past trading volume can forecast the size of future price momentum and whether it is permanent (Lee and Swaminathan, 2000). They also state that past trading volume is an estimate for investor interest in a share and therefore may have an effect on the speed, at which new information is adopted and reflected in the prices.

In the case of underreaction investors can not apply information in a timely fashion. Therefore, asset prices do not react at all or react too moderately to new information. Therefore, prices will only gradually approach to their intrinsic value, which means that price movements are lagged. This causes short-term trends, as prices slowly adjust to values, which corresponds to the newly revealed information.

Investors' cognitive biases also cause the behavioural bias that has the opposite impact. The overreaction is attributable to investors learning that fundamentals are better than previously assumed. Majority of the investors adjust their expectations according to this newly revealed information, so that they fully reflect new information. However, some investors extrapolate this positive news into the future. Prices adjust so that they correspond to their intrinsic values. However, due to the extrapolation of information into the future, prices continue to rise and exceed the value that reflects the fundamentals. Both forms of this behavioural bias force asset prices to deviate from their fundamental values permanently. They can, however, also strengthen the profitability of value strategies. The theory of overreaction bias assumes that prices will finally adjust to reflect the new information correctly.

Another behavioural finance theory explaining the existence of momentum is the disposition effect. This refers to the pattern that people, in general, avoid realizing paper losses and seek to realize paper gains. This effect can be found in a large number of small gains being realized, and only few losses. The disposition effect can also be observed in aggregate share trading volumes. When the market is bullish, trading volume grows. Similarly, when the market turns bearish, trading volume appears to decrease (Ritter, 2003).

3.2. Carry trade research

Momentum phenomenon is closely related to the carry trade research, which is another breach against the efficient market hypothesis besides momentum and is often referred to as the forward premium. Carry trade is a strategy, in which an investor sells a certain currency with a relatively low interest rate and uses the funds to purchase a different currency yielding a higher interest rate. A trader using this strategy attempts to capture the difference between the rates. It is based on the documented failure of the uncovered interest rate parity.[2] Academic literature has attempted to explain this failure and the reported positive returns from carry trades, but has so far not succeeded in finding a consensus explanation. Brunnermeier et al. (2008) found that carry trades are exposed to currency collapse risk. Therefore, the portfolios are negatively skewed, which can be, according to Brunnermeier et al. (2008), explained by the transitory changes in the funding liquidity available for the speculators. As the liquidity is decreased over a short period, traders rapidly liquidate their positions, causing sudden adjustments in the exchange rates against the carry traders.

Jylhä et al. (2008) found that the inflation risk is higher in the countries that are in the carry trade long portfolio than in the countries of the short portfolio, and that under limited arbitrage capital carry trades are profitable. Moreover, they report that the increase in arbitrage capital reduces returns generated from carry trade portfolios. They also state that it is probable that the transaction costs enabling the execution of the strategy for the non-professional investors have considerably decreased over time. Finally, Jylhä et al. (2008) report that carry trade activity results in an appreciation (depreciation) of the currencies in the carry trade long (short) portfolio.

Roll and Yan (2000) challenge the accuracy of the statistical conclusions drawn in the early forward premium puzzle research. Yet, there is wide empirical support for the profitability of carry trades, which can not be explained by the inaccuracy of the statistical inference procedures.[3] Another explanation for the carry trade premiums is the assumption that the forward premium includes a time-varying risk premium element, which is negatively correlated with the expected change in the exchange rate resulting in the forward premium puzzle.[4] Models based only on risks have, however, been challenged in the literature. For

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[2]Uncovered interest rate parity condition states that the difference in interest rates between two countries is equal to the expected change in exchange rates between the countries' currencies. If this parity does not exist, there is an opportunity to make profit.

[3] See, for example, Burnside et al., 2006; Lustig et al., 2008; and Jylhä et al., 2008.

[4] See, for example, Fama (1984); Backus et al. (2001); Alvarez et al. (2007); and Verdelhan (2007).

example, Lustig and Verdelhan (2007) report that consumption growth risk can expound the cross section of carry trade portfolios solely when the representative agent is very risk averse. Bansal and Shaliastovich (2006) suggest that long-run risks can explain the forward premiums when consumption volatility is stochastic and agents' substitution elasticity is at an enough exalted level. Moreover, Mark and Wu (1998) suggest that the excess returns resulting from the breach of the uncovered interest rate parity can not be explained by intertemporal asset pricing model with habit persistent utility.

Another category of the carry trade research discusses the information processing imperfections. Albuquerque (2007) studies agents who do not observe monetary policy directing shocks completely accurately. Gourinchas and Tornell (2004) show that agents learn about the characteristics of the interest rate shocks. However, they show the existence of an irrational misassumption about the second moments of interest rate forecasts that is never vanished, which leads to the forward premium puzzle. Furthermore, Bacchetta and van Wincoop (2006) suggest that it is rational for agents to limit the trading with their foreign currency portfolios if the costs overrun the profits generated by actively managing the portfolio. Han et al. (2007) explain the forward premium puzzle by behavioural variables by applying a model of agents overreacting to the private signs.

Market microstructure frictions form the final source of forward premium literature. Burnside et al. (2007) form a model where a risk neutral market maker has an adverse selection problem between informed and uninformed traders, because it is not generally known, which traders are informed and which uninformed. Appreciation or depreciation of the currency determines the probability of informed orders and as a result, bid and ask forward rates are defined asymmetrically. The profitability of carry trades leads to continuation of the phenomenon when carry trade costs and financing side effects are present (Plantin and Shin, 2008).

3.3. Trading rule research

Another way to test the market efficiency hypothesis besides carry trading is to use filter rules. Probably the simplest rule is a j percent rule, which means buying the currency when the exchange rate increases j percent above its most recent minimum and selling when it

decreases *j* percent below its most recent peak. If foreign exchange market is efficient and the uncovered interest rate parity holds, this strategy should not generate any profits after interest rate costs. Several studies have tested filter rules and many of them indicate that simple rules are profitable (e.g. Levich and Thomas, 1993). However, the optimal filter rule size can often not be clearly defined ex ante, and filter rules can generate substantial subperiod losses even if they turn out to be profitable during a longer term. More indirect evidence on the profitability of trading rules was found by Engel and Hamilton (1990). They found that US dollar was subject to "long swings" that are subject to mechanical trading rules.

According to Fama (1965), exchange rates should fluctuate randomly if the foreign exchange market is completely efficient and taking into account interest rate differentials and disclosure of new information. There is, however, vast amount of empirical evidence that does not support the random walk hypothesis in the foreign exchange market and that simple trading rules are actually applied by traders. Taylor and Allen (1992) found evidence that the foreign exchange dealers in London use technical analysis rather than fundamental analysis in their short-term forecasting. However, they also found that fundamental analysis progressively increases its significance when the trading horizon widens. Sweeney (1986) studied six different currencies against US dollar using simple filter rules and found excess profits, which can not be explained by the risk premium. Schulmeister (1988) found that US dollar and Deutsche mark (the most traded currencies in the 1970s and 1980s) follow a pattern of upward and downward trends, which are interrupted by non-directional movements. He also states that this has been exploited by currency speculators using technical analysis, which again reinforces the pattern. Therefore, Schulmeister (1988) claims that the foreign exchange market between US dollar and Deutsche mark is not weakly efficient.

Levich and Thomas (1993) studied five currencies during 1976-1990 using technical trading models. They found that the earlier documented profitability of these methods continued to be successful during the time period of their study. Taylor (1994) studied foreign exchange futures during 1988-1990 using the channel rule, which takes long (short) positions when the price exceeds (goes below) the maximum (minimum) price observed over the previous L days. The results showed that channel rules can be profitable and confirmed the notion of the foreign exchange market inefficiency. Yet, the author states that the result can also be explained by the risk premium or by central bank interventions. Gencay (1999) studied five currencies over a time period spanning from 1973 to 1992 and found that simple moving

average rules provide significant, correct sign predictors when estimating the future spot currency rates.

Kho (1996) studied futures of four different currencies during 1981-1991 using different technical trading rules. The findings of his study are well in line with the abovementioned studies and confirm the excess returns from technical trading strategies. However, Kho (1996) states that these returns are not excessive when taking into account the risk premium and therefore, they are not unusual compared to the volatility. Neely et al. (1997) applied trading rules for six exchange rates series during 1974-1995. They found significant variance in the excess profits. However, the excess returns during the period under review remained clearly positive and they found no evidence that these excess profits are compensation for bearing systematic risk. LeBaron (1999) studied Deutsche mark and Japanese yen during 1979-1992 using daily and weekly data. He made similar findings as in the previous studies. In addition, he studied the impacts of Federal Reserve intervention in the foreign exchange market and the causal relation between the intervention and trading rule profitability. He found a clear causal relation. However, he states that the relation is not easy to interpret for Federal Reserve intervention may have several objectives, e.g. overall price stability.

Marsh (2000) studied Markov switching models as a technical trading strategy instead of simple trading rules used by, for example, Sweeney (1986). In the Markov model currency is always in one of two unobserved states. The currency is expected to appreciate by μ_1 % if it is in state 1 and by μ_2 % if it is in state 2. If just one of μ_1 and μ_2 is negative, the different states correspond to appreciation and depreciation. The Markov model also generates the probabilities of switching from one state to another. If the probability of remaining in a state for successive periods is high and μ_1 and μ_2 are of opposite sign, then the process is characterized by sustained periods of appreciation followed by sustained periods of depreciation. This kind of pattern can generate excess returns. A more recent study is the one performed by Okunev and White (2003). They used seven currencies during 1975-2000. They confirmed that technical trading rules have remained profitable during the 1990s like the empirical evidence had previously showed for the 1970s and 1980s. The authors state that these returns are significantly larger than what can be explained by transaction costs or risk. The trading strategy applied by Okunev and White (2003) was different from many other studies researching profitability of trading rules, because it does not require frequent trading.

The strategy applied the momentum technique of Jegadeesh and Titman (1993) to a sample of eight currencies.

To some extent, the foreign exchange market efficiency has also been tested using data from the 21st century. Dueker and Neely (2007) combined simple trading rules and Markov switching models and created ex ante trading rules for the Deutsche mark, euro, Japanese yen, British pound, and Swiss franc markets. They found that Markov switching models deliver strong portfolio returns in the foreign exchange market and these portfolios outperform simple moving average rules significantly. No clear source for the trends could be identified but permitting the mean to depend on higher moments of the exchange rate distribution modestly increased returns. Bianchi et al. (2005) studied G7[5] countries' currencies during 1980-2003. They found that momentum still exists in the foreign exchange market and is significantly temporary, however, skewed towards short periods. They also found that excess profit opportunities can be exploited by large trading institutions but transaction costs hinder small corporate or retail clients from benefiting them.

3.4. Regression based models

Regression based models of spot and forward exchange rates are widely used methods for testing the foreign exchange market efficiency. Taylor (1995) defines the forward rate as the agreed rate for currency exchange at a certain time in the future. The forward premium is the percentage difference between the current forward rate of a certain maturity and the current spot rate. Empirical studies testing efficient foreign exchange markets theory with regression models, which explain the change in spot rates with forward rates, have found evidence against the efficient markets theory (e.g. Fama 1984). Fama (1984) studied nine major currencies in 1973-1982 and found that the data do not support the efficient market theory. He brings four possible explanations to this. The first explanation is that the market truly would be inefficient. The second explanation is that the spot rates are affected by governmental intervention. The third explanation is the "doomsday theory", which suggests that there are often brief periods when the distribution of the anticipated changes in the exchange rates is highly skewed (e.g. when market participants expect the monetary policy so that it will have a

[5] G7 countries include Canada, France, Germany, Italy, Japan, the U.K., and the U.S.

significant effect on the inflation rate relative to other countries). Finally, the fourth explanation is that the empirical findings result from stochastic deviations from the purchasing power parity.

Empirical studies using regression models have revealed a special feature about the regression coefficient. Estimates of the coefficient against the dollar are usually closer to negative than positive (Froot and Thaler, 1990). Many authors have interpreted this so-called "forward discount bias" as evidence that forward premium falsely expects the direction of the change in the spot rate. However, these interpretations ignore the impact of the constant term in the regression model. The negativity of the coefficients means, however, that the more the foreign currency is at a premium in the forward market; the less the home currency is expected to depreciate over the period of maturity of the forward rate (Taylor, 1995). Early regression models testing the foreign exchange market efficiency used the logarithm of the spot rate and regressed that onto the lagged logarithm of the forward rate. These models usually estimated the regression coefficient close to one (e.g. Frenkel, 1976). It was, however, found that standard regression analysis was not appropriate, because the series are non-stationary.

During the 1970s the trend in the foreign exchange market efficiency literature was towards more econometric and sophisticated methods. This meant that early tests for a random walk in the spot rate were replaced by linear regression models of uncovered interest rate parity. These were again a replaced application of the use of sophisticated rational expectations estimators, which enabled the use of more accurately sampled data (Hansen and Hodrick, 1980). This increasing sophistication of the models provided increasingly strong evidence against the simple, no-risk-premium speculative efficiency hypothesis (Taylor, 1995).

3.5. Sources of excess returns in the foreign exchange market

The sources of excess momentum returns in the foreign exchange market are a point of debate with several theories trying to explain the market efficiency anomaly. The two most common explanations for the inefficiencies in the foreign exchange market are central bank intervention and noise trading. One hypothesis is that noise traders, who decide about their trading strategies according to directional movements, dominate the foreign exchange market. Shleifer and Summers (1990) found that this kind of trading activity can make asset prices

deviate from their true values. In addition, even if individual market participants notice mispricing of assets, they may be unwilling to trade against the market due to their own loss limit restrictions. As a matter of fact, individual traders may be willing to stimulate serial correlation in the foreign exchange market if they think that investors' sentiment will remain unchanged in the short term. They can trade with the market over a relatively short period and, therefore, reinforce the currency prices' deviation from their true values (Shleifer and Summers, 1990).

Another way to explain the inefficiency in the foreign exchange markets besides noise trading is the central bank intervention. Central banks lack profit motive when trading. The primary objective of any central bank is not to generate profits from foreign exchange, but instead decrease the volatility and to make sure that currencies trade at politically acceptable levels. Central bank intervention generates non-random exchange rate changes, and several empirical studies have tested if this creates profitable trading opportunities in the foreign exchange market. For example, Sweeney (1997) states that in the case of US Federal Reserve and Swedish Riksbank, excess returns have a significant but rather small effect on central bank intervention. Szakmary and Mathur (1997) studied five currencies during 1977-1991 and again found significant, transaction cost adjusted excess profits using trading rules. The study also revealed that these trading rule profits and central bank interventions are related. Frenkel et al. (2001) studied the foreign exchange market interventions of the European Central Bank (ECB), and their short and medium term effects. They found that the interventions, in general, were not effective and if they had an effect, it was only minor and tended to be reversed on the following trading day. Thus, the analysis revealed that ECB was able to affect the exchange rate only in the intervention day, if at all. Szakmary and Mathur (1997) and LeBaron (1999) found that trading against central bank interventions with moving average trading rules generated excess returns and demonstrate that central banks suffered losses.

On the contrary to the studies presented earlier in this chapter 3.5, Neely (1998) studied the intervention of US Federal Reserve and found that during the longer trading periods central bank interventions can be profitable. It is not generally accepted that central banks' intervention leads to excess trading profits. Neely (2000) found that excess returns are generated prior to the central bank intervention. The study used intra-day data and revealed that rather than causing excess profit opportunities, the central bank interventions resulted

from currency movements that had previously generated the technical trading rule profit opportunities.

Rejection of the simple, risk-neutral efficient markets hypothesis could be explained by the market participants' risk aversion or by the departure from the pure rational hypothesis, or both. If market participants are risk averse, the uncovered interest parity condition may be biased by a risk premium, for example because agents demand higher rate of return than the interest differential in return for the risk of holding non-domestic currency. Therefore, arbitrage will make sure that the interest rate differential is equal to the expected gain from holding foreign currency plus a certain risk premium (Taylor, 1995). Researchers have studied risk premium as a function of the variance of forecast errors, or of exchange rate movements (Domowitz and Hakkio, 1985 and Giovannini and Jorion, 1989). According to Taylor (1995) these models have not, however, faced significant success and do not seem to be applicable to different data sets and time periods. They have remained unable to explain the excess profits from forward market speculation.

Another way to explain the rejection of the simple efficient markets hypothesis besides risk aversion is that there is a failure of the expectations component of the joint hypothesis. These are, for example, the "peso problem", rational bubbles, learning about regime shifts (Lewis, 1988), or inefficient information processing (e.g. Bilson, 1981). The peso problem means the circumstances where agents put a small probability to a large change in the economic fundamentals, which does not appear in the sample. This can cause a skew in the distribution of forecast errors even if the expectations of the agents are rational, and therefore may generate evidence of excess returns from currency speculation. In addition to the peso problem, rational bubbles can also show up as non-zero excess returns even if agents are risk-neutral. Likewise, when agents are learning about their environment they may not be able to completely take advantage of clear arbitrage opportunities, which can be found in the data ex post. Problem with these explanations, however, is that a large number of empirical studies have found that the direction of bias is always the same, i.e. slope is close to minus unity (Taylor, 1995). For example, when studying the relation of US dollar appreciation with learning about the US money supply process, Lewis (1989) found persistence in the forward rate errors, which is evidence against the learning explanation.

4. Theoretical background

In this chapter, I discuss some background theory behind the efficient markets hypothesis and the applications of this hypothesis to the foreign exchange market. The asset market theory of exchange rate determination, which was discovered by Dornbusch (1976), Frenkel (1976) and Mussa (1976), usually emphasises the significance of expectations, which are invisible and challenging to model empirically. This theory suggests that exchange rates are only the relative prices of assets, which are established in organised markets and where prices are altered immediately to the current, correct price according to the market. In this sense, exchange rates are similar to any other asset prices traded on organised markets (Frenkel and Mussa, 1980). Some doubts have been expressed towards the successful application of this theory in the foreign exchange market. The main criticism has been that these models fail to take into account the activities of central banks on the foreign exchange market, which can have a significant effect on the performance of exchange rates and the efficiency of the foreign exchange market. These effects can be particularly strong when they are left unattended by other market participants (Baillie and McMahon, 1989).

The initial idea of the efficient market hypothesis was discovered by Fama (1965), who defined an efficient market as consisting of a "large number of rational, profit maximisers actively competing with each other to predict future market values of individual securities and where important current information is almost freely available to participants". Therefore, if asset prices are to fulfil their function as signals for resource allocation they need to process and transfer all relevant information concerning future market development to the asset suppliers and demanders. As a result, exchange rates must always totally reflect all relevant and available information to foreign exchange market to be efficient. Foreign exchange market efficiency, however, is quite different from economic efficiency and perfect markets because market efficiency does not require that the resulting market equilibrium prices are optimal from any perspective (Baillie and McMahon, 1989). The definition of market efficiency is thus much narrower than that of Pareto optimality in the economic theory. When market is efficient, prices reflect all relevant information available and therefore no excess profit opportunities are available. These prices are formed at equilibrium and are conditional on all information available at their establishment. Therefore, the market is regarded to be an efficient processor of all new information with prices moving when the market responses to

this information. The concept of efficient foreign exchange market is actually only the theory of informationally efficient financial markets with the international extension (Baillie and McMahon, 1989).

A dynamic theory of the exchange rate obliges the consideration of expectations. There is, however, no theory concerning the formation of expectations that can be derived from the fundamental principles of economic behaviour. Rational expectations equilibrium has the characteristic that there are not any systematic errors in the future forecasts. This means that prices must change randomly so that one can not predict the changes from past behaviour of the prices. Market efficiency is usually divided into three categories (Baillie and McMahon, 1989):

1. *The weak form*, where current prices are assumed to include all the information that is enclosed in the past prices.
2. *The semi-strong form*, where current prices include all the publicly known information, including their own past prices.
3. *The strong from*, where prices reflect all information that is possible to know. Thus, the activities conducted by analysts and other insiders eliminate any opportunities to permanently earn above average returns from any investor class. The strong form is not likely to hold in the foreign exchange market because undisclosed non-random central bank intervention takes place in the markets.

Geweke and Feige (1979) have further categorized the semi-strong form into two more specific classes:

a. *Single market efficiency*, where all publicly available information important for a single exchange rate is included in the information set.
b. *Multi market efficiency*, where the information set contains available information on all other exchange rates and/or all available international economic information.

Suppose that at a specific time point t, market participants have available a given information set Ω_t^m, which is presumed to have production costs equal to zero. This given information set needs, in efficient market, to be equal to the information set Ω_t, which contains all relevant information required for price establishment, so that $\Omega_t^m = \Omega_t$. Since all available information at time $t - j$ (j = 1,2,...) is also available at time t, it needs to be true that $\Omega_{t-j} \subseteq$

$\Omega_{t-j+1} \subseteq \ldots \Omega_t$, so that information set Ω_t includes the current and past values of the recent variables and information on how they are interrelated. Therefore, Ω_t includes the probability distribution of future prices conditional on the information held within Ω_t, so that moments can be calculated. Participants in an efficient market know Ω_t and also completely understand the implications of this information. Therefore,

$$f^m(p_{t+n} \mid \Omega_t^m) = f(p_{t+n} \mid \Omega_t) \tag{1}$$

where f^m represents the market participants' specification of the density function of future prices. A fall of the Eq. (1) can happen if market participants either do not have all the information needed or they do not completely understand its implications. This concept is related to the way agents or market participants create expectations. It is evident that market participants need to form rational expectations to make Eq. (1) hold. They are, in other words, assumed to be aware of the true economic model and take advantage of all available and relevant information when forming their expectations concerning the future price performance. In this case the price becomes an adequate statistic of the information distribution (Baillie and McMahon, 1989).

In weak form of market efficiency, market participants create expectations in an optimal way dependent on the fact that Ω_t only includes past prices. Therefore, market participants take the optimal advantage of their limited of information. An important consequence of the EMH is that all the investors are unable to make unexploited profit opportunities by using the available information in their forecasts of future price development.

If expectations are uncertain, the situation is slightly different. In this case, all the investors are unable to make unexploited profit in excess of the normal market rate of return. This indicates that unexploited profits can not be generated by applying ex ante available information. Because now investors do not know future prices with certainty, but they are stochastic, it may be possible for individual market players to make excess ex post profits. Still, the expectation of these profits is zero, so that the ex post profit or loss of an investment with an n period maturity is derived by

$$Z_{t+n} = R_{t+n} - E(R_{t+n} | \Omega_t^m) \quad (2)$$

where R_{t+n} is the actual rate of return and $E(R_{t+n} | \Omega_t^m)$ is the expected rate of return. When market is efficient,

$$E(Z_{t+n} | \Omega_t^m) = 0 \quad (3)$$

so that Z_t is a fair game regarding the sequence Ω_t^m.

The above equality assumes risk-neutrality of the investors. Risk-averse investors will need risk premium to cover the risk they undertake. This leads to an equilibrium model that has to identify the relation between the expected return and the risk associated with the particular investment. This is a very common definition of an efficient market and when it is tested empirically, it requires understanding of the information set Ω_t^m and the existing equilibrium model defining pricing behaviour. As a result, testing the market efficiency hypothesis is a joint test of the equilibrium model of pricing and the efficient use of information. Rejection of the hypothesis can be attributable to inappropriateness of either one or both of the joint conditions.

There is a practical problem in empirical testing of the above joint hypothesis, which concerns the specification of Ω_t^m. Given an information set Ω_t^m, it is possible to find out if this information is totally enclosed in the current prices. Again, it is evident that there is a natural relation between information sets and the normal definitions of market efficiency, as stated by Fama (1965, 1970). Fama (1970) also suggested that efficiency demands that actual prices, or rates of return, follow a fair game procedure relative to expected equilibrium prices. Because expected equilibrium prices are not required to be constant or follow a linear growth pattern, efficiency does not mean that prices follow a random walk with a zero mean or constant drift.

4.1. Martingale, sub-martingale and random walk models

One perspective on testing market efficiency is based on the assumption that the equilibrium value of the security rate can be written in terms of the expected return on the security. At time t, the expected return at time t+1 given Ω_t can be regarded as the expected relative change in the price of the security. Therefore,

$$E(R_{t+1}|\Omega_t) = \frac{E(p_{t+1}|\Omega_t) - p_t}{p_t} \tag{4}$$

where R is the rate of return in one period of time and p is the price of the security. The expected price for the next period of time is thus given by

$$E(p_{t+1}|\Omega_t) = [1 + E(R_{t+1}|\Omega_t)]\, p_t . \tag{5}$$

When we are discussing the foreign exchange market p_t can be interpreted as the spot rate S_t, which leads to

$$E(S_{t+1}|\Omega_t) = [1 + E(R_{t+1}|\Omega_t)]\, S_t \tag{6}$$

The term $E(R_{t+1}|\Omega_t)$ can be interpreted as the expected yield from a spot market speculation, which means that the market speculator buys currency at the spot exchange rate S_t to make profit later when selling at the rate of $E(S_{t+1}|\Omega_t)$. Therefore, the expected future exchange rate is heavily dependent on the assumptions of the expected yield.

To be able to test market efficiency, a more accurate definition of the equilibrium yield is needed. To form this kind of model, it is essential to assume that financial and foreign exchange markets are perfect. This means that no transaction costs, taxes, risk of default, credit availability constraints or any other market imperfections exist. Free availability of information is also required and foreign and domestic assets and liabilities need to be considered as identical in their properties of maturity and risk. Thus, the only difference between domestic and foreign assets and liabilities is the currency denomination.

Furthermore, monetary authorities are assumed to make no interventions in the foreign exchange market and market participants are assumed to form rational expectations and be neutral towards risk.

4.1.1. Martingale models

In the martingale-random walk model, it is assumed that expected return is zero, so that $E(R_{t+1} \mid \Omega_t) = 0$. Using Eq. (5) leads to

$$E[(S_{t+1} - S_t) \mid \Omega_t] = 0 \tag{7}$$

which suggests that the sequence S_t is a martingale concerning information set Ω_t. Therefore, all available information about the future performance of the spot rate is enclosed in S_t by the activities of market participants. Using other information, for example the historical spot exchange rates, will not improve the forecast. Therefore, the spot rate at the time t is the most accurate forecast of the spot rate at time t+1 and for all other future points of time $t + j$. This implies that the probability of appreciation and depreciation of a currency is equal, which can be formulated as

$$P(\Delta S_t > 0) = P(\Delta S_t < 0) = 0.5. \tag{8}$$

A conclusion of martingale theory is that adjustments in the exchange rates are serially uncorrelated, which makes them appear random. Random here does not, however, mean chaotic. Actually, random means that because exchange rates react to new information which is disclosed randomly, the spot rate will move according to an unpredictable pattern, which, however, is a rational reaction to this new information. In addition, the sequences Z_{t+1} and X_{t+1} where $Z_{t+1} = R_{t+1} - E(R_{t+1} \mid \Omega_t)$ and $X_{t+1} = S_{t+1} - E(S_{t+1} \mid \Omega_t)$ are both fair games, which implies that $E(Z_{t+1} \mid \Omega_t) = E(X_{t+1} \mid \Omega_t) = 0$. This can be alternatively indicated that for the given information sets, the expected profit from speculation is equal to zero. Moreover, this means that the examination of past price changes of S_t do not result in ex ante profit opportunities. (Baillie and McMahon, 1989)

After the paper published by Working (1958), it has been widely accepted that the random model of prices observed on speculative markets are determined according to the expectations of rational market players positioning unique talents in the processing and the distribution of market information. When new information is disclosed in the market, this changes the expectations of market participants, which, in an efficient market, results in an immediate adjustment of prices. This, in turn eliminates all excess profit opportunities.

New information can appear only randomly, because if one or more market participants can anticipate information before its disclosure, it is neither new nor random information. New information can be defined to be independent of all information available previously. Therefore, the price changes following the discovery of new information are also independent of past price changes. The main difference between the martingale model and the random walk model is that when the martingale model assumes that market equilibrium can only be described in terms of expected yields or expected price changes, the random walk model suggests that the distributions of yields or price changes are independent and identical. This implies that not only the equilibrium value, but also the whole distribution of yields, or price changes, must be taken into account when describing the equilibrium. However, it is only required that the distribution is stationary, so that the random walk model is a special case of the more general martingale model.

Formally, the random walk model can be written as

$$S_{t+1} = S_t + \varepsilon_{t+1} \tag{9}$$

where $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_s) = \begin{cases} \sigma^2, s = t \\ 0, s \neq t \end{cases}$. Also ε_t is presumed to be a series of identically distributed, independent random variables so that the joint density $f(\varepsilon_t \varepsilon_s) = f(\varepsilon_t) f(\varepsilon_s)$, for $s \neq t$. In the contrary, the martingale model only assumes ε_t and ε_s to be uncorrelated rather than independent. The random walk model arises several testable restrictions concerning the spot exchange rate S_t. Firstly, Eq. (9) means that

$$S_{t+1} = S_t + \sum_{j=1}^{l} \varepsilon_{t+j} \tag{10}$$

and therefore the conditional expectation based on available information at point of time t and denominated by E_t is $E_t S_{t+1} = S_t$. The forecast error is thus defined by

$$e_{t,l} = \sum_{j=1}^{l} \varepsilon_{t+j} \,. \tag{11}$$

The forecast error has zero mean and variance of $l\sigma^2$ so that the forecast variance is relative to the forecast time horizon, or lead time l.

4.1.2. Sub-martingale models

The simple random walk and martingale models can only be derived under strict conditions for the foreign exchange market. In addition to the interest obtained abroad, a rational market speculator will also consider the opportunity costs of a domestic investment because speculation needs capital. The speculator is indifferent when the expected yield of the domestic and foreign investment is equal. This is true when

$$E\,[(1+r)\,|\,\Omega_t\,] = E\,[(1+r_f)(S_{t+1}/S_t)\,|\,\Omega_t\,], \tag{12}$$

where r = domestic interest rate and r_f = foreign interest rate. Presuming that r, r_f and S_t are known with certainty at time point t, it means that

$$\frac{E(S_{t+1}\,|\,\Omega_t) - S_t}{S_t} = \frac{r - r_f}{1 + r_f} \tag{13}$$

and

$$E(S_{t+1}\,|\,\Omega_t) = \frac{1+r}{1+r_f} S_t \,. \tag{14}$$

The pure random walk model and martingale models both assume that the expected yield is zero. In the situation above, the expected yield can be defined with

$$E(R_{t+1} \mid \Omega_t) = \frac{r - r_f}{1 + r_f} \tag{15}$$

which is zero only if $r = r_f$, so that the domestic interest rate equals the foreign interest rate. When assuming more realistic circumstances where domestic and foreign interest rates of similar assets are not equal, it leads to

$$E(S_{t+1} \mid \Omega_t) \neq S_t, \text{ or } E(R_{t+1} \mid \Omega_t) \neq 0. \tag{16}$$

Under the above inequalities S_t is called a sub-martingale with the given information set Ω_t. Moreover, the sequence $(-S_t)$ which appears when $E(R_{t+1} \mid \Omega_t) < 0$, is called a super martingale. The forecasting model of Eq. (14) is seemingly uncomplicated, because as a matter of fact only three explanatory variables are needed, which are the spot exchange rate S_t, and the matching interest rates r and r_f.

When the stock and securities markets are in concern, it is usually assumed that risk neutral, profit maximising market participants require a positive return from an investment for compensating the undertaking of non-diversifiable risk. Baillie and McMahon (1989) consider this too strict a condition to be applied in the foreign exchange market. When considering speculation in the foreign exchange spot market, the strategy of a speculating investor with expectations of negative yield from the purchase of spot foreign exchange, assumes a one period credit in the foreign currency. The expected return from this variation of spot market speculation can, on the other hand, be assumed to be positive with a negative yield expectation from a purchase of spot foreign exchange.

A testable implication of the hypothesis, that the expected yield in a certain period is unequal to zero, is based on the fact that in an efficient market no investment method based on information set Ω_t can generate more than a normal market return, based on a buy and hold

strategy. The hypothesis does not mean that in an efficient market the exchange rate follows a simple random procedure. It, however, requires the randomness of the deviations of the exchange rate from their expected values. It can not be immediately omitted that the expected return based on some systematic determinants follows a pattern, which is not white noise.

The most important point regarding the existence of market efficiency is solely that the deviation of the actual returns or exchange rates from their expected values are random, i.e. the sequence $R_{t+1} - E(R_{t+1} \mid \Omega_t)$, or $S_{t+1} - E(S_{t+1} \mid \Omega_t)$, is a fair game. This is suggesting that in an efficient market the expected value of abnormal returns is zero. It emphasizes the significance of the more accurate definition of the equilibrium exchange rate pattern, when testing the foreign exchange market efficiency hypothesis (Baillie and McMahon, 1989).

4.1.3. Random walk models

Another special case with significant role in the efficiency theory literature, is the so-called random walk model with a drift or trend parameter. This is based on the assumption that the expected return is constant (c) over time, which leads to

$$E(R_{t+1} \mid \Omega_t) = c\,. \tag{17}$$

This assumption means that the expected relative exchange rate change is also constant, so that

$$\frac{E[(S_{t+1} \mid \Omega_t) - S_t]}{S_t} = c\,. \tag{18}$$

This assumption includes an assumption of a constant difference between domestic and foreign interest rates, which was also stated in the Eq. (14). Assuming that the foreign exchange market is efficient, the relative changes in the exchange rate varies randomly around a fixed value, which is defined by the interest rate differential

$$\frac{S_{t+1} - S_t}{S_t} = c + \varepsilon_{t+1} \tag{19}$$

where ε_{t+1} is a white noise disturbance term as defined in the Eq. (9).

The logarithmic transformation of Eq. (19) leads us to the following model, which is often applied in the empirical literature:

$$\log S_{t+1} - \log S_t = c + \xi_{t+1} \tag{20}$$

which uses the approximation $\log(1+c) = c$. In the Eq. (20), ξ_t is lognormal. The sequence S_t is, along with the definition in the Eq. (20), a sub or supermartingale, depending on whether $c > 0$ or $c < 0$. If the assumption that the random variable ξ_{t+1} is identically distributed is added, the Eq. (20) can be interpreted to be the random walk model including a trend parameter (Baillie and McMahon, 1989).

4.2. Practical problems with the concept of an efficient market

The hypothesis of a perfect market makes some difficult assumptions, which seem to deviate it somewhat from reality. According to Fama's (1970) definition, there is a world free of imperfections, where information is available without a cost to all market participants and where transaction costs do not exist. Market participants are presumed to have similar expectations and assess new information in a completely similar way. These assumptions are far from realistic but they have sometimes been defended on the grounds that even if market participants hold non-similar expectations and make different evaluations, simpler forms of the hypothesis are too unspecific to be tested. Later research has examined the consequences more thoroughly and derived some significant new theorems, important in reformulation of the EMH.

Research by Grossman and Stiglitz (1980) found an explicit cost of information and suggested that the Fama's (1970) concept of market efficiency is in conflict with competitive equilibrium when information costs do exist. It implies that prices in competitive markets do not completely reflect all information available, because then there would be no compensation for the market participants that invest in obtaining new information. Therefore, if prices

always completely enclose all relevant information, there is no motivation for individual market participants to gain access for new information, which can be found from the price system without a cost. In a competitive market, prices are a fixed set of information for all market participants, who are assumed to be identical. Therefore, if any significant group of investors invest in obtaining new information, equilibrium is not possible.

The other extreme, where no market participants have the ability to invest in obtaining new information also means that there is no equilibrium in the market. This is because all market participants can realise profits at given prices by yielding new information in the market. The existence of information costs means that even if prices completely reflect all information available it is impossible for equilibrium to exist.

The theorem established by Grossman and Stiglizt (1980) is, in general, the consequence of a free-rider problem, which can result in the erosion of futures markets as a means of processing and distributing information. This also emphasises the problems encountered by comparative static equilibrium analysis in trying to capture the prominent characteristics of speculative markets. If the circumstances are such that prices include all information, which informed market participants gather, other traders can get the information for free by just watching market prices. Therefore, speculative markets can exist only if they are not efficient from the informational perspective. As a result, those who invest resources in acquiring new information, i.e. choose to be informed, earn higher returns than those who remain uninformed. But this excess return exists only to compensate for the cost of gaining new information. As long as the information collection is competitive with free entry and exit, no excess returns can be earned by obtaining new information. In equilibrium the marginal cost of obtaining the information equals to the marginal revenue from using additional information in the market. If the information production industry, however, is not fully competitive, information can have insider features and excess profits can be generated.

An extension of the analysis by Grossman and Stiglitz (1980) was developed by Verrechia (1982), who used a model with the same basic structure but uses a differential information assumption and continuous information cost function. Verrechia (1982) presents that the information each market participant obtains is a decreasing function of the informativeness of the price mechanism and that the informativeness of the price is non-decreasing because information costs decrease. According to Verrechia (1982), an increase in noise suggests that

the informativeness of the price mechanism decreases. Therefore, the increase in obtaining information by agents emerging from an increase in noise does not, in equilibrium, offset the decrease in information discovered by the price attributable to the increased noise.

A further issue concerns the dynamics of the situation. Given the time pattern of transactions, the information externality emerged via trading can only jeopardise the existence of a speculative market, if an informed market participant has no opportunity of trading before sharing the informational advantage with other market participants. Speculative markets can not be totally efficient at every point of time. Inefficiency from the dynamic perspective is a part of the procedure of finding and distributing information, and it is the consequence of some market players being able to trade at a transitory informational advantage.

The excess profit is a gain from being more rapid in obtaining new information and interpreting it correctly as well as reinterpreting the existing information available. This competition for a temporary control of informational advantage defines the informational quality of prices as well as the pace at which changes in expectations and underlying information are distributed. Private speculating investors are not willing to conduct stabilizing speculation measures, when market distortions exist. In the case that central bank makes interventions in the foreign exchange market, speculators may think that this market power will be used to influence the market, so that it generates profit for the central banks at the expense of the speculators (Baillie and McMahon, 1989).

Figlewski (1978) developed another model, which achieves an equilibrium solution in a speculative market, where prices do not completely reflect all information available. He assumes that market players have heterogeneous information, price expectations and various wealth expectations. Because the market values information according to its ability to generate financial wealth, and not based on its fundamental value, the exceptional of a market player, holding limited wealth, can lead to the market price being undervalued by the market. Therefore, the market seems to be inefficient. On the other hand, it is possible that less precious information is overvalued. As a result, market players that hold undervalued information generate profit and those who have overvalued information carry a loss. Over time this pattern leads to a redistribution of wealth to the informed market participants with increasing informational content of market prices, but the condition for market efficiency is not fulfilled. A consequence of the model is that a market player with overvalued information

is not completely pushed out of the market, because the loss is limited to the total market overvaluation of the possessed information.

The existence of transaction costs also brings an argument for the case that usually prices in equilibrium do not include all relevant information available. This is because, in this case, it would not be profitable for rational profit maximising speculators to incur with arbitrage a total equivalency between the actual price and expected price, as assumed by the martingale model. The size of transaction costs, however, linked to the foreign exchange business is moderately small and would only cause small deviations from the martingale model. Because the return on risky assets depends on the market's view of the valuation of that asset in the future, it is essential to consider the problem of sequential trading.

Let us assume a straightforward speculative market for a risky asset, where the current price in the time point t depends on the expected spot price in the time point $t + 1$. Assuming rational expectations, market players will also notice that the price at time point $t + 1$ depends on the expected price in the time point $t + 2$ and so on. Sequence structure means that false variables may affect the solution. This may also happen when expectations are homogeneous. Therefore, completely irrelevant variables may affect the equilibrium and this may lead to the existence of infinity of equilibriums. This in turn means that completely speculative bubbles are in line with the assumption of rational expectations. Moreover, the burst of the bubble and the return of market being defined by fundamentals are also in line with the assumption of rational expectations. If the foreign exchange market is informationally efficient and the expectations of future prices become indefinite, asset prices depending on expectations are also indefinite, and thus are defined in an arbitrary way similar to Keynes' analogy between a beauty contest and the financial market operation. This vagueness means that it becomes unachievable to define accurately the information, which is essential for the pricing of assets, because any information which agents assume to be essential and relevant gradually gets to be reflected in the equilibrium prices of these financial assets (Baillie and McMahon, 1989).

5. Formation of the hypotheses

In this thesis I use the approach proposed by Jegadeesh and Titman (1993, 2001) and applied by Okunev and White (2003). Jegadeesh and Titman (1993, 2001) used technical indicators in ranking stocks from best to worst. This strategy orders the superiority of the sample stocks according to the previous *n*-month return. Thereafter, a long strategy or short strategy is applied, including the stocks with the highest previous *n*-month return (top decile) in the long portfolio and the lowest *n*-month return (low decile) stocks in the short portfolio.

I use two different methods for ranking the currencies. First, I use a similar method as applied by Okunev and White (2003), which includes using a variety of combinations of moving averages. The aim is to identify the most attractive and the least attractive currencies according to momentum using these moving average rules. My second ranking approach is similar to that of Jegadeesh and Titman (1993), which simply ranks the currencies according to their past performance.

After the best and worst currencies have been identified, a long or short position is initiated by buying the highest momentum currency and selling short the weakest momentum currency. If, for example, a trader in Sweden notices that Norwegian krone is the least unattractive currency and US dollar is the most attractive currency relative to Swedish krona, using this moving average strategy the dealer would sell futures contracts on Norwegian krone and buy futures contracts on US dollar. One of the problems with previous studies is that most of them have selected only a limited number of moving average strategies, using the strategies that are widely employed by traders. Filtering a limited number of moving average strategies may bias the returns and the results to those strategies that have performed well ex post. Another problem here is data snooping; the selection of only a few moving average strategies may well be a result of examining the data and making the selection based on the features of the selected data period and currency set. In order to avoid this, I use a large number of different moving average strategies.

This study applies the perspective of a long-term investor with a foreign currency exposure in the Euro area, Sweden, Norway, Iceland, Switzerland, Japan, the UK and the US. This could be a global equity manager with stock portfolio including stocks in the abovementioned

countries. This could also be a multinational corporation with exports to all of the countries mentioned above. Finally, the foreign exchange position is revaluated after different holding periods.

If applying these moving average rules turns out to be successful in generating excess returns that can not be explained by the existence of transaction costs, this would suggest that the foreign exchange market is not completely efficient and the foreign exchange rates are not completely determined by fundamental information. Therefore, the following hypothesis can be formed and tested:

> *H_1: Foreign exchange market is efficient and no excess returns can be generated by using moving average strategies.*

This thesis has two methods for testing the efficiency of the foreign exchange market. The complementing method uses and analyses the profitability of simpler trading rules in the foreign exchange market. Therefore, another complementing hypothesis can be formed and tested

> *H_2: Foreign exchange market is efficient and no excess returns can be generated by using simple momentum strategies.*

The following chapter introduces the data set and methodology how I will empirically test the above two hypotheses.

6. Data and methodology

This chapter presents the data used in this thesis, provides descriptive statistics about the data set and gives an overview of the methodology used. The data set consists of eight currencies during the time period ranging from January 1993 to March 2008. My methodology is based on two momentum strategies, which both are based on the Jegadeesh and Titman (1993, 2001) approach.

6.1. Data set

This thesis studies the exchange rates of euro and seven other currencies; Swedish krona, Norwegian krone, Icelandic krona, Great Britain pound, United States dollar, Japanese yen and Swiss franc. Originally, the data set also included Russian rouble, but it was left out from the final sample due to lack of reliable interest rate data for a sufficiently long time period. The data set consists of the daily exchange rates between these eight currencies during the period ranging from January 1, 1993 to March 31, 2008. Total number of observations is 224,336. The monthly currency returns are calculated using each currency as the domestic currency. The currencies used in this thesis were chosen because Nordic currencies have gained less research interest and furthermore, there have not been many studies after the launch of single European currency unit, euro, in the beginning of year 2002. Euro is among the most traded currencies in the world with US dollar, British pound, Japanese yen and Swiss franc (BIS, 2007). Because Danish krone is quite strictly bound to euro, it was not included in the currency portfolio.

The exchange rate and interest rate data used in this empirical study is collected from a large Nordic bank. The interest rates are one-month rates, using the daily one-month Euribor as a domestic currency for euro. However, the one-month Euribor was not available until December 30, 1998. Therefore, prior to this I have applied the one-month DEMNBOR, which was the Deutsche mark nominated interest rate. In addition, I have also applied STIBOR, REIBOR, NIBOR, USDLIBOR, GBPLIBOR, TIBOR and CHFLIBOR for Swedish krona, Icelandic krona, Norwegian krone, US dollar, UK pound, Japanese yen and Swiss franc, respectively. This set of interest rate data includes a total of 32,048 observations.

Although currency trades also take place on weekends, trading on Saturdays and Sundays is limited. Therefore they are excluded from the data set. Because this empirical study consists of eight different currencies and foreign exchange markets, calendar holidays are not completely identical. Any weekdays with missing data have been replaced with the value of the previous day. In the final data set, the total count of the banking days is 4,006.

Both the base and interest-adjusted monthly returns, as defined in more detail in the methodology Chapter 6.2, were calculated using each currency as a base currency. Originally,

the returns were calculated in two different ways: First, as presented in the Eq. (21) and second, as a logarithmic change, i.e. $\ln S_t - \ln S_{t-1}$ for the base returns and $\ln S_t - \ln F_{t-1}$ for the interest-adjusted returns. The latter method is, to some extent, used in the existing academic literature (see for example Neely, 2000), because it mitigates the problem of the different absolute value of percentage change, when the exchange rate first rises and then falls to the same point as in the start. As we can see from Tables (11) and (12) in the Appendix A, the difference between these methods is not significant and therefore I apply the first, more straightforward method in calculating the currency returns. The monthly returns are calculated using the mid exchange rates in the last day of the month.

Table 1 shows that Icelandic krona has, during the period ranging from February 1, 1993 to March 31, 2008, experienced the most significant depreciation of the currency portfolio studied in this thesis. This average 0.275% depreciation value against the equally weighted currency portfolio is, however, not significant even at the 10% confidence level. Swiss franc, in the contrary, has appreciated the most during the period under review. Again, its average 0.109% return is not significantly different from zero even when using the 10% confidence level. The average base currency returns are not significantly different from zero, because of the relatively large standard deviations, as we can see from the Table 1.

Table 1 – Descriptive Statistics, Base Currency Returns (simple returns)

Descriptive Statistics (Base Currency Returns)

	Europe	Sweden	Norway	Iceland	UK	US	Japan	Switzerland	Equal
Europe									
Mean return (%)	N/A	0.000	0.049	-0.192	0.051	-0.096	0.050	0.102	-0.005
Median return (%)	N/A	0.014	0.116	-0.062	-0.032	-0.276	-0.345	-0.013	-0.048
Std. Deviation (%)	N/A	1.598	1.500	2.518	1.957	2.562	3.310	1.126	1.153
t-Statistic	N/A	0.003	0.440	-1.028	0.355	-0.505	0.202	1.223	-0.059
Sweden									
Mean return (%)	0.025	N/A	0.067	-0.169	0.072	-0.074	0.076	0.130	0.018
Median return (%)	-0.014	N/A	0.051	-0.148	-0.187	-0.327	-0.361	-0.204	0.071
Std. Deviation (%)	1.589	N/A	1.862	2.906	2.361	2.932	3.716	2.118	1.860
t-Statistic	0.211	N/A	0.486	-0.786	0.413	-0.338	0.275	0.829	0.132
Norway									
Mean return (%)	-0.026	-0.033	N/A	-0.222	0.021	-0.129	0.019	0.075	-0.042
Median return (%)	-0.116	-0.051	N/A	-0.101	-0.022	-0.259	-0.580	-0.210	-0.144
Std. Deviation (%)	1.508	1.858	N/A	2.811	2.319	2.717	3.526	1.869	1.649
t-Statistic	-0.236	-0.238	N/A	-1.065	0.124	-0.643	0.073	0.544	-0.344
Iceland									
Mean return (%)	0.259	0.257	0.304	N/A	0.292	0.142	0.303	0.364	0.275
Median return (%)	0.062	0.148	0.101	N/A	-0.225	-0.016	-0.278	-0.021	0.020
Std. Deviation (%)	2.672	3.035	2.929	N/A	2.678	3.067	4.126	3.009	2.591
t-Statistic	1.308	1.143	1.401	N/A	1.473	0.625	0.991	1.634	1.430
UK									
Mean return (%)	-0.013	-0.017	0.032	-0.223	N/A	-0.137	0.020	0.089	-0.036
Median return (%)	0.032	0.187	0.022	0.226	N/A	-0.165	-0.446	0.116	0.038
Std. Deviation (%)	1.960	2.349	2.304	2.584	N/A	2.172	3.386	2.277	1.666
t-Statistic	-0.092	-0.099	0.186	-1.164	N/A	-0.854	0.078	0.528	-0.290
US									
Mean return (%)	0.161	0.159	0.203	-0.051	0.185	N/A	0.178	0.266	0.157
Median return (%)	0.277	0.328	0.259	0.016	0.165	N/A	-0.027	0.059	-0.043
Std. Deviation (%)	2.567	2.940	2.727	2.990	2.180	N/A	3.296	2.905	2.209
t-Statistic	0.848	0.731	1.005	-0.230	1.143	N/A	0.728	1.237	0.961
Japan									
Mean return (%)	0.056	0.057	0.101	-0.142	0.091	-0.073	N/A	0.148	0.034
Median return (%)	0.347	0.362	0.584	0.279	0.448	0.027	N/A	0.368	0.341
Std. Deviation (%)	3.217	3.606	3.421	3.934	3.287	3.207	N/A	3.109	3.030
t-Statistic	0.235	0.214	0.397	-0.486	0.373	-0.307	N/A	0.643	0.151
Switzerland									
Mean return (%)	-0.089	-0.086	-0.041	-0.278	-0.037	-0.183	-0.050	N/A	-0.109
Median return (%)	0.013	0.205	0.210	0.021	-0.116	-0.059	-0.366	N/A	-0.049
Std. Deviation (%)	1.118	2.096	1.854	2.855	2.278	2.879	3.170	N/A	1.581
t-Statistic	-1.080	-0.553	-0.297	-1.315	-0.222	-0.856	-0.213	N/A	-0.932

The data set consists of monthly returns for individual currencies from January 1993 through March 2008. The period consists of 182 months. The base currency is denoted in the far left and the columns to the right give the return statistics of the seven other currencies in relation to the base currency. Equal currency returns are calculated relative to the base currency and equal column calculates the currency return assuming an equal proportion allocated to the seven non-domestic currencies. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 2 presents the interest-adjusted currency returns for the currency portfolio. These are the actual returns for the investor investing in these currencies. It is notable that the interest-adjusted average returns are more significantly different from zero than the base returns.

Quite surprisingly, Japanese yen is the currency that has depreciated the most during this period, taking interest rate differential into account. It has experienced an average negative return of 0.388% in relation to the equally-weighted currency portfolio. However, the return is only significantly different from zero, when applying the 10% confidence level. This is quite in contrast to what Okunev and White (2003) found, but could be explained by the different time period and different set of currencies used. We can also note that when observing interest-adjusted returns, the rankings of performance differ considerably from what they are in the Table 1. The Icelandic krona is now the star-performing currency, even though it was the most depreciating currency compared to other currencies of the set in the Table 1. On the other hand, the Swiss franc no longer is the most appreciating currency, but one of the poorest performers. This difference in rankings between base and interest-adjusted returns is in line with what Okunev and White (2003) state.

Table 2 – Descriptive Statistics, Interest-Adjusted Returns (simple returns)

Descriptive Statistics (Interest-Adjusted Currency Returns)

	Europe	Sweden	Norway	Iceland	UK	US	Japan	Switzerland	Equal
Europe									
Mean return (%)	N/A	0.057	0.149	0.224	0.185	-0.065	-0.220	-0.053	0.040
Median return (%)	N/A	0.029	0.170	0.273	0.099	-0.290	-0.608	-0.153	-0.009
Std. Deviation (%)	N/A	1.622	1.511	2.528	1.964	2.581	3.296	1.122	1.153
t-Statistic	N/A	0.477	1.328	1.195	1.268	-0.339	-0.901	-0.636	0.463
Sweden									
Mean return (%)	-0.031	N/A	0.110	0.190	0.149	-0.099	-0.250	-0.081	-0.002
Median return (%)	-0.029	N/A	0.124	0.305	-0.119	-0.330	-0.680	-0.343	0.035
Std. Deviation (%)	1.609	N/A	1.883	2.923	2.377	2.955	3.708	2.128	1.872
t-Statistic	-0.264	N/A	0.792	0.877	0.846	-0.451	-0.911	-0.514	-0.012
Norway									
Mean return (%)	-0.126	-0.075	N/A	0.094	0.055	-0.197	-0.350	-0.179	-0.111
Median return (%)	-0.170	-0.124	N/A	0.164	0.037	-0.297	-0.876	-0.427	-0.176
Std. Deviation (%)	1.514	1.879	N/A	2.813	2.338	2.740	3.505	1.878	1.653
t-Statistic	-1.120	-0.540	N/A	0.450	0.318	-0.972	-1.346	-1.284	-0.907
Iceland									
Mean return (%)	-0.157	-0.102	-0.013	N/A	0.009	-0.243	-0.382	-0.207	-0.157
Median return (%)	-0.272	-0.304	-0.163	N/A	-0.437	-0.235	-1.125	-0.500	-0.358
Std. Deviation (%)	2.642	3.014	2.896	N/A	2.660	3.051	4.094	2.984	2.561
t-Statistic	-0.803	-0.459	-0.061	N/A	0.045	-1.074	-1.260	-0.935	-0.825
UK									
Mean return (%)	-0.146	-0.093	-0.001	0.060	N/A	-0.239	-0.382	-0.198	-0.143
Median return (%)	-0.099	0.119	-0.037	0.439	N/A	-0.196	-0.766	-0.138	-0.054
Std. Deviation (%)	1.962	2.362	2.320	2.591	N/A	2.174	3.376	2.287	1.670
t-Statistic	-1.005	-0.532	-0.007	0.311	N/A	-1.485	-1.527	-1.169	-1.155
US									
Mean return (%)	0.131	0.186	0.273	0.335	0.287*	N/A	-0.122	0.081	0.167
Median return (%)	0.291	0.331	0.298	0.236	0.197	N/A	-0.351	-0.114	0.012
Std. Deviation (%)	2.587	2.969	2.756	3.009	2.187	N/A	3.311	2.929	2.233
t-Statistic	0.684	0.846	1.337	1.501	1.773	N/A	-0.496	0.374	1.012
Japan									
Mean return (%)	0.326	0.385	0.471*	0.545*	0.495**	0.229	N/A	0.263	0.388*
Median return (%)	0.612	0.685	0.883	1.137	0.771	0.352	N/A	0.486	0.654
Std. Deviation (%)	3.223	3.626	3.431	3.966	3.308	3.246	N/A	3.119	3.045
t-Statistic	1.365	1.431	1.852	1.855	2.018	0.950	N/A	1.139	1.718
Switzerland									
Mean return (%)	0.065	0.126	0.214	0.293	0.251	0.004	-0.165	N/A	0.113
Median return (%)	0.153	0.344	0.428	0.503	0.138	0.115	-0.484	N/A	0.177
Std. Deviation (%)	1.118	2.118	1.874	2.879	2.302	2.913	3.172	N/A	1.599
t-Statistic	0.790	0.802	1.541	1.371	1.471	0.016	-0.701	N/A	0.950

The data set consists of interest-adjusted monthly returns for individual currencies from January 1993 through March 2008. The period consists of 182 months. The base currency is denoted on the far left and the columns to the right give the return statistics of the seven other currencies with respect to the base currency. Equal currency returns are calculated relative to the base currency and equal column calculates the currency return assuming an equal proportion allocated to the seven non-domestic currencies. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

6.2. Methodology

In this thesis I apply two empirical methods, which should complement each other. First, I test the existence of momentum in the foreign exchange market with a more simple method, which simply invests in the foreign currencies that have performed best during the last 1, 3, 9 or 12 months. This method was applied in the equity momentum literature by, for example, Jegadeesh and Titman (1993). The second method is somewhat more sophisticated, using a significant number of different moving average combinations when determining the investment strategy for the next investment period. To my best knowledge, this method was first introduced and applied in the foreign exchange market by Okunev and White (2003).

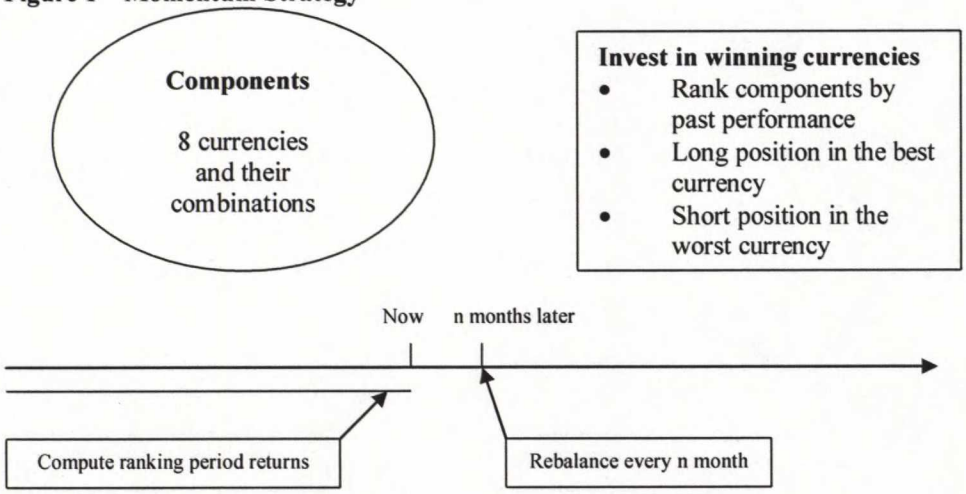
6.2.1. Momentum strategy

The momentum strategy applied in this thesis was first introduced in the equity literature. Studies on momentum in the equity markets have generally used ranking and holding periods spanning from three to twelve months. I will also use a shorter period of one month to test the existence of momentum from a short-term perspective. Another difference is that momentum strategies in the equity literature commonly include all the equities in their portfolio, so that the top half forms the long position and the bottom half the short position. I use a more aggressive and risky strategy and create the long position from the past top performing currency and short the poorest performing currency. In addition, I use each currency as a base currency.

Fig. 1 illustrates the momentum strategy applied. First, monthly returns are calculated for the ranking period. At the end of the ranking period R, currencies are ranked in ascending order according to their performance during the ranking period R. Based on these rankings I form the long and short positions. The long position is taken with the best performing currency and the poorest performing currency is sold short.

At the end of holding period H, the currencies are ranked according to their performance on the ranking period and the portfolio is adjusted accordingly. As the rankings of the currencies vary over time, they can be bought in one period and sold short in the other.

Figure 1 – Momentum Strategy



There are an unlimited number of possibilities to form a momentum portfolio, because the ranking and holding periods can be chosen in infinite different ways. The focus of my thesis is on the simple means of estimating the short-term momentum impact, which mitigates the data snooping problem. To keep the number of observed combinations reasonable, I use ranking periods of one, three, six, nine and twelve months and holding periods of one, three, six and nine months. The total number of combinations based on these ranking and holding periods is 20 and it is studied using each currency as a base currency to expand the view and thus generate more reliable results.

The next section discusses the moving average strategy applied in this thesis. These strategies are basically based on the same framework and the main difference is related to the currency ranking process.

6.2.2. Moving average strategy

This thesis applies the moving average method introduced by Okunev and White (2003). This strategy is concentrated on the long-term exchange rate adjustments by adjusting the portfolio on a monthly basis. Although daily trading strategies could have the advantage of recognising the changes in the market sentiment more accurately, this could also cause a high frequency of noise trading that could turn out to be expensive when taking the transaction costs into account. The performance of individual technical trading rules may vary significantly from one subperiod to the next, as noted by Okunev and White (2003).

The returns are calculated using each currency as the domestic currency, which means that all possible combinations of currency returns for the eight different currencies are calculated. This set of currency returns is defined to be the base currency returns series. The base period applied in this thesis is one month. The base currency returns from time point $t-1$ to t are calculated as follows:

$$R_{B,t} = \frac{S_t}{S_{t-1}} - 1 \tag{21}$$

where the base currency return is $R_{B,t}$, the spot exchange rate at the time point t is S_t, and the spot exchange rate at the time point $t-1$ is S_{t-1}. Every exchange rate is expressed as the ratio of units of domestic currency per unit of foreign currency. Furthermore, I also calculate a comparable series of currency returns adjusted for interest rate differentials. A trader using futures contracts to invest in foreign currencies, or borrowing in one country to invest in another, would encounter these returns in reality. The futures contract price at time point $t-1$ is defined as F_{t-1}. The returns adjusted for interest rate differentials from time point $t-1$ to t are calculated as follows:

$$R_{I,t} = \frac{S_t}{F_{t-1}} - 1 \tag{22}$$

where $F_{t-1} = S_{t-1} \exp\left[(r - r_f) * \left(\frac{1}{12}\right)\right]$, $R_{I,t}$ is the return adjusted for interest, r is the domestic interest rate, and r_f is the foreign interest rate. Note that

$$R_{I,t} \approx (r_f - r) * \left(\frac{1}{12}\right) + \frac{S_t}{S_{t-1}} - 1. \tag{23}$$

It is possible to further divide the actual returns for the foreign exchange investor into two separate components: firstly, the return attributable to the interest differential between the foreign and domestic currency and secondly, the return attributable to clean currency

appreciation. Direct observation of Eq. (22) discloses the return attributable to the interest rate differential to be

$$(r_f - r) * \left(\frac{1}{12}\right) \tag{24}$$

and the return attributable to the clean currency appreciation is

$$\frac{S_t}{S_{t-1}} - 1. \tag{25}$$

Equations (23) and (24) reveal that the return from investing in a moderately strong currency can be cushioned by the corresponding interest rate differential between the foreign and domestic countries.

The idea of this empirical study is to replicate the performance of the moving average rules, using the returns from the base currency to define the currency allocations and the currency returns adjusted for the interest rate differentials, and calculate the actual materialised returns. Therefore, this strategy would simulate the returns of an investor who uses futures contracts in the foreign exchange market or borrows in one currency to invest in another. This strategy is quite straightforward: I use the base currency to calculate a short-run and a long-run moving average using previous monthly returns for each currency in comparison to the domestic base currency. After this, I organise these seven foreign currencies in the order of superiority according to the difference between the short-run moving average and the long-run moving average. Thereafter, according to the rank of the currency, a long position is applied to the currencies with the highest rank, and a short position to the currencies with the lowest rank. Finally, to test if the results are systematic, the strategy is replicated applying each of the eight currencies as the base currency.

After ranking the currencies, the moving average rules are to be determined. At time point t the short-run moving average and the long-run moving average are computed using the following equations

$$SR_{j,t} = \frac{R_{B,t} + (j-1)SR_{j,t-1}}{j} \tag{26}$$

and

$$LR_{k,t} = \frac{R_{B,t} + (k-1)LR_{k,t-1}}{k} \tag{27}$$

where $SR_{j,t}$ is the short-run moving average at time point t applying the j previous months of returns and $LR_{k,t}$ is the long-run moving average at time point t applying the previous k months of returns.

In this analysis, the short-term moving average values vary from one to twelve months and the long-term moving average values vary in the range of two to 36 months. In all cases of the short-term/long-term moving average rules, the number of months used to calculate the short-term moving average must be less than those used to calculate the long-term moving average. For instance, when the one month short-term moving average is applied, the currency position is determined using $SR_{1,t} - LR_{2,t}, SR_{1,t} - LR_{3,t}, ..., SR_{1,t} - LR_{36,t}$. When the two months short-term moving average is applied, the currency position is determined with $SR_{2,t} - LR_{3,t}, SR_{2,t} - LR_{4,t}, ..., SR_{2,t} - LR_{36,t}$. As a whole, a total number of 354 moving average combinations are observed. These combinations are consolidated at the end of each month to rank the currencies.

At the end of each period for each moving average combination, the seven foreign currencies are organised according to their order of superiority from the best to the worst by applying the return-based momentum indicator, which equals to the difference between the short-term and the long-term moving average. The currency with the largest positive difference is the most lucrative and is defined as Rank 1, and so on for Rank 2 and other rankings. The least attractive currency is defined as Rank 7. These rankings are set for each of the moving average rules and each of them will define both a Rank 1 and Rank 7 currency. All the short-term/long-term moving average combinations are given equal weights. Thus, each of the foreign currencies gets a weighted allocation according to what the positions are taken. The

rankings are revaluated on a monthly basis and positions are then adjusted accordingly, if necessary.

Like Okunev and White (2003), this thesis uses four different strategies that apply the short-term/long-term moving average combinations. The first rule was presented above and weighted all momentum strategies equally. In this strategy short-run moving average rules vary from one to twelve months and the long-run from two to 36 months. However, the number of months applied in calculating the short-term moving average is always less than the number of months applied in determining the long-term moving average. Therefore, the *first strategy* consists of 354 moving average combinations, which are all equally weighted. According to this strategy, an investor invests in the currency with the best rank determined, as discussed above, and sells short the currency with the worst rank.

The *second strategy* applies the same moving average rules as the first strategy. However, according to the second strategy, an investor invests in the top three ranks with a one-third weight to each, and sells short the lowest rank. The *third strategy* is similar to the first strategy with the exception that it only includes moving average combinations with the short-term moving average months varying from four to six and the long-term months varying from five to 36 months. The total number of moving average combinations in the third strategy is therefore 93. The *fourth strategy* is similar to the second strategy. The fourth strategy, however, only includes moving average combinations with short-term moving average months varying from four to six and long-term moving average months varying from five to 36 months.

With all the above strategies, rankings can be precisely the same using different individual moving average rules. As indicated in the equations (23) and (24), the moving average rules apply base currency returns when defining the short-term/long-term moving average ranks. Tests are carried out using each currency as a base currency in its turn. Fig. 2 presents an overview of the moving average strategies.

Figure 2 – Moving average strategies

Definition of Strategies

Strategy	Moving average rule range	Long/Short
First	[1,2] - [12,36]	Long Rank 1 Short Rank 7
	(354 equally weighted MA combinations)	(for each combination)
Second	[1,2] - [12,36]	Long Ranks 1,2,3 Short Rank 7
	(354 equally weighted MA combinations)	(for each combination)
Third	[4,5] - [6,36]	Long Rank 1 Short Rank 7
	(93 equally weighted MA combinations)	(for each combination)
Fourth	[4,5] - [6,36]	Long Ranks 1,2,3 Short Rank 7
	(93 equally weighted MA combinations)	(for each combination)

Each month from January 1993 through March 2008 is ranked from one to seven based upon the difference between the short-run moving average and the long-run moving average of prior returns using either 354 (*the first and the second strategy*) or 93 (*the third and the fourth strategy*) different combinations. Each of the returns to the moving average combinations is given equal weight each month, generating monthly returns for strategies from one to four. In the above table, the notation [1,2] corresponds to a ranking of individual currencies using the difference between a short-run moving average with the parameter 1 and a long-run moving average using the parameter 2. The notation [1,2] – [12,36] would imply considering all short-run/long-run moving average combinations where the short-run moving average parameter ranges from one to twelve months and the long-run moving average parameter ranges from one + the short-run moving average parameter to 36.

7. Empirical findings

This chapter presents the empirical results of the study and discusses their relation to the existing academic literature. The two strategies provide somewhat different results: Based on the simpler momentum strategy, evidence of momentum in the foreign exchange market does exist whereas the moving average combination strategies indicate that no excess profit-making potential is available in the foreign exchange market. This may, however, be attributable to the fact, that even if carried out simultaneously, one of the two different strategies could turn out to be profitable when the other does not.

7.1. Momentum strategy

7.1.1. Euro as a base currency

As discussed in the chapter 3, previous research has, in general, found evidence against the market efficiency hypothesis. My empirical momentum results using euro as a base currency are, to a large extent, in line with the existing academic literature. Table 3 presents the returns from momentum based portfolios with different ranking and holding periods using euro as the base currency. The average monthly returns from the momentum portfolios are, with no exception, positive. In general, the average monthly returns from momentum portfolios are significantly different from zero when one month holding period is used. This supports the notion that momentum still exists in the foreign currency markets.

When ranking period is one or three months and holding period of one month is applied, the average momentum return is 0.256% or 0.280%, respectively. These values are significantly different from zero at 5% confidence level. When the ranking period is prolonged to either nine or twelve months, the average returns are 0.257% and 0.264%, respectively. They are, however, significantly different from zero only when using the 10% confidence level. In addition, average return from the momentum portfolio is significantly different from zero if we use a combination of nine month ranking period and a holding period of three months. This strategy generates an average return of 0.148%, which is statistically significantly different from zero at the 10% confidence level. When a holding period of six or nine months is used, the monthly momentum returns are roughly the same size than those of with one or three months holding period. The longer holding periods, however, do not generate returns statistically significantly different from zero as the shorter periods do.

Excess returns from the momentum portfolios compared to equally weighted currency portfolios, are like the average momentum returns, in general, positive. However, only if the ranking and holding periods are set to be nine and three months, respectively, the average excess return, 0.162%, is significantly different from zero. This does not necessarily have to indicate a lack of momentum with the excess profit-making potential in the foreign exchange market because, on average, every strategy generates a positive excess return. As a

conclusion, momentum trading strategies with short holding periods tend to be statistically significantly profitable in the euro market. These profits, however, do not significantly exceed the returns generated by the equally weighted portfolio with the exception of three months holding period, even though all holding periods generate positive excess monthly returns.

My findings are to a large extent in line with the previous academic research in this field. As discussed in the chapter 3, also other studies have found significant excess returns when applying simple technical trading rules.[6] They all, however, use different trading strategies and moreover, their findings do not hold across all the tested strategies. Therefore, my findings support the momentum hypothesis and indicate that the initiation of the single European currency euro has significantly improved the foreign exchange market efficiency. The data used in the previous literature generally spans from the 1970s to the 1980s or the 1990s at the latest. Therefore, those studies are not completely comparable to this thesis, because euro was not initiated until the first decade of 21st century. Furthermore, the currencies used in the majority of the existing studies match only partly the currency selection of my thesis, for the earlier data sets have included currencies now replaced with euro.

There has also been empirical evidence of the profitable use of technical trading rules using more recent data (for example Dueker and Neely, 2007 and Bianchi et al., 2005). Bianchi et al. (2005) found evidence of transitory momentum, which is skewed towards the short-term portfolio formation periods. According to my best knowledge, the Nordic currency exchange rates have not been applied in the previous studies researching the profitability of simple technical trading rules. As a result, my findings are not completely comparable to the existing academic literature due to differences in the currency set applied.

7.1.2. Swedish krona as a base currency

Empirical tests with Swedish krona as a base currency produce quite similar results to those using euro as a base currency. Table 4 presents the monthly returns from momentum based portfolios with different ranking and holding periods using Swedish krona as a base currency. The average monthly returns from the momentum portfolios are, again, positive with no

[6] For example, Sweeney (1986); Schulmeister (1988); Kho (1996); Neely et al. (1997); and Okunev and White (2003).

exception. The average momentum returns are, in general, at the same level than those with euro, ranging from 0.020% to 0.291%. The largest average momentum returns are generated when a holding period of one month is applied. They are in the range spanning from 0.133% to 0.254%. These returns are quite closely in the same range as for the euro based portfolio.

The results are statistically significantly different from zero at 5% confidence level when the ranking period is either three or nine months and the holding period is one month, or when the ranking period is one or three months and the holding period is six months. This is also true when a ranking period of six months and a holding period of nine months, or a combination of a nine month ranking period and a three month holding period are applied. When the ranking period is set to either one or twelve months and the holding period to one month, or both the ranking and the holding periods to nine months, the average momentum returns are significant at 10% confidence level.

All excess returns are positive, but differ significantly from zero only when the ranking period is nine months and the holding period is three months, or when the ranking and holding periods are six and nine months, respectively (both at 10% significance level). The average excess returns are 0.021% at the lowest and 0.289% at the highest. Therefore, a clear statistically significant excess profit-making opportunity can not be observed, but clearly the positive results indicate that some excess profit potential might be available, especially in the strategies with semi-annual or longer holding periods. With the shorter holding periods, the results are in line with the findings made in the euro based portfolios.

According to my best knowledge, momentum related to Swedish krona exchange rates has not been studied before in the academic literature. Therefore, these results are not completely comparable to the existing academic literature. My findings are, however, generally in line with the previous studies in terms of the size of the monthly returns. This indicates that momentum profit potential also exists in the Swedish krona based foreign exchange markets.

Table 3 – Returns from the EUR-based momentum portfolios

Returns of the momentum Portfolios (Base Currency EUR)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.367**	-0.144	0.256**	0.224	0.142	-0.003	0.072	0.061	0.027	-0.010	0.018	0.017	0.036	-0.037	0.037	0.029
Median return (%)	0.096	0.046	0.112	0.207	-0.088	-0.030	0.049	0.036	0.063	-0.071	0.108	0.020	0.082	-0.082	0.110	0.788
Std. Deviation (%)	2.343	2.692	1.710	2.084	1.338	1.449	0.948	1.132	0.944	1.020	0.630	0.819	0.993	0.930	0.629	3.888
t-Statistic	2.107	-0.720	2.014	1.446	0.815	-0.016	0.583	0.414	0.154	-0.053	0.154	0.112	0.158	-0.173	0.256	0.033
Information ratio	0.157	-0.053	0.150	0.107	0.106	-0.002	0.076	0.054	0.029	-0.010	0.029	0.021	0.036	-0.040	0.059	0.007
Ranking period of 3 months																
Mean return (%)	0.156	-0.409**	0.280**	0.235	-0.033	-0.085	0.026	0.030	-0.017	-0.074	0.028	0.033	0.547	-0.487	0.517	0.570
Median return (%)	-0.207	-0.356	0.106	0.209	-0.195	-0.127	0.069	-0.045	0.119	-0.072	0.053	0.070	-0.013	-0.351	1.231	1.124
Std. Deviation (%)	2.438	2.675	1.701	2.799	1.425	1.392	0.937	1.153	1.078	0.972	0.614	0.768	8.375	7.429	4.585	5.461
t-Statistic	0.856	-2.046	2.202	1.123	-0.307	-0.810	0.368	0.345	-0.207	-1.001	0.600	0.565	0.852	-0.855	1.470	1.361
Information ratio	0.064	-0.153	0.165	0.084	-0.023	-0.061	0.028	0.026	-0.016	-0.076	0.046	0.043	0.065	-0.066	0.113	0.104
Ranking period of 6 months																
Mean return (%)	-0.016	-0.193	0.089	0.055	0.013	-0.003	0.008	0.011	0.003	-0.098	0.051	0.061	0.623	-0.596	0.610	0.690
Median return (%)	0.003	-0.204	0.004	0.264	0.040	-0.084	0.161	-0.058	0.089	-0.191	0.112	0.136	-0.005	-0.794	1.409	1.253
Std. Deviation (%)	2.398	2.917	1.807	3.683	1.580	1.514	1.020	1.191	1.217	1.046	0.731	0.830	8.882	7.910	5.249	5.786
t-Statistic	-0.089	-0.878	0.653	0.198	0.108	-0.026	0.103	0.121	0.032	-1.222	0.910	0.958	0.906	-0.974	1.502	1.541
Information ratio	-0.007	-0.066	0.049	0.015	0.008	-0.002	0.008	0.009	0.002	-0.094	0.070	0.073	0.070	-0.075	0.116	0.119
Ranking period of 9 months																
Mean return (%)	0.312*	-0.203	0.257*	0.194	0.158	-0.138	0.148*	0.162*	0.101	-0.072	0.087	0.101	0.775	-0.235	0.505	0.582
Median return (%)	0.184	-0.204	0.285	0.965	0.264	-0.228	0.286	0.291	0.160	-0.149	0.136	0.210	0.073	0.117	1.353	0.932
Std. Deviation (%)	2.351	2.902	1.771	4.275	1.578	1.503	1.054	1.206	1.219	1.098	0.729	0.819	9.145	7.827	5.281	5.667
t-Statistic	1.746	-0.920	1.909	0.597	1.305	-1.197	1.831	1.751	1.071	-0.847	1.542	1.594	1.085	-0.384	1.225	1.315
Information ratio	0.133	-0.070	0.145	0.045	0.100	-0.092	0.140	0.134	0.083	-0.066	0.119	0.123	0.085	-0.030	0.096	0.103
Ranking period of 12 months																
Mean return (%)	0.392**	-0.136	0.264*	0.190	0.221**	-0.024	0.123	0.134	0.094	0.009	0.042	0.052	0.446	0.328	0.059	0.097
Median return (%)	0.169	-0.352	0.294	0.781	0.222	-0.126	0.162	0.284	0.091	-0.005	0.072	0.070	-0.099	0.375	0.581	0.201
Std. Deviation (%)	2.379	2.862	1.777	5.096	1.418	1.604	0.979	1.174	1.147	1.065	0.710	0.808	9.016	7.762	5.144	5.568
t-Statistic	2.148	-0.620	1.937	0.486	2.014	-0.193	1.624	1.475	1.050	0.108	0.758	0.824	0.628	0.536	0.146	0.221
Information ratio	0.165	-0.048	0.149	0.037	0.156	-0.015	0.126	0.114	0.082	0.008	0.059	0.064	0.049	0.042	0.011	0.017

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 4 - Returns from the SEK-based momentum portfolios

Returns of the momentum Portfolios (Base Currency SEK)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.286	-0.192	0.239*	0.271	0.142	-0.024	0.083	0.077	0.048	-0.034	0.041	0.040	-0.009	-0.054	0.022	0.026
Median return (%)	-0.083	-0.016	0.104	0.189	0.021	-0.087	0.018	0.110	0.100	-0.194	0.091	0.058	-0.056	-0.149	0.084	0.085
Std. Deviation (%)	2.834	3.187	1.729	2.521	1.572	1.792	0.906	1.395	1.124	1.124	0.614	0.896	1.218	1.075	0.641	0.791
t-Statistic	1.358	-0.811	1.860	1.446	1.212	-0.180	1.229	0.741	0.230	-0.163	0.360	0.240	-0.032	-0.219	0.150	0.143
Information ratio	0.101	-0.060	0.138	0.107	0.090	-0.013	0.092	0.055	0.043	-0.030	0.067	0.045	-0.007	-0.050	0.034	0.033
Ranking period of 3 months																
Mean return (%)	0.096	-0.416*	0.253**	0.258	-0.053	-0.094	0.020	0.021	-0.042	-0.083	0.021	0.029	0.025	-0.069	0.047	0.055
Median return (%)	-0.120	-0.380	0.113	0.322	0.000	-0.231	0.033	-0.003	-0.059	-0.199	0.076	0.026	0.013	-0.145	0.098	0.030
Std. Deviation (%)	2.982	3.003	1.639	3.538	1.621	1.615	0.881	1.323	1.247	1.104	0.577	0.836	1.031	0.914	0.509	0.689
t-Statistic	0.431	-1.853	2.065	0.976	-0.434	-0.772	0.301	0.211	-0.443	-0.989	0.479	0.456	0.316	-0.984	1.204	1.041
Information ratio	0.032	-0.139	0.154	0.073	-0.033	-0.058	0.023	0.016	-0.034	-0.075	0.036	0.035	0.024	-0.075	0.092	0.080
Ranking period of 6 months																
Mean return (%)	0.007	-0.259	0.133	0.099	0.049	-0.053	0.051	0.079	0.040	-0.117	0.078	0.098	0.118	-0.065	0.092**	0.101*
Median return (%)	-0.403	-0.377	0.154	0.389	0.028	-0.230	0.157	0.080	0.017	-0.322	0.116	0.176	0.086	-0.222	0.165	0.177
Std. Deviation (%)	2.735	3.285	1.814	4.866	1.758	1.750	1.016	1.418	1.416	1.149	0.723	0.854	1.117	0.949	0.578	0.689
t-Statistic	0.034	-1.046	0.973	0.270	0.367	-0.398	0.660	0.733	0.368	-1.328	1.407	1.496	1.365	-0.885	2.057	1.894
Information ratio	0.003	-0.079	0.073	0.020	0.028	-0.030	0.050	0.056	0.028	-0.102	0.108	0.115	0.106	-0.068	0.159	0.147
Ranking period of 9 months																
Mean return (%)	0.254	-0.327	0.291**	0.289	0.158	-0.161	0.160**	0.182*	0.111	-0.083	0.097*	0.105	0.115	-0.042	0.078*	0.084
Median return (%)	0.202	-0.368	0.322	0.011	0.106	-0.286	0.303	0.218	0.185	-0.218	0.135	0.166	0.072	-0.157	0.151	0.179
Std. Deviation (%)	2.737	3.210	1.745	5.453	1.745	1.667	1.050	1.362	1.364	1.156	0.736	0.862	1.118	0.932	0.605	0.705
t-Statistic	1.221	-1.340	2.193	0.697	1.181	-1.259	1.987	1.742	1.052	-0.928	1.703	1.574	1.317	-0.577	1.651	1.526
Information ratio	0.093	-0.102	0.167	0.053	0.091	-0.097	0.152	0.134	0.081	-0.072	0.132	0.122	0.103	-0.045	0.129	0.119
Ranking period of 12 months																
Mean return (%)	0.315	-0.194	0.254*	0.258	0.200*	-0.052	0.126	0.131	0.107	-0.012	0.060	0.066	0.068	0.022	0.023	0.026
Median return (%)	0.047	-0.294	0.294	0.199	0.000	-0.258	0.154	0.167	0.090	-0.142	0.073	0.153	0.010	-0.050	0.064	0.016
Std. Deviation (%)	2.617	3.231	1.718	6.175	1.565	1.768	1.012	1.406	1.268	1.129	0.717	0.891	1.067	0.929	0.563	0.710
t-Statistic	1.569	-0.783	1.928	0.545	1.651	-0.380	1.609	1.204	1.081	-0.136	1.072	0.949	0.809	0.300	0.518	0.465
Information ratio	0.120	-0.060	0.148	0.042	0.128	-0.029	0.125	0.093	0.084	-0.011	0.084	0.074	0.064	0.024	0.041	0.037

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

7.1.3. Norwegian krone and Icelandic krona as base currencies

The returns from Norwegian krone and Icelandic krona based momentum portfolios are, to a large extent, similar to those of euro and Swedish krona based portfolios. Again, momentum returns are, in general but not always, positive. Still, the same combinations of ranking and holding periods generate momentum returns statistically significantly different from zero as in the euro and Swedish krona based portfolios, although the portfolios with Icelandic krona as a base currency generate these significant, monthly returns more often than those with Norwegian krone. Furthermore, the Norwegian portfolio generates even one negative momentum return, although statistically insignificantly. In comparison, the Icelandic portfolio generates a few negative excess returns. They are, however, also statistically insignificant.

For Norwegian krone all the combinations with a one month holding period generate positive returns that are significantly different from zero, except when a ranking period of six months is used. Also, combinations with a nine month ranking period and either a three or six month holding periods have significantly positive momentum returns. Finally, a nine month holding period has significantly positive momentum return with a three month ranking period. The size of all these monthly returns is slightly larger than with euro or Swedish krona portfolios, although the difference is not big. The significant monthly returns (at 5% confidence level minimum) vary from 0.184% to 0.348%.

The portfolios with Icelandic krona as a base currency generate significantly positive returns with nearly the same combinations than with the Norwegian base, although these significant returns are generated more often. The comparable range of returns for the Icelandic portfolios is between 0.086% and 0.280% i.e. at the same size level than those with euro or Swedish krona. According to my knowledge, Norwegian krone and Icelandic krona have not been included in the currency portfolios of the previous studies in the academic literature. Therefore, this thesis expands the perspective of the previous academic literature in these foreign exchange markets as well.

For Icelandic krona only the combination of one month ranking and holding periods creates statistically significant excess returns above the equally weighted currency portfolio; 0.362% at 10% confidence level. For Norwegian krone, total eleven combinations generate

statistically significant excess returns within all studied holding periods. Furthermore, these returns are generally larger than in any of the abovementioned results. At 5% confidence level, these excess returns vary between 0.132% and 0.793%. The largest and the most frequent excess returns are observed in the one month holding period portfolios.

As a conclusion, the portfolios with Icelandic krona or Norwegian krone generate statistically significantly positive monthly returns as frequently as the Swedish krona portfolios. The size of the monthly momentum returns is largest in the Norwegian market. Also excess returns above the equally weighted currency portfolio are found most frequently in the Norwegian foreign exchange market, where they are also the largest. Furthermore, momentum trading strategies tend to be generally significantly profitable in the Norwegian market in excess of the equal portfolio. In the Icelandic market, momentum trading strategies generate generally significant monthly returns as these significant returns are found in all different holding periods with various ranking periods. These returns, however, rarely are in excess of the equally weighted portfolio and thus are not that interesting investor-wise.

Table 5 - Returns from the NOK-based momentum portfolios

Returns of the momentum Portfolios (Base Currency NOK)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.248	-0.331	0.289**	0.398**	0.082	-0.111	0.096	0.156	-0.038	-0.072	0.017	0.073	-0.045	-0.093	0.024	0.077
Median return (%)	0.131	-0.279	0.115	0.314	-0.058	-0.203	0.105	0.157	-0.024	-0.085	0.106	0.100	-0.048	-0.128	0.091	0.060
Std. Deviation (%)	2.607	2.987	1.699	2.443	1.419	1.755	0.954	1.444	0.986	1.113	0.648	0.922	1.099	1.035	0.657	0.815
t-Statistic	1.280	-1.491	2.288	2.192	0.444	-0.486	0.773	0.830	-0.208	-0.348	0.141	0.426	-0.178	-0.392	0.159	0.412
Information ratio	0.095	-0.111	0.170	0.163	0.058	-0.063	0.101	0.108	-0.039	-0.065	0.026	0.079	-0.041	-0.090	0.037	0.094
Ranking period of 3 months																
Mean return (%)	0.048	-0.627***	0.334***	0.502*	-0.061	-0.255	0.097	0.172*	-0.066	-0.161**	0.047	0.112	-0.001	-0.147**	0.073*	0.133**
Median return (%)	-0.104	-0.671	0.111	0.554	-0.086	-0.305	0.111	0.212	-0.008	-0.230	0.054	0.023	-0.005	-0.205	0.119	0.121
Std. Deviation (%)	2.800	2.859	1.661	3.425	1.512	1.617	0.913	1.370	1.047	1.067	0.622	0.899	0.903	0.865	0.543	0.729
t-Statistic	0.229	-2.934	2.690	1.961	-0.535	-2.092	1.409	1.666	-0.829	-1.985	0.994	1.639	-0.014	-2.216	1.753	2.379
Information ratio	0.017	-0.219	0.201	0.147	-0.040	-0.158	0.106	0.126	-0.063	-0.151	0.076	0.125	-0.001	-0.170	0.134	0.182
Ranking period of 6 months																
Mean return (%)	-0.119	-0.367	0.124	0.437	-0.072	-0.095	0.011	0.091	-0.034	-0.164**	0.065	0.135*	0.027	-0.107	0.067	0.132**
Median return (%)	-0.219	-0.465	-0.009	0.823	-0.044	-0.250	0.136	0.218	0.012	-0.270	0.112	0.231	0.009	-0.138	0.174	0.220
Std. Deviation (%)	2.604	3.192	1.802	4.241	1.653	1.687	1.002	1.395	1.185	1.083	0.742	0.934	0.929	0.894	0.601	0.758
t-Statistic	-0.606	-1.525	0.913	1.367	-0.573	-0.741	0.144	0.858	-0.374	-1.974	1.142	1.885	0.376	-1.547	1.441	2.250
Information ratio	-0.046	-0.115	0.069	0.103	-0.044	-0.056	0.011	0.065	-0.029	-0.151	0.088	0.145	0.029	-0.120	0.111	0.174
Ranking period of 9 months																
Mean return (%)	0.229	-0.467*	0.348**	0.793**	0.110	-0.258**	0.184**	0.271**	0.056	-0.149*	0.102*	0.178**	0.048	-0.088	0.068	0.134**
Median return (%)	0.228	-0.418	0.302	0.920	0.092	-0.422	0.300	0.437	0.013	-0.182	0.178	0.269	0.058	-0.111	0.142	0.238
Std. Deviation (%)	2.501	3.164	1.804	4.900	1.633	1.682	1.073	1.450	1.182	1.128	0.750	0.928	0.985	0.862	0.608	0.709
t-Statistic	1.204	-1.941	2.537	2.129	0.878	-2.000	2.236	2.437	0.612	-1.707	1.758	2.479	0.624	-1.307	1.432	2.420
Information ratio	0.092	-0.148	0.193	0.162	0.067	-0.153	0.171	0.187	0.047	-0.132	0.136	0.192	0.049	-0.102	0.112	0.189
Ranking period of 12 months																
Mean return (%)	0.212	-0.277	0.245*	0.787*	0.043	-0.096	0.069	0.160	0.003	-0.032	0.018	0.091	-0.015	-0.002	-0.007	0.057
Median return (%)	0.040	-0.340	0.140	0.815	-0.016	-0.197	0.136	0.268	-0.021	-0.041	0.067	0.192	-0.042	-0.004	0.059	0.070
Std. Deviation (%)	2.540	3.197	1.823	5.573	1.628	1.758	1.037	1.392	1.207	1.097	0.728	0.862	0.982	0.828	0.577	0.657
t-Statistic	1.088	-1.130	1.752	1.841	0.341	-0.706	0.860	1.485	0.032	-0.374	0.317	1.352	-0.194	-0.031	-0.154	1.101
Information ratio	0.083	-0.087	0.134	0.141	0.026	-0.055	0.067	0.115	0.002	-0.029	0.025	0.106	-0.015	-0.002	-0.012	0.087

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 6 - Returns from the ISK-based momentum portfolios

Returns of the momentum Portfolios (Base Currency ISK)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.083	-0.317	0.200*	0.362*	0.141	-0.012	0.076	0.017	0.039	0.010	0.015	-0.048	0.049	-0.002	0.026	-0.037
Median return (%)	-0.128	-0.383	0.065	0.562	0.047	-0.175	0.033	0.154	-0.012	-0.173	0.075	0.160	-0.029	-0.131	0.080	0.183
Std. Deviation (%)	3.119	3.221	1.497	2.939	1.884	2.079	0.915	1.929	1.332	1.383	0.601	1.294	1.318	1.409	0.566	1.084
t-Statistic	0.358	-1.324	1.797	1.657	0.575	-0.044	0.638	0.068	0.158	0.039	0.134	-0.200	0.162	-0.006	0.200	-0.149
Information ratio	0.027	-0.098	0.134	0.123	0.075	-0.006	0.083	0.009	0.029	0.007	0.025	-0.037	0.037	-0.001	0.046	-0.034
Ranking period of 3 months																
Mean return (%)	-0.132	-0.535**	0.199*	0.009	0.012	-0.092	0.052	0.028	0.063	-0.034	0.048	-0.001	0.149*	-0.023	0.086**	0.036
Median return (%)	-0.477	-0.552	0.121	0.350	-0.068	-0.375	0.078	0.087	-0.004	-0.107	0.076	0.199	0.032	-0.131	0.119	0.214
Std. Deviation (%)	3.273	3.244	1.448	5.061	2.030	2.015	0.888	1.873	1.310	1.327	0.568	1.301	1.082	1.105	0.462	1.028
t-Statistic	-0.540	-2.206	1.839	0.024	0.078	-0.606	0.777	0.198	0.633	-0.337	1.112	-0.010	1.795	-0.271	2.427	0.457
Information ratio	-0.040	-0.165	0.137	0.002	0.006	-0.046	0.059	0.015	0.048	-0.026	0.085	-0.001	0.138	-0.021	0.186	0.035
Ranking period of 6 months																
Mean return (%)	-0.192	-0.404	0.106	-0.325	0.104	-0.009	0.057	0.039	0.112	-0.048	0.080	0.038	0.128	-0.028	0.078*	0.037
Median return (%)	-0.324	-0.838	0.098	0.974	0.107	-0.311	0.145	0.186	0.044	-0.184	0.163	0.220	0.062	-0.141	0.151	0.292
Std. Deviation (%)	3.121	3.492	1.652	7.076	1.951	2.079	0.899	1.917	1.296	1.362	0.650	1.344	1.106	1.167	0.518	1.078
t-Statistic	-0.816	-1.535	0.851	-0.609	0.701	-0.057	0.834	0.268	1.127	-0.460	1.605	0.369	1.496	-0.310	1.946	0.444
Information ratio	-0.062	-0.116	0.064	-0.046	0.053	-0.004	0.063	0.020	0.086	-0.035	0.123	0.028	0.116	-0.024	0.151	0.034
Ranking period of 9 months																
Mean return (%)	0.005	-0.311	0.158	-0.457	0.165	-0.130	0.147**	0.138	0.164	-0.069	0.116**	0.084	0.145*	-0.036	0.090**	0.054
Median return (%)	-0.101	-0.674	0.209	0.867	0.147	-0.438	0.208	0.451	0.094	-0.375	0.169	0.439	0.060	-0.215	0.159	0.285
Std. Deviation (%)	3.091	3.257	1.522	8.250	1.900	1.994	0.935	1.935	1.291	1.486	0.652	1.407	1.091	1.221	0.520	1.119
t-Statistic	0.021	-1.256	1.365	-0.729	1.132	-0.850	2.050	0.930	1.642	-0.600	2.299	0.772	1.702	-0.378	2.216	0.618
Information ratio	0.002	-0.095	0.104	-0.055	0.087	-0.065	0.157	0.071	0.127	-0.046	0.178	0.060	0.133	-0.029	0.173	0.048
Ranking period of 12 months																
Mean return (%)	0.031	-0.529**	0.280**	-0.451	0.147	-0.133	0.14**	0.141	0.102	-0.062	0.082*	0.052	0.080	-0.031	0.056	0.020
Median return (%)	-0.251	-0.862	0.113	1.107	0.089	-0.404	0.148	0.439	0.037	-0.254	0.082	0.280	-0.003	-0.253	0.093	0.246
Std. Deviation (%)	2.990	3.439	1.615	8.986	1.827	2.128	0.861	1.956	1.276	1.491	0.610	1.408	0.990	1.238	0.488	1.168
t-Statistic	0.135	-2.006	2.261	-0.654	1.040	-0.808	2.101	0.932	1.024	-0.533	1.721	0.473	1.025	-0.318	1.456	0.217
Information ratio	0.010	-0.154	0.173	-0.050	0.080	-0.063	0.163	0.072	0.080	-0.042	0.134	0.037	0.081	-0.025	0.115	0.017

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

7.1.4. Returns from the GBP, USD, JPY and CHF –based portfolios

Tables 7-10 present the monthly momentum portfolio returns when the base currency is UK pound, US dollar, Japanese yen or Swiss franc. The monthly momentum returns for these currencies are, in general, larger or similar in size than observed with euro and the Scandinavian currencies. The average returns remain positive in most of the cases and all the significant average monthly returns are positive, but they differ statistically significantly from zero seemingly seldom, except for Japanese yen, which has roughly the same amount of significant momentum findings than the Nordic currency and euro based portfolios. Throughout the currencies other than US dollar, the one month holding period with various ranking periods is most frequently statistically significant. US dollar, however, does not have a single significant momentum return finding but only excess return findings.

A curious note about the dollar market is that nearly all the monthly excess returns above the equally weighted portfolio, and all the significant excess returns are negative. The size of the returns is quite in line with the other studied currencies, but the sign of the excess returns is different. The size of the negative returns increases as the holding period is getting longer. This finding indicates that momentum trading strategies do not appear profitable in any combination in the US dollar based foreign exchange market; they are, in fact, rather unprofitable with the largest negative monthly excess return being -0.187% at 5% confidence level. It may also indicate the existence of reversal momentum, which assumes that the best past performers that seem to perform well at a short term, perform poorly when the holding period is getting longer. Similarly in the Japanese yen based market, all monthly excess returns are negative with similar or even larger returns than in the US dollar based market. The Japanese market generates negative excess returns with all studied holding periods, ranging from -0.127% to -0.516%.

When Swiss franc is used as a base currency, only four combinations of ranking and holding periods lead to average monthly momentum returns that are significantly different from zero. Like the Nordic currencies and euro, the most profitable momentum portfolios use one month holding period with various ranking periods. In addition, when the ranking period is set to nine months and the holding period to three months, a significant (at 10% confidence level)

average momentum return of 0.143% is generated. In general, the average monthly returns from the momentum strategies are at a similar level than with other studied currencies. Furthermore, most of them are positive. Excess returns are not significantly different from zero in any of the combinations. Still, they are again positive with only few exceptions.

In the UK pound based market, the average monthly momentum returns are positive and similar in size than with the Nordic currencies. Only two combinations of the ranking and holding periods lead to momentum returns that are significantly different from zero. These are, again, combinations of one month holding period and three or nine month ranking period, when the strategies generate returns of 0.297% and 0.238%, respectively.

Excess returns are significant in four cases. If the ranking period is either three or nine months and the holding period is one month, the excess returns are significantly different from zero at 5% confidence level. If using a one month ranking and holding periods, or a three month ranking period combined with a nine month holding period, the results are significant at 10% confidence level. The significant excess returns vary from 0.106% to 0.530%, which means they are moderately large in size.

When the holding period is one month, all the base currencies show results significantly different from zero. Almost all ranking periods generate significant and positive returns in excess of the equally weighted portfolio, when the holding period is one month and UK sterling is used as a base currency. For Swiss franc, no significant excess returns can be found and for US dollar and Japanese yen, these excess returns are quite surprisingly negative. This means that the equally weighted currency portfolio has generated larger average returns than the momentum portfolio. Significant excess returns can also be found when a holding period of nine months is applied. This is, however, not applicable to the Swiss franc and the excess returns are positive with this holding period only when UK pound is used as a base currency.

Bianchi et al. (2005) use similar strategies to study the momentum in some of the currencies of my thesis. For a period spanning from the 1980 to the year 1998, they find excess returns only for the UK sterling when using a look back period of three months. They do not report excess returns for US dollar or the Japanese yen. Interestingly, my results do not show excess returns for British pound using three month periods but do when a one month holding period

is used. The same is true for Swiss franc; for the period ranging from 1999 to 2004 they do not report any excess momentum returns for these currencies, neither for euro.

Neely et al. (1997) find excess returns ranging from 1.0% to 2.3% for the same currencies than in my thesis using a genetic programming approach for a period from the 1980s to 1995. My findings are, in general, in line with theirs. LeBaron (1999) studied weekly and daily returns for Japanese yen and found significant excess returns. These results are not completely comparable to mine due to the different time period, but the returns are moderately larger than what I find for Japanese yen. Levich and Thomas (1993) use filter rules and they show larger profits for British pound, Japanese yen and Swiss franc. The filter rules applied by them generate average profits significantly larger than what I find.

As a conclusion, clear evidence of momentum is observed with this simple momentum trading strategy for all the studied base currencies. Generally, using various ranking periods and a holding period of one month provides monthly returns even as large as 0.348%, which means returns that are significantly in excess of the equally weighted currency portfolio. These results indicate that momentum is still present in the foreign exchange market. This also seems to be true for the Nordic currencies. Therefore, I can reject my hypothesis H_2, suggesting an efficient foreign exchange market with no excess profit potential for simple momentum trading strategies.

Table 7 - Returns from the GBP-based momentum portfolios

Returns of the momentum Portfolios (Base Currency GBP)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.037	-0.323*	0.180	0.338*	-0.011	-0.142	0.066	0.135	-0.086	-0.096	0.005	0.070	-0.052	-0.132	0.040	0.109
Median return (%)	0.036	-0.239	0.107	0.221	-0.168	-0.148	0.065	0.129	-0.045	-0.114	0.090	0.109	0.038	-0.151	0.086	0.142
Std. Deviation (%)	2.252	2.637	1.523	2.363	1.205	1.695	0.959	1.429	0.926	1.058	0.605	0.916	0.984	1.073	0.603	0.815
t-Statistic	0.221	-1.648	1.590	1.924	-0.070	-0.643	0.529	0.726	-0.500	-0.489	0.045	0.412	-0.230	-0.536	0.289	0.583
Information ratio	0.016	-0.122	0.118	0.143	-0.009	-0.084	0.069	0.094	-0.093	-0.091	0.008	0.076	-0.053	-0.123	0.066	0.134
Ranking period of 3 months																
Mean return (%)	0.018	-0.583***	0.297**	0.530**	-0.080	-0.194	0.057	0.125	-0.124	-0.152*	0.014	0.080	-0.049	-0.125*	0.038	0.106*
Median return (%)	0.044	-0.413	0.111	0.252	-0.234	-0.099	0.070	0.190	-0.043	-0.154	0.051	0.171	0.020	-0.130	0.105	0.106
Std. Deviation (%)	2.523	2.814	1.729	3.158	1.462	1.575	0.984	1.346	1.018	1.058	0.598	0.921	0.847	0.915	0.529	0.803
t-Statistic	0.095	-2.772	2.298	2.245	-0.726	-1.634	0.768	1.232	-1.602	-1.890	0.308	1.142	-0.754	-1.781	0.937	1.721
Information ratio	0.007	-0.207	0.172	0.168	-0.055	-0.123	0.058	0.093	-0.122	-0.144	0.023	0.087	-0.058	-0.137	0.072	0.132
Ranking period of 6 months																
Mean return (%)	-0.213	-0.343	0.065	0.133	-0.095	-0.089	-0.003	0.067	-0.119	-0.149*	0.015	0.077	-0.040	-0.108	0.034	0.105
Median return (%)	-0.289	-0.428	0.004	0.005	-0.238	-0.175	0.146	0.193	0.028	-0.220	0.110	0.100	0.018	-0.129	0.130	0.094
Std. Deviation (%)	2.576	3.095	1.856	1.947	1.530	1.599	1.012	1.374	1.133	1.111	0.734	1.000	0.907	0.939	0.605	0.837
t-Statistic	-1.097	-1.470	0.465	0.906	-0.817	-0.732	-0.039	0.641	-1.369	-1.749	0.266	1.004	-0.570	-1.486	0.726	1.621
Information ratio	-0.083	-0.111	0.035	0.068	-0.062	-0.056	-0.003	0.049	-0.105	-0.134	0.020	0.077	-0.044	-0.115	0.056	0.125
Ranking period of 9 months																
Mean return (%)	0.089	-0.388*	0.238*	0.373**	0.032	-0.193	0.112	0.171	-0.002	-0.118	0.058	0.123	-0.015	-0.081	0.033	0.107
Median return (%)	0.395	-0.484	0.285	0.507	-0.041	-0.184	0.248	0.273	0.059	-0.116	0.127	0.101	0.019	-0.130	0.104	0.104
Std. Deviation (%)	2.560	3.048	1.804	2.470	1.536	1.681	1.036	1.435	1.153	1.199	0.753	1.048	0.917	0.947	0.619	0.860
t-Statistic	0.457	-1.674	1.735	1.986	0.272	-1.497	1.410	1.554	-0.022	-1.272	0.995	1.517	-0.209	-1.095	0.683	1.593
Information ratio	0.035	-0.127	0.132	0.151	0.021	-0.115	0.108	0.119	-0.002	-0.098	0.077	0.117	-0.016	-0.086	0.053	0.124
Ranking period of 12 months																
Mean return (%)	0.161	-0.245	0.203	0.330*	0.128	-0.081	0.104	0.182	-0.005	-0.038	0.016	0.093	-0.062	-0.019	-0.021	0.061
Median return (%)	0.206	-0.454	0.028	0.451	-0.057	-0.133	0.161	0.247	0.016	0.015	0.070	0.101	-0.045	-0.063	0.039	0.000
Std. Deviation (%)	2.554	3.033	1.798	2.486	1.385	1.738	1.029	1.449	1.101	1.163	0.734	1.019	0.901	0.918	0.585	0.820
t-Statistic	0.822	-1.053	1.472	1.731	1.194	-0.602	1.306	1.623	-0.058	-0.418	0.279	1.169	-0.873	-0.263	-0.455	0.944
Information ratio	0.063	-0.081	0.113	0.133	0.092	-0.047	0.101	0.126	-0.005	-0.033	0.022	0.091	-0.069	-0.021	-0.036	0.074

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 8 - Returns from the USD-based momentum portfolios

Returns of the momentum Portfolios (Base Currency USD)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.422**	0.054	0.184	0.005	0.177	0.127	0.025	-0.115	0.161	0.198	-0.018	-0.169	0.240	0.158	0.041	-0.108
Median return (%)	0.345	-0.098	0.065	-0.180	-0.004	0.144	-0.002	-0.152	0.166	0.064	0.060	-0.197	0.328	0.039	0.087	0.002
Std. Deviation (%)	2.894	3.014	1.701	2.756	1.586	1.834	0.970	1.707	1.150	1.261	0.645	1.178	1.166	1.220	0.644	1.044
t-Statistic	1.962	0.241	1.455	0.024	0.857	0.532	0.198	-0.517	0.754	0.846	-0.150	-0.773	0.897	0.565	0.278	-0.451
Information ratio	0.146	0.018	0.108	0.002	0.112	0.069	0.026	-0.067	0.140	0.157	-0.028	-0.143	0.206	0.130	0.064	-0.103
Ranking period of 3 months																
Mean return (%)	0.182	-0.154	0.166	-0.290	0.103	0.165	-0.031	-0.190	0.067	0.122	-0.028	-0.187**	0.119	0.161**	-0.021	-0.179**
Median return (%)	0.128	-0.314	0.018	-0.212	0.070	0.210	-0.042	-0.205	0.085	0.068	0.013	-0.285	0.131	0.111	0.044	-0.304
Std. Deviation (%)	3.008	3.466	1.787	4.400	1.704	1.800	0.989	1.664	1.211	1.256	0.687	1.187	0.967	1.041	0.575	1.032
t-Statistic	0.810	-0.594	1.243	-0.882	0.802	1.216	-0.416	-1.515	0.728	1.278	-0.536	-2.072	1.605	2.017	-0.476	-2.262
Information ratio	0.061	-0.044	0.093	-0.066	0.060	0.092	-0.031	-0.114	0.055	0.097	-0.041	-0.158	0.123	0.155	-0.037	-0.173
Ranking period of 6 months																
Mean return (%)	0.057	0.048	0.004	-0.154	0.165	0.187	-0.011	-0.180	0.134	0.134	0.000	-0.171*	0.166**	0.137*	0.015	-0.146*
Median return (%)	0.144	-0.004	-0.007	-0.035	0.033	0.003	0.008	-0.001	0.181	0.010	0.092	-0.213	0.222	0.181	0.071	-0.301
Std. Deviation (%)	2.917	3.213	1.815	2.233	1.791	1.795	1.014	1.647	1.238	1.291	0.728	1.268	1.008	1.017	0.588	1.015
t-Statistic	0.259	0.198	0.029	-0.915	1.212	1.370	-0.143	-1.437	1.411	1.353	0.000	-1.758	2.128	1.741	0.330	-1.859
Information ratio	0.020	0.015	0.002	-0.069	0.092	0.104	-0.011	-0.109	0.108	0.104	0.000	-0.135	0.165	0.135	0.026	-0.144
Ranking period of 9 months																
Mean return (%)	0.346	-0.031	0.188	0.009	0.233*	0.083	0.075	-0.107	0.150	0.171*	-0.010	-0.18*	0.137*	0.171**	-0.017	-0.171*
Median return (%)	0.507	-0.190	0.285	-0.219	0.027	-0.088	0.215	-0.095	0.176	0.108	0.093	-0.179	0.108	0.094	0.053	-0.290
Std. Deviation (%)	3.009	3.167	1.807	2.790	1.829	1.866	1.087	1.752	1.276	1.328	0.786	1.313	1.008	1.033	0.615	1.046
t-Statistic	1.512	-0.129	1.368	0.042	1.661	0.580	0.900	-0.796	1.519	1.664	-0.164	-1.772	1.741	2.120	-0.354	-2.094
Information ratio	0.115	-0.010	0.104	0.003	0.127	0.044	0.069	-0.061	0.118	0.129	-0.013	-0.137	0.136	0.166	-0.028	-0.163
Ranking period of 12 months																
Mean return (%)	0.474*	0.149	0.163	-0.013	0.288*	0.270*	0.009	-0.155	0.189*	0.256**	-0.033	-0.185*	0.145*	0.246***	-0.050	-0.185**
Median return (%)	0.545	-0.014	0.319	-0.040	0.188	-0.030	0.130	0.024	0.166	0.179	0.034	-0.215	0.146	0.115	0.024	-0.341
Std. Deviation (%)	3.020	3.067	1.711	2.666	1.759	1.881	1.048	1.719	1.251	1.318	0.742	1.268	0.980	1.046	0.577	1.035
t-Statistic	2.046	0.633	1.242	-0.064	2.116	1.855	0.111	-1.165	1.935	2.487	-0.570	-1.868	1.877	2.984	-1.100	-2.268
Information ratio	0.157	0.049	0.095	-0.005	0.164	0.144	0.009	-0.090	0.151	0.194	-0.044	-0.146	0.148	0.235	-0.087	-0.179

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 9 - Returns from the JPY-based momentum portfolios

Returns of the momentum Portfolios (Base Currency JPY)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.596**	0.293	0.152	-0.282	0.302	0.256	0.023	-0.207	0.240	0.221	0.010	-0.212	0.322	0.185	0.069	-0.147
Median return (%)	0.634	0.563	0.043	-0.623	0.404	0.404	-0.044	-0.370	0.448	0.064	0.045	-0.146	0.439	0.268	0.123	-0.129
Std. Deviation (%)	3.450	3.763	1.457	3.429	2.016	2.122	0.812	1.994	1.404	1.429	0.545	1.331	1.435	1.422	0.573	1.115
t-Statistic	2.324	1.048	1.404	-1.106	1.151	0.927	0.218	-0.797	0.921	0.833	0.099	-0.858	0.978	0.567	0.525	-0.575
Information ratio	0.173	0.078	0.104	-0.082	0.150	0.121	0.028	-0.104	0.171	0.155	0.018	-0.159	0.224	0.130	0.120	-0.132
Ranking period of 3 months																
Mean return (%)	0.544**	0.255	0.143	-0.516	0.275*	0.313**	-0.019	-0.293**	0.275**	0.228**	0.023	-0.219**	0.289***	0.204**	0.043	-0.186**
Median return (%)	0.572	0.500	-0.078	-1.123	0.387	0.397	-0.075	-0.367	0.509	0.212	0.049	-0.222	0.387	0.121	0.027	-0.262
Std. Deviation (%)	3.510	3.828	1.655	5.620	1.994	1.973	0.878	1.922	1.445	1.331	0.600	1.285	1.165	1.064	0.512	1.016
t-Statistic	2.074	0.891	1.156	-1.228	1.830	2.105	-0.287	-2.022	2.503	2.253	0.504	-2.242	3.234	2.500	1.095	-2.387
Information ratio	0.155	0.067	0.086	-0.092	0.138	0.159	-0.022	-0.152	0.190	0.171	0.038	-0.170	0.248	0.192	0.084	-0.183
Ranking period of 6 months																
Mean return (%)	0.542**	0.292	0.125	-0.149	0.337**	0.252	0.042	-0.243	0.268**	0.102	0.083*	-0.162	0.281***	0.151	0.065*	-0.175**
Median return (%)	0.998	0.595	0.075	-0.096	0.631	0.372	0.068	-0.279	0.522	0.104	0.107	-0.228	0.453	0.089	0.082	-0.282
Std. Deviation (%)	3.220	3.776	1.569	2.526	1.920	2.021	0.858	1.959	1.437	1.421	0.588	1.339	1.108	1.202	0.505	1.090
t-Statistic	2.233	1.026	1.057	-0.783	2.309	1.640	0.644	-1.632	2.432	0.936	1.840	-1.577	3.277	1.623	1.663	-2.075
Information ratio	0.168	0.077	0.080	-0.059	0.176	0.125	0.049	-0.124	0.186	0.072	0.141	-0.121	0.254	0.126	0.129	-0.161
Ranking period of 9 months																
Mean return (%)	0.688***	0.112	0.288**	-0.213	0.383**	0.076	0.153**	-0.127	0.281**	0.086	0.097**	-0.159	0.235***	0.152	0.042	-0.206**
Median return (%)	1.177	0.512	0.260	-0.440	0.435	0.272	0.076	-0.367	0.509	0.129	0.077	-0.286	0.395	0.074	0.057	-0.327
Std. Deviation (%)	3.205	3.780	1.637	3.560	1.942	2.112	0.902	2.028	1.444	1.480	0.604	1.362	1.144	1.217	0.517	1.108
t-Statistic	2.823	0.390	2.314	-0.787	2.571	0.469	2.212	-0.817	2.515	0.751	2.075	-1.509	2.631	1.599	1.040	-2.381
Information ratio	0.215	0.030	0.176	-0.060	0.197	0.036	0.170	-0.063	0.195	0.058	0.161	-0.117	0.205	0.125	0.081	-0.186
Ranking period of 12 months																
Mean return (%)	0.723***	0.277	0.223*	-0.280	0.436***	0.190	0.123*	-0.184	0.300***	0.188	0.056	-0.214*	0.245***	0.241**	0.002	-0.254***
Median return (%)	1.184	0.579	0.223	-0.543	0.551	0.309	0.120	-0.194	0.443	0.154	0.075	-0.262	0.367	0.222	0.082	-0.372
Std. Deviation (%)	3.335	3.609	1.569	3.441	1.865	2.201	0.888	2.079	1.391	1.525	0.621	1.438	1.122	1.211	0.507	1.131
t-Statistic	2.827	1.001	1.853	-1.061	3.021	1.116	1.790	-1.144	2.762	1.579	1.155	-1.906	2.771	2.525	0.050	-2.850
Information ratio	0.217	0.077	0.142	-0.081	0.234	0.086	0.139	-0.089	0.216	0.123	0.090	-0.149	0.218	0.199	0.004	-0.225

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 10 - Returns from the CHF-based momentum portfolios

Returns of the momentum Portfolios (Base Currency CHF)

	Holding period of 1 month				Holding period of 3 months				Holding period of 6 months				Holding period of 9 months			
	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess	Rank 1	Rank 7	Momentum	Excess
Ranking period of 1 month																
Mean return (%)	0.442**	-0.118	0.28**	0.171	0.129	-0.065	0.097	0.108	0.009	-0.050	0.030	0.054	0.019	-0.022	0.020	0.041
Median return (%)	0.283	0.111	0.111	0.040	-0.003	0.056	0.067	0.040	-0.068	-0.082	0.110	0.087	-0.013	-0.048	0.068	0.102
Std. Deviation (%)	2.640	2.954	1.722	2.402	1.568	1.506	0.947	1.231	1.051	1.126	0.634	0.924	1.081	0.976	0.637	0.845
t-Statistic	2.252	-0.537	2.188	0.958	0.632	-0.332	0.787	0.674	0.046	-0.239	0.255	0.315	0.077	-0.098	0.137	0.211
Information ratio	0.167	-0.040	0.163	0.071	0.082	-0.043	0.102	0.088	0.009	-0.044	0.047	0.058	0.018	-0.023	0.031	0.049
Ranking period of 3 months																
Mean return (%)	0.222	-0.339	0.277**	0.321	0.003	-0.131	0.067	0.076	-0.039	-0.108	0.035	0.051	0.038	-0.083	0.061	0.075
Median return (%)	0.145	-0.108	0.141	0.122	-0.112	-0.148	0.078	-0.037	0.044	-0.198	0.053	0.031	-0.056	-0.150	0.104	0.113
Std. Deviation (%)	2.651	2.917	1.642	3.368	1.591	1.456	0.905	1.244	1.207	0.984	0.628	0.806	1.043	0.813	0.541	0.655
t-Statistic	1.120	-1.555	2.257	1.275	0.025	-1.194	0.982	0.810	-0.425	-1.444	0.733	0.832	0.475	-1.331	1.470	1.493
Information ratio	0.084	-0.116	0.169	0.095	0.002	-0.090	0.074	0.061	-0.032	-0.110	0.056	0.063	0.036	-0.102	0.113	0.115
Ranking period of 6 months																
Mean return (%)	0.057	-0.100	0.079	0.088	0.017	-0.030	0.024	0.016	-0.011	-0.095	0.042	0.048	0.036	-0.052	0.044	0.048
Median return (%)	0.074	0.068	-0.044	-0.116	0.061	-0.076	0.151	-0.065	-0.078	-0.199	0.095	0.056	-0.062	-0.128	0.124	0.118
Std. Deviation (%)	2.642	3.090	1.793	2.016	1.764	1.546	1.015	1.261	1.294	1.080	0.738	0.908	1.023	0.915	0.585	0.751
t-Statistic	0.286	-0.429	0.585	0.579	0.127	-0.255	0.311	0.167	-0.111	-1.147	0.742	0.689	0.455	-0.734	0.972	0.826
Information ratio	0.022	-0.032	0.044	0.044	0.010	-0.019	0.024	0.013	-0.009	-0.088	0.057	0.053	0.035	-0.057	0.075	0.064
Ranking period of 9 months																
Mean return (%)	0.462**	-0.103	0.282**	0.152	0.207	-0.083	0.145*	0.133	0.090	-0.052	0.071	0.070	0.059	-0.011	0.035	0.031
Median return (%)	0.378	0.037	0.342	0.174	0.201	-0.160	0.262	0.246	0.044	-0.036	0.122	0.117	0.008	-0.107	0.129	0.115
Std. Deviation (%)	2.621	3.157	1.788	2.438	1.765	1.597	1.060	1.310	1.311	1.118	0.743	0.895	1.037	0.899	0.606	0.760
t-Statistic	2.318	-0.429	2.074	0.820	1.529	-0.678	1.784	1.324	0.887	-0.601	1.235	1.011	0.729	-0.157	0.740	0.522
Information ratio	0.176	-0.033	0.158	0.062	0.117	-0.052	0.137	0.102	0.069	-0.047	0.096	0.078	0.057	-0.012	0.058	0.041
Ranking period of 12 months																
Mean return (%)	0.441**	-0.008	0.225	0.080	0.165	0.011	0.077	0.055	0.034	0.038	-0.002	-0.014	0.010	0.050	-0.020	-0.036
Median return (%)	0.353	-0.014	0.191	0.025	0.212	-0.035	0.159	0.251	0.033	0.053	0.068	0.024	-0.007	0.042	0.072	0.010
Std. Deviation (%)	2.658	3.102	1.793	2.453	1.679	1.694	1.034	1.328	1.268	1.117	0.734	0.913	1.030	0.896	0.575	0.729
t-Statistic	2.163	-0.034	1.636	0.425	1.270	0.084	0.962	0.535	0.343	0.436	-0.035	-0.196	0.123	0.708	-0.441	-0.627
Information ratio	0.166	-0.003	0.125	0.033	0.098	0.006	0.074	0.041	0.027	0.034	-0.003	-0.015	0.010	0.056	-0.035	-0.049

The momentum portfolios are formed based on R-month returns and held for H months. The length of the ranking and holding periods for the different strategies are indicated in the first column and row, respectively. The currencies are ranked in ascending order based on the ranking period return. The best performer (Rank 1) is bought and the worst performer (Rank 7) is sold short. The average monthly returns are presented in the table. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

7.2. Moving average strategies

Table 11 presents the summary descriptive statistics of the performance of the applied moving average strategies. In general, the first two strategies perform moderately well. The monthly average returns generated from these strategies are all positive but not statistically significant. None of the average returns is significantly different from zero, which is quite surprising, when comparing these results to the returns generated using the simple momentum strategies, and past academic research using moving average strategies. The lowest average monthly return of 0.013% is produced using Swiss franc as a base currency and the first short/long strategy. The largest, yet insignificant, average return of 0.112% is generated by applying the second short/long strategy and British pound as a base currency.

The above results deviate quite largely from what Okunev and White (2003) found. The method is identical to that applied by them, but the currency set and data period are quite different. The monthly returns in my results are much smaller than those Okunev and White (2003) found. For example, they found that the strategy one returns for US dollar was 0.505%, whereas my findings indicate monthly returns of 0.072% (although my findings are statistically insignificant).

The mean returns from the first strategy are, with no exception, smaller than those of the second strategy. Okunev and White (2003) found partly similar results. For example, for Swiss franc they found that the monthly average return is 0.461% from strategy two compared to 0.456% in the first strategy. Similarly, for sterling pound, the strategy one returns are smaller than the returns from strategy two. However, for the other studied currencies they found that the strategy one returns are larger than the returns of strategy two. They state that the larger mean returns of the first strategy can be, at least partly, explained by the larger risk of the strategy. Therefore, my findings are different than theirs, for the risk measured by the standard deviation of the return in the first strategy is somewhat larger than in the second strategy. However, because the mean returns are not significantly different from zero, the rankings can not be confirmed. Furthermore, the information ratios reinforce the idea that the second strategy might be more profitable than the first, as the information ratios for the second strategy returns all outperform their counterparts in the first strategy.

Because there is no generally accepted benchmark for the currency returns, the returns are compared to zero-profit and to the equally weighted currency portfolio, using a buy-and-hold strategy. Okunev and White (2003) discuss that if currency returns are considered random and unpredictable, the suitable benchmark would be the expected return of zero. They state that another possible benchmark could be a broad international currency index, like MSCI or an equally weighted currency exposure. Because no consensus for the right benchmark exists, Okunev and White (2003) use all of these three benchmarks in their study.

The paired t-test statistic measures the statistical significance of the moving average portfolios' excess returns compared to the equally weighted buy-and-hold portfolios. As can be observed, the excess returns are not statistically significant and moreover, they are even negative for Icelandic krona, US dollar and Japanese yen. However, the probability of the moving average portfolios to generate excess returns compared to the equally weighted currency portfolio is over 50%, Japanese yen and Swiss franc being the exceptions in the first strategy and yen in the second strategy as well. This percentage actually measures the number of months when the strategy was more profitable than the equally weighted portfolio per the total number of months in the data set.

The statistical insignificance of the results is not, however, that new to the existing academic literature. Using the first strategy, Okunev and White (2003) found significant excess returns only for Deutsche mark, Japanese yen and US dollar. When using the second strategy, they found that in addition to the currencies significant in the first strategy, the portfolio with Swiss franc as a base currency also generates significant excess returns compared to the equally weighted portfolio.

Table 11 – Descriptive Statistics of the Performance of the Long/Short strategies

Performance of Long/Short Strategies

	Europe	Sweden	Norway	Iceland	UK	US	Japan	Switzerland
First strategy								
Mean return (%)	0.041	0.065	0.052	0.039	0.033	0.072	0.033	0.013
Median return (%)	-0.104	-0.061	-0.057	0.187	0.024	0.110	0.003	-0.098
Std. Deviation (%)	1.708	1.634	1.675	1.508	1.709	1.758	1.602	1.631
Information Ratio	0.024	0.040	0.031	0.026	0.019	0.019	0.008	0.008
Probability > 0 (%)	46.927	49.162	49.721	53.073	50.279	51.397	50.279	48.045
Probability > Equal (%)	52.514	53.631	51.397	53.073	50.838	50.838	44.693	47.486
paired *t*-test	0.376	0.367	0.537	-0.974	0.310	-0.318	-0.201	0.678
Second strategy								
Mean return (%)	0.076	0.087	0.097	0.086	0.112	0.080	0.035	0.053
Median return (%)	0.062	0.076	0.156	0.100	0.062	0.088	-0.009	0.096
Std. Deviation (%)	1.467	1.426	1.418	1.267	1.508	1.444	1.424	1.421
Information Ratio	0.052	0.061	0.068	0.068	0.074	0.074	0.037	0.037
Probability > 0 (%)	52.514	51.397	55.866	55.307	52.514	51.397	49.162	52.514
Probability > Equal (%)	56.983	55.307	53.631	52.514	50.838	51.955	46.369	53.631
paired t-test	0.644	0.494	0.810	-0.796	0.813	-0.303	-0.200	0.949
Third strategy								
Mean return (%)	-0.090	-0.022	-0.017	0.018	-0.026	0.061	0.025	-0.077
Median return (%)	-0.101	-0.118	-0.042	-0.027	-0.009	-0.044	-0.008	-0.081
Std. Deviation (%)	1.701	1.563	1.689	1.444	1.737	1.632	1.565	1.677
Information Ratio	-0.053	-0.014	-0.010	0.012	-0.015	-0.015	-0.046	-0.046
Probability > 0 (%)	44.886	46.023	49.432	48.864	50.000	49.432	50.000	46.023
Probability > Equal (%)	52.841	50.000	50.568	52.841	50.568	49.432	46.023	50.000
paired t-test	-0.252	0.089	0.300	-0.843	-0.057	-0.623	-0.538	0.157
Fourth strategy								
Mean return (%)	0.012	0.044	0.041	0.040	0.082	0.106	0.085	0.005
Median return (%)	0.018	-0.009	0.062	0.047	0.075	-0.002	-0.005	0.025
Std. Deviation (%)	1.521	1.367	1.513	1.233	1.557	1.346	1.319	1.501
Information Ratio	0.008	0.032	0.027	0.032	0.053	0.053	0.003	0.003
Probability > 0 (%)	50.000	49.432	52.273	53.977	51.705	49.432	49.432	50.568
Probability > Equal (%)	55.682	50.568	51.705	52.273	50.000	53.409	46.023	53.977
paired t-test	0.394	0.459	0.634	-0.774	0.562	-0.423	-0.322	0.636

The base currency is denoted at the top of each column. The mean monthly return is denoted with an asterisk if it is significantly different from zero. The information ratio is the ratio of the mean return to standard deviation. The [Probability >] rows give the percentage of the total number of months when the given strategy exceeded zero and the Equal benchmark. The paired *t*-test is used to test the significance of the excess returns. The data period spans from January 1993 to March 2008. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

The descriptive statistics of the more specific and more selective long/short strategies are also presented in the Table 11. They are the third and the fourth strategies. The third strategy is at the first look the worst performing strategy, with negative average monthly returns in several markets. Only when Icelandic krona, US dollar or Japanese yen are used as a base currency, the mean monthly returns are positive. The lowest average return of -0.090% is generated when euro is used as a base currency and the highest of 0.061% when US dollar is the base currency. Again, the average returns remain insignificant, even if one would use the 10% confidence level.

The fourth strategy generates positive average returns in all the studied markets and they vary between 0.005% for Swiss franc and 0.106% for US dollar. The information ratios further indicate the superiority of the fourth strategy over the third strategy. This is, again, somewhat contradictory to the findings of Okunev and White (2003), who find that these more selective strategies provide average returns higher than those generated by the simpler strategies.

The significance of the excess returns compared to the equally weighted portfolios is low, also for the third and the fourth strategy. For the third strategy, five out of the eight average excess returns are negative, which indicates that the portfolio following this strategy rather loses compared to the equal portfolio. The average excess returns remain positive only for Swedish krona, Norwegian krone and Swiss franc. The excess returns from the fourth strategy are more in line with those of the first and the second strategy. Here, only the portfolios based on Icelandic krona, US dollar or Japanese yen generate negative excess returns compared to the equally weighted portfolio. However, the t-statistics remain low and insignificant, even at lower significance levels. Quite surprisingly, Okunev and White (2003) find that these, more selective strategies not only provide larger average returns but also returns that are, in general, more statistically significant.

The third strategy provides, in most markets, positive monthly returns in less than 50% of the months studied in this thesis. However, it seems to struggle with the equally weighted portfolio, as the probabilities for the third strategy to beat the equal portfolio are at least 50%. Still, the fourth strategy performs better also in this sense as the probabilities for both exceeding the zero-profit strategy and the equally weighted currency portfolio are, in most studied markets, higher than when using the third strategy.

8. Conclusions

The existing academic literature has found significant momentum returns in the foreign exchange market since 1970s. My thesis intended to find out if momentum can still generate significant, positive excess returns. The previous studies have mainly concentrated in the most liquid and traded currencies like British pound and US dollar. This thesis expands this literature by examining markets from the Nordic region, more specifically Iceland, Sweden and Norway. Moreover, five other markets have also been included in the data set to verify

the existing academic findings. These other currencies include UK sterling, US dollar, Swiss franc, Japanese yen and the single European currency unit, euro.

I have used two different ways to test for the existence of momentum in these markets. These are based on different ranking approaches. The first method is straightforward, by simply based on the rank of past monthly returns. The second method uses various combinations and strategies with several hundreds of moving average returns. The data set spans from January 1993 to March 2008.

My empirical findings indicate that momentum still exists in most of the foreign exchange markets studied in this thesis. Although the average monthly momentum returns are not necessarily significant, they are almost always positive and higher than those generated by applying an equally weighted currency portfolio when using the first method of simple past returns. Momentum is most statistically significantly observed when using a holding period of one month combined with a ranking period of various lengths. In the US dollar based market, however, momentum was not found. None of the average monthly momentum returns is significantly positive and all the significant excess returns are negative. Although the Japanese yen based market generates significantly positive monthly momentum returns, these returns are significantly smaller than those generated by the equally weighted portfolio. This indicates that momentum exists in the yen market, although these trading strategies do not turn out to be profitable.

The Swiss franc based and the UK sterling based foreign exchange markets experience a small probability of momentum returns. These momentum returns are found almost only while using a one month holding period, but for Swiss franc these returns are not in excess of the equally weighted portfolio. For UK pound, these momentum returns are excessive but found only using a one month holding period, indicating that only weak momentum exists in that market. The same is true for the euro market. The Nordic currencies, however, generate more generally significant, positive monthly momentum returns. To my best knowledge, this thesis is the first to study momentum in these Nordic markets. All of these markets experience somewhat high momentum, although the Icelandic and Swedish markets do not generate excessive returns. Especially in the Norwegian market these momentum returns are more generally in excess of the equally weighted portfolio, indicating that the Norwegian market has very high momentum potential.

For all the studied markets, the monthly average momentum returns are in the range between 0.097% and 0.348% at 5% or 1% confidence level. The highest returns are generally found in the Norwegian based market and lowest in the Japanese yen market. The moving average approach generated mainly positive average monthly momentum returns but these returns were neither statistically significant nor generally larger than the equally weighted currency portfolio. Furthermore, the size of these returns was considerably lower than those found in the existing academic literature.

As this thesis has indicated, momentum trading possibilities do still exist in the foreign exchange market. Investors have long argued that market inefficiencies make these momentum trading strategies profitable, at least in the short-term. My findings support the investors' arguments as the profitability of various momentum trading strategies contradicts the market efficiency hypothesis. Because momentum turned out to be at its largest in the Nordic foreign exchange markets, an interesting way forward would be to study the Nordic currency markets more closely. This could be done by applying various new trading strategies, using more high-frequent data and prolonging the data set.

Appendices

Appendix A

Table 12 – Descriptive Statistics, Base Returns (logarithmic returns)

Descriptive Statistics (Base Currency Returns)

	Europe	Sweden	Norway	Iceland	UK	US	Japan	Switzerland	Equal
Europe									
Mean return (%)	N/A	-0.012	0.038	-0.225	0.032	-0.129	-0.004	0.096	-0.029
Median return (%)	N/A	0.014	0.116	-0.062	-0.032	-0.276	-0.346	-0.013	-0.051
Std. Deviation (%)	N/A	1.593	1.504	2.589	1.958	2.564	3.258	1.122	1.155
t-Statistic	N/A	-0.104	0.338	-1.172	0.224	-0.677	-0.015	1.151	-0.339
Sweden									
Mean return (%)	0.012	N/A	0.050	-0.213	0.045	-0.116	0.009	0.108	-0.015
Median return (%)	-0.051	N/A	0.051	-0.148	-0.187	-0.327	-0.362	-0.205	0.060
Std. Deviation (%)	1.155	N/A	1.860	2.964	2.354	2.934	3.655	2.106	1.857
t-Statistic	0.104	N/A	0.362	-0.967	0.256	-0.535	0.032	0.692	-0.110
Norway									
Mean return (%)	-0.038	-0.050	N/A	-0.262	-0.005	-0.166	-0.041	0.058	-0.072
Median return (%)	-0.116	-0.051	N/A	-0.101	-0.022	-0.259	-0.582	-0.210	-0.157
Std. Deviation (%)	1.504	1.860	N/A	2.865	2.310	2.720	3.469	1.861	1.644
t-Statistic	-0.338	-0.362	N/A	-1.236	-0.031	-0.825	-0.161	0.421	-0.592
Iceland									
Mean return (%)	0.225	0.213	0.262	N/A	0.257	0.096	0.221	0.321	0.228
Median return (%)	0.062	0.148	0.101	N/A	-0.226	-0.016	-0.279	-0.021	0.013
Std. Deviation (%)	2.589	2.964	2.865	N/A	2.628	3.025	4.021	2.925	2.518
t-Statistic	1.172	0.967	1.236	N/A	1.321	0.429	0.742	1.478	1.221
UK									
Mean return (%)	-0.032	-0.045	0.005	-0.257	N/A	-0.161	-0.036	0.063	-0.066
Median return (%)	0.032	0.187	0.022	0.226	N/A	-0.165	-0.447	0.116	0.029
Std. Deviation (%)	1.958	2.354	2.310	2.628	N/A	2.175	3.331	2.276	1.666
t-Statistic	-0.224	-0.256	0.031	-1.321	N/A	-0.999	-0.146	0.375	-0.536
US									
Mean return (%)	0.129	0.116	0.166	-0.096	0.161	N/A	0.125	0.224	0.118
Median return (%)	0.276	0.327	0.259	0.016	0.165	N/A	-0.027	0.059	-0.046
Std. Deviation (%)	2.564	2.934	2.720	3.025	2.175	N/A	3.246	2.890	2.203
t-Statistic	0.677	0.535	0.825	-0.429	0.999	N/A	0.519	1.047	0.722
Japan									
Mean return (%)	0.004	-0.009	0.041	-0.221	0.036	-0.125	N/A	0.099	-0.025
Median return (%)	0.346	0.362	0.582	0.279	0.447	0.027	N/A	0.367	0.332
Std. Deviation (%)	3.258	3.655	3.469	4.021	3.331	3.246	N/A	3.136	3.078
t-Statistic	0.015	-0.032	0.161	-0.742	0.146	-0.519	N/A	0.428	-0.109
Switzerland									
Mean return (%)	-0.096	-0.108	-0.058	-0.321	-0.063	-0.224	-0.099	N/A	-0.138
Median return (%)	0.013	0.205	0.210	0.021	-0.116	-0.059	-0.367	N/A	-0.055
Std. Deviation (%)	1.122	2.106	1.861	2.925	2.276	2.890	3.136	N/A	1.590
t-Statistic	-1.151	-0.692	-0.421	-1.478	-0.375	-1.047	-0.428	N/A	-1.175

The data set consists of monthly returns for individual currencies from January 1993 through March 2008. The period consists of 182 months. The base currency is denoted in the far left and the columns to the right give the return statistics of the seven other currencies in relation to the base currency. Equal currency returns are calculated relative to the base currency and equal column calculates the currency return, assuming an equal proportion allocated to the seven non-domestic currencies. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 13 – Descriptive Statistics, Interest-Adjusted Returns (logarithmic returns)

Descriptive Statistics (Interest-Adjusted Currency Returns)

	Europe	Sweden	Norway	Iceland	UK	US	Japan	Switzerland	Equal
Europe									
Mean return (%)	N/A	0.044	0.137	0.191	0.165	-0.098	-0.274	-0.059	0.015
Median return (%)	N/A	0.029	0.170	0.273	0.099	-0.290	-0.610	-0.153	-0.016
Std. Deviation (%)	N/A	1.615	1.512	2.579	1.962	2.583	3.255	1.120	1.154
t-Statistic	N/A	0.371	1.224	0.999	1.137	-0.512	-1.134	-0.713	0.179
Sweden									
Mean return (%)	-0.044	N/A	0.093	0.147	0.121	-0.142	-0.318	-0.104	-0.035
Median return (%)	-0.029	N/A	0.124	0.304	-0.119	-0.330	-0.683	-0.343	0.031
Std. Deviation (%)	1.615	N/A	1.880	2.963	2.368	2.960	3.661	2.122	1.871
t-Statistic	-0.371	N/A	0.666	0.668	0.689	-0.649	-1.171	-0.658	-0.255
Norway									
Mean return (%)	-0.137	-0.093	N/A	0.054	0.028	-0.235	-0.411	-0.196	-0.141
Median return (%)	-0.170	-0.124	N/A	0.164	0.037	-0.297	-0.879	-0.428	-0.188
Std. Deviation (%)	1.512	1.880	N/A	2.850	2.328	2.746	3.464	1.876	1.649
t-Statistic	-1.224	-0.666	N/A	0.255	0.163	-1.155	-1.600	-1.413	-1.157
Iceland									
Mean return (%)	-0.191	-0.147	-0.054	N/A	-0.026	-0.289	-0.465	-0.250	-0.203
Median return (%)	-0.273	-0.304	-0.164	N/A	-0.438	-0.236	-1.131	-0.501	-0.365
Std. Deviation (%)	2.579	2.963	2.850	N/A	2.623	3.026	4.022	2.925	2.508
t-Statistic	-0.999	-0.668	-0.255	N/A	-0.132	-1.289	-1.558	-1.154	-1.092
UK									
Mean return (%)	-0.165	-0.121	-0.028	0.026	N/A	-0.263	-0.439*	-0.225	-0.174
Median return (%)	-0.099	0.119	-0.037	0.438	N/A	-0.197	-0.769	-0.138	-0.070
Std. Deviation (%)	1.962	2.368	2.328	2.623	N/A	2.180	3.336	2.294	1.672
t-Statistic	-1.137	-0.689	-0.163	0.132	N/A	-1.630	-1.775	-1.321	-1.401
US									
Mean return (%)	0.098	0.142	0.235	0.289	0.263	N/A	-0.176	0.039*	0.127
Median return (%)	0.290	0.330	0.297	0.236	0.197	N/A	-0.352	-0.115	0.000
Std. Deviation (%)	2.583	2.960	2.746	3.026	2.180	N/A	3.273	2.919	2.226
t-Statistic	0.512	0.649	1.155	1.289	1.630	N/A	-0.724	0.179	0.772
Japan									
Mean return (%)	0.274	0.318	0.411	0.465	0.439*	0.176	N/A	0.214	0.328
Median return (%)	0.610	0.683	0.879	1.131	0.769	0.352	N/A	0.485	0.646
Std. Deviation (%)	3.255	3.661	3.464	4.022	3.336	3.273	N/A	3.141	3.080
t-Statistic	1.134	1.171	1.600	1.558	1.775	0.724	N/A	0.920	1.436
Switzerland									
Mean return (%)	0.059	0.104	0.196	0.250	0.225	-0.039	-0.214	N/A	0.083
Median return (%)	0.153	0.343	0.428	0.501	0.138	0.115	-0.485	N/A	0.168
Std. Deviation (%)	1.120	2.122	1.876	2.925	2.294	2.919	3.141	N/A	1.603
t-Statistic	0.713	0.658	1.413	1.154	1.321	-0.179	-0.920	N/A	0.698

The data set consists of interest-adjusted monthly returns for individual currencies from January 1993 through March 2008. The period consists of 182 months. The base currency is denoted on the far left and the columns to the right give the return statistics of the seven other currencies with respect to the base currency. Equal currency returns are calculated relative to the base currency and equal column calculates the currency return, assuming an equal proportion allocated to the seven non-domestic currencies. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

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