



# Technical analysis in the Foreign Exchange Market

*Testing the profitability of technical trading rules*

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## Abstract

In this analysis, three simple technical trading rules - filter rules, moving average rules and channel breakout rules - are tested in the foreign exchange market in the period from 1986-2016. The technical trading rules are tested on three currencies; British Pound, Japanese Yen and Swiss Franc relative to the US-dollar. The study applies three performance measures; mean excess return, Sharpe ratio and Jensen's alpha to evaluate the predictability of technical trading rules. The performance is tested by using a standard t-test and a residual bootstrap by Lebaron (1998). To correct for data snooping, it is included additional weeks to the technical trading rules. The full-sample t-test suggest that several trading strategies generate significant profitable returns. However, some of the trading rules reveal data snooping bias and the profitability is due by chance rather than merit. In addition, the positive returns do not survive risk adjustments and reveal small signs of robustness. The residual bootstrap indicates that the technical trading rules show lack of predictive power to exploit the foreign exchange market. Overall, the study suggests that the frequent recommendations of technical analysis by practitioners is most likely explained by opportunistic choice of individual rules, which happened to perform well in the past.

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## 1.0 Introduction

Technical analysis (TA) is widely used in the foreign exchange market (FX market) and seeks to disclose patterns and trends to forecast future prices. The purpose is to use technical trading rules (TTR) to time market positions in order to outperform the market. Technical analysts believe traders are able to earn abnormal returns without taking on a greater risk, so called “free lunch”. Many practitioners have studied the properties of exchange rates and found that TTR are valuable in the FX market.

On a theoretical foundation, academics are skeptical towards the TA. Fama (1970, 76, 91) claims that in an efficient market, the prices should reflect all available information and the future prices are unpredictable, which eliminate the value of TTR. Moreover, TA has been criticized for cherry-picking results and the willingness of concealing the full set of alternatives is strengthened.

The contradicting views between academics and practitioners have provided several empirical studies of TA. However, the studies have not given any clear solutions to whether the TTR actually work in reality. This study is inspired by the controversy and will contribute to the field of research of TA and market efficiency, by answering the research question: Can the use of technical trading rules be successful in the foreign exchange market? In light of this, the performance of common and simple trading rules is tested on three currencies; British Pound, Swiss Franc and Japanese Yen relative to the US dollar.

To evaluate the performance of the trading rules, some relevant factors that must be considered. First, the TTR need to consistently outperform the FX market and have a predictive power, given the risk involved. Second, issues of data snooping bias may occur. In this case, the profitability might be caused by pure chance or due to inefficiencies in the FX market. Third, the profitability of the TTR can be affected by market conditions, meaning that the strategies seem profitable during certain trends in the market and thereby show lack of robustness in the long-run. Lastly, market characteristics such as autocorrelation, normality and stationarity must be taken into account. These characteristics could possibly

explain the outperformance of the trading strategies and do not necessarily indicate that the strategies have a predictive power.

This thesis is structured in the following way: In chapter two, appropriate theory on market efficiency are assessed. Chapter three considers the aspects of a TA and give an introduction to the selected technical indicators. Then, in chapter four, literature review is shown. Chapter five presents methods that will assist to determine the performance of the TTR, followed by a discussion and test results in chapter six. Finally, conclusions are presented in chapter seven. There are different paths to assess the foreign exchange market and no financial theory is finite.

## 1.1 Introduction to the Foreign Exchange Market

Before the second world war, the Gold standard was the monetary system in the foreign exchange market. The gold standard imposed currency values in terms of their fixed amount in gold. In 1944, the Bretton Wood agreement was established to replace the Gold standard. This agreement grew out of a desire to avoid the monetary chaos of the interwar period to make the market more stable and disciplined. In terms of the Bretton Wood agreement, FX rates were controlled by a fixed rate against the gold. In 1973, the Bretton Wood system broke down and the market went from having a fixed dollar rate against the gold, to many currencies floating against each other. Since then, gold has lost its role in the international monetary system. (World Gold Council, 2018).

Nowadays, FX rates are formed by the purchase and sale of two different currencies, meaning the supply and demand determine the exchange rates for each currency. The supply and demand of exchange rates are affected by different factors essentially political events, the world economy, interest rates and speculation. (Bekaert & Hodrick, 2018, p. 192).

The FX market is the most traded market in the world. During the last 40 years, the daily volume of currency trading has grown significantly due to the process of globalization. (Bekaert & Hodrick, 2018, p. 47-50). According to the Bank of international Settlements

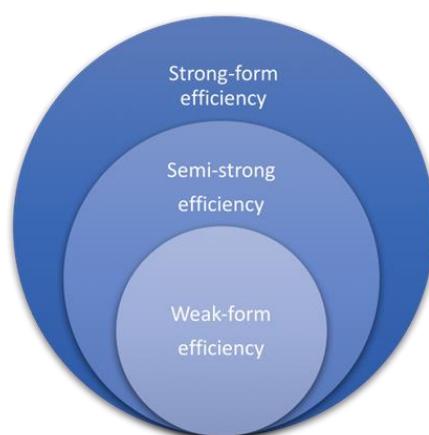
(1973, 2016), the estimated daily trading volume was approximately 10-20 billion USD in 1973 which increased to 5 trillion USD by 2016. The FX market is open 24 hours a day, five days a week and will therefore react more instant to financial news compared to the stock market. (Bank for International Settlements, 2010).

## 2.0 The efficient market hypothesis

The efficient market hypothesis (EMH) was introduced by Fama (1970, 76, 91) and states that the market prices should fully reflect all available information and the rationality of the trader's behavior. In addition, the market will instantly react to new information. This implies that it is impossible to exploit past prices to predict future price movements. Certainly, given the EMH, there are no arbitrage opportunities in the market and the estimates will be unbiased, meaning that there is no correlation between the asset prices and the underlying values in the market. (Basu, 1977).

### 2.1 Three forms of EMH

Fama (1970, 76, 91) developed a framework with different degrees of market efficiency. The three degrees of market efficiency are weak-, semi-strong- and strong form. To what extent the market is efficient is defined by how much information is available and reflected in the market prices.



*Figure 2.1 - The degree of efficiency.*

### 2.1.1 Weak form efficiency

If the market is weak-form efficient, the asset prices will reflect all historical information. This means that the investors will not be able to gain superior amount of returns by only looking at price charts. In addition, observing historical prices will not give identifiable price patterns to exploit the future market. Thereby, the rates of return in the market will be independent from previous patterns, which supports the “random walk theory”.

### 2.1.2 Semi-strong efficiency

A market is defined semi-strong efficient when all historical- and publicly available information is reflected in the asset prices. Financial statements, market data and announcements are examples of publicly available information. If semi-strong efficiency holds, it is not possible for an investor to beat the market by trading on new public information.

### 2.1.3 Strong-form efficiency

The strong-form efficiency is fulfilled when all historical-, publicly available- and private information is reflected in the asset prices. If the market is strong form efficient, traders should not be able to use private information to gain abnormal returns in the market. Private information can be an example of financial information within a company which is not yet publicly released but is used as an advantage within trading.

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## 3.0 Technical Analysis

Technical analysis (TA) is used to forecast future price movements by observing historical prices and volume data. TA applies TTR to reveal patterns and trends, and signal when the investor should buy and sell currencies in order to exploit the market. (Taylor & Allen, 1992).

TA is based on three principles. The first principle, market action discounts everything, states that all information in the market is actually reflected in the asset price. The asset price will reflect everything related to the fundamental-, economic- and psychological factors within the market. The second principle, prices move in trends, can be identified by Newton's first law of motion; saying that a trend in motion is more likely to continue in the same direction rather than move in a different direction. This implies that future prices can be predicted by trends from historical data, which is essential in terms of the success of the TA. (Murphy, 1986). The trend indicate predictability and the trader will be able to profit from a buy (sell) strategy when the prices rise (fall). (Neely & Weller, 2011). The last principle, history repeat itself, states that future patterns can be discovered from past history. These patterns are based on studies of human psychology, where market participants tend to act in the same way over time. (Murphy, 1986).

The three principles seem somewhat contradictory. The first assumption states that the prices reflect everything in the market, meaning that past trends should also be included in the prices and therefore the future prices should be unpredictable. However, the second principle explicitly states that the prices move with trends indicating the possibility to discover future price movements. According to this, the first- and second principle are contradictory. In addition, if prices reflect past trends, TA assumes the markets to only be weak-form efficient.

### 3.1 Overview of technical trading rules

Technical trading rules (TTR) are strategies used to buy/sell assets and foreign currencies. These rules are widely used by traders in the stock- and FX market. To apply TTR, two

assumptions must be fulfilled. First, the speculator can invest in long- or short positions in the FX market. Second, the speculator has the necessary initial wealth to trade FX contracts.

TTR can be classified as either simple- or complex rules and generate signals for market positions. Simple rules include one or few indicators, while complex rules rely on many indicators. The indicators are defined as either leading- or lagging indicators. Leading indicators send trade signals to the investor before the asset value starts to follow a specific pattern or trend, which gives the investor the opportunity to perfectly time the market. In terms of this, leading indicators often give higher profits compared to lagging indicators. However, leading indicators tend to send false signals since the trading signals is given before the actual change in the trend or pattern. Lagging indicators follow the price action by observing historical prices to determine future trends. The lagging indicators following existing trends indicate that the usefulness of the indicators is higher in trending periods compared to non-trending periods. Since the lagging indicators focus more on trends, they create less buy and sell signals. This implies that the trader will capture more of the trend and hold their position longer instead of being forced out of their position. Both leading- and lagging indicators are useful to discover trends in assets and volatility which is quick and unpredictable changes in prices and momentum; the strategy of observed rising prices tend to keep rising and falling prices will continue to fall. (Reilly & Brown, 2003).

Earlier research has shown that the use of too few TTR can cause biases in statistical inference due to data snooping. On the other hand, including too many TTR will reduce the power of the testing. (Hansen, 2003). Data snooping appears when data is used more than once for purposes of model selection or inference. With the occurrence of data snooping, tests using the same time series are likely to give misleading results where satisfactory results obtained may be due to pure luck rather than to any merit inherent in the method yielding the results. (White, 2000).

Our analysis in section 5 will include the following three TTR; filter rules, moving average rules and channel breakout rules. This selection can be motivated as follows. First, these trading rules are simple and based on observable lagging indicators. Second, according to

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previous academic literature, filter-, moving average- and channel breakout rules are commonly used by traders and easy to implement in the market. Lastly, given the widespread use of many decades, this mitigates data snooping concerns.

### 3.1.1 Currency pairs

Currency pair is a quotation between two different currencies used in trading, where one currency is quoted against the other currency.  $S(f/h)$  is an indirect quote and defined as the spot exchange rate between the foreign- and home currency. The foreign currency (f) is the quote currency, while the home currency (h) is the base currency. That is,  $S$  yields the number of foreign currency units that are required to purchase or sell one unit of the home currency.

Major currency pairs include currencies that are paired from countries with highly developed financial systems and economy. In the analysis, the currencies; Swiss Franc (CHF), Great British Pound (GBP) and Japanese Yen (JPY) are quoted against the U.S dollar (USD). These currencies quoted against the USD are characterized as major currency pairs. In the FX market, the USD is the most traded currency and almost 90% of all currencies are traded against it. (BIS, 2016). In this study, the USD is defined as the home currency, whilst the other three currencies are defined as the foreign currencies. Further, our interpretation of the trading strategies will be based on the quotation  $S = S(f/h)$ .

### 3.1.2 Filter rules

Filter rules are based on momentum strategies and generate buy or sell signals to the speculator. A filter rule would predict that if the closing price  $S(f/h)$  rises by  $b\%$  or more from its recent low, the speculator would want to short sell the foreign currency and use the proceeds to buy the home currency. Contrary, if the closing price  $S(f/h)$  drops by at least  $b\%$  from its recent high, the speculator borrows the home currency and use the proceeds to buy the foreign currency. The recent high position is defined by the highest price over a period of  $n$  weeks, while the recent low position is the lowest price over a period of  $n$  weeks (Neely & Weller, 2011).

### 3.1.3 Moving average rules

Moving average rules (MA) are used to profit from a momentum strategy or trends in asset prices. The MA use the average of past price movements to spot trends instead of examine day-to-day fluctuations. The MA rules generate buy (sell) signals by comparing the long- and short moving average of past prices computed over a period of  $n$  weeks, including the current rate. When the short moving average (in foreign currency) of a home currency increases by  $b\%$  above the long moving average, the speculator will short sell the foreign currency and buy the home currency. If the long moving average of a foreign currency intersects the short moving average by  $b\%$ , the speculator borrow the home currency and use the proceeds to buy the foreign currency. (Neely & Weller, 2011).

### 3.1.4 Channel breakout rules

Channel breakout rules (CBR) is a trend following indicator. A channel appears when the highest price of  $S(f/h)$  is within a  $x\%$  of the lowest price over the previous  $n$  weeks. If  $S(f/h)$  exceeds the highest point on the channel length by  $b\%$ , the speculator will short sell the foreign currency and buy the home currency. If the  $S(f/h)$  moves below the lowest point on the channel length by  $b\%$ , the speculator borrow the home currency to buy the foreign currency. (Sullivan et al. 1999).

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## 4.0 Literature Review

In this section, studies on market efficiency and TA in both the stock- and FX markets are reviewed.

### 4.1 Evidence on market efficiency

The importance of market efficiency has motivated many researchers to examine to what extent the EMH holds in the market. Although the market implies to be efficient in theory, practitioners have criticized the EMH. It is uncertain whether inefficiencies in the market are driven by predictability or misleading assumptions in the pricing models. (Fama, 1991).

#### 4.1.1 Evidence on stock market

Numerous studies have explored different aspects of the EMH on the stock market. Previous research has mostly studied weak-form efficiency, but also examined markets for semi-strong- and strong-form efficiency.

##### *Weak form efficiency*

The first extended study on efficiency in the stock markets were done in the early 1950s. Roberts (1959) researched the American stock market for a random walk and concluded that the stock prices followed random patterns which support the weak-form EMH.

Fama (1970) published a survey article where he used autocorrelation tests for market efficiency, mainly focusing on informational efficiency. Autocorrelation examines the degree of similarity between a given variable and a lagged version (past period) of the same variable. Problems of autocorrelation occurs when the error terms in the analysis follows a specific pattern and generate wrong results in the model. By adding lagged values, the data get rid of unwanted biases and weakens the autocorrelation effects. The results from the tests suggested that the stock markets were weak- and semi-strong efficient. Later on, Fama (1991) did a further research on market efficiency. In this study, Fama found stronger

evidence of predictability of stock returns on both lagged values of the returns as well as publicly available information.

Rosenthal (1983) examined serial correlation on weekly, biweekly and monthly returns on 54 foreign equities on the American depository receipts (ADR) from 1974-1978. The research discovered how well past prices can predict future prices of the stock. The results from the research showed consistencies in the market indicating weak forecast power. Later on, Karemera et al. (1999) studied the stochastic properties of local currency and the US-dollar based equity returns in 15 emerging capital markets. The purpose of stochastic properties, is to estimate how credible outcomes are within a forecast to predict conditions for different situations. The test suggested that the emerging markets were weak-form efficient and that investors are unlikely to make profits without additional risk. The results support the random walk hypothesis.

More recent, Gu and Finnerty (2002) did a study on autocorrelation in daily returns on the Dow Jones Industrial Average in the U.S stock market from 1896-1998. The researchers found that the autocorrelation fluctuates significantly over time on the Dow Jones Industrial Average. In addition, the test showed that the trends of autocorrelation declined after the second world war (1945). Further, the study found evidence of market efficiency and expansion of the U.S stock market between late 1970 to 1998.

Borges (2008) studied the weak-form efficiency in the UK, France, Germany, Portugal, Spain and Greece in the period 1993-2007. First, they did a the full-sample test followed by a sub-sample test from 2003-2007. Four stock markets showed evidence supporting the weak-form efficiency in the full sample, while the Portuguese and Greece stock markets showed signs of autocorrelation indicating inefficiencies. However, in the sub-sample test; all six stock markets fulfilled the assumptions of weak-form efficiency. Ito & Sugiyama (2009) examined time varying autocorrelation of stock returns in the US. stock market in the period 1955-2006. The test found evidence of efficiency in the U.S stock market between 1960-1980. However, during the 1980s the U.S stock market were highly inefficient

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according to the results. From 2000-2006, the researchers concluded that the market were consistent with the EMH, despite the fluctuations in the earlier periods.

On the other hand, Grieb and Reyes (1999) analyzed individual stocks and the stock market indexes in Mexico and Brazil. They rejected the null hypothesis of weak-form efficiency which indicated inconsistencies in the Mexican- and Brazilian stock market. Further, Narayan et al. (2015) studied the EMH on the US stock market in the period 1980-2007. They tested 156 stocks on a monthly basis from the New York time exchange for weak form efficiency using the GARCH-model for unit root. The model tested for heteroscedasticity in the dataset to discover whether the variance in the error terms is constant. In addition, the test used unit root to figure out how dependent one variable is on previous values of the same variable. The results showed that 40% of the stocks rejected the unit root null hypothesis. They concluded that most of the stocks outperformed the market and showed evidence of inefficiencies.

#### *Semi-strong efficiency*

Charest (1978) did a study on common stock returns in relation to split events and dividend change events revealed on the New York Stock Exchange (NYSE) in the period 1947-1967. The evidence on split events, where companies increase their number of shares, were consistent with the EMH. However, the study on dividend change events showed inefficiencies in the market. In the following months after a dividend change announcement, the NYSE under-reacted especially when the dividend payments decreased. This indicate that the market does not fulfill the semi-strong EMH and the investors were able to exploit the market.

The same year, Ball (1978) did a study on evidence contained in 20 previous studies on the stock price reaction to earnings announcements. He found possibilities of abnormal profits post to the announcement, after adjusting for risk. However, Ball argues that these possibilities are not due to inefficiencies in the market, but because of inadequacies in the two parameters used in the asset pricing model to adjust for risk differentials.

Dowen and Bauman (1997) investigated the effect of insider ownership in small and large firms in the US market. If the semi-strong EMH holds, a change in agency costs should be reflected in the stock prices after a significant change in ownership. The researchers found mixed evidence of efficiency. First, they tested small and large firms excluding control variables. The tests showed insignificant results which supports the semi-strong EMH. Further, they included the control variables: size, research concentration ratio and earnings yield to study the relationship between the dependent- and independent variables. After including the control variables, the tests on both small and large firms gave significant results. Overall, the researchers concluded that the market is inconsistent and does not fulfill the semi-strong EMH.

### *Strong form efficiency*

Finnerty (1976) did a study to determine whether insiders earn more profits than average from their market transactions, including both buy- and sell transactions. The study examined the Securities and Exchange Commission's official summary of stock transactions on the New York Stock Exchange in the period 1969-1972. Results from the study indicated that insiders earn above average returns when they buy securities of their respective corporations. In addition, the price of the securities sold by insiders decreased more than the general market declined in the period. Overall, Finnerty concluded that insiders were able to outperform the market by identifying both profitable and unprofitable situations within their corporations. The study rejected the strong-form efficiency in the market.

Later on, Damodaran and Liu (1993) studied the strong-form efficiency and examined the chance of arbitrage opportunities for insider-traders prior to public announcements. They studied equity real estate investment trusts and concluded that insider-traders take advantage of the private information. They concluded with inconsistencies in the market and rejected the strong-form efficient market hypothesis.

However, Rohini et al. (2008) published a paper with a study on the return of various mutual funds compared to the return of randomly constructed portfolios in different US stock markets from 2003-2007. The researchers found evidence supporting the strong-form

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efficiency as the mutual fund managers with access to insider information did not outperform the randomly selected portfolio of index stocks.

To summarize, empirical evidence of the EMH on weak-form, semi-strong- and strong-form efficiency in the stock market varies. Many researchers have found strong evidence supporting the EMH in the weak-form, whilst others have discarded the hypothesis. Some suggest that outperformance within an efficient market can be explained by pure luck, but states that it is unlikely to happen over time. Both semi-strong- and strong-form efficiency show less evidence supporting the hypothesis of market efficiency. As a result, the EMH under semi-strong- and strong-form are less likely to hold over time due to the complexity in these degrees. However, the stock market tends to be weak-form efficient, but could change depending on the time-period and country departments.

#### 4.1.2 Evidence on FX market

Foreign exchange rates play a major role in the determination of macroeconomic policies across the world. Menkhoff and Taylor (2007) stated that the global FX market is highly liquid and has a greater turnover than the largest stock exchanges. In addition, a survey done by Bloomberg (2014) showed that 90% of retail FX traders failed to beat the market and ended up losing money. While the remaining 10% of the traders outperformed the market. The studies in the FX market draw attention to evidence related to weak-form market efficiencies.

##### *Weak-form efficiency*

After the monetary system was established, Burt et al. (1977) did an empirical analysis on the Canadian Dollar, German Mark and British Pound in the FX market. The purpose was to test whether the exchange rates changed accordingly to the expected value in an efficient market. The results showed efficiency in the German Mark and British Pound. However, the Canadian Dollar did not support the random walk. They concluded that markets were reasonably efficient.

Hakkio & Rush (1989) did a cointegration analysis of the British Pound and Deutsche Mark to test various aspects of market efficiency. A cointegration analysis discovers whether variables are cointegrated, meaning that a combination of two variables are stationary, even though each variable are non-stationary (unpredictable and lead to spurious results). The results revealed evidence of cointegration between the future spot- and current forward rates in both currencies which indicated that the rates are close together (cointegrated) according to the hypothesis. This implies weak-form efficiency however the evidence is poor. In order to receive more credible results, the researchers were able to use error-correction equations to test the joint hypothesis of no risk premium and rationality. The researchers received significant results and thereby they rejected the joint hypothesis. Even though this indicate that the weak-form efficient market is inconsistent, they did not assert that the rejection is due to market inefficiencies.

MacDonald and Taylor (1989) examined the efficiency in the FX market. They tested ten FX rates quoted against the USD in the period 1973-1985. The first test studied the order of integration of the individual FX rates. The results showed that the logarithm of the FX rates does not follow a random walk. The second test examined the cointegration between the FX rate series. The test found no evidence of cointegration in any of the FX series. Over all, the study supports the hypothesis of FX markets to be efficient. Further, Liu and Maddala (1992) tested the EMH in in the FX market using survey data on expectations in the period 1982-1989. They tested the British Pound, Deutsche Mark, Swiss Franc and the Japanese Yen, all quoted against the US dollar using both weekly and monthly data. First, they did a test for rationality of expectations before examining the efficiency in the FX market. After testing the spot-, expected- and forward rates, they concluded that all currencies and rates followed a random walk.

More recent, Azad (2008) did an empirical study on market efficiency by testing for a random walk in 12 Asia-Pacific FX markets quoted against the US-dollar. The study used daily (high frequency) and weekly (medium/low frequency) data from the period 1998-2007. The results from the daily data suggest that the majority of the markets follow a random walk indicating market efficiencies. The weekly data showed evidence of correlation in the majority of the exchange rates, indicating that the EMH can be rejected. A few years later, Chiang et al. (2010) tested the weak-form efficiency in four Asian countries; Japan, South

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Korea, Taiwan and the Philippines in the period 1998-2006. The tests found random walk patterns in Japan, South Korea and in the Philippines indicating that these FX markets are efficient. However, the FX market in Taiwan showed no evidence of random walk, indicating inefficiencies in the Taiwan market.

Overall, the previous studies disclose mixed evidence of weak-form efficiency in the FX market. The majority of the studies reviewed, states that the FX market is weak-form efficient and that the patterns follow a random walk. Nevertheless, some studies found evidence of inefficiencies in the FX market. These suggest that the significant results might be affected by other aspects such as quality, frequency or country departments. Academic researchers claim that the FX market is weak-form efficient, though fluctuations can occur in some periods.

## 4.2 Evidence on technical analysis

TA is still widely applied by practitioners in the market. The extensive use of TA has provided several studies examining the performance of TTR in the stock- and FX market. Researchers have reported contradicting results regarding the success of the TTR in the past decades. (Fama, 1970).

### 4.2.1 Evidence on Stock market

For many decades, several empirical studies have evaluated the use of TA in the stock market. These studies attempt to examine whether it is possible exploiting for profit within the market by applying TTR.

#### *Early studies*

Brock et al. (1992) evaluated technical trading rules' ability to forecast future price movements of US equity returns in the period 1897-1986. They tested moving average oscillator and trading range break and mitigated the data-snooping problem by utilizing a long data series using the Dow Jones Index. Their results supported the TA and showed that the TTR have predictive power. However, it is emphasized in the research to carefully

consider the transaction costs because the costs impact the performance of the trading strategies and thereby the results in the analysis could change.

Bessembinder and Chan (1998) further evaluated the significance of Brock et al. findings. They confirmed the basic of Brock et al. results, but underlined that measurement errors can arise from non-synchronous trading and that the forecast ability is not exclusively. Non-synchronous data can appear from either trading effects or timing effects. Trading effects are instruments that are traded infrequently or fail to trade for a period of time. While timing effects are related to instrument trading in different time zones or different schedules (stocks have different trading frequencies). The problem with non-synchronous data, the inferred correlations will be lower and autocorrelation between different risk factors will occur. Bessembinder and Chan (1998) conclude that the evidence from their results support the TA, but argues that these evidences do not necessarily contradict the EMH. They imply that non-synchronous trading can coexist with the theory of market efficiency.

Further, Ito (1999) did a research on the Pacific-Basin equity markets. The test used an equilibrium asset pricing model with time-varying expected returns to examine the profitability of TTR. An equilibrium asset pricing model focus on balancing the forces of supply and demand of financial assets. If time-variation is not included in the asset pricing model, the expected returns will stay constant over a specific period. Expected constant returns are unrealistic because the returns might not reflect the actual expected returns in the market and will therefore reduce the forecast power of the TTR. The test showed significant results of the forecast power in the Canadian, Indonesian, Japanese, Mexican and Taiwanese equity indices, meaning that these stock markets are exposed to arbitrage opportunities. However, evidence supporting the TA in the US stock market were not found indicating that the use of TTR do not provide any additional value in this market.

### *Modern studies*

Hsu and Kuan (2005) did a study on the profitability of the TTR in the period 1989-2002 in the US stock market. The researchers used 40.000 trading strategies from both simple- and complex TTR. They tested two sub groups: newer- and mature markets. The study applied

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White's reality check and Hansen's SPA to correct for data snooping bias. The results from the analysis showed that traders are able to profit from TTR in newer markets. However, the researchers did not find evidence of abnormal profits in mature markets. The analysis also discovered that the complex trading rules generated more profits than the simple trading rules.

Moreover, Metghalchi et al. (2008) examined the profitability of MA in the Swedish stock market in the period 1986-2004. Daily data in the analysis were obtained from the OMX Stockholm 30 index. The researchers also used a percentage band to filter out false signals. The profitability of MA was examined using a t-test after accounting for transaction costs of 0.5 % per trade. The results from the study showed that the MA, using more than one moving average to generate signals, disclosed evidence of profitability of the TTR in the Swedish stock market. Whilst the MA using only one moving average found no evidence of profitability in the stock market. Further, the study applied White's reality check to correct for data snooping bias. However, White's reality check indicated that the performance of the trading rules is unbiased. Overall, Metghalchi et al. (2008) concluded that some of the MA generate abnormal profits in the Swedish stock market.

On the other hand, Marshall et al. (2008) investigated the US equity market using TA to explore whether it is possible to profit from TTR in the period 2002-2003. The research examined the profitability of 7846 trading rules using filter-, MA-, support and resistance-, CB- and on-balance-volume rules. They studied the 5-minute intraday basis using data from the Standard and Poor's Deposit Receipts (SPDR). The SPDR are tradable exchange-traded funds that closely follow the benchmark on the S&P 500 index. The research divided the analysis into two sub-samples, whereas 2002 represents a bear market and 2003 represents a bull market. A bear market represents a market in decline, where share prices are dropping and investors believe the market follows a downward trend. Contrary, the bull market represents an increasing market where share prices are rising and investors believe the market follows an upward trend. Some of the TTR applied showed evidence of profitability. However, after adjusting for data snooping bias through White's reality check none of the TTR showed any evidence of being valuable in either bull or bear markets.

To summarize, both early and modern studies found mixed evidence of the profitability of TTR. The early studies indicate that traders are able to exploit some of the stock markets, however, researchers arise questions to whether these profits are due to TTR or other factors such as non-synchronous trading. The majority of modern studies imply that most TTR underperform the market and the TA is not valuable. However, a few of these studies have discovered evidence suggesting otherwise. In light of both early and modern studies, the stock markets seem to decline and have become more efficient over time.

#### 4.2.2 Evidence FX market

After the floating exchange rates started in the early 1970s, TA has been highly used in the FX market. (Neely & Weller, 2011). In 1990, a survey from London showed that 90% of FX dealers emphasize TA to predict future prices movements. (Taylor & Allen, 1996).

##### *Early studies*

In the late 1970s, several studies indicate profitability of TTR, though without accounting for exposure to risk factors. Dooley and Shafer (1976) found results supporting the profitability of TTR in the short term. In addition, Sweeney and Surajaras (1993) documented excess returns from TTR in the FX market. They tested three trading rules. Alexander filter rule which is the actual exchange rate and double- and single MA which use moving averages to smooth out the noise in the exchange rate. Further, the researchers compared the trading rules to examine which trading rule that created the best performance. Their results were significant, showing that traders are able to take advantage of the market.

Levich and Thomas (1993) presented new evidence of TTR in the FX market. Their test was based on bootstrap methodology by utilizing a new database and looking at futures contracts. The research collected future prices from five currencies; Japanese Yen, British Pound, Swiss Franc, German mark and the Canadian dollar in the period 1976-1990. The full sample results showed profitability and statistical significance of TTR. Further, they researched three sub-sample periods. All of the periods showed significant profitability of the TTR. However, the profitability of some trading rules declined in the last sub-sample test. Later on, Lebaron et al. (1999) examined the arbitrage opportunities in the FX market by applying MA and TRB on the Dow Jones Index in the period 1897-1986. They used a

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standard statistical test and bootstrap techniques. The paper reported strong evidence of large profits from TTR after deducting transaction costs.

On the other hand, Lee and Mathur (1996) did a study to see if MA could give abnormal profit. The study analyzed six European spot cross-rates in the period 1988-1993. They found evidence of MA to be marginally profitable in only two of the six FX rates analyzed. Over all, Lee and Mathur (1996) concluded with the cross-rates examined to be sufficiently transparent to eliminate MA profit. Similarly, Cheung and Wong (1997) tested four Asian exchange rates against the USD by using filter rules and concluded that the abnormal return of TTR disappeared after risk adjustments.

Lee et al. (2001) did a study on daily in the period 1988-1995. They tested nine Asian exchange rates quoted against the USD for random walk behavior using MA and CBR. First, they did a joint variance test, which examines if the variance of the increments in a random walk is linear in the sampling interval. The joint variance test found little evidence of serial correlation in the daily FX rates, in addition the research found no evidence of MA nor CBR to generate abnormal return.

### *Modern studies*

More recent studies have implied that a possible reason to discover evidence of abnormal profits by using TTR come from ignoring data-snooping bias. (Park & Irwin, 2005). Due to this, the traders can earn profits due to pure luck and not from TTR. White (2000) published a paper where he explained the issues considering data-snooping. The paper proposed a formal test, White's reality Check, to avoid spurious inferences caused by data snooping.

Qi and Wu (2006) did a research on seven exchange rates against the dollar between 1973-1998. This was one of the first studies on TA in the FX market applying White's reality check to control for data snooping. The paper tested 2.127 TTR and applied four trading rules; filter rules, moving average rules, trading range break rule and channel breakout rules. The study included a full-sample test and two sub-sample tests. The results from both the full-sample- and the first sub-sample test showed no evidence of data snooping at 1%

significance level. However, the results given in the second sub-sample showed more evidence of data snooping and less profit. The researchers concluded TTR to be significant profitable, but that the FX market has become more efficient over the years.

Charlebois and Sapp (2007) included information from the option market in their standard test to investigate movements of the exchange rates to explore profitability of TTR. The test used moving average rules on US dollar-Deutsche Mark spot exchange rates between 1988-1998. The test generated statistically significant returns over the sample period. However, considering data of the open interest differentials on options, the test showed more consistent returns indicating that the TTR created additional value.

Olson (2004) did an out-of-sample research of profitability of simple moving average rules. The results showed significant risk-adjusted profits by using TTR in the 1970s. In the 1980s the results were both significant and insignificant, but the significant risk-adjusted profits were smaller than the profits earned in the 1970s. In the 1990s the profits were equal to zero. The researcher claims that trading rule profits in the foreign currency market have declined over time.

Throughout the years, both early and modern studies disclose various evidence of profitability of the TTR. The majority of the early studies suggest that there are evidence supporting the excess profitability of TTR implying that traders are more likely to exploit the market. Nevertheless, these studies have revealed concerns related to data snooping bias, risk- and transaction costs estimation and ex-post selections of trading rules. These concerns may be due to price anomalies in the FX markets which could create misleading results which reduce the successfulness of the TTR. More modern studies indicate that the FX markets have become less volatile and more consistent over time due to less discovers of arbitrage opportunities.

## 5.0 Methodology

This section will strive to motivate the purpose of this paper, present methods that will assist to determine the profitability of TTR and give a more detailed explanation of the applied trading strategies to evaluate the performance.

### 5.1 Technical trading rules strategies

The TTR generate different signals based on price movements in the market. These signals, buy and sell, indicate which position a trader should take in order to exploit the market. The buy signals imply a long position, while the sell signals imply a short position. The rules have either fixed- or variable holding. The fixed holding implies that while holding a given long- or short position for a period of  $n$  weeks all other signals are ignored. Variable holding position will be affected by signals in the subsequent period and the previous signals will no longer be valid. The TTR will apply a fixed holding period of 2 weeks.

Observations of small price fluctuations can generate false signals in the FX market. In order to filter out these signals, a filter of percentage band is imposed. The percentage band is the change of a specific percentage that need to take place before the signals are generated.

Based on previous research a percentage band of 1% is applied, as the use of a small percentage band will more likely be successful rather than a large percentage band. (Brock et. al, 1992). In addition, several weeks are utilized depending on the TTR in the short- and long-term period which are presented in the following sections.

The weekly returns are defined as the weekly change in the price relative to the FX rates as follows:

$$R_t = (S_t / S_{t-1}) \quad (1)$$

Where the  $R_t$  is defined as the return at time  $t$ .  $S_t$  is the closing price at time  $t$  and  $S_{t-1}$  is the closing price at time  $t-1$ .

### 5.1.1 Filter rules

Filter rules were first introduced by Alexander (1961) and is one of the most popular trading rules which trigger many signals in the FX market. The rules generate buy (sell) signals when the price rise (drops) by a percentage band of 1% from its recent low (high) position. The recent low (high) position is defined as the lowest (highest) price over a period of 5, 6 and 7 weeks in the short-term- and 50, 51 and 52 weeks in the long-term period. In total, six filter rules are tested for each currency.

### 5.1.2 Moving average rules

Moving average rules can be divided into simple moving average (SMA), exponential moving average (EMA) and linear moving average (LMA). SMA use equal weight on each observation over a defined trading period, while EMA and LMA react to price changes on more recent days. The different strategies generate similar results although the computations differ. For consistency, we will use SMA as these moving averages smooth out large price fluctuations and makes it easier to disclose trends in the market. SMA will be referred to as MA throughout the thesis.

To identify moving trends in the market, we will use moving average crossover, where a short MA is compared to a long MA. The moving average lengths are 1-5, 2-6 and 3-7 weeks in the short-term period and 1-50, 2-51 and 3-52 weeks in the long-term period. LeBaron (1998) mentions that these lengths are commonly used and that the profitability is not immensely vulnerable to the actual length of MA. In total, we will test six SMA for each currency.

### 5.1.3 Channel breakout rules

The CBR represents two trend lines, where the maximum level is the highest price over a certain period and the minimum level is the lowest price over the same period. To receive buy and sell signals, the prices need to break through a channel which are produced by the trend lines. The channel appears when the highest price is within 10% of the lowest price over a certain period. The channel lengths in the short-term period are 5, 6 and 7 weeks and

20, 21 and 22 weeks in the long-term period. In total, six CBR are tested for each currency. (Sullivan et al, 1999).

## 5.2 Performance Measures

To test the performance of the TTR we will use three different performance measures; Mean excess return, Sharpe ratio and Jensen's alpha. The performance measures are calculated annually. In addition, we will apply standard t-tests and examine the p-values for each measurement to determine whether the results from the performance measures are significantly different from the benchmark.

### 5.2.1 The mean excess return

In literature, mean excess return is the most applied measurement of performance. The mean excess return measures the average excess return of the risk premium. According, Levish and Thomas (1993), the mean excess return of the  $k^{\text{th}}$  trading rule at time  $t$  is computed as:

$$R_{k,t} = (P_s / (P_b - 1)) * (n / 52) * (1 - r_f) * (1 - g)$$

The  $R_{k,t}$  represents the zero-net investment for an investor taking a position in the FX market.  $P_s$  represents the closing price an investor sells units of the foreign currency and  $P_b$  represents the closing price an investor buys units of the foreign currency. Second, the  $n$  is defined as the number of weeks a buy signal is held until a sell signal is generated. To compute the yearly mean excess return of the generated buy and sell signals, the  $n$  is divided by 52. The U.S three-month treasury bill is applied as the risk-free rate and defined as  $r_f$ . Lastly, we adjust for one way transaction costs which represent the  $g$ . Due to a large variation between the number of trading signals generated by the strategies, it is necessary to explicitly account for them in the return computation.

Specifically, we will use a fixed one-way transaction costs on the FX rates. Researchers have different opinions according the values of one-way transaction costs. LeBaron (1999) suggest 0.1 % is a proper measurement of the average one-way transaction costs in the FX market. While more recent studies, Olson (2004) stated that the one-way costs should be equal to 0.025%. In addition, Qi and Wu (2006) argued that a charge of 0.025% were reasonable. Also, they examined whether the effects of transaction costs would impact the results by considering an additional transaction cost of 0.05%. Increasing the transaction costs from 0.025% to 0.05% did not reveal significantly changes in the excess return. As a result, changing the transaction costs will likely generate similar results. Based on previous research, we will use a one-way transaction cost of 0.025% which is adjusted for in the mean excess return computation.

The recent years, transaction costs have been held to a minimum as the FX market has become more liquid as the competition between brokers has increased. Today, brokers still charge a small amount of transaction costs when trading in the FX market. Though the charge is low, transaction costs might have a significant impact on the investment strategies in the market that allows for long- and short positions. Hence, to obtain valid results from the trading strategies it is important to use a proper estimate of transaction costs. Due to the minimum charge of transaction costs, we will use equal one-way transaction costs on long- and short positions in the market. (Alexander, 2000).

### 5.2.2 Sharpe ratio

William Sharpe (1966) invented the Sharpe ratio which is widely used to measure portfolio performance in the financial market. The Sharpe ratio is defined as the risk-adjusted return of a financial portfolio, which measures the average excess return per unit of total (stand-alone) risk. The Sharpe ratio of the  $k^{\text{th}}$  trading rule at time  $t$  is computed as:

$$G_{k,t} = R_{k,t} / \sigma$$

Where  $G_{k,t}$  is defined as the risk-adjusted return and  $R_{k,t}$  is the computed mean excess return (zero net investment) for an investor who take a speculative position in the market. In terms of  $R_{k,t}$ , the risk-free rate is already implemented and is therefore not considered in the computation of Sharpe ratio. Further, the  $\sigma$  represents the standard deviation of the excess return.

Many researchers have criticized the Sharpe ratio due to limitations of the model. Sharpe (1966) pointed out several constraints because of its simplification. He specified that the Sharpe ratio should be supplemented by other performance measures since the effects of correlation towards other assets are ignored. In addition, the Sharpe ratio assumes that the values in the model are normally distributed. This is difficult to obtain because many financial variables such as FX rates tend to exhibit fat tails and high degrees of skewness and kurtosis. As a result, the risk can be difficult to quantify due to misleading measurements of the standard deviation. On the other hand, the Sharpe ratio is easy to implement and is highly applicable by practitioners in the FX market. Thus, we find it properly to apply this performance measure in order to evaluate whether the profitability of the TTR.

### 5.2.3 Jensen's Alpha

Michael Jensen (1967) developed Jensen's alpha by deriving a risk adjusted measure of portfolio performance. Jensen's alpha measures the excess return of a portfolio by adjusting for market risk. It is measured by the alpha parameter,  $\alpha_{k,t}$ , in the CAPM model. Jensen's alpha of the  $k^{\text{th}}$  trading rule at time  $t$  is computed as:

$$R_{k,t} = \alpha_{k,t} + \beta_k (r_m - r_f) + e$$

To compute  $\alpha_{k,t}$  and the equation is rewritten as follows:

$$\alpha_{k,t} = R_{k,t} - [r_f + \beta_k (r_m - r_f)] - e$$

The  $\beta_k$  represents the beta which measures the systematic risk on the asset relative to the total market. The  $r_m$  is defined as the market excess return which is the total return in the period at time  $t-1$ . We will apply the S&P 500 index as the  $r_m$ . Further,  $r_f$  is defined as the risk-free rate in the market and  $e$  is defined as the error terms from the regression. The error terms are assumed to satisfy all seven classical assumptions for an ordinary least squares (OLS) linear regression. In a perfect efficient market the parameter  $\alpha_{k,t}$  is equal to 0. If  $\alpha_{k,t}$  is positive, the model indicates that the chosen asset or portfolio outperforms the market. Contrary, if  $\alpha_{k,t}$  is negative, the model implies that the asset or portfolio underperforms the market.

Jensen's Alpha has received criticism due to constraints of the model. The model only considers the systematic risk and is relatively sensitive to the choice of market index. The predictability of  $\beta$  is limited because it is based on historical price movements. Moreover, the  $\beta$  is a subject to changes as the risk measurement does not stay constant over time which makes it difficult to determine the value of the  $\beta$  in the FX market. However, the Jensen's alpha has been widely used to measure the performance of portfolios. Based on this, we will apply the performance measure in our analysis to discover whether the market is efficient or if the trading strategies are likely to exploit the market.

### 5.3 Correcting for data snooping

Data snooping occurs when many empirical studies are performed on the same data set. For time-series, the issue of data snooping is nearly impossible to avoid. In most cases, data snooping tends to show very small and almost unnoticeable biased results. The bias attempt to improve the performance by refining too many parameters. This means that the occurrence of data snooping will lead to misleading results. However, a small change in the data set can very often lead to considerable large changes relative to investment strategies. It seems that the trading strategies generate significant mean excess returns but instead the results are a caused by pure luck when data snooping bias is observed. (White, 2000).

Since the TTR only find the profitability ex post and at the beginning of a period, the issue of data snooping will be solved by including additional weeks to disclose the differences in the returns and examine whether the returns deviate from each other. This contributes to more accuracy of our analysis. The TTR need to perform well for several weeks in order to be a valuable tool used to exploit the market.

## 5.4 Generating buy-sell signals

We assume that the trader will take a position at the closing price the same day as the buy and sell signals are observed. The returns from the buy and sell signals are calculated immediately after the signals are generated from the given TTR. The buy and sell signals will vary depending on the trading strategies and currencies changes related to time- and country departments. The analysis will primarily focus on the buy-sell signals generated from the TTR and discover whether the signals generate a greater significant mean excess return over the benchmark. The buy and sell signals will be weighted equally.

## 5.5 Testing the performance of technical trading rules

To evaluate the performance of the TTR, we will apply the mean excess return, Sharpe ratio and the Jensen's alpha. Second, the significance of the performance measures is tested using a standard t-test formed by Brock et al. (1992). If the measures show superior performance, it means that the trading rules are significantly different from zero. The null hypothesis of the mean excess return is defined as follows:

$$H_0^{return}: \max[E(R_k)] \leq 0 \quad (2)$$

The null hypothesis of Sharpe ratio:

$$H_0^{sharpe}: \max[(G_k)] \leq 0 \quad (3)$$

The null hypothesis of Jensen's alpha:

$$H_0^{Jensen}: \max[(\alpha_k)] \leq 0 \quad (4)$$

The t-test will determine whether the mean excess return, Sharpe ratio or Jensen's alpha are significantly different from zero. The null hypothesis is rejected if the p-values of the t-statistics exceed the critical value of  $t_{\alpha/2}$ . The  $\alpha$ -parameter is defined as the significance level. The critical value of a two-tailed test is 1,97 which is consistent with a 95% confidence interval. The standard t-test is defined as follows:

$$t = \frac{\bar{r}_{(bs)} - \bar{r}}{\sqrt{\frac{\sigma_{b(s)}^2}{N_{b(s)}} + \frac{\sigma^2}{N}}} \quad (5)$$

The underlying assumptions of a t-test is that the data must be normally distributed, have equal variances and have a randomly selected sample. For time series, the assumptions are not always fulfilled due to the occurrence of market characteristics such as autocorrelation, heavy tails and random walk. However, Markowski and Markowski (1990) studied the t-test by using data that did not fulfill the requirements and suggested that the t-test was robust if the sample size of two variables are equal. In addition, they argued that for large samples, small differences would still generate precise and accurate results.

### 5.5.1 Testing the robustness

To evaluate the robustness of the TTR, we will conduct the full sample into two sub-samples with relatively equal lengths. Sub-sample one represents the early years in the period from 1986-2000 and sub-sample two represents more recent years in the period from 2001-2016. By applying the TTR on both sub-samples we can discover whether the trading rules are affected by specific changes and trends in the market. In addition, certain market inefficiencies will be disclosed by evaluating the two sub-samples. The hypotheses (2-4) will be tested on both sub-samples by applying a t-test and thereby examine whether the results

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are significant. If the profitability is caused by time-dependent market changes and trends, then the trading strategies' performance are not robust.

## 5.6 Bootstrap methodology

To examine the performance of the trading strategies it is common to use a standard t-test. However, since financial time series often exhibit fat tails, non-stationarities and are non-normally distributed, the t-test might be unreliable. Accordingly, the trading strategies tend to reveal data snooping bias which affect the inference. Therefore, the residual bootstrap by LeBaron (1997) is applied to analyze the results in the original sample. The bootstrap will help determine whether the performance of the trading strategies have a predictive power or if the profitability is due to inefficiencies in the market. Hypotheses (2-4) will be tested.

The bootstrap method was invented by Bradley Efron (1979). Throughout the years, several researches such as LeBaron (1997) and Brock et al. (1992) have implemented multiple ways to bootstrap time-series data using different tools and estimations. The bootstrap is an effectively method for time-series data to avoid problems of market characteristics. The bootstrap enables to conduct the inference without considering complex distributional assumptions by resampling the FX rates from the original series. This will generate more accurate results and remove the time-dependent structure in the data. Moreover, the bootstrap method tends to generate more robust results compared to classical statistical models. The original series represent the full-sample period.

The bootstrap is conducted in the following way:

1. Randomly resample the FX rates from the original series.
2. Repeat the procedure 500 times.
3. Apply the TTR on the bootstrapped sample and test hypothesis (2-4) with a t-test (5).
4. Compare the bootstrapped performance measures and correspondingly the p-values to the original series.

Further, we will examine whether the bootstrapped mean excess returns are equal or greater than the mean excess returns from the original series. The null hypothesis is as follows:

$$H_0: R_{k,0} \leq R_{k,i}, \quad (6)$$

Where the  $R_{k,0}$  is defined as the mean excess return from the original series and the  $R_{k,i}$  is defined as the mean excess return retrieved from the bootstrapped test. The intuition of the bootstrap is to identify if the successfulness of the trading strategies in the original series is not accurate. If the original series lead to higher returns and are significantly different from the bootstrap results, the original series contain information and predictive patterns in the market that can be detected by the TTR.

### 5.6.1 Identifying market characteristics

To identify market characteristics that may occur in time series data, tests for stationarity, normality and autocorrelation are performed. Fama (1991) states that the market is not merely inefficient if some trading strategies outperform the FX market. However, the outperformance can be caused by market effects that could impact the performance to vary over time.

The augmented Dickey Fuller test for unit root is applied to test whether the data are stationary. If the data set has unit root=1 it means that the data are non-stationary and follows a random walk. In this case, the analysis can lead to spurious and unpredictable results. The null hypothesis for the augmented Dickey Fuller test is defined as follows:

$$H_0: \theta = 0 \quad (7)$$

If the null hypothesis is rejected, the data are stationary and does not follow a random walk.

Second, we test for normality by performing a Jarque-Bera test. The test identifies normal distribution in the data set. The kurtosis should be close or equal to 3 and the skewness equal to 0. The Jarque-Bera test are widely used on data sets with many observations as it generates the most reliable results compared to other normality tests. This is essential in order to examine whether the returns generated from the trading strategies represent the true value. The null hypothesis of the Jarque-Bera test is defined as follows:

$$H_0: \text{Data are from a normal distribution} \quad (8)$$

Lastly, a Box-Pierce Q statistics is used to test for joint significance of autocorrelation in our time series data. In literature, autocorrelation have been widely discussed in relation to FX rates. Zhou (1996) and Cont (2001) found evidence of autocorrelation in FX rates due to impacts of market effects from week to week. Accordingly, the FX rates tend to follow trends in the market which means that autocorrelation will most likely occur. The null hypothesis of no autocorrelation is tested by the following Q statistic:

$$Q = N (N + 2) \sum_{j=1}^h \frac{P^2}{N-j} \quad (9)$$

The N represent the sample size, P is defined as the autocorrelation in lags and h represent the number of tested lags. We will apply six lags to examine whether the autocorrelation is significant for all three currencies. The null hypothesis states that the data are random and show no signs of autocorrelation. If the null hypothesis is rejected, the data reveal evidence of autocorrelation between the FX rates.

## 6. Empirical results and analysis

This chapter will present data collection, results from testing the performance and predictive power of the applied trading rules. In addition, results from the bootstrap analysis are presented. The hypotheses are tested at a 5% significance level.

### 6.1 Data collection

The sample consists of weekly exchange rates from three currencies; GBP, JPY and CHF relative to the USD. The weekly spot exchange rates are the closing price collected every Wednesday in the sample-period. The exchange rates are described as the price of foreign currency units for one unit of USD, defined as the quotation,  $S(f/h)$ . The FX rates of GBP, JPY and CHF are obtained from Datastream. The S&P 500 index and the three-month US treasury bill is collected on a weekly basis and are used in the performance measures. The S&P 500 index is applied as the market return and defined as the total period return from the close of the previous day. The index is obtained from Bloomberg. The three-month US treasury bill is used as the risk-free rate and collected from the Federal Reserve Board.

In total, the sample has 1617 observations for each currency and a universe of 18 TTR. Researchers such as Qi & Wu (2006), Olson (2004) and Charlesbois & Sapp (2007) argued that the FX market has become highly liquid and more efficient in the 2000s compared to the late 1980s. Based on this, the sample period is from 1/1/86-28/12/16. In addition, the data are divided into two subsamples; 1/1/86-29/12/00 and 3/1/01-28/12/16, to examine whether the returns from the trading strategies are subject to any market effects.

#### 6.1.1 FX rates development

The graph below displays the weekly price development in the FX rates of the currency pairs; GBP/USD, JPY/USD and CHF/USD.

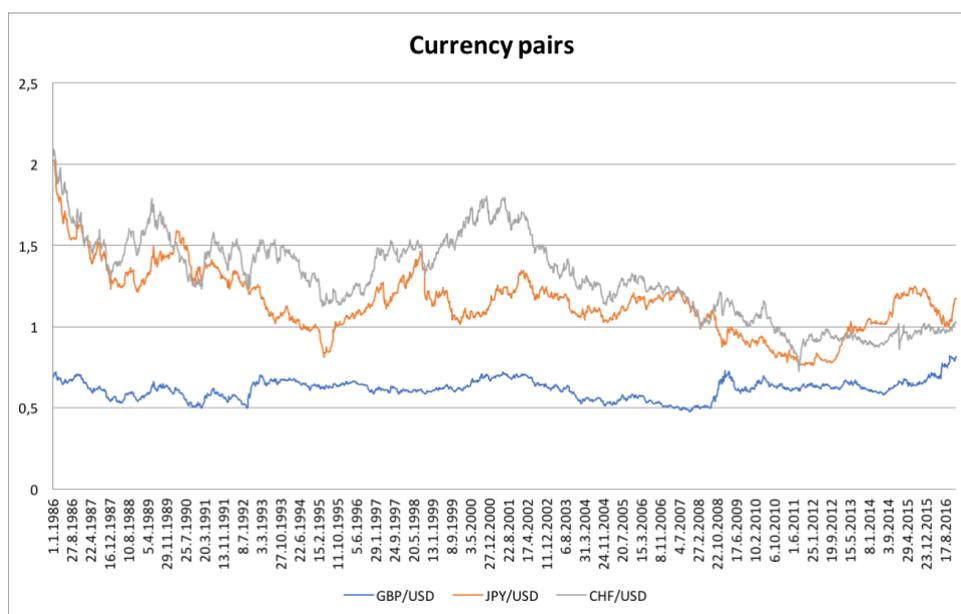


Figure 6.1 - Price development of the weekly FX rates from 1986-2016. The Y-axis show the closing price of foreign currency for one unit of USD. The currency pair, JPY/USD is divided by 100 to get a greater view of the variation in the currency pairs.

The figure shows the closing price movements for all three currencies throughout the sample-period. The closing prices of JPY and CHF seem to follow a similar trend. On the other hand, GBP are less volatile and does not seem to follow a specific pattern. The three currencies tend to fluctuate, especially JPY and CHF, which are not unexpected as the FX rates are volatile.

Throughout the years, the US has experienced several crises which are important to consider as such structural changes might impact the FX rates. In the period between 2007-2010, the price of one unit of USD change from 121.07 JPY to 76.19 JPY. In addition, the prices of CHF show similar changes. Large price fluctuations can lead to mispricing of assets as the market might become less efficient during crises. This might explain the big changes in JPY and CHF in the sample-period. (Choudhry et al., 2014).

### 6.1.2 Summary statistics

	<b>GBP</b>	<b>JPY</b>	<b>CHF</b>
<b>Mean * 100</b>	0.0198	-0.0218	-0.0295
<b>Min return</b>	-0.0516	-0.1179	-0.1585
<b>Max return</b>	0.0905	0.7178	0.0876
<b>St. deviation</b>	0.0138	0.0148	0.0162
<b>Skewness</b>	0.8683	-0.4634	-0.5749
<b>Kurtosis</b>	7.0366	6.9059	10.1385
<b>P (1)</b>	-0.0000	0.0093	-0.0120
<b>P (2)</b>	-0.0164	0.0762	0.0072
<b>P (3)</b>	0.0611	-0.0050	-0.0014
<b>P (4)</b>	-0.0180	-0.0043	-0.0078
<b>P (5)</b>	-0.0074	0.0460	-0.0039
<b>P (6)</b>	0.0573	-0.0134	-0.0051

*Table 6.1 - Descriptive statistics of weekly changes in the FX rates. The FX rates are defined the price in foreign currency for one unit of USD.  $P(k)$  is the  $k^{\text{th}}$  order serial correlation of  $(s_t - s_{t-1})$ .*

The mean returns from Table 1 indicate that the GBP on average depreciates against the USD, whilst the JPY and CHF on average appreciates against the USD. The FX rates show the weekly volatility reflected in the standard deviation in the range between 1.38% (GBP) to 1.62% (CHF). The weekly volatility shows the pricing behavior of the FX rates and measures the amount of uncertain risk involved in a size change in the currency rate. If the volatility is high, the FX rate can change dramatically over a short period in either direction.

The maximum weekly appreciation and depreciation of the GBP, JPY, and CHF relative to the USD is shown in the max/min return. The results show a maximum weekly appreciation between 11.79% (JPY) and 15.75% (CHF). Whilst the maximum weekly depreciation of the foreign currencies relative to the USD is 9.05% (GBP).

The kurtosis is used to measure the weights in both tails of the distribution. The value of kurtosis with a normal distribution is equal to 3. If the kurtosis is greater than 3, it indicates that the dataset has heavy tails. Contrary, if the kurtosis is smaller than 3, the dataset has light tails compared to the normal distribution. For all three currencies, the kurtosis is

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significantly larger than the normal distribution, meaning that traders in the FX market will occasionally experience great positive or negative returns. The skewness measures the symmetry in the distribution in the dataset. If the dataset is perfectly symmetrical, the value of skewness will be equal to 0. The returns of JPY and CHF relative to the USD tend to skew left which indicate a negative skewed distribution, while the GBP relative to the USD show signs of positive skewness as the currencies appear to skew right.

The serial-correlation looks at the relationship between a variable and the lagged version of itself. The lag at time 0 will be perfectly correlated. If the value equals to -1, it means that the compared variables move in the opposite direction of each other. Vice versa, if the serial-correlation equals to 1, the variables move in the same direction. The serial correlation of the first order are in range between 0.0093 (JPY) and -0.0120 (CHF). The range increases when more lags are added. To examine the significance of the observed autocorrelation, a Box-Pierce Q statistics are applied and found in the appendix. The Box-Pierce Q statistics null hypothesis (9) states that all correlation up to the  $k^{\text{th}}$  observation are equal to zero. The lagged values of first order for all currencies show a Q statistic between 0.68 (CHF) and 0.99 (GBP). The currencies therefore fail to reject the  $H_0$  in the first order lagged values indicating that the currencies show no evidence of autocorrelation. Moreover, CHF cannot reject the  $H_0$  for remaining lagged values and the variables are independent. In JPY, the lagged values from the second- to sixth order reveal signs that the data are affected by autocorrelation. Lastly, the GBP shows signs of autocorrelation in the third and sixth lagged values.

In addition, we did an augmented Dickey Fuller test with 3 lags for all three currencies. The results are shown in the appendix. The null hypothesis (7) test if the data has unit root. The augmented Dickey Fuller test strongly reject the null hypothesis of unit root for all significance levels of all three FX rates. This indicate that the data are stationary and does not follow a random walk.

Lastly, we did a Jarque-Bera test for normalities in the data, shown in the appendix. The null hypothesis (8) states that the skewness and the kurtosis are equal to the normal distribution.

For all three currencies, the  $H_0$  is strongly rejected meaning that there are differences between our observations and the normal distribution.

## 6.2 Technical trading rules' performance

The TTR of the full sample are examined by testing hypotheses 2-4. The hypotheses test the significance of the performance of the trading rules by using a standard t-test (5). The results from the tests are presented in the tables below. The returns from the trading strategies are adjusted for transaction costs and the risk-free rate.

The trading rules are tested on three currencies; GBP, JPY and CHF. The performance of the TTR are measured as mean excess return, Sharpe ratio and Jensen's alpha. The trading strategies are divided into several weeks to disclose anomalies such as data snooping bias which will impact the performance of the TTR. The trading rules are compared to the benchmark which is equal to zero. The tables display the yearly average results for each performance measure, where  $N(\text{buy/sell})$  is defined as the total number of buy and sell signals generated from the trading strategies.

### 6.2.1 Full sample results

The full-sample show various results across the three currencies. The tables below display the results from the trading strategies for GBP, JPY and CHF relative to the USD. The number of signals differ depending on the type of trading strategy and currency.

*GBP/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	97	-0.52	(0.00)	-0.22	(0.26)	-12.45	(0.00)
<b>MA 2-6</b>	66	0.16	(0.32)	0.17	(0.60)	-11.73	(0.00)
<b>MA 3-7</b>	72	-0.29	(0.06)	-0.17	(0.72)	-12.20	(0.00)
<b>MA 1-50</b>	36	0.83	(0.00)	0.22	(0.11)	-11.05	(0.00)
<b>MA 2-51</b>	30	0.23	(0.26)	0.05	(0.18)	-11.66	(0.00)
<b>MA 3-52</b>	23	0.95	(0.00)	0.15	(0.15)	-10.94	(0.00)
<b>Filter 5w</b>	126	3.02	(0.00)	0.21	(0.07)	-8.81	(0.04)
<b>Filter 6w</b>	118	-0.01	(0.97)	-0.01	(0.48)	-11.90	(0.00)
<b>Filter 7w</b>	102	0.17	(0.91)	0.11	(0.17)	-11.71	(0.00)
<b>Filter 50w</b>	11	-3.09	(0.30)	-0.28	(0.00)	-15.11	(0.00)
<b>Filter 51w</b>	11	-3.09	(0.00)	-0.28	(0.00)	-15.11	(0.00)
<b>Filter 52w</b>	11	-2.39	(0.00)	-0.27	(0.00)	-14.39	(0.00)
<b>CBR 5w</b>	48	1.36	(0.00)	0.00	(0.14)	-10.46	(0.00)
<b>CBR 6w</b>	43	3.70	(0.00)	0.67	(0.14)	-10.32	(0.01)
<b>CBR 7w</b>	37	0.78	(0.00)	0.13	(0.07)	-11.11	(0.00)
<b>CBR 20w</b>	20	0.73	(0.02)	0.06	(0.05)	-11.13	(0.01)
<b>CBR 21w</b>	20	-0.55	(0.04)	-0.06	(0.04)	-12.46	(0.01)
<b>CBR 22w</b>	19	3.52	(0.00)	0.25	(0.00)	-6.60	(0.09)

Table 6.2 - Full-sample results of GBP/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually. The significance level is 5%, with a critical value of 1.97.

In table 3, the overall number of trades is very low and varies between 11 and 126. This corresponds to the total sample period of 1617 weeks. As a consequence, the long-term trading rules are likely to pick up the average long-term depreciation of the GBP. Second, observing of the short-term strategies the profitability shows a sign flip depending on whether the rules are 5, 6 or 7 weeks. While not a statistical test, the sign flips suggest the likely existence of a serious data snooping bias among practitioner recommendations of certain well-performing short-term trading strategies. This problem is also revealed in the long-term strategies of CBR.

Short-term CBR and long-term MA strategies are significantly profitable. However, the profitability does not survive risk adjustment (Sharpe ratios or Jensen Alpha) and hence, a free lunch does not seem to exist.

*JPY/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	96	-1.05	(0.00)	-0.44	(0.95)	-12.98	(0.00)
<b>MA 2-6</b>	68	-1.28	(0.00)	-0.33	(0.02)	-13.22	(0.00)
<b>MA 3-7</b>	72	0.28	(0.26)	0.14	(0.00)	-11.62	(0.00)
<b>MA 1-50</b>	28	2.67	(0.00)	0.26	(0.37)	-9.17	(0.01)
<b>MA 2-51</b>	24	3.50	(0.00)	0.37	(0.38)	-8.28	(0.02)
<b>MA 3-52</b>	22	1.72	(0.00)	0.24	(0.63)	-10.17	(0.01)
<b>Filter 5w</b>	129	1.81	(0.00)	0.92	(0.00)	-10.01	(0.00)
<b>Filter 6w</b>	121	1.58	(0.00)	0.72	(0.00)	-10.24	(0.00)
<b>Filter 7w</b>	103	0.87	(0.01)	0.35	(0.00)	-10.99	(0.00)
<b>Filter 50w</b>	6	-8.89	(0.00)	-0.30	(0.00)	-21.13	(0.00)
<b>Filter 51w</b>	6	-8.89	(0.00)	-0.31	(0.00)	-20.49	(0.00)
<b>Filter 52w</b>	6	-4.80	(0.00)	-0.24	(0.00)	-16.78	(0.00)
<b>CBR 5w</b>	48	2.96	(0.00)	0.45	(0.23)	-0.99	(0.48)
<b>CBR 6w</b>	42	3.42	(0.00)	0.39	(0.15)	-8.49	(0.01)
<b>CBR 7w</b>	32	5.60	(0.00)	0.39	(0.16)	-6.29	(0.07)
<b>CBR 20w</b>	26	6.72	(0.00)	0.22	(0.27)	-5.25	(0.40)
<b>CBR 21w</b>	24	14.05	(0.00)	0.25	(0.32)	-3.22	(0.65)
<b>CBR 22w</b>	23	8.26	(0.00)	0.23	(0.48)	-3.70	(0.59)

*Table 6.3 - Full sample test of JPY/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually with a significance level of 5%.*

Table 4 show the results from testing the trading rules on JPY. Likewise the GBP, the number of trading signals is low and varies from 6 to 129 depending on the trading strategy. The short-term strategies of MA reflect data snooping bias. The signs of the returns from the strategies change from negative to positive which informs how random the profitability is in reality. It is unlikely that the profitability would shift so rapidly including one more week. As a result, the short-term strategies of MA are not consistent.

Moreover, short-term strategies of filter rules and long-term strategies of MA generate significant profitability. These strategies do not detect any issues related to data snooping. Accordingly, the strategies of CBR show considerably high profitability. This imply that there is information in the market that can be exploited for profit by the trading strategies. By rejecting the null hypothesis, the FX market reflect inefficiencies which is not consistent with the literature. (Fama, 1990). Following the risk adjustments, some trading strategies yield superior Sharpe ratios. As a consequence, the Sharpe ratio will compensate the

volatility relative to the significant positive returns from the trading strategies. However, the magnitude of Jensen's alphas is significantly negative. This means that the risk adjustment will likely explain the profitability and the trading strategies are unable to outperform the market. After adjusting for risk, the trading strategies are not efficient.

### CHF/USD

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	91	-0.47	(0.29)	-0.19	(0.59)	-12.37	(0.00)
<b>MA 2-6</b>	68	-0.31	(0.53)	-0.09	(0.37)	-12.21	(0.00)
<b>MA 3-7</b>	56	-1.03	(0.01)	-0.38	(0.04)	-13.93	(0.00)
<b>MA 1-50</b>	27	0.78	(0.03)	0.18	(0.16)	-11.12	(0.00)
<b>MA 2-51</b>	24	1.05	(0.00)	0.31	(0.32)	-10.85	(0.00)
<b>MA 3-52</b>	16	0.23	(0.45)	0.05	(0.32)	-11.66	(0.00)
<b>Filter 5w</b>	122	0.25	(0.42)	0.14	(0.50)	-11.65	(0.00)
<b>Filter 6w</b>	109	0.12	(0.63)	0.07	(0.39)	-11.77	(0.00)
<b>Filter 7w</b>	98	-0.48	(0.28)	-0.16	(0.49)	-12.37	(0.00)
<b>Filter 50w</b>	11	-3.86	(0.00)	-0.24	(0.00)	-15.75	(0.00)
<b>Filter 51w</b>	11	-3.44	(0.00)	-0.23	(0.00)	-15.34	(0.00)
<b>Filter 52w</b>	11	-3.37	(0.00)	-0.22	(0.00)	-13.86	(0.00)
<b>CBR 5w</b>	59	1.03	(0.00)	0.33	(0.00)	-10.80	(0.04)
<b>CBR 6w</b>	49	1.32	(0.00)	0.39	(0.24)	-10.51	(0.00)
<b>CBR 7w</b>	45	1.25	(0.00)	0.29	(0.00)	-10.58	(0.00)
<b>CBR 20w</b>	24	1.16	(0.01)	0.00	(0.00)	-9.05	(0.00)
<b>CBR 21w</b>	24	1.02	(0.01)	0.00	(0.00)	-9.21	(0.00)
<b>CBR 22w</b>	21	0.88	(0.04)	0.08	(0.00)	-10.94	(0.00)

Table 6.4- Full sample test of CHF/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.

The trading strategies used on CHF generate a considerably low number of trading signals considering the sample period. Correspondingly with GBP, the short-term strategies of filter rules reveal evidence of data snooping bias. As a result, the profitability is due to pure chance and not the performance, following the change in the return between 5, 6 and 7 weeks. Data snooping affects the inference of the results and thereby undermines the validity of the strategies.

Contrary, the long-term strategies of MA show significant profitability except 3-52 weeks. The strategies seem successful, however, due to low returns and the corresponding p-value of 3-52 weeks, it is doubtful. Moreover, the strategies of CBR are significantly profitable and suggest that the strategies are valuable in the FX market even though the returns are relatively low. This challenge the EMH which state that the FX market is efficient. The Jensen's alphas are significantly negative for short- and long-term strategies. The alphas suggest that the strategies are not able to beat the benchmark and traders would end up losing money. It seems unlikely that the trading rules will perform well after adjusting for risk in the FX market.

To summarize, the trading strategies do not give any clear conclusions. However, there are observed differences regarding the performance and signaling between the strategies. Several trading strategies generate significantly positive profitability and it seems these strategies are beneficial and carry information. However, these results do not survive risk adjustment as Sharpe ratios are not different from zero and alphas are mostly negative. Thereby, no "free lunch" is observed.

Previous literature has continuously proven the successfulness of MA in terms of profitability and performance. (Qi & Wu, 2006, Levich & Thomas, 1999). However, our results show no such signs of MA due to the exposure of data snooping bias. The CBR are observed to be the most successful strategies based on the performance measures. This would support the critique to where researchers might cherry-pick their results in the desire of concealing negative results and only report the best strategies. Thereby, the full set of alternatives is ignored. Considering data snooping bias that arise in the strategies, White (2000) stated that such bias would lead to wrong inference. The performance of the trading rules appears successfully, while in reality the profitability is random. This give reason to believe that some of the generated positive returns cannot be explained by the strategies as the results are misleading.

Moreover, Jensen's alpha indicate that the hypothesis of market efficiency holds. The alphas are significantly negative for almost all the trading strategies applied on each currency.

Thereby, it is likely that the performance of risk can explain the profitability due to underperformance in the market. The Sharpe ratios are relatively low and will not have a causal impact on the performance of the trading strategies.

## 6.3 Robustness

The robustness of the trading strategies is essential in the evaluation of whether the trading strategies have a predictive power in the FX market. In the following, the sample period is divided into two sub-samples, whereas sub-sample one presents the early period and sub-sample two presents the modern period. Second, the yearly returns and the distribution of the returns are presented to disclose any anomalies that could impact the robustness of the results from the trading strategies.

### 6.3.1 Sub-samples results

The sub-samples results reflect whether the two sub-samples are subject to any market changes throughout the period. The results for each currency from the trading strategies are displayed in the following. Sub-sample one present results from the period 1986-2000 and sub-sample two from 2001-2016.

*Sub-sample one**GBP/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	44	-0.89	(0.00)	-0.35	(0.67)	-17.97	(0.00)
<b>MA 2-6</b>	31	0.31	(0.16)	0.29	(0.39)	-16.70	(0.00)
<b>MA 3-7</b>	35	-0.14	(0.00)	-0.08	(0.73)	-17.17	(0.00)
<b>MA 1-50</b>	15	0.58	(0.01)	0.22	(0.32)	-16.42	(0.00)
<b>MA 2-51</b>	13	0.60	(0.02)	0.23	(0.36)	-16.41)	(0.00)
<b>MA 3-52</b>	10	1.56	(0.00)	0.26	(0.00)	-15.47	(0.00)
<b>Filter 5w</b>	55	0.72	(0.00)	0.59	(0.18)	-14.18	(0.00)
<b>Filter 6w</b>	54	0.02	(0.93)	0.01	(0.41)	-17.00	(0.00)
<b>Filter 7w</b>	46	0.16	(0.49)	0.22	(0.58)	-14.79	(0.00)
<b>Filter 50w</b>	6	-1.95	(0.00)	-0.35	(0.00)	-19.13	(0.00)
<b>Filter 51w</b>	6	-1.95	(0.00)	-0.35	(0.00)	-19.13	(0.00)
<b>Filter 52w</b>	6	-1.45	(0.00)	-0.24	(0.00)	-18.59	(0.00)
<b>CBR 5w</b>	22	1.13	(0.00)	0.33	(0.30)	-15.81	(0.00)
<b>CBR 6w</b>	20	1.53	(0.00)	0.35	(0.32)	-15.40	(0.00)
<b>CBR 7w</b>	18	-0.20	(0.38)	-0.09	(0.13)	-17.22	(0.00)
<b>CBR 20w</b>	13	2.42	(0.00)	0.18	(0.08)	-14.53	(0.02)
<b>CBR 21w</b>	13	2.10	(0.00)	0.17	(0.12)	-14.86	(0.02)
<b>CBR 22w</b>	12	2.58	(0.00)	0.21	(0.00)	-12.05	(0.02)

*Table 6.5 - Sub-sample 1 results of GBP/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.*

Sub-sample one displays a much lower frequency of number of trading signals compared to full sample. However, the variation between the trading signals is not as large. Overall, the short-term and the long-term strategies generate higher significant profitability relative to the full-sample. It seems that the strategies are successful and have a predictive power in the market. Researchers claim that the market was exposed to high volatility in the early years. As a consequence, the market efficiency is not consistent.

Data snooping is still a concern. The profitability varies depending on the 5, 6 and 7 weeks in the short-term strategies of MA and CBR and is due to pure luck rather than merit. Interestingly, observations from full-sample do not reveal data-snooping bias in CBR. The Sharpe ratio and Jensen's alpha show somewhat similar results relative to the full-sample and do not give any clear indication that the trading rules show predictability. However, it

seems that the performance of the trading strategies does not survive the risk adjustment and as a result, the risk measures will likely explain the positive significant returns due to evidence of efficiency within the FX market.

### *JPY/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	46	-1.18	(0.01)	-0.47	(0.57)	-18.26	(0.00)
<b>MA 2-6</b>	33	0.06	(0.76)	-0.05	(0.15)	-16.95	(0.00)
<b>MA 3-7</b>	37	-0.35	(0.48)	-0.16	(0.05)	-17.38	(0.00)
<b>MA 1-50</b>	12	1.66	(0.00)	0.16	(0.68)	-15.26	(0.00)
<b>MA 2-51</b>	9	3.14	(0.00)	0.37	(0.38)	-13.68	(0.00)
<b>MA 3-52</b>	8	-0.16	(0.88)	-0.01	(0.32)	-17.09	(0.00)
<b>Filter 5w</b>	60	1.71	(0.00)	1.51	(0.00)	-15.21	(0.00)
<b>Filter 6w</b>	47	1.56	(0.00)	1.10	(0.00)	-15.37	(0.00)
<b>Filter 7w</b>	39	0.56	(0.13)	0.37	(0.01)	-16.45	(0.00)
<b>Filter 50w</b>	3	-8.09	(0.00)	-0.29	(0.00)	-25.64	(0.01)
<b>Filter 51w</b>	3	-8.09	(0.00)	-0.29	(0.00)	-25.64	(0.01)
<b>Filter 52w</b>	4	-0.94	(0.04)	-0.23	(0.00)	-18.05	(0.00)
<b>CBR 5w</b>	25	2.96	(0.00)	0.38	(0.23)	-3.34	(0.03)
<b>CBR 6w</b>	23	2.34	(0.00)	0.34	(0.52)	-14.54	(0.00)
<b>CBR 7w</b>	17	5.02	(0.00)	0.30	(0.36)	-11.71	(0.02)
<b>CBR 20w</b>	11	3.88	(0.00)	0.23	(0.17)	-12.87	(0.02)
<b>CBR 21w</b>	11	7.78	(0.00)	0.39	(0.32)	-8.70	(0.32)
<b>CBR 22w</b>	10	7.00	(0.00)	0.23	(0.46)	-9.62	(0.25)

*Table 6.6 - Sub-sample 1 results of JPY/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.*

Sub-sample one reveals a significantly decline in the profitability from the trading strategies relative to the full-sample and market changes do not seem to have a causal impact on the strategies. The CBR strategies still show the best performance and the TA is beneficial in terms of the significant positive returns. However, data snooping is disclosed through the sign flip in the profitability between the weeks in some of the short- and long-term strategies. Thus, the strategies not have a predictive power.

The frequency of the Sharpe ratios is strengthened and have a significantly high value (for two strategies) that corresponds with the acceptable value by traders. Hence, the risk would

be bearable to traders. However, Jensen's alpha reflects the underperformance in the market by the considerably negative values. It seems that the FX market are more exposed to risk relative to the positive returns which means that the positive significant returns are undermined.

### CHF/USD

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
MA 1-5	46	0.00	(0.97)	-0.01	(0.49)	-17.06	(0.00)
MA 2-6	38	0.00	(0.97)	0.00	(0.51)	-15.21	(0.00)
MA 3-7	27	-0.67	(0.33)	-0.37	(0.11)	-15.91	(0.00)
MA 1-50	15	1.05	(0.02)	0.24	(0.32)	-13.80	(0.00)
MA 2-51	13	2.03	(0.00)	0.43	(0.00)	-13.32	(0.00)
MA 3-52	7	0.52	(0.38)	0.09	(0.00)	-14.72	(0.00)
Filter 5w	57	0.50	(0.38)	0.21	(0.13)	-14.80	(0.00)
Filter 6w	52	0.41	(0.47)	0.18	(0.12)	-15.43	(0.00)
Filter 7w	47	-0.24	(0.77)	-0.06	(0.52)	-15.43	(0.00)
Filter 50w	5	-1.71	(0.02)	-0.16	(0.00)	-18.74	(0.00)
Filter 51w	5	-0.84	(0.25)	-0.11	(0.00)	-17.87	(0.00)
Filter 52w	5	-0.84	(0.25)	-0.11	(0.00)	-15.79	(0.00)
CBR 5w	28	2.48	(0.00)	0.68	(0.45)	-14.41	(0.00)
CBR 6w	27	2.13	(0.00)	0.62	(0.90)	-14.77	(0.00)
CBR 7w	26	1.49	(0.00)	0.38	(0.36)	-15.46	(0.00)
CBR 20w	11	3.90	(0.00)	0.26	(0.00)	-10.62	(0.07)
CBR 21w	10	3.63	(0.00)	0.27	(0.00)	-10.91	(0.05)
CBR 22w	9	2.38	(0.00)	0.18	(0.00)	-14.53	(0.05)

Table 6.7 - Sub- sample 1 results of CHF/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.

The results in sub-sample one of CHF/USD show a slight increase in the profitability compared to the full-sample. Considering market changes, the FX market are more volatile and will likely explain the positive significant returns. However, several trading strategies do not reveal significant returns and thereby the strategies are not different from the benchmark. As a result, the performance of the trading strategies has declined. Sub-sample one are still exposed to data snooping and the profitability of short-term strategies of MA and Filter rules are due by chance rather than skills from the trading strategies.

The exposure of risk increases is still significantly high. This reduces the predictability of the trading strategies and implies that the strategies cannot beat the benchmark. In other words, the after adjusting for risk, the positive returns do not survive.

### *Sub-sample two*

#### *GBP/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	53	-0.17	(0.40)	-0.09	(0.29)	-7.26	(0.12)
<b>MA 2-6</b>	35	0.02	(0.97)	0.03	(0.89)	-7.07	(0.14)
<b>MA 3-7</b>	37	-0.43	(0.00)	-0.25	(0.82)	-7.54	(0.11)
<b>MA 1-50</b>	21	1.06	(0.00)	0.22	(0.15)	-6.01	(0.19)
<b>MA 2-51</b>	17	-0.13	(0.63)	-0.02	(0.24)	-7.22	(0.16)
<b>MA 3-52</b>	13	0.39	(0.00)	0.05	(0.15)	-6.71	(0.19)
<b>Filter 5w</b>	71	5.18	(0.00)	0.25	(0.26)	-2.76	(0.80)
<b>Filter 6w</b>	64	-0.03	(0.61)	-0.02	(0.86)	-7.12	(0.14)
<b>Filter 7w</b>	56	0.19	(0.43)	0.09	(0.22)	-8.15	(0.16)
<b>Filter 50w</b>	5	-4.15	(0.00)	-0.29	(0.00)	-11.35	(0.04)
<b>Filter 51w</b>	5	-4.15	(0.00)	-0.29	(0.00)	-11.35	(0.04)
<b>Filter 52w</b>	5	-3.28	(0.00)	-0.29	(0.00)	-10.45	(0.04)
<b>CBR 5w</b>	26	1.62	(0.00)	0.21	(0.06)	-5.46	(0.22)
<b>CBR 6w</b>	23	1.51	(0.00)	0.21	(0.19)	-5.56	(0.21)
<b>CBR 7w</b>	19	1.71	(0.00)	0.21	(0.25)	-5.37	(0.22)
<b>CBR 20w</b>	7	-0.85	(0.02)	-0.10	(0.21)	-7.93	(0.19)
<b>CBR 21w</b>	7	-3.04	(0.00)	-0.69	(0.17)	-10.21	(0.04)
<b>CBR 22w</b>	7	4.40	(0.00)	0.27	(0.00)	-1.50	(0.79)

*Table 6.8 - Sub-sample 2 results of GBP/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.*

Table 9 present sub-sample two results for the GBP/USD and reflect the modern years. The results display more negative returns compared to sub-sample one. In line with literature, the volatility has declined and the efficiency in the FX market is more consistent which is also reflected in the Sharpe ratios. However, the positive significantly returns indicate that the TA is efficient and thereby the strategies can carry out valuable information. Yet, data snooping arises as a concern in some of the short- and long-term strategies which decreases the successfulness. The trading strategies are subject to risk and Jensen's alphas do not generate

any significantly positive values. Accordingly, the strategies will not have superior predictability, but instead underperform the benchmark.

### *JPY/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	50	-0.92	(0.00)	-0.38	(0.08)	-8.02	(0.09)
<b>MA 2-6</b>	35	-2.54	(0.00)	-0.51	(0.02)	-9.73	(0.03)
<b>MA 3-7</b>	35	-0.87	(0.00)	0.58	(0.01)	-6.21	(0.18)
<b>MA 1-50</b>	16	3.62	(0.00)	0.33	(0.13)	-3.45	(0.51)
<b>MA 2-51</b>	15	3.84	(0.00)	0.36	(0.68)	-3.22	(0.53)
<b>MA 3-52</b>	14	4.07	(0.00)	0.41	(0.47)	-2.97	(0.57)
<b>Filter 5w</b>	69	1.91	(0.00)	0.74	(0.00)	-5.13	(0.27)
<b>Filter 6w</b>	64	1.61	(0.00)	-0.58	(0.03)	-5.44	(0.23)
<b>Filter 7w</b>	56	0.56	(0.00)	0.37	(0.01)	-5.91	(0.19)
<b>Filter 50w</b>	3	-9.65	(0.00)	-0.29	(0.00)	-16.90	(0.09)
<b>Filter 51w</b>	3	-8.48	(0.00)	-0.30	(0.00)	-15.66	(0.11)
<b>Filter 52w</b>	2	-8.41	(0.00)	-0.30	(0.00)	-15.60	(0.11)
<b>CBR 5w</b>	23	3.64	(0.00)	0.46	(0.00)	-1.20	(0.59)
<b>CBR 6w</b>	23	2.34	(0.00)	0.35	(0.14)	-14.54	(0.56)
<b>CBR 7w</b>	15	5.79	(0.00)	0.46	(0.16)	-1.21	(0.80)
<b>CBR 20w</b>	15	8.96	(0.00)	0.22	(0.00)	1.89	(0.80)
<b>CBR 21w</b>	13	19.05	(0.00)	0.27	(0.00)	1.91	(0.81)
<b>CBR 22w</b>	13	8.92	(0.00)	0.21	(0.00)	1.84	(0.81)

*Table 6.9 - Sub-sample 2 results of JPY/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.*

The number of trading signals in sub-sample two is similar to the sub-sample one. Overall, the strategies seem to perform better in the recent years. The trading strategies do not show any flip signs in the profitability and data snooping does not seem to affect the returns. In addition, the profitability of the long-term strategies of MA and CBR is higher compared to sub-sample one. Also, Jensen's alpha from long-term strategies of CBR are positive but relatively low. As a consequence, the market is less likely to be fully efficient due to the successfulness of the strategies of CBR after adjusting for risk. This is contradictory with the literature, as it suggests that the market becomes more efficient throughout the years. On the other hand, the alphas generated by the other trading strategies are negative and the profitability is unlikely to survive the risk.

*CHF/USD*

Trading rule	N(buy/Sell)	Yearly mean excess return		Sharpe Ratio		Jensen's alpha	
		Mean return	P-value	Sharpe ratio	P-value	Jensen's alpha	P-value
<b>MA 1-5</b>	45	0.00	(0.07)	-0.35	(0.94)	-7.97	(0.06)
<b>MA 2-6</b>	30	-0.05	(0.32)	-0.14	(0.47)	-7.62	(0.12)
<b>MA 3-7</b>	29	-1.37	(0.00)	-0.42	(0.15)	-8.46	(0.07)
<b>MA 1-50</b>	12	0.10	(0.69)	0.08	(0.16)	-6.99	(0.13)
<b>MA 2-51</b>	11	0.13	(0.64)	0.09	(0.32)	-6.96	(0.13)
<b>MA 3-52</b>	9	-0.04	(0.93)	-0.04	(0.35)	-7.13	(0.13)
<b>Filter 5w</b>	65	0.01	(0.85)	0.01	(0.88)	-7.08	(0.13)
<b>Filter 6w</b>	57	-0.15	(0.86)	-0.18	(0.97)	-7.24	(0.12)
<b>Filter 7w</b>	51	-0.70	(0.15)	-0.42	(0.76)	-7.79	(0.08)
<b>Filter 50w</b>	6	-5.87	(0.00)	-0.30	(0.00)	-12.96	(0.04)
<b>Filter 51w</b>	6	-5.87	(0.00)	-0.29	(0.00)	-12.96	(0.04)
<b>Filter 52w</b>	6	-5.74	(0.00)	-0.28	(0.00)	-12.05	(0.04)
<b>CBR 5w</b>	31	-0.32	(0.33)	-0.23	(0.05)	-7.42	(0.11)
<b>CBR 6w</b>	22	0.55	(0.24)	0.17	(0.08)	-6.51	(0.15)
<b>CBR 7w</b>	19	1.06	(0.02)	0.23	(0.24)	-6.01	(0.19)
<b>CBR 20w</b>	12	-1.41	(0.00)	-0.27	(0.00)	-7.60	(0.05)
<b>CBR 21w</b>	14	-1.42	(0.00)	-0.27	(0.00)	-7.60	(0.05)
<b>CBR 22w</b>	12	-0.52	(0.22)	-0.07	(0.00)	-7.56	(0.15)

*Table 6.10 - Sub-sample 2 results of CHF/USD. The mean returns and Jensen's alpha are in percentage terms. All measurements are calculated annually.*

The short- and long-term strategies in CHF/USD show less performance due to decline in the positive returns from the previous period. For short-term strategies between 5, 6 and 7 weeks, data snooping is still a concern. The profitability of the strategies is caused by pure luck rather than merit. In addition, the long-term strategies of CBR and Filter rules reveal significantly negative returns indicating that the rules do not work. Moreover, the Sharpe ratio have decreased depending on the return and the volatility. Jensen's alpha reveal signs of underperformance of all trading strategies as the alpha-values are negative.

Correspondingly, this indicates that the market has become significantly more efficient. Sub-sample two find supporting evidence against the robustness of the trading rules and the TA.

To summarize, the two sub-samples disclose that sub-sample one performs better for GBP and CHF. The profitability shows a significant decline throughout the period. Many

researchers have stated that the market has become more efficient the recent years which correlates with our results from the two currencies. Contrary, JPY show ambiguous results. The sub-periods do not follow the same trend and JPY has become less efficient throughout the years. Accordingly, this strengthens the robustness towards JPY. Karemera (1999) disclose inefficiencies in the Asian exchange rates, which might explain the performance of the strategies in the sub-periods of JPY.

However, it is likely that market changes will impact the FX-rates and thereby affect the predictive power of the TTR. In this case, the trading strategies are not robust across the two sub-periods. However, some trading rules generate excess returns in the absence of the changes, which imply that market effects might not be the only source of the returns. As a consequence, the trading strategies have to somewhat extent predictive power over the given benchmark. Nevertheless, several strategies disclose data snooping bias across both sub-samples which interrupts the inference of the trading strategies performance. As in reality, the profitability appears random. In addition, the mean excess returns are not as sufficient in the two sub-samples as in the full-sample.

The risk measures are essential and could be a potential explanation of the returns. Jensen's alpha is negative in both sub-periods and suggests that the rules underperform the market. This indicates that the positive returns generated from the TTR are unlikely to survive the risk adjustment, and are thereby the trading strategies have lack of predictability and appear unsuccessful. Accordingly, it reduces the robustness of the trading strategies.

### 6.3.2 Yearly returns

The yearly excess returns are defined as average returns from each year, generated from the buy and sell signals from the trading strategies. The yearly excess returns are adjusted for transaction costs and the risk-free rate. In the tables below, the yearly excess returns are presented as net returns. For convenience, the short-term strategies of 5 weeks and the long-term strategies of 20- and 50 weeks are displayed. Under the assumption, the trader needs to hold a given position until a new signal is generated, the strategies generate same amount of buy and sell signals.

<b>GBP</b>	<b>1986</b>	<b>1987</b>	<b>1988</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	
<b>MA5</b>	0.01	-7.82	-1.62	-1.62	-0.07	1.31	3.42	0.66	-0.93	-0.37	-5.66	-0.47	-0.93	-0.03	1.17	
<b>MA50</b>	0.00	0.00	-0.94	-0.07	-0.26	0.18	0.00	10.11	-0.16	-0.13	0.33	-0.22	-0.02	-0.08	0.00	
<b>FILTER 5</b>	-0.07	-0.16	2.04	4.12	0.22	1.58	-0.65	1.03	-0.21	0.31	0.09	0.64	-0.19	0.38	1.57	
<b>FILTER 50</b>	0.00	0.00	0.00	-20.82	0.00	-2.12	1.27	0.00	0.00	-1.57	0.00	0.00	0.00	-7.55	1.58	
<b>CBR 5</b>	0.62	-0.36	1.81	4.43	-0.37	4.37	2.77	-0.83	-3.43	-0.13	-0.45	-1.31	-0.44	-0.63	0.00	
<b>CBR 20</b>	0.00	-6.52	-3.50	0.00	9.72	-5.66	-0.14	0.00	47.54	0.00	-3.73	-1.33	0.00	0.00	0.00	
	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>
<b>MA5</b>	-2.06	-4.49	-1.00	-0.01	-0.06	0.00	-1.72	4.05	-0.61	0.23	-1.22	0.05	1.56	1.73	-0.07	0.90
<b>MA 50</b>	-5.50	-0.08	-0.04	0.00	-2.94	0.00	0.00	-0.11	17.32	-0.09	-3.53	-0.20	-0.59	0.00	1.77	0.00
<b>FILTER 5</b>	0.08	-1.00	-0.64	0.23	0.60	-0.42	-0.88	4.39	-4.18	0.87	79.48	0.16	0.58	-0.53	0.91	3.25
<b>FILTER 50</b>	1.58	0.00	0.00	0.00	-5.71	0.00	0.00	-10.76	0.00	0.00	0.49	0.00	2.58	-1.42	0.00	0.00
<b>CBR 5</b>	0.06	-5.59	-0.95	-0.46	-0.35	-0.80	-1.29	0.09	29.19	2.59	-0.34	-0.51	0.66	0.00	1.55	3.36
<b>CBR 50</b>	26.93	0.00	-2.50	-7.35	0.00	-2.69	0.00	0.00	0.00	-3.88	0.00	0.00	-11.98	-11.98	0.00	0.00

*Table 6.11. Yearly excess return for GBP/USD*

<b>JPY</b>	<b>1986</b>	<b>1987</b>	<b>1988</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	
<b>MA5</b>	-0.09	0.42	-3.43	0.44	-3.45	-0.11	-8.16	0.09	-2.99	0.01	0.63	1.24	-2.55	0.08	0.15	
<b>MA50</b>	0.00	0.00	-0.77	-0.09	16.52	-20.15	-0.06	0.00	-0.12	0.00	0.00	28.42	1.47	0.00	-0.30	
<b>FILTER 5</b>	1.26	0.47	2.57	1.92	1.81	1.53	1.64	-0.06	1.69	2.36	1.54	4.79	0.41	1.35	2.44	
<b>FILTER 50</b>	0.00	0.00	0.00	-15.7	0.00	0.00	0.00	0.00	0.00	-105	0.00	0.00	0.00	0.00	0.00	
<b>CBR 5</b>	-0.62	-0.34	0.05	4.73	2.37	-2.69	-0.29	0.00	-0.24	0.00	19.19	3.88	5.48	-0.64	-0.33	
<b>CBR 20</b>	0.00	-2.01	-7.22	0.00	28.72	-3.53	-3.83	0.00	-7.74	0.00	0.00	56.87	-1.79	-1.22	0.00	
	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>
<b>MA5</b>	0.33	-1.10	-0.30	-0.03	-2.81	0.03	-0.52	-0.11	-5.06	-0.08	-0.46	-0.54	0.87	2.55	0.03	-7.50
<b>MA 50</b>	0.02	0.00	0.00	-0.16	-0.22	-0.04	-0.26	-0.09	0.00	-0.25	0.00	-0.33	0.00	39.73	19.53	0.00
<b>FILTER 5</b>	3.68	1.11	-1.25	0.77	3.01	1.84	2.06	1.81	-2.07	1.42	0.65	1.52	9.33	4.74	1.23	0.65
<b>FILTER 50</b>	-2.42	0.00	0.00	0.00	-21.3	0.00	0.00	0.00	0.00	0.00	-129	0.00	0.00	0.00	0.00	-1.11
<b>CBR 5</b>	8.84	2.33	-0.83	-1.43	-0.22	1.76	2.19	0.33	0.20	-0.61	-0.43	-0.29	25.5	1.02	20.5	-0.54
<b>CBR 50</b>	11.63	-0.58	-8.08	-2.77	0.00	1.91	-6.48	-1.93	-0.27	-2.49	-8.03	0.00	0.00	0.00	0.00	160.5

*Table 6.12. Yearly excess return for JPY/USD*

<b>CHF</b>	<b>1986</b>	<b>1987</b>	<b>1988</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	
<b>MA5</b>	-0.16	-0.02	-2.90	3.67	-2.34	1.70	-0.13	4.37	-5.59	0.39	0.28	0.16	0.50	0.16	-0.64	
<b>MA50</b>	0.00	0.00	-11.87	4.83	0.00	2.75	-0.25	-0.87	0.00	0.00	0.35	15.05	0.16	0.42	12.25	
<b>FILTER 5</b>	-4.74	0.30	4.84	0.65	0.22	1.80	-0.34	0.36	-0.62	-1.55	0.15	5.27	0.84	0.38	0.42	
<b>FILTER 50</b>	0.00	0.00	5.32	0.00	0.00	-10.5	0.00	5.43	0.00	0.00	-36.31	0.00	0.00	10.39	0.00	
<b>CBR 5</b>	-1.14	-2.13	7.19	2.95	-0.21	5.00	0.67	4.39	-0.03	-1.05	2.35	10.46	0.08	6.84	1.78	
<b>CBR 20</b>	0.00	-8.83	0.00	0.00	-2.14	-4.22	0.00	4.33	0.00	-6.97	0.00	30.38	-2.38	0.00	48.29	
	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>
<b>MA5</b>	-0.62	-7.51	0.01	-2.85	1.39	0.50	0.14	-5.56	-1.46	0.65	2.05	0.77	0.22	0.16	-1.28	0.06
<b>MA 50</b>	0.00	0.00	-0.08	0.00	0.00	3.84	0.00	-0.73	0.20	-0.14	0.00	1.41	-0.42	0.00	-1.90	-0.58
<b>FILTER 5</b>	0.30	-0.28	0.40	-0.54	0.56	-0.04	-1.06	0.87	-0.29	1.17	1.01	0.42	-0.43	0.19	-1.93	-0.21
<b>FILTER 50</b>	0.00	0.00	0.00	0.00	-77.35	0.00	0.00	-18.8	0.00	4.53	0.00	-6.25	0.00	2.88	1.08	0.00
<b>CBR 5</b>	0.26	-0.07	-0.52	-1.65	0.55	-0.62	-1.98	0.72	-0.50	0.93	2.18	0.95	-0.69	0.00	-4.06	-0.65
<b>CBR 50</b>	1.22	-2.18	-3.41	-3.78	0.00	10.75	0.00	-1.04	-1.04	0.00	-16.45	-3.22	-3.31	0.00	0.00	0.00

*Table 6.13. Yearly excess return for CHF/USD*

Profitability varies depending on the applied trading strategies, time-period and type of currency. Correspondingly, there is a remarkable widespread between the yearly returns. The short-term strategies generate buy and sell signals approximately every year for all currencies and fluctuate on average around 0. Thus, the short-term strategies seem to have

lack of predictability. However, in some years, the short-term strategies generate a mean excess return between 79.48% (Filter5, GBP) and -7.82% (MA5, GBP), which makes it hard to determine whether the trading strategies are really successful or if it is due to anomalies in the market.

The long-term strategies do not generate a high frequency number of buy-sell signals. This indicates that it is difficult to fulfill the requirements of the TTR and the traders holding position can be held for several years before any new signals are generated. In this period, the FX rates might be affected by many different market factors such as political events, supply and demand and interest rates. Thereby, the sell price of the currency might be much higher (lower) than the buy price which can give extremely high (low) returns which corresponds to the distribution of the returns. Several trading strategies show a yearly percentage change between 50-160% in the returns. These drastic changes seem unreasonable. Hence, the trading strategies will be unreliable and thereby not robust.

### 6.3.3 Distribution of excess returns

The figures presented below show the distribution of the excess returns for each currency; GBP, JPY and CHF. For convenience, the short-term period of 5 weeks and the long-term period of 20 weeks for CBR and 50 weeks for MA and filter rules are displayed.

#### *GBP/USD*

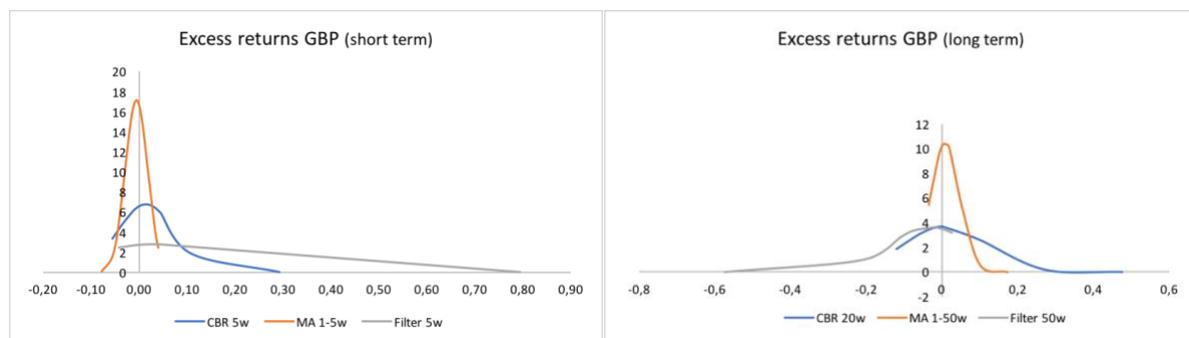


Figure 6.2 - distribution of excess returns of GBP relative to USD.

## JPY/USD

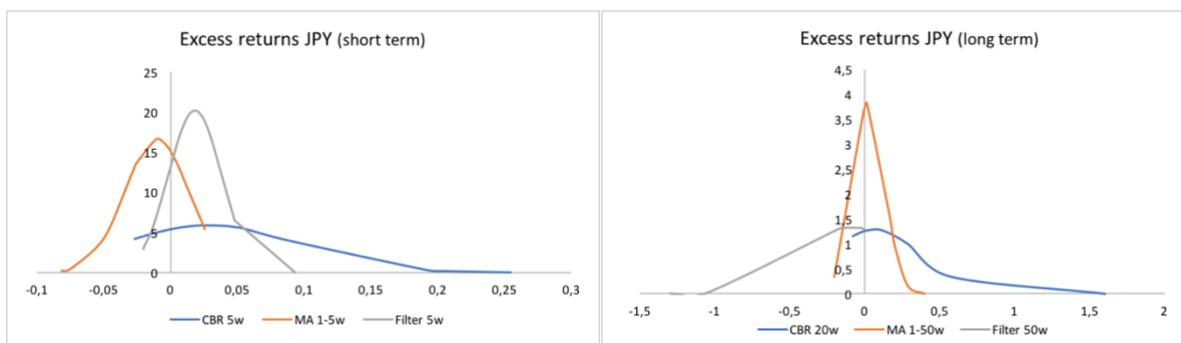


Figure 6.3 - distribution of excess returns of JPY relative to USD.

## CHF/USD

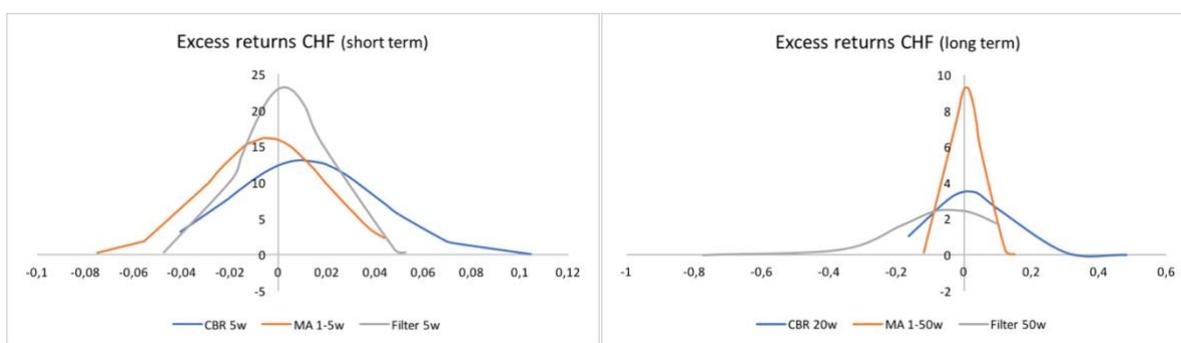


Figure 6.4 - distribution of excess returns of CHF relative to USD.

The FX market tend to have large price movements and traders will potentially experience fluctuations in the returns due to high standard deviation, which is revealed in yearly excess returns. As a consequence, most of the calculated returns from the trading strategies deviate from a normal distribution shown in the figures. The returns generated by the trading strategies reveal signs of leptokurtosis and heavy tails. Accordingly, the density for some of the returns' value is higher at the ends of the probability curve. This indicates that the distributions of the excess returns are non-normal and the robustness of the positive significant profitability of the trading strategies cannot be supported. The significance level of the returns depends on whether the distributions are normal and will thereby interfere with our results from the strategies.

## 6.4 Simulating the FX market (Bootstrap)

This section displays the results from the bootstrap of the full-sample series. First, market characteristics are presented that can potentially explain the profitability of the trading strategies. Second, the results from the simulated FX market are compared to the original series.

To determine the market characteristics, the FX rates are tested for stationarity, normality and autocorrelation. The results from the augmented Dickey Fuller test suggest that the returns are stationary. Correspondingly, the Jarque-Bera test and the distribution of the returns indicate that the results deviate from a normal distribution. Moreover, the Box-Pierce Q statistics show varying results for each currency. The results indicate different degrees of autocorrelation, where CHF does not reveal evidence of autocorrelation, while JPY have high autocorrelation between the returns. As a result of all currencies, the returns show somewhat dependency in the weekly changes in the FX rates.

The bootstrap is applied to correct for such market characteristics to examine whether the original series generate accurate results. If the bootstrap analysis reveals higher mean excess returns compared to the original series and the results cannot be rejected, the profitability of the trading strategies in the original series might be explained by the market characteristics. Thus, the trading strategies in the original series are not successfully proven in the FX market. The table below presents the results for all currencies; GBP, JPY, CHF.

Rule	USD/GBP			USD/JPY			USD/CHF		
	Buy-sell signals	Mean excess return	P-value	Buy-sell signals	Mean excess return	P-value	Buy-sell signals	Mean excess return	P-value
<b>MA 1-5W</b>	175	-5.40	(0.00)	188	-9.29	(0.00)	155	-10.53	(0.00)
<b>MA 2-6W</b>	152	-4.15	(0.00)	192	-7.38	(0.02)	138	-7.32	(0.00)
<b>MA 3-7W</b>	117	-4.18	(0.00)	162	-2.50	(0.00)	120	-6.71	(0.04)
<b>MA 1-50W</b>	166	-6.25	(0.00)	160	-5.42	(0.00)	161	-13.84	(0.00)
<b>MA 2-51W</b>	136	-6.12	(0.01)	133	-4.17	(0.00)	127	-11.04	(0.00)
<b>MA 3-52W</b>	102	-5.02	(0.01)	106	-1.69	(0.01)	114	-13.63	(0.00)
<b>FILTER 5W</b>	151	0.58	(0.31)	125	1.57	(0.86)	144	-5.65	(0.00)
<b>FILTER 6W</b>	127	0.82	(0.48)	116	1.24	(0.76)	124	-4.43	(0.02)
<b>FILTER 7W</b>	115	-1.72	(0.03)	107	1.41	(0.60)	112	-4.85	(0.02)
<b>FILTER 50W</b>	26	-0.83	(0.08)	19	2.94	(0.01)	19	1.76	(0.16)
<b>FILTER 51W</b>	26	-0.92	(0.09)	19	3.54	(0.01)	18	1.56	(0.22)
<b>FILTER 52W</b>	26	-0.54	(0.12)	19	3.50	(0.02)	19	13.86	(0.12)
<b>CBR 5W</b>	21	6.89	(0.20)	27	2.26	(0.71)	29	-4.51	(0.27)
<b>CBR 6W</b>	14	5.03	(0.17)	14	-6.47	(0.06)	19	-1.98	(0.00)
<b>CBR 7W</b>	8	2.56	(0.19)	9	1.54	(0.97)	8	-1.62	(0.00)
<b>CBR 20W</b>	9	-0.95	(0.90)	10	5.62	(0.59)	6	-2.36	(0.00)
<b>CBR 21W</b>	7	-5.22	(0.14)	10	1.13	(0.67)	5	1.04	(0.00)
<b>CBR 22W</b>	7	12.30	(0.11)	9	-2.31	(0.43)	4	-1.64	(0.00)

*Table 6.14 - Mean excess return for all currency pairs from BLL Bootstrap, all returns are presented in percentage terms.*

Looking at GBP, the short-term strategies of filter rules for 5- and 6 weeks fail to reject H0 but only 6 weeks generate higher return compared to the original series. The filter rule of 7 weeks reveals significantly negative return and show signs of data snooping bias. In addition, the long-term strategies of filter rules indicate that the original series are inaccurate. Moreover, the long-term nor the short-term strategies of CBR cannot be rejected and several strategies generate higher profitability compared to the original series. These strategies suggest to perform better in the bootstrap than the original series. This create reasonable doubt to the predictability of short- and long-term strategies for filter rules and CBR.

The short-term filter rules for JPY show similar mean excess returns compared to the original series and cannot reject the null hypothesis. In addition, the short-term strategies of CBR generate a positive profitability which exceeds the profitability in the original series, except in 7 weeks. These short-term strategies indicate that the results in the original series are not reliable and show weak evidence supporting the profitability of the TTR. The returns from the long-term strategies of CBR are insignificantly lower relative to returns in the original series. Even though it seems like these strategies in the original series are successful,

the results from the bootstrap suggest that the profitability can be explained by market characteristics. Thereby, the strategies are not valuable in the FX market.

For CHF, the results from long-term strategies of filter rules suggest that the original series are not accurate. However, the mean excess return in these strategies show no evidence of outperformance in the FX market in the original series. Further, the short-term strategies of CBR show ambiguous results. The strategies generate lower mean excess returns in the bootstrap relative to the original series. However, 5 weeks cannot reject the null hypothesis which claim that the strategy does not seem to work in the original series. In this sense, it seems unlikely that the strategies of CBR in 6- and 7 weeks are beneficial towards the market. The long-term strategies of CBR in the original series show correct results according to the bootstrap. As a consequence, it appears that these strategies are successful due to the significant profitability in the original series.

Applying for all currencies, the long-term strategies of MA suggest that the returns in the original series are accurate. As those returns are significantly profitable it could indicate that the trading rules have a predictive power in the FX market. However, recall that the bootstrap analysis does not further risk-adjust returns.

To summarize, the bootstrap contributes to more insight and information about how well TTR perform in the market. Markowski and Markowski (1990) indicated that the standard t-test applied on the original series still generate proper results even though the data might not fulfill the requirements. However, all filter rules and CBR fail to generate accurate results for the GBP and JPY, as the bootstrap outperforms the original series. Furthermore, the bootstrap in CHF for the long-term filter rules and short-term CBR finds weak evidence supporting the accuracy of the results in the original series. Overall, the results from the bootstrap imply that the short- and long-term strategies of CBR and Filter rules in GBP and JPY do not support the profitability in the original sample. On the other hand, the strategies seem more successful in CHF. According to previous research, they found strong evidence supporting the profitability of TTR in the FX market in the bootstrap analysis (LeBaron et al., 1999; Levish & Thomas, 1992). No such signs are found in the results from the

bootstrap as the results vary depending on the TTR and currencies. The bootstrap does not give a clear indication towards the accuracy of the profitability in the original sample.

## 7.0 Conclusion

Numerous of previous studies have found evidence supporting the profitability of TTR, meaning that the trading strategies are successful in the FX market. On the other hand, many academics believe the EMH holds, which eliminates the value of TTR. In this analysis, we have tested three simple TTR; Filter-, moving average- and channel breakout rules on GBP, JPY and CHF relative to USD between 1986-2016 in the FX market. The purpose of this study is to determine whether TTR are successful the foreign exchange market. The performance of trading strategies is tested by evaluating the profitability and the predictive power considering data snooping, robustness and market characteristics. In this section, the results are summarized, followed by limitations to our study and a conclusion.

The results in the full-sample show that the majority of the trading strategies generate significant profitability and it seems that these strategies are beneficial and carry information. However, data snooping bias is a big concern which indicate that some of the profitability is random and not due to the performance of the trading rules which assumes that the TA is not consistent. The results from the strategies of CBR show superior performance relative to the strategies of MA and Filter rules. This supports the critique among researchers who tend to cherry-pick and over-regress the results, as they support the successfulness of the MA. Overall, the positive significant returns in almost all trading strategies do not survive risk adjustment. This supports evidence against the successfulness of the TTR in the FX market.

The conducted sub-samples test the robustness of the trading rules and show distinctive results. Sub-sample one show that the TTR either perform better or equivalent to the full sample. The majority of the trading strategies for all currencies were found significantly profitable indicating inefficiencies in the period between 1986-2000. Sub-sample two reveal evidence supporting the EMH in CHF as none of the trading strategies are exploited for profit considering data snooping bias. In addition, the trading strategies in GBP are highly exposed to data snooping. This is consistent with several studies that reveal the FX market has become more efficient over time. (Qi & Wu, 2006; Irwin & Park, 2007). However, the trading strategies in JPY performed better in sub-sample two implying that the Japanese FX

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market is less efficient. The profitability of the TTR show to somewhat extent robustness, but the performance is considerably reduced given the risk involved.

The bootstrap analysis found that the profitability of several trading strategies applied on the three currencies can be explained by market characteristics and the original series show inaccurate results. For GBP and JPY, the trading strategies do not seem to outperform the market in the original series due to unreliable results, except the long-term strategies of MA. On the other hand, in CHF, the long-term strategies of CBR and MA indicate that the trading strategies are predictable towards the market. The bootstrap analysis does not give any clear indications towards the accuracy of the profitability of the TTR in the original series. However, the bootstrap analysis has not considered the risk adjustments.

There are several noteworthy limitations to our study. First, only three simple TTR are tested on three currencies relative to the USD. By including a larger number of currency pairs and more complex TTR, the results may have been more reliable towards the performance of the trading strategies. Second, the number of TTR tested on each currency is limited. Neither taxes or regulations are considered, which might reduce traders' profitability. Lastly, we do not consider the effects different transaction costs have on the profitability, as only one set of one way transaction costs is adjusted for in the returns. However, the options presented are too extensive for this research.

In this analysis, the results provide no evidence supporting the profitability of the TTR in the long run, as almost all the trading strategies do not survive the risk adjustment. This supports the hypothesis of market efficiency. Although the trading strategies are not equally unprofitable, the TA is not consistently successful within the FX market. The study suggests that the frequent recommendation of TA by practitioners is most likely explained by opportunistic choice of individual rules which happened to perform well in the past. The financial market is continuously changing, where innovation is essential. New theories and approaches will be developed in the future. Nevertheless, practitioners will always strive to find ways to outperform the market.

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## 9.0 Appendix

### 9.1 Box-Pierce Q statistics

GBP/USD

<b>Lag</b>	<b>AC</b>	<b>PAC</b>	<b>Q</b>	<b>Prob&gt;Q</b>
<b>1</b>	-0.0000	-0.0000	0.00	0.9995
<b>2</b>	-0.0164	-0.0165	-0.44	0.8038
<b>3</b>	0.0611	0.0612	6.48	0.0903
<b>4</b>	-0.0180	-0.0185	7.01	0.1353
<b>5</b>	-0.0074	-0.0054	7.10	0.2132
<b>6</b>	0.0573	0.0532	12.44	0.0528

JPY/USD

<b>Lag</b>	<b>AC</b>	<b>PAC</b>	<b>Q</b>	<b>Prob&gt;Q</b>
<b>1</b>	0.0093	0.0093	0.138	0.7094
<b>2</b>	0.0762	0.0761	9.553	0.0084
<b>3</b>	-0.0050	-0.0064	9.594	0.0224
<b>4</b>	-0.0043	-0.0101	9.623	0.0473
<b>5</b>	0.0460	0.0473	13.06	0.0228
<b>6</b>	-0.0134	-0.0132	13.35	0.0378

## CHF/USD

Lag	AC	PAC	Q	Prob>Q
1	-0.0102	-0.0102	0.169	0.6801
2	0.0072	0.0071	0.255	0.8805
3	-0.0014	-0.0013	0.258	0.9678
4	-0.0078	0.0079	0.356	0.9859
5	-0.0039	0.0041	0.381	0.9958
6	-0.0051	-0.0051	0.424	0.9986

## 9.2 Augmented Dickey Fuller results

## GBP/USD

Augmented Dickey-Fuller test for unit root Number of obs =1617

	Test statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-19.651	-3.430	-2.860	-2.570

MacKinnon approximate p-value for Z(t) = **0.0000**

## JPY/USD

Augmented Dickey-Fuller test for unit root Number of obs =1617

	Test statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-19.516	-3.430	-2.860	-2.570

MacKinnon approximate p-value for Z(t) = **0.0000**

## CHF/USD

Augmented Dickey-Fuller test for unit root Number of obs =1617

	Test statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-20.201	-3.430	-2.860	-2.570

MacKinnon approximate p-value for Z(t) = **0.0000**

### 9.3 Jarque-Bera test results

Skewness/Kurtosis tests for Normality						
Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	joint		
				adj	chi2(2)	Prob>chi2
GBP	1,617	0.0000	0.0000	.		0.0000
YEN	1,617	0.0000	0.0000	.		0.0000
CHF	1,617	0.0000	0.0000	.		0.0000

The reason for no values for the chi2(2) is explained by the values in the data are too low. However, the test show valid results even if the chi2(2) cannot be calculated.