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ALGORITHMIC TRADING STRATEGIES FOCUSED ON
CURRENCIES

Bachelor thesis

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Statement:

I hereby declare that I have elaborated my Bachelor Thesis on the topic: "Algorithmic trading strategies focused on currencies" independently under the supervision of a bachelor thesis supervisor and I have listed all used materials and literature.

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Author's signature:

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Introduction

From the beginning of time, it is in the very nature of men to keep finding a way how to facilitate unnecessarily complications and to pursue any designated goal. The financial markets are no exception, the allure of large potential profits brings more players into the game. Nowadays trading on financial markets is more accessible than ever before which is gaining even greater public awareness and popularity. This trend has experienced an immersive grown and development thanks to the new tradable assets, which have been added to the market and the new technological improvements. For decades many people were trying to understand the true character of the financial markets and then monetize it, but in reality, they are more similar to untamed wilderness. Therefore various strategies and indicators were created to help identify the market's behavior and generate profit. Their purpose is to generate the biggest possible profits thought computer programs. Outdated algorithms can prove insufficient on the presentday market, that is why constantly new designed algorithms are being implemented. There exist many computer programs, such as MetaTrader 5, RoboX or Protrader, designed especially for backtesting algorithmic trading strategies, although these programs require enhanced knowledge in computer programing. (Chaboud, Chiquoine, Hjalmarsson & Vega, 2009) In order the strategy would prove to be adequate the user has to obtain usually very expensive historical data, for the precision of the whole process. Although the financial markets have a tendency to repeat its movement, it would be impossible to make predictions based only on historical data. (Rangappa, 2018)

The goal of this thesis is to backtest algorithmic trading strategies on three types of technical indicators: Stochastic oscillator, CMF indicator and EMA indicator. The backtesting process will be implemented on a 4-hour interval historical data. The backtesting and calculation process of selected indicators will be made in Microsoft Excel. After the calculation process, three strategies are going tested. From these tested strategies buy and sell signals will be generated and we will be able to find out if the strategy generated any profit. The main reason why Microsoft Excel was chosen as an

operating platform was that Excel is very accessible and most people are already familiar with the software. It is easy to use compared to other more complex computer programs and a huge amount of information is available online about improving Excel skills, which makes Excel a comfortable environment to program. A huge number of technical indicators can be programmed and the trading logic can be as simple or complicated as needed. Although there is a big amount of information about MS Excel, the reason also why I have chosen this topic is because the availability of no paid materials and resources on algorithmic trading strategies is still very limited and maybe by completing this research sharing my findings with my fellow colleagues will hopefully help them with their research and they will have an easily accessible material. That is why this research will implement the process of backtesting on this more available and publicly known program. All MS Excel calculations are available on a CD attached to the thesis. The strategies are going to be backtested on time series of the length of one year. These historical data consist of open/close price, which is the first/last price traded at the beginning/end of a given period and the high/low price, which is the highest/lowest price traded during a given period. The data used in the later backtesting process also contain dates, hours and volume values from 08. 12. 2017 to 11. 04. 2019. The performance of the chosen algorithmic trading strategies measured in Excel (in terms of total revenues/losses) will be compared in the respective time-period and overall the Buy & Hold strategy will be used as a universal benchmark.

An investor is always seeking the data with the best accuracy, the historical data for this research were provided by GKFX platform, luckily having only insignificant limitations. The data more delicate in precision are expensive and they are needed to be purchased. To compare how strategies function, it is assumed, that at the beginning of the trade an investor has enough initial capital to purchase the first unit of currency pair. Before the trade is initiated, the investor does not own any unit, that is why the strategies are firstly set to generate a buy signal. After a time of considering the right moment a sell signal follows, generated by the studied strategy. The main condition for the strategies is an alternate number of buy and sell signals. We are looking for a balance between buy and sell signals. The strategies are set to finish with a sell signal, if

it's not supported by the strategy, a sell signal is forced to be generated, at the end of the period under investigation. The calculation process is not only testing if the strategy works on historical data but also the strategy's performance.

The theoretical part of the research will firstly discuss the Forex exchange market. The Forex exchange market is one of the biggest in the world and currencies are the primal trading asset, representing the hottest traded topic on the market. Then, the paper will cover currencies on Forex, major currency pairs and we will take a closer look at EUR/USD and USD/JPY pairs. The next part will explain algorithmic trading and its advantages and disadvantages. The practical part will be consisted of Chart indicators, explaining various indicators based on trend, volume, momentum, and volatility. Next, Methodology will describe the calculation process for the picked indicators. The part, Chosen strategies will explain strategies used for the chosen indicators. The research is concluded by the evaluation of Results and Summary.

THEORETICAL PART

1 FOREX

The FOREX exchange market is a market where participants buy, sell and exchange currencies. The Forex market is the largest, most liquid investment market in the world with trillions of dollars daily turnover. The investors can enter or exit the market at any time they want almost during any market condition. There is no central location, instead, money is traded through the network of international dealers and brokers. Businesses use the Forex market when they are buying products from other countries. Supposing the US company wants to buy a car engine from Japan. The engine is transferred from Japan to the US and the US company has to convert US dollars to yen to pay for the goods and the US company uses the Forex market to convert dollars to yen at the current exchange rate. Speculators will attempt to buy currencies that they think will increase in value and sell currencies they assume will decrease in value. Unlike a stock, currency valuation is relative to other currencies and that is why the price is given in relation to a second currency. There are many factors that contribute to a change in the exchange rate including monetary policy, political stability, interest rates, and imports and exports. (Gallo, 2014)

The Forex (FX) exchange allows the possibility to trade almost any existing currency in the world, always trading one currency for another with minimal transaction costs. Transactions costs are expenses incurred from buying and selling securities. Over time they substantially reduce returned in a row the capital is available to invest so they should be considered every time. Financial intermediaries that provide easy access to trading such as banks and brokers charge a fee for their services. In addition to a securities price, these transaction costs can include commissions, fees or spread referring to the difference between what dealer pays and charges for the security. The investors weighs the impact of transaction costs into their investments and seek opportunities to minimize them. (Mendes, Godinho and Dias, 2012)

In April 2010, the daily amount of traded capital in FX reached \$4 trillion on the New York Stock Exchange (NYSE). A few years later the market has enlarged even more. In 2016 the amount of daily traded volume overstepped total \$6.514 trillion and in April, 88% of executed trades were between the US dollar and some other currency. (Amadeo, 2018)

The Forex exchange market includes forex trading robots. These trading robots are automated software programs set to generate trading signals, buy and sell, under specific conditions on the market. Trading robots work on pre-set instructions and they are based on a scripting language, which lets traders generate trading signals or place orders and manage trades. (Wahid, 2013)

Generally, buy and sell signals are conditions, selected by a trader as a notification for entering or exiting a specified investment. In algorithmic trading buy and sell signals are generated and automated by trading systems, they can be observed by analyzing chart patterns or technical indicators. Buy and sell signals may be used by short-term traders and long-term investors. Automated trading systems generate buy and sell signals automatically based on a set of rules. Buy and sell signals can be generated from a variety of signaling methods. Chart patterns generate a buy or sell signal when the asset's price moves beyond or below a certain level. Next, there are technical indicators. They can generate a buy/sell signal when an indicator's specific conditions are met. For example, the RSI indicator generates a buy signal when it moves below oversold conditions at value of 30 and when it rises above value of 80 the indicator generates a sell signal. (Moosa, 2003)

For finding arbitrage opportunities trading robots can be used to facilitate the human traders work as they also have an ability to scan the market. For example, these opportunities happen in situations when two trades are executed at the same time as one of them is for purchasing and the next for selling the same asset pair with different prices. For arbitrage exists because of the inefficiency of the market, if the market would be perfectly efficient there would be no arbitrage. (Mancini-Griffoli, Rinaldo, 2011) The trading pairs are determined as statistical arbitrage. It allows simultaneously

to open both short and long positions, taking advantage of irrelevant pricing in correlated securities. These instruments are naturally connected to one another or in some way they are influenced by each other. For example the mutual relationship between Swiss franc and Gold. When the exchange rate of the first asset moves the second should move the same way. When the Swiss franc increases and the price of gold decreases, both assets should converge to each other in the future. The Swiss franc can be sold, inversely gold is bought. The behavior of Swiss franc and Gold is very similar. (Pole, 2007)

The main participants in the financial markets are the so called bulls and bears. Bulls are standing for buyers and bears are representing sellers. When talking of stocks and securities it is common, that an investor has a long or short position. Not being exactly a reference to length, instead, long positions and short positions are referring to what a trader has and has not, more especially what a trader does owns or owes. If a trader has a long position, it means that the trader has bought and owns those particular shares of stocks. On the contrary, if the trader has a short position, it means that the trader owes those stocks to somebody else, but does not actually own them yet. (Milton, 2019)

As already mentioned, on Forex, the most traded are currencies. For trading also other categories, investors turn to Over the Counter Market (OTC). OTC represents every possibly tradable asset, it's a place where basically everything can be exchangeable. Traders invest their money into commodities, currencies, cryptocurrencies, stocks, bonds and plenty of others. There is no marketplace, with centrally fixed prices, meaning the execution of the trades is made online on a computer, phone or through other accessible devices. The markets are spread all over the world and their current number is 82. The most essential ones would be for example the New York Stock Exchange (NYSE). Located on Wall Street, NYSE is the largest market of all the tracked OTCs. The first foundations for NYSE were drawn in March 1817 and shortly after the organization gained its official name: the New York Stock & Exchange Board for physical trading stated NYSE in 1863. (New York Stock Exchange, NYSE Overview 2019) Next, there would be NASDAQ. Established also in New York city,

originally short for National Association of Securities Dealers Automated Quotations has a title of the first electronic stock market. Later, NASDAQ became the first market where automated trading and volume reporting was possible. For all listed times the NASDAQ uses the America/New York timezone. (NASDAQ Stock Exchange, NASDAQ Overview, 2019) Then there is The London Stock Exchange Group (LSE). It was created formally in 1801, experiencing problems in early years in 1812 a detailed document was constructed which became a trading bedrock. (London Stock Exchange, LSE Overview 2019) Trading assets is a bit different from Exchange markets. Also what attracts traders is a fact that financial derivatives can be traded on the OTC too. (Amadeo, 2018)

There are many players on the market. Starting from individuals, people who like to operate and execute trades for their own interests, it can be work or hobby. Next, there are companies. Those with enough capital are usually looking for a new way to invest but, for them the situation is a bit different, they do not only represent bulls and bears on the market, but also their own stocks which are traded world wide. They contribute about 9 % of daily turnover. Then there are numerous organizations featuring on the market who represent multiple individuals or companies. Other indispensable players on the market are banks. The banks are the biggest traders, representing 24% of daily turnover on Forex market. The market is a very vast and complex place, therefore many countries have joined to global trading, they trade with multiple assets and they possess a lot of capital. In trading there are basically only 3 options - buy, sell and hold. It is possible to make money even though the market stagnates. On the market, it is not important if the prices are going up, down or staying still, it is still possible to make a profit. It is possible to make money even though the market stagnates. Although there is an importance on closing and opening time sessions, which is an essential aspect to consider. (Singh, 2013)

The Forex currency market has 4 major markets, one of them is New York Exchange market where all trades are executed in USD, then there is London where we have GBP, Tokyo where dominates JPY and Sydney where traders use AUD. Forex market is open

24 hours a day, during week days. The Forex market opens for traders every Sunday at 22:00 pm of Greenwich Mean Time (GMT) and then it closes each Friday at 22:00 pm (GMT). It provides a great opportunity for traders to trade at any time in the week in day or night. However, when it seems to be not so important at the beginning, the right time to trade is one of the most crucial points in becoming a successful Forex trader. The week starts with the Asian session (Tokyo, Hong Kong, Seoul, Singapore). Just before the Asian session closes, the European session opens (London, Paris, Zurich, Frankfurt). Halfway through the European trading day, the American session takes over (New York, Chicago, Toronto). (Foreign exchange market, Forex centres with a corresponding time zone, 2019)

According to the Bank for International Settlements one of the reasons why is Forex so enormous is because of low volatility. The volatility continues to hover at low levels now more than for the last 2 decades. In comparison with the late 1990s where it rose above 20 percent with US dollar versus Japanese yen trades, nowadays volatility is below 10 percent. There are two major components why volatility is low. First is that inflation has been low and stable in most world economies and second is a high transparency of policies of central banks. Volatility represents an important factor on the Forex market, with low volatility the risk for investors is reducing. (Bank for International Settlements, 2017)

Also, the newest technology helps traders to have faster responses from the market. This leads to unnecessarily complex currency adjustments. (Garner, 2012) In an issue for the Journal of Banking and Finance Harris and Chiu are explaining the importance of volatility. Volatility in financial markets is a statistical measure of the dispersion of returns for a given asset. For example, when the stock market rises and falls more than one percent over a sustained time period, then it is called a "volatile" market. Volatility of security is a key point when pricing options contracts. A higher volatility signifies that an asset's value can potentially be spread out over a larger range of values. Meaning that the price of the security can change dramatically over a short period of time in either direction. Volatility is often associated with risks, but the trader must not forget

that it also can easily turn into an opportunity. The risk can, for example, occur when the trader handles the risk management insufficiently or when the business strategy is poorly planned. On the other hand, for a trader who follows risk management and has a well-established business plan, trading with higher volatility can become a very rewarding activity. (Harris, Chiu, 2016) Later in chapter 4 "Technical chart indicators" further information on volatility will be provided and volatility-based indicators will be examined.

1.1 Technical analysis

Technical analysis is a trading discipline, which is used by investors to recognize trading opportunities and be able to evaluate their investments. In technical analysis, traders are able to analyze statistical trends gathered from trading activity, such as price momentum and volume. Technical analysis can be employed on any security with historical trading data, including stocks, futures, currencies, commodities, and other securities. Investors using technical analysis are focusing on patterns of price movements and trading signals to evaluate a strength or weakness of security. Technical analysis is more prevalent in commodities and Forex market where investors focus on short-term price movements. Strategies in technical analysis are based on involving indicators such as Ichimoku cloud, Fibonacci sequence, moving average or relative strength index. (Lien, 2009)

2 Currencies

Currencies are traded on the Forex market 24h a day, five days a week, that is only closed from Friday evening to Sunday evening. Therefore these trading sessions are confusing and sometimes causing that certain currency pairs will have more volume during certain sessions. All currencies are traded in pairs. On contrary to the Global Stock Market, where a single stock can be bought, in FOREX there is no other way than to buy one currency and sell another currency. All currency pairs have the same rules - the first currency in a pair is called the major currency, and the other is called the minor currency. Taking the EUR/USD currency pair as an example, where the EUR (euro) is

the major currency and the USD (US dollar) is the minor currency. For example, you can see the EUR / USD price is around 1.1250. This means that 1.1250 minor currency units are necessary to get one unit of the major currency. In other words, for 1.250 \$ can be bought one euro. There exist many currency pairs because most countries use their own currency. That is why foreign currencies are always sought by foreign traders, there is usually a great demand for any currency pair. The Major currency pairs are the most liquid ones. (Ehrman, 2006)

2.1 Major currency pairs in Forex trading

Exchange rates on the foreign exchange market are constantly being taken from currency pairs. Not all currencies in the world are traded worldwide, there are several countries whose currencies are traded more. These are countries that are both politically and economically stable. On Forex, there is an immense amount of currency pairs, but only a few are called major currency pairs. The major pairs are the four most heavily used for investment purposes. The four major pairs are the Euro against US dollar, US dollar against Japanese yen, British pound against US dollar, and US dollar against Swiss franc. (Bickford, Archer, 2007)

Bickford and Archer state the most traded and the most liquid currency pairs as following:

- US Dollar (USD) and British Pounds (GBP) - GBP/USD
- Euro (EUR) and US Dollar (USD) - EUR/USD
- Japanese Yen (JPY) and US Dollar (USD) - USD/JPY
- Swiss Franc (CHF) and US Dollar (USD) - USD/CHF

Taking the main currency like the US dollar, the euro, the Japanese yen or the British pound and comparing it to each other, we get something that is known in the market as

'FX pairs'. Forex is a growing market where traders prefer to buy or sell a currency for a 'regular rate' rather than sell it for a better rate, resulting in a rise or fall in value the next day or week. (Wang, 2003). Currency pairs are most active when the sessions for their region are active and can be traded online at any hour of each weekday. Traders of FX pairs need to pay attention to every announcement, news or any other valuable information to determine which factors could affect the growth or decline in currency value. For example, monitoring one of the most popular FX currency pairs, such as GBP/USD, then the trader should follow the UK announcements. Data such as a fall in unemployment or an increase in interest rates in the UK are all factors that would normally strengthen the pound. It is also worth paying attention when the government is taking measures such as quantitative easing - when it pours money into the economy to boost growth because traders can find that a related currency weakens slightly. Klein (1991) denotes that, the news explain about 40 percent of FX price changes, back in those days. This claim is later supported by Eddelbuttel and McCurdy (1998). Other also often exchanged currencies that appear on the currency market are the Australian dollar (AUD), the Canadian dollar (CAD) and the New Zealand dollar (NZD). (Eddelbuttel and McCurdy, 1998)

The thesis will further focus on EUR/USD, USD/JPY currency pairs. These two currency pairs were considered from the beginning for they are the most traded currency pairs on Forex. In the case of EUR/USD, there is very high liquidity and the pair has lower volatility. The EUR/USD currency pair has globally the largest trading volume and it represents a combination of two of the biggest economies in the world. Also, large economies have a tendency for more price stability. That is why this pair cannot be overlooked by traders for its daily price movement and volatility. The USD/JPY currency pair was chosen because it is the second most liquid and tradable currency pair in the world. Japan belongs to the largest world economies, with one of the highest GDP among nations; it is also one of the largest exporters, in dollar terms. USD/JPY has a higher volatility compared to other major currencies. The government and national bank of Japan focus on keeping the yen stable at artificially low levels. These low levels are

advantageous to the huge export sector of the country's economy and are fostered by national monetary policy. (Bradfield, 2018)

2.2 EUR vs USD

The US dollar and the Euro are two of the most significant and best-known currencies in the world. The EUR/USD currency pair has globally the largest trading volume and is, therefore, the most traded currency pair. This pair should not also be overlooked because of its daily volatility and price movement. The US Dollar (USD) and Euro (EUR) are the official currencies of the respective US economic zone and countries in the European Union. The FOMC (Federal Open Market Committee) consists of the Federal Reserve System (FRS) and Federal Reserve Bank of New York that determines the direction of monetary policy for the US, which in turn affects the value and perceived value of the US dollar. The European Central Bank (ECB) is the main central bank for the euro and the eurozone and the impact on currency is similar. Currencies have currency signs to indicate the units of the currency, the US dollar sign is \$ and the Euro sign is € and both of these two currencies are an important part of the Forex exchange market. In the Forex market, the price of one currency moves up, or down to another currency. Both EUR and USD also generate currency pairs with other currencies such as the Euro against the British Pound (EUR/GBP) or the US Dollar versus the Canadian Dollar (USD/CAD). (Archer, 2008)

As stated in a Triennial Central Bank survey published by Bank for International Settlements and conducted in September 2016, the US dollar (USD) is the most traded currency in the world and the euro is claiming second place. It is important to note that the following percentage values were adjusted by the survey for local and cross-border inter-dealer double-counting. As two currencies are involved in each transaction, the sum of shares in individual currencies will total 200%. The USD daily share is 87.6% of all currency-related business activity, which is almost 3 times more than the EUR 31.4% share. The rest of the top five consists the shares of the Japanese Yen with

21.6%, British pound 12.8% and the Australian Dollar 6.9%, the Canadian Dollar 5.1% and the Swiss Franc with 4.8%. (Bank for International Settlements, 2016)

The price movement EUR/USD reflects the change between the euro and the dollar. Explaining on an example:

- When the exchange rate of the EUR/USD currency pair increases from 1.15 to 1.17, the euro becomes more valuable and the USD becomes less relative to the other currency.
- When the price of the EUR/USD falls from 1.22 to 1.19 the euro becomes less valuable and the USD becomes more valuable.
- In the opposite case, movements of USD/EUR are alike, when the USD versus the euro increases, the USD becomes more valuable. It is important to note that this version of the abbreviation is not very common.
(Gatev, Evan, Goetzmann, 2006)

When the price moves up or down, it means that one currency becomes stronger or the other weaker, or even both. If the EUR/USD exchange rate is higher, it could mean that the euro is strengthening against the US dollar, or that it may weaken the US dollar - or both. No matter what price change is, the fact is that traders can monitor the current balance of power by simply tracking price movements on the EUR/USD currency pair. The EUR/USD is either listed by the broker at 4 decimal places, which is 0.0001 pip, or some brokers are able to list EUR/USD at 5 decimal places, 0.00001 pip. (Barbosa & Belo 2008)

A pip is defined as a measurement of the price change in currency pair trading on the Forex market. Most currency pairs are priced to four decimal places and the smallest change is the last (fourth) decimal point. This is the equivalent of 1/100 of 1%. But this is not adequate for the USD/JPY (Japanese Yen) currency pair which is quoted with 2

decimal places, marking a notable exception. USD/JPY, the value of a pip is 1/100 divided by the exchange rate. For example, if the EUR/JPY is quoted as 132.62, one pip is $1/100 \div 132.62 = 0.0000754$. This can be explained on an example. A trader is looking for a USD/CAD currency pair, which is quoted at 1.1005 and he/she wants to buy 10 000 CAD worth of Canadian dollars, which for the quoted price he/she must pay about 9,086.78 \$ calculated from established equation $1/1.1005 * 10\ 000$. When the pip sees one pip increase to 1.1006, trader now has to pay 9,085.95 \$, which is a difference of 93 cents. (Di Lorenzo, 2012) The subsequent figure 2.0 presents the daily price movement of EUR/USD currency pair. The source for figure 2.0 is TradingView.com (Copyright © 2019 TradingView)

Exchange rate of EUR/USD

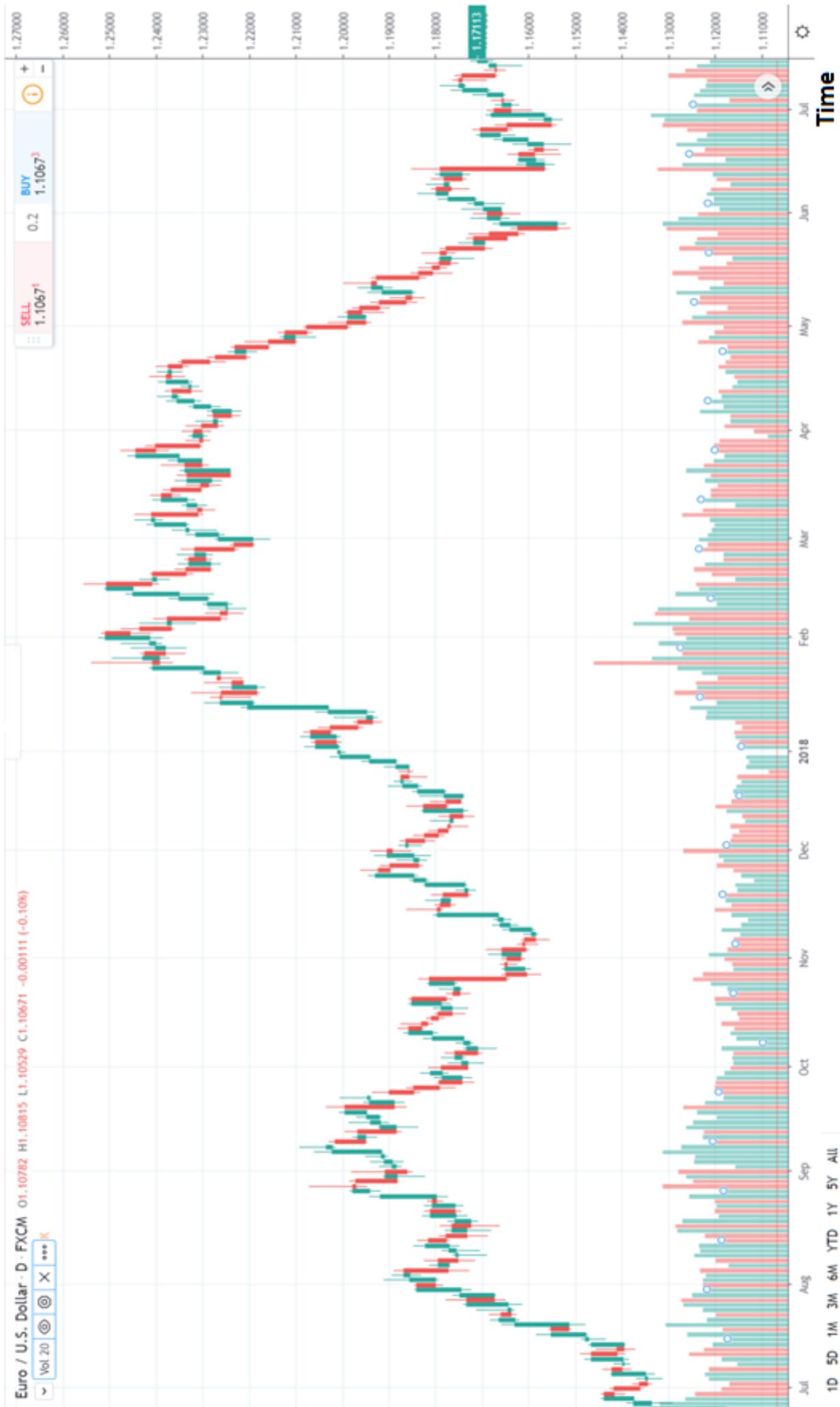


Figure 2.0: EUR/USD Daily price movement

2.3 USD vs JPY

The couple USD/JPY is the second most liquid currency pair in the world. The Japanese Yen denotes the third major international currency and represents the globe's second-largest economy in the account of its GDP, after the United States. The official sign for the Japanese yen is ¥. The interest rate differential between the Federal Reserve System (FRS) and the Bank of Japan (BoJ) affects the value of USD/JPY when compared to each other. Additionally, correlations between the US and Asian equity markets are a key determinant of the exchange rate. The USD/JPY pair has a positive interrelationship with the USD/CHF along with USD/CAD currency pairs as they both conclude the US dollar as the major currency. USD/JPY has the largest range of traders among the majors and also tends to trade with a higher degree of volatility across all trading sessions. (Lee, 2018) Comparing the saving rates of both countries, where the US stands at -1% and Japan move around 15%. This is a hint that Japanese traders and banks are in possession of a larger amount of funds that they can invest. (Chen and İmrohoroğlu, 2006)

The pair USD/JPY is extremely liquid and it has a tendency to move around a particular price level before there is a sudden rapid movement to a different price level. A trader who wishes to trade USD/JPY pair has to pay attention to the daily or monthly yen price chart to observe the overall trend of the currency in order to determine in which direction it might move. The high-frequency trader bulls who mainly works with technical indicators keeps an eye on the selling pressure zone. Taking into consideration the historical scale of USD/JPY pair. In *Physica A* journal T. Mizuno and S. Kurihara state that it usually ranges from an average low of 85 to a high of around 120. Meaning that the currency pair is most frequently moving to meet 120 or it can decline to 85, though under specific market conditions the range can be much wilder. (Mizuno, Kurihara, 2013) Following figure 2.1 shows the daily price movement of USD/JPY currency pair, it can be seen that the price moves around 111. The source for figure 2.1 is to DailyFX.com (FX Publications Inc). The link for the source can be found in references.

Simon Baptist (2018) states that one of the pleasant surprises in the global economy in 2017 was the strong performance of yen, which originated from strong global demand for exports of Japan, plus government spending and lots of liquidity from the Bank of Japan. Since Japan's exports are all contracted in the US dollar, strong yen with an upper hand over the US dollar has the potential to cause profit difficulties for Japanese exporters. (Taguchi, 2017). In the case, the yen would sustain its strength, it would mean a delay for Japan's efforts to meet its 2 percent inflation target. Japan has the smallest share of its denominated exports in its industrialized countries. Japanese exports denominated in its currency, according to Bacchetta and Wincoop (2002), are approximately 23%, compared to US exports (over 90%). (Bacchetta and Wincoop, 2002)

2.4 The best time to trade EUR/USD, USD/JPY

The best time to trade the EUR/USD, USD/JPY and like any other currency pair, is when the market is active, which means that there is a decent price volatility and movement. Currency pairs tend to be more active when a session for one or both currencies is open, in a given country or economic zone. EUR/USD pair is most active from 12:00 GMT to 20:00 GMT. (Archer, 2008)

USD/JPY does not follow the consecutive-opening sessions. This particular pair is a bit tricky regard to the best suitable time for a trade. Let's have a look at times when it is best to avoid to trade USD/JPY and than on best suitable ones for the execution of the trade. The figure 2.2 shows for how many pips the USD/JPY average volatility moves hourly throughout the day. As can be seen, movement throughout the day is mostly stable, although there are periods with noticeable drops in volatility. The USD/JPY pair is sedated between 21:00 pm GMT and at 00:00 am GMT. As Tokyo begins to fade, and before London rises, the pair sees yet another drop in volatility between 03:00 am GMT, and 05:00 am GMT. On the contrary, if traders are able to, day trade the USD/JPY between 12:00 pm GMT and 15:00 pm GMT it maximizes their trading

efficiency, as the increased volatility provides more opportunities to get profit. New York and London sessions are both open for almost hole time of this period. Even though Tokyo is not opened yet, in this two to three hour window sometimes volatility preserves high up till 16:00 pm GMT. (Mitchell, 2017) The figure 2.2 provides a graphical representation.

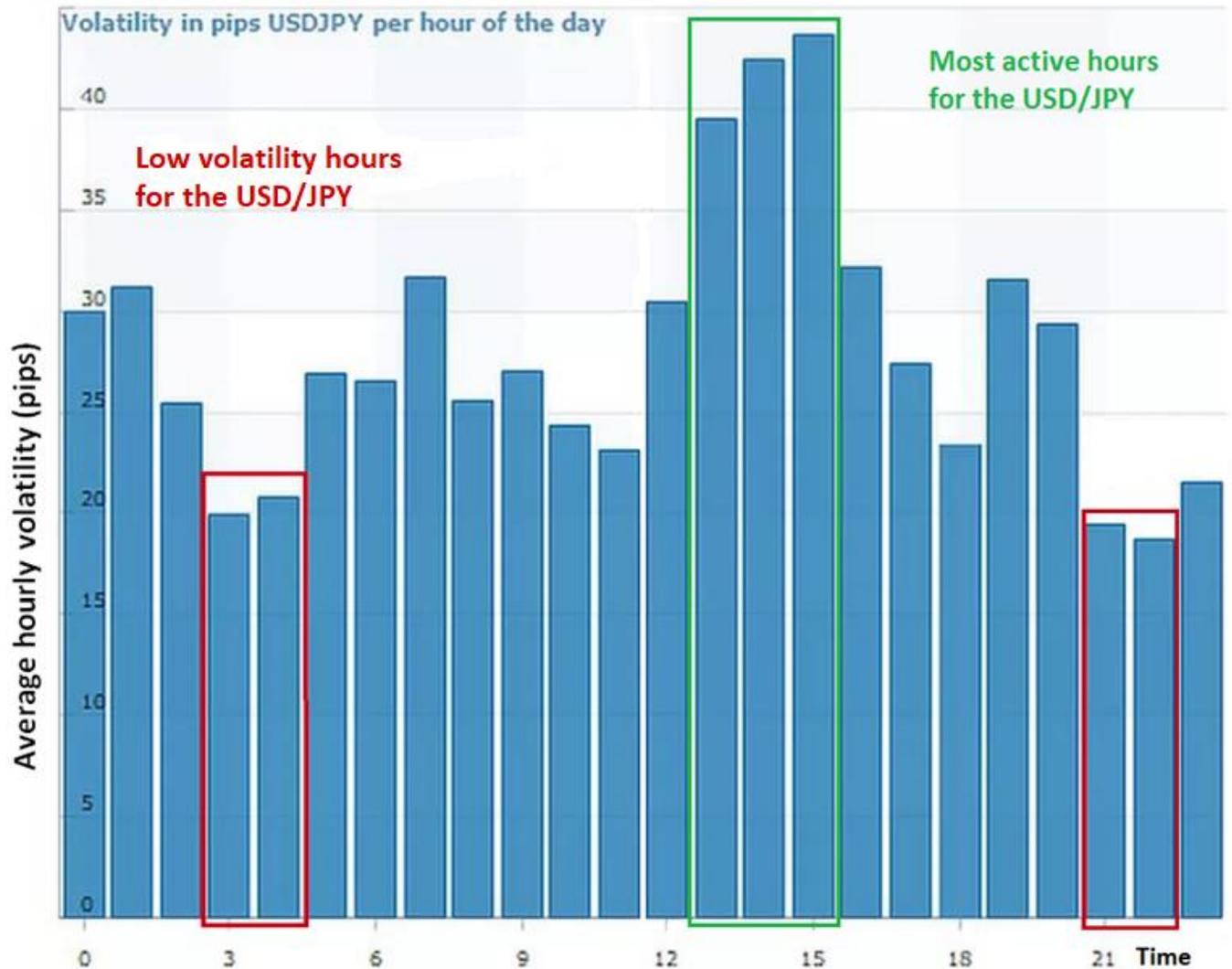


Figure 2.2: Volatility in pips USD/JPY per hour of the day

3 Algorithmic trading

Algorithmic trading or automated trading is a computerized trading process for executing orders utilizing automated and pre-programmed trading instructions (algorithms) to place a trade. Algorithms in automated trading systems are defined within the software's programming language. Algorithmic trading (AT) is using high-speed computers and platforms, programmed to follow pre-set instructions for the opening and closing of trades, based on trading strategies designed by investors. AT also makes use of complex formulas, combined with mathematical models and human oversight, to make decisions to buy or sell financial securities on an exchange market. AT improves market liquidity and trading is more systematic and computer programs help to exclude the impact of human emotions on trading activities. (Hendershott and Jones, 2011) Although the history in financial markets has a tendency to repeat itself. It was in the 1970s where right after the introduction of computer trading systems the usage of algorithmic trading increased, but the real expansion algorithmic trading experienced in the 1990s. (Rangappa, 2018) AT is capable to send buy and sell signals much faster than a human trader, which gives AT a distinct advantage over the personal execution of trades. Algorithmic trading comprehends a large number of strategies. (Ravi Kashyap, 2017) This paper will be describing some subdivisions of strategies operating only with technical analysis. Chapter 3 will cover the characterization of trading indicators and will give more information about strategies.

Furthermore, often it happens that transaction costs are overlooked, in real market conditions. The quantities traded are always equal to one lot and one mini lot. One lot is worth 100 000 units of base currency and one mini-lot is worth 10 000 units of the base currency. The term lot refers to the standardized quantity of financial instrument such as stock or bond that an exchange or regulatory body defines. A lot is a number of shares purchased in one transaction. An investor may buy for example one lot of stocks and that one lot can represent 100 shares. Also, options put and call are usually priced so that each contract or each lot represents exercised rights for 100 underlying shares of stock.

A call option gives the holder the right to buy a stock and a put option gives the holder the right to sell a stock. By standardizing price quotes investors know how many underlying shares they buying with each lot and how much they cost. If the lots were not standardized options trading would be much more cumbersome. (Di Lorenzo, 2012)

The programmed systems (algorithms) are applied on the process of backtesting which consists of evaluating trading strategies on historical data. Those who develop these algorithms are working with numerous types of simulations which includes a necessary process of backtesting to evaluate and improve the benefit of their algorithmic strategies. That means that positive feedback of backtesting these strategies does not secure profit on the market in the present time, nor in the future. Using strategy on one time period and one asset pair is not significant because the strategy can be altered to present excellent results. E. Chan refers to the financial market as a gigantic wilderness, where there is always a little uncertainty. (Chan, 2017)

Algorithmic trading contains High-frequency trading and Ultra high-frequency trading. In these areas, trades are executed in a very small time series. High-frequency trading (HFT) is characterized by an extremely short time period of holding position, where trades are closed in a few seconds or milliseconds. HFT is using complex algorithms to analyze multiple markets and execute orders based on market conditions. According to Ch. Jones, in 2011 already 77% of transactions in the UK market were done through HFT (Jones, 2013). Ultra high-frequency trading also known as low-latency trading works on the same principle like HFT though executions of trades are performed in sub-millisecond. (Rosenbaum, 2017) The HFT is not a strategy in itself, but rather a set of techniques to trade. As it trades frequently, the pressure on very good market knowledge, mathematics and statistics is growing. Infrastructure and people are worth a lot of money and the chosen strategy must justify these costs. The HFT is therefore logically appropriate for strategies where it is often traded, for example, in markets where stock exchange quotes need to be changed very quickly and often. Also in some types of statistical arbitrage, where the trader is trying to exploit the slight correlations between traded assets, or for classical speculation, where the trader is targeting once

again minute, rapidly disappearing market inefficiencies, can also make good use of HFT. On the contrary, it is not really adequate for long-term investors to invest in HFT technology. The advent of HFT undoubtedly pushed some traders out of the market. (Huang, Huan, Xu and Zheng, 2019)

The HTF is often criticized for allowing large companies to profit at the expense of the institutional and retail investors and pushing them out of the market. An additional critique of HFT is that the cost of acquiring and operating HFT technology is relatively high. While speculating on the decline in Japanese stocks over the six-month horizon is a relatively inexpensive matter, being a high-frequency trader requires considerable resources. Especially if traders do not want to underestimate market conditions and try to eliminate risks, such as regular algorithm calibration, backup systems, constant monitoring of algorithm behavior on the market is advised. The HFT also brings benefits to the financial market such as the possibility to monitor some strategies more effectively. (Ravi Kashyap, 2017)

The major benefit of HFT is, that it has improved market liquidity and removed bid-ask spreads. Bid-ask spread is a difference in what a seller is asking for security and what a buyer is willing to pay. It is also simply referred to as bid-ask or sell spread and it is measured in the same way. For example, a seller wants to sell a share of stocks. The price bit for the stocks is 4.50 \$ per share, however, the seller demands 5.00 per share. The difference of 50 cents for share is called bid-ask spread. During the course of a normal trading day there can be several bid prices and ask prices for a stock, yet only the highest bid offered is used to calculate a bid-ask spread. Simply put, a bid-ask spread is a negotiation in progress for current securities. Securities with the lowest bid-ask spread are those considered the most liquid or easily converted into new cash assets. Currencies are considered the most liquid of securities traded and therefore usually have the lowest bid-ask spread. Such a standard is often used as a measure of liquidity for any stock. (Hendershott and Riordan, 2011)

Although algorithmic trading represents a challenging opportunity for research and creation of new strategies even when working with the right data and with a sufficient

computer system HFT has an occasional crash potential. It was on May 6, 2010 when the Dow Jones Industrial Average, which is an indicator of stock market prices; based on the share values of 30 blue-chip stocks listed on the New York Stock Exchange, dropped about 1 trillion USD of market value including individual stocks in several minutes. To avoid such problems the whole system implementing algorithmic trading strategy has to be carefully back-tested. As for HFT and Ultra high-frequency trading, it will not be employed into this strategy testing research. Backtesting refers to a specific type of testing on historical data that defines the performance of the applied strategy. Although backtesting does not guarantee trader to foresee if the strategy will be beneficial in future conditions. Its main benefit dwells in discovering and in understanding the vulnerabilities of a strategy. It is a simulation of a clash with real-market conditions of the past. The trader who designed the strategy is capable to “learn from history” where in reality the faults were never made so trader did not lose any capital. The process of backtesting is an extremely important aspect in any algorithmic strategy formation. (Treleaven, Philip and Galas, 2013)

3.1 Advantages of Algorithmic trading

Algorithmic trading has become very popular for traders in the past few years. This is due to the advantages that algorithmic trading has to offer. The most interesting valuables would be technical reliability, speed, and backtesting.

a) Speed

The main advantage of all is obviously speed, because algorithms are developed in the past and are executed automatically. The speed at which trades are executed is measured in fractions of second even milliseconds, much faster than a human trader can comprehend. Trading algorithms have a possibility to examine the market and perform trades on multiple indicators at a speed that is impossible for a human trader. The fast execution of trade creates more opportunities and even for better prices. (Nasdaq.com 2019 Advantages of Algorithmic Trading)

b) Technical reliability

The next advantage of algorithmic trading is accuracy, that is, removing human mistakes and emotions from the market. Under the market's extreme pressure and a vast variety of scenarios, it is easy for a human trader to make a mistake, associated with buying or selling a wrong asset. Before algorithmic trading is initiated, a computer double-checks to make sure the correct order is placed. Eliminating human emotions from the trade is very helpful ability. The trades are controlled with a set of predefined criteria making trades more efficient. Greed, fear, uncertainty are the emotions leading to irrational decisions, which can create an unnecessary loss of profit. (Markus and Gomber, 2009)

c) Backtesting

This advantage of algorithmic trading lies in the ability to backtest. The backtesting process consists of evaluating the performance of trading strategies on historical data. The backtesting allows traders to generate results and then evaluate, which trading strategy is appropriate for the next execution of trades, if the conditions on the market do not change. The backtesting also allows to remove any flaws of a trading strategy before it is run on the live market. (Nasdaq.com 2019, Advantages of Algorithmic Trading)

d) Reduction of transaction costs

Last, but not least advantage of automated trading is the reduced transaction costs. The computers are technologically superior, with the ability to react faster to the changing market conditions and unplanned events. With a well-designed trading plan, the computers are better capable to ensure consistency between the investment decision and trading instructions, which results in decreased market impact cost, less timing risk, and a higher percentage of completed orders. Traders do not have to spend a lot of time monitoring the markets, as trades can be executed without continuous supervision. Without using the computer trading programs the investor would have to spend a lot of time monitoring the markets and always react to changes in price movement. The

computer program will aid to improve the precision of the trading process and to exclude negative effects as uncertainty, fear, fatigue or greed. Also, some computer trading programs can give traders immediate notifications about some big unexpected changes on the market. The investor can check the situation, make improvements and adjust the program. Although the supervision cannot be skipped completely, a well pre-set program will help the trader to act on the market. After being initiated, programs scan the market and determine when to enter into the trade and when to exit the trade. It is wise to check the program every now and then by a human trader, for there can be an issue in internet connection or power problems. Some trading robots can be set to automatically shut themselves down before the announcement of macroeconomic news. The time invested in trading is considerably lower, which can also reduce the transaction costs, due to the constant monitoring of the market. (Kunz, Martin, 2013)

3.2 Disadvantages of Algorithmic trading

Although trading with algorithms has many possibilities and advantages as is often a habit, there are a few downsides as well. One of the disadvantages of algorithmic trading is high expenditures. Market brokers that are supporting the execution of automated trades create unnecessary high expenditures. Traders are obliged to open their accounts with a large amount of capital, which naturally in most cases individuals do not possess. This complication is step by step changing for the better as more brokers add the FIX protocol into their systems. Financial Information exchange protocol has revolutionized the trading environment, providing a fundamental standards-based way to execute trades and also supporting equities trading in the pre-trade and trade environment. (Das, 2016)

The technology included in automated trading makes the whole process look easy. In reality, automated trading is a very sophisticated method for trading, however, it is not yet flawless. In the case, if the internet connection has been interrupted the market would not be able to accept programmed order. Some complications can also appear in controlling the automation. If the trade order is designed inaccurately, the program is

launched and the trader is unable to control losses. Therefore they are needed to be tested properly in order to avoid losing a profit. (Kunz, Martin, 2013)

What can be considered as a quality can also be proved as a weak point due to extreme velocity of the financial markets the professional algorithmic traders have to spend large sums of their capital to get access to legitimate historical data and to correctly develop strategies another additional cost is for a trader to have a powerful computer capable of high performance. The internet connection has to be extremely fast for the order to be placed before the price is changed by the market. Algorithmic trading requires to have knowledge about programming in specific program languages. This difficulty can create disorder in applying theoretically developed strategy on live market conditions. (Hamilton, 2019)

PRACTICAL PART

4 Technical chart indicators

There exist over 5000 technical chart indicators developed with a desire to facilitate the trading process and to gain better accuracy in trading. Technical indicators use the application of mathematical formulas to price time-series data, they are the crucial tools of technical analysts to foresee future price trends and action. They can be used to measure volatility and define the interrelationship between price and volume data and also to clarify the price trend. They provide a means to grasp the market behavior of the past and use that information to predict future prices. Technical market indicators can be classified into 4 groups: trend, volume, momentum and volatility-based indicators. (Pring, 2002)

Because traders have a different trading style the choice of the indicator is very individual. The three selected indicators CMF, Stochastic Oscillator, and EMA were considered to be the most adequate for being successfully calculated in Excel and combined with strategy. (other calculations were not successful) Many other tested indicators turned out to be too complex for the calculation or they were not compatible with the strategy (strategy generated an uneven number of buy/sell signals.) These indicators are popular among traders, they are the most discussed indicators on the market. The equations are not too complex and the calculation process is more accurate. The indicators based on moving average like Simple Moving Average or MACD are highly used by traders. This chapter will describe technical chart indicators, for later application of strategies and calculation process only CMF, EMA and Stochastic Oscillator are going to be used.

Trend

The trend is the general direction of a market or an asset's price. The indicators that follow the price action and are commonly referred to as trend-following indicators. These indicators function best when markets develop strong trends. They are designed to get traders in and keep them in as long as there is no impact on the trend. Trend-following indicators are very useful tools that can help identify the trend and warn when it is reversing. There are uptrends and downtrends. Uptrends are marked by rising data points, such as higher swing highs and higher swing lows. Downtrends are marked by falling data points, such as lower swing lows and lower swing highs. (Fernández, Bodas-Sagi, Soltero, 2008)

4.1 EMA

Exponential Moving Average (EMA) is an indicator, that places a greater weight and significance on the most recent data points. EMA belongs to Moving Average (MA) family along with Simple, Smoothed, Weighted Moving Averages. Like all of its family members, this technical indicator is used to produce sell and buy signals based on crossovers and divergences from the historical average. The EMA is also referred to as the exponentially weighted moving average. An exponentially weighted moving average reacts more essentially to recent price changes than a Simple Moving Average (SMA), which applies the same weight to all monitored assets in the time period. The default strategy for MA is Simple moving average which is based on the arithmetic average of the prices. The calculation of exponential moving average is as follows:

$$SMA = \frac{\sum_{i=1}^N C_i}{N}$$

$$EMA_N = (C_N \times P) + [EMA_{N-1} \times (1 - P)]$$

First equation represents a standard calculation of MA basic strategy Simple Moving Average, where SMA denotes simple moving average. N stands for the number of time

periods and C_i represents close price $\text{SUM}(C_i)$ signifies the sum of closes price in last N time periods. Second computation states Exponential Moving Average, where EMA_N , which symbolizes the value of exponential moving average of today. Inside the equation EMA_{N-1} denotes previous time period's exponential moving average value, C_N is the current period close price and period close price P stands for the percentage of using the close price value. Standard calculations suggest $P = \frac{2}{N+1}$, therefore $P \in [0, 1]$.

The source for theoretical description of EMA was posted by StockCharts.com, titled "Indicators & Oscillators". (Öztürk, 2015) provides the equation for SMA and EMA_N . Link for StockCharts.com can be found in references.

4.2 TEMA

TEMA, which is short for Triple Exponential Moving Average, a type of indicator created by Patrick G. Mulloy. It was introduced in January 1994 by its creator, in an article "Smoothing Data with Faster Moving Averages" in the Technical Analysis of Stocks & Commodities magazine. As the name already implies, the support base of TEMA is exponential moving average. The TEMA is combined from a single, a double and a triple exponential moving average. This connection enhances price movements and the adjourn between the indicator. The quality of TEMA is the efficiency of smoothing price changes. The calculation for this indicator can be seen below. (Mulloy P. 1994)

$$\text{TEMA} = 3 \times \text{EMA1} - 3 \times \text{EMA2} + \text{EMA3}$$

The calculation process EMA1 denotes the exponential moving average of the close price, next EMA2 represents the exponential moving average of EMA1 and at last EMA3 is the exponential moving average of EMA2 in time periods. The source for the informational content on TEMA indicator is GitHub, with the headline "Indicators &

Oscillators" and the computation reference is to be to (Öztürk, 2015). Link for GitHub can be found at the end of the research in references.

Volume

Indicators based on volume contribute the intel about the number of shares or contracts traded on the financial market in a given period of time. For every seller, there is always a buyer and each transaction deal is a part of the total volume. There are very few types of indicators whose value is not only based on price. The volume is not the case of primary price based types of indicators, it depends on the selected time period. The traded amount of assets at any period of time can indicate as to whether the trend is going to persist or it might reverse. If the volume records an augmentation, it signifies an emerging trend and when a drop in volume is recorded, it refers to an end of the trend. The indicators of volume nature can be applied alone or in combined usage with other indicators. (TradingView.com, 2019)

4.3 The ADL indicator

ADL is an indicator created by Marc Chaikin in 1970s. It stands for Accumulation Distribution Line. In an interview for Stocks & Commodities magazine written by Hartle 1994, Marc Chainkin describes the ADL indicator. This indicator is depending on money flow volume.

Money flow volume defines the position of the close price regarding to the minimum and maximum price of the period measured with volume. The calculation proceeds by taking into account the total sum of the money flow volume values. The following equations indicate the calculation process of the ADL indicator. (Hartle, 1994)

$$MFM = \frac{(C - L) - (H - C)}{(H - L)}$$

$$MFV_N = MFM \times V_N$$

$$ADL_N = ADL_{N-1} + MFV_N$$

In the first equation, MFM indicates the money flow multiplier. The values C, L, H presented in numerator and denominator are close, low and high prices for the ongoing time period. The next step is a calculation of the money flow volume (MFV_N). MFM is multiplied by V_N (volume), representing the present time period's volume. The final equation is constructed from ADL_N and MFV_N representing the current period's ADL and money flow volume and then ADL_{N-1} indicates the previous period's ADL value. (Öztürk, 2015)

4.4 The CMF indicator

Another indicator, implemented on selected strategies is CMF. Developed by once already mentioned author Marc Chaikin, Chaikin Money Flow (CMF) is an indicator depending on the Money Flow Volume specified in ADL indicator, earlier in the Indicators section. The difference between these two indicators lies in their calculation. Accumulation Distribution Line is calculated by the running total of Money Flow Volume values, on contrary the calculation of ADL's relative CMF is that the total Money Flow Volume values are divided by the volume total in a specified time period. The CMF is computed as follows:

$$MFM = \frac{(C - L) - (H - C)}{(H - L)}$$

$$MFV_N = MFM \times V_N$$

$$CMF_N = \sum_{N=1}^{20} \frac{MFV_N}{V_N}$$

Where MFM represents the money flow multiplier, C indicates close price, H denotes the highest price and L signifies the lowest price, all in the current time period. Next, the money flow volume (MFV) is calculated. MFV_N denotes the money flow volume and V_N is volume, both in the current time period. The third computation denotes the current time period's value of CMF_N . The $SUM(V_N)$, $SUM(MFV_N)$ is standing for the sum of volume values and the sum of money flow volume in current time periods. In

standard calculations value of the time period is 20. For further use of this calculation than in this reseach work, N value is an aspect to change. (Öztürk, 2015)

Momentum

Momentum signifies the difference between two prices taken over a fixed interval. It could be explained as the distance covered over time. It is a form of smoothing price movement and same as a trend can serve the same purpose. Although the momentum values are not as mellow as a moving average, larger momentum periods reduce the extremes. (Kaufman, 2013)

4.5 The RSI indicator

The indicator itself is depending on Relative Strength (RS). In a selected time period RS is the ratio of average gain divided by average loss. The RSI is a momentum type of indicator, the speed and changes in price are refected by RSI. Its purpose lies also to identify the overbought/oversold levels of price. The values of RSI indicator are between 0 and 100, these values are oscillating. Where 0 is telling us when the price is oversold and 100 represents overbought price. The set of equations for calculating RSI indicator is following:

$$AG_i = \left(\frac{1}{14}\right) \times \sum_{i=1}^N (C_i - C_{i-1})$$

$$\forall C_i > C_{i-1}$$

$$AL_i = \left(\frac{1}{14}\right) \times \left| \sum_{i=1}^N (C_i - C_{i-1}) \right|$$

$$\forall C_i < C_{i-1}$$

$$RS = \frac{AG_i}{AL_i}$$

$$RSI = 100 - \frac{100}{(1 + RS)}$$

The first two equations considering AG_i and AL_i , signify Average Loss and Average Gain. Both of them are the present average gain and loss in N periods. $SUM(C_i)$ denotes close price for current period and $SUM(C_{i-1})$ is the past period's close price. The sum indicates a difference between the two for 14 periods, positive and negative difference between present and past period's close price. A period for standard calculation can be changed. (Kaufman. 2013)

Oscillators

Oscillators are very much connected with momentum-based indicators, they are a common type of technical indicator. For example, Kaufman (2013) states an oscillator may have a low of -100 and a high of +100 where -100 represents oversold conditions and +100 represents overbought conditions. The standard momentum computation is transformed into the normalized shape with a maximum value of +100 and a minimum value of -100, divide the momentum calculation by its maximum value over the identical rolling time period. (Kaufman, 2013)

4.6 The Stochastic Oscillator

The last indicator implemented into the selected strategy is the Stochastic Oscillator. Developed by George C. Lane in the late 1950s the Stochastic Oscillator is used to measure the level of the close relative to the high-low range over a selected time period for each candlestick bar they are divided into a minute, an hour, four hours, or a day. This indicator oscillates around a central point. Frequently the values of central point ranges are moving from 20 to 80. When the value drops below 20 it indicates that price is near its low for the given period of time and when the value gets above 80 it signifies that price is near its high for the given period of time. The Stochastic Oscillator

is also useful for identifying overbought and oversold levels. (Murphy, 1999) For calculating the Stochastic Oscillator the formula is:

$$K = 100 \times (C_N - L_{N-1}) / (H_{N-1} - L_{N-1})$$

Having K as a value of the stochastic indicator, which is moving from 0-100, for the value of $H_{N-1} \geq C_N$ and at the same time these values are positive so values are positive. C is the closing price at the current candlestick/period. L_{N-1} is the lowest price of the last n candlesticks/periods. H_{N-1} is the Highest price of the last n candlesticks/periods. This indicator will be later used for generating buy and sell signals. (Moldovan, Moca and Nitchi, 2011).

Candlestick is one of the 3 most popular types of Forex charts. Along with candlesticks, there is a line chart and bar chart. Forex charts are graphical representations of an asset's historical price action that connects a series of data points. A simple line chart is a way of visually representing an asset's price history using a single, continuous line from one closing price to the next closing price. Bar charts show multiple price bars over time. Each bar shows the price movement over a chosen time period. Being more complex than a line chart, a bar chart shows the opening and closing prices, as well as the highs and lows for a specified period of time. A candlestick is a type of price chart used to show the high, low, open, and closing prices of an asset throughout the time period specified by the trader. Candlesticks are used in technical analysis to determine when to enter or exit trades. Traders use the candlesticks to make trading decisions based on regularly occurring patterns that help forecast the short-term direction of the price. (Thomsett, 2011)

4.7 Chaikin Oscillator

Chaikin Oscillator is an indicator also based on ADL indicator. Chaikin Oscillator as well as ADL were developed by the same designer.

It is solved that, the longer period exponential moving average of ADL values are subtracted from the shorter period exponential moving average ADL values all done in specified time period. Chaikin Oscillator is a kind of indicator, which has the ability to

display the momentum of ADL values, naturally shows the selling/buying pressure of decreasing/increasing ADL values. The calculation for Chaikin Oscillator indicator can be found below.

$$\mathbf{Chaikin\ Oscillator} = EMA \times (N1period\ of\ ADL) - EMA \times (N2period\ of\ ADL)$$

Identifying Chaikin Oscillator's value with EMA(N1period of ADL) and EMA(N2period of ADL) these are the exponential moving average of ADL indicator values in N periods. The standard setting computations define N time period as N1 = 3 and N2 = 10, the two values are a subject to change for possible further usage. (Chen, 2019)

Volatility

Volatility-based indicators are rare technical analysis tools that are looking at the adjustments in market prices over a specified period of time. The height of volatility is depending on whenever the price changes are fast or slow. Slow price changes cause low volatility. The faster the price change is, the higher the volatility. The way how are volatility-based indicators measured and computed is based on historical prices and can be used to identify a trend. The overbought market signals that the price is illegitimately high on the other hand, when the market is oversold the price is illegitimately low, pointing to possible reversal or stalling of the trend. The indicators of this type are regularly used in combination with additional signal generating circumstances. The base of using volatility rests in the identification of trading opportunities. (TradingView.com,2019)

4.8 ATR

Average True Range (ATR) is an indicator designed by J. Welles Wilder. ATR indicator is mentioned for the first time in his book *New Concepts in Technical Trading Systems*, 1978. This indicator is based upon True Range (TR). TR is an instrument for measurement the volatility of the price. Therefore the TR decreases or increases directly

proportional to the market activity. The set of three equations define the maximum of TR and the following computation belongs to ATR indicator. (Wilder, 1978)

$$TR_i = MAX \begin{cases} (H_i - L_i) \\ (H_i - C_{i-1}) \\ |(L_i - C_{i-1})| \end{cases}$$

$$ATR_i = \frac{(n - 1) \times ATR_{i-1} + TR_i}{n}$$

The first step is a calculation of TR_i value, where MAX denotes absolute value. H_i stands for the highest price, L_i represents the lowest price for a current time period and C_{i-1} signifies the previous period's close price. Next step, the computation of Average True Range. TR_i in the equation is TR_i value detected in previous computing and ATR_{i-1} is the value of Average True Range for previous time period. In standard calculations n is expressed by value 14, thus it is an aspect to change for further usage.

The source for the informational content on TR is Linnsoft.com, more specifically it is to be found in the section called "True Range (TR)". The equation for True Range (TR) was also provided by Linnsoft.com (Linnsoft.com, 2019)

The ATR computation reference is to be to Ta-guru.com, which can be found in fourth part "Technical Analysis", subsection "Average True Range (ATR)". (Ta-guru.com, 2010)

4.9 Bollinger Bands

This type of indicator is called Bollinger Bands and it is named after its inventor John Bollinger. It is constructed of 3 bands (Middle Band, Upper Band, Lower Band), a key of these bands is moving average. Middle Band is a moving average of price in a specified period, Upper and Lower Bands are two trading bands placed above and below this moving average. Essential is computing the lower and upper Bollinger Bands, which is standing on deviation of the price in the specified time period of the moving average.

Price volatility alters whether the lower and upper bands widen or narrow. The following equation demonstrates the calculation of Bollinger Bands.

$$\sqrt{\frac{\sum_{i=1}^N (x_i - \mu)^2}{N}} = SD$$

$$\mathbf{MiddleBand} = SMA(C_N)$$

$$\mathbf{UpperBand} = SMA(C_N) + SD(C_N) \times 2$$

$$\mathbf{LowerBand} = SMA(C_N) - SD(C_N) \times 2$$

First step to get Bollinger bands values, SD must be computed. SD signifies the standard deviation, In the numerator, x stands for data point and μ indicates the average of data points. In the denominator N means the number of points in selected period of time.

Where in 3 bands equations $SMA(C_N)$ denotes the simple moving average of close prices in N time periods and $SD(C_N)$ denotes the standard deviation of close prices in N time periods. The results would give the middle, lower and upper Bollinger bands values. (Bollinger. 2001)

5 Methodology and data

This paper will use some of these algorithms using the backtesting process, firstly on currency pair EUR/USD and then USD/JPY. The historical data used for the research has been provided by GKFX trading platform. Established in 2010, GKFX platform was accepted very well by traders and by every year, the company continues to be among the most awarded and popular trading platform in the world. For example, GKFX has gained award for Best Forex Platform at the ADVFN International Financial Awards 2017. A four hour long time period is stated for every carefully planned time period there are 5 input, data available for the paper are Open, High, Low, Close price and Volume. The data are modified to get the value of indicators which are later generated as buying and selling signals. The total number of records is 2071, that is from 08. 12. 2017 to 11. 04. 2019 are available for the USD/JPY and 2071 records from

08. 12. 2017 to 11. 04. 2019 for EUR/USD pair as well. It is important to note that backtested strategies with positive results do not guarantee any profits in live market conditions.

Stochastic Oscillator

Calculating K, the value of Stochastic Oscillator is finding the lowest low price and highest high price for last 14 time periods. C_N in the computation denotes close price minus L_{N-1} , which is lowest low price, then divided by the result of H_{N-1} which signifies the highest high price minus L_{N-1} . All being multiplied by 100 at the end.

The first set of figures 5.0 and 5.1 shows the calculation process of Stochastic Oscillator applied on EUR/USD, USD/JPY in Excel, without alternate buy and sell signals.

The second set of figures 5.2 and 5.3 shows the calculation process of Stochastic Oscillator applied on EUR/USD, USD/JPY historical data after applying a strategy capable to generate alternate buy and sell signals.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	
1	Date	Hour	Open	High	Low	Close	Volume	Date and time											Sell/Buy	k>80	k<20	sell	buy	sum sell	sum buy	PROFIT	aver buy	aver sell	perc change		
2	08.12.2017	8:00:00	113.38	113.578	113.371	113.552	13693	08.12.2017																							
3	08.12.2017	12:00:00	113.554	113.561	113.216	113.338	13896	08.12.2017																							
4	08.12.2017	16:00:00	113.336	113.579	113.12	113.509	21123	08.12.2017																							
5	08.12.2017	20:00:00	113.512	113.538	113.43	113.43	14235	08.12.2017																							
6	11.12.2017	0:00:00	113.522	113.682	113.446	113.605	24959	11.12.2017																							
7	11.12.2017	4:00:00	113.605	113.634	113.488	113.54	18041	11.12.2017																							
8	11.12.2017	8:00:00	113.544	113.563	113.311	113.355	21983	11.12.2017																							
9	11.12.2017	12:00:00	113.356	113.429	113.233	113.397	14050	11.12.2017																							
10	11.12.2017	16:00:00	113.399	113.436	113.267	113.426	16818	11.12.2017																							
11	11.12.2017	20:00:00	113.426	113.568	113.42	113.544	9258	11.12.2017																							
12	12.12.2017	0:00:00	113.534	113.569	113.434	113.444	9086	12.12.2017																							
13	12.12.2017	4:00:00	113.445	113.536	113.427	113.444	11252	12.12.2017																							
14	12.12.2017	8:00:00	113.445	113.487	113.362	113.443	14639	12.12.2017																							
15	12.12.2017	12:00:00	113.444	113.533	113.413	113.483	11746	12.12.2017																							
16	12.12.2017	16:00:00	113.485	113.741	113.364	113.617	18425	12.12.2017																							
17	12.12.2017	20:00:00	113.617	113.634	113.479	113.533	14693	12.12.2017																							
18	13.12.2017	0:00:00	113.495	113.565	113.407	113.476	14623	13.12.2017																							
19	13.12.2017	4:00:00	113.477	113.498	113.116	113.311	15536	13.12.2017																							
20	13.12.2017	8:00:00	113.309	113.443	113.296	113.389	10978	13.12.2017																							
21	13.12.2017	12:00:00	113.39	113.414	112.944	113.051	15716	13.12.2017																							
22	13.12.2017	16:00:00	113.052	113.362	112.993	113.119	18842	13.12.2017																							
23	13.12.2017	20:00:00	113.119	113.122	112.45	112.526	25235	13.12.2017																							
24	14.12.2017	0:00:00	112.514	112.786	112.514	112.598	15129	14.12.2017																							
25	14.12.2017	4:00:00	112.597	112.68	112.546	112.561	13041	14.12.2017																							
26	14.12.2017	8:00:00	112.563	112.874	112.56	112.767	14574	14.12.2017																							
27	14.12.2017	12:00:00	112.767	112.825	112.571	112.752	18214	14.12.2017																							
28	14.12.2017	16:00:00	112.752	112.79	112.329	112.349	18316	14.12.2017																							
29	14.12.2017	20:00:00	112.349	112.416	112.056	112.384	20235	14.12.2017																							
30	15.12.2017	0:00:00	112.369	112.391	112.228	112.228	16319	15.12.2017																							
31	15.12.2017	4:00:00	112.241	112.381	112.103	112.243	15879	15.12.2017																							
32	15.12.2017	8:00:00	112.244	112.268	112.022	112.144	15543	15.12.2017																							
33	15.12.2017	12:00:00	112.144	112.251	112.108	112.216	16399	15.12.2017																							
34	15.12.2017	16:00:00	112.215	112.734	112.207	112.674	23971	15.12.2017																							
35	15.12.2017	20:00:00	112.679	112.728	112.542	112.57	19569	15.12.2017																							
36	18.12.2017	0:00:00	112.701	112.821	112.402	112.691	24253	18.12.2017																							
37	18.12.2017	4:00:00	112.652	112.785	112.685	112.652	15438	18.12.2017																							
38	18.12.2017	8:00:00	112.652	112.735	112.603	112.625	19106	18.12.2017																							
39	18.12.2017	12:00:00	112.656	112.66	112.44	112.507	14212	18.12.2017																							
40	18.12.2017	16:00:00	112.506	112.549	112.305	112.461	16332	18.12.2017																							
41	18.12.2017	20:00:00	112.461	112.601	112.418	112.53	12198	18.12.2017																							
42	19.12.2017	0:00:00	112.523	112.656	112.523	112.599	15075	19.12.2017																							
43	19.12.2017	4:00:00	112.601	112.635	112.516	112.579	8808	19.12.2017																							
44	19.12.2017	8:00:00	112.58	112.626	112.501	112.604	14778	19.12.2017																							
45	19.12.2017	12:00:00	112.605	112.794	112.54	112.785	12218	19.12.2017																							
46	19.12.2017	16:00:00	112.784	113.058	112.712	113.035	22135	19.12.2017																							
47	19.12.2017	20:00:00	113.036	113.07	112.835	112.871	15128	19.12.2017																							
48	20.12.2017	0:00:00	112.835	113.001	112.8	112.894	10958	20.12.2017																							
49	20.12.2017	4:00:00	112.893	113.063	112.848	112.947	10862	20.12.2017																							
50	20.12.2017	8:00:00	112.946	113.158	112.939	113.142	13958	20.12.2017																							
51	20.12.2017	12:00:00	113.143	113.283	113.084	113.273	13001	20.12.2017																							

Figure 5.2: Calculation process of Stochastic Oscillator K on USD/JPY data – correct alternation

EMA

Finding out the EMA_N value, where the close price is subtracted by previous exponential moving average multiplied by 2 and divided by $n + 1$, where in this case n signifies 10 time periods, in the end, attributed one more time by EMA_{N-1} .

The figures 5.4 and 5.5 show the calculation process of EMA_N applied on EUR/USD, USD/JPY historical data is as follows:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	
1	Date	Hour	Open	High	Low	Close	Volum	Sloupe																		
2	08.12.2017	8:00:00	113,38	113,578	113,371	113,552	13693	08.12.2017 - 08.00.00																		
3	08.12.2017	12:00:00	113,554	113,561	113,216	113,328	13896	08.12.2017 - 12.00.00																		
4	08.12.2017	16:00:00	113,326	113,579	113,12	113,509	21123	08.12.2017 - 16.00.00																		
5	08.12.2017	20:00:00	113,512	113,538	113,43	113,43	14235	08.12.2017 - 20.00.00																		
6	11.12.2017	0:00:00	113,522	113,682	113,446	113,605	24959	11.12.2017 - 00.00.00																		
7	11.12.2017	4:00:00	113,605	113,634	113,488	113,54	18041	11.12.2017 - 04.00.00																		
8	11.12.2017	8:00:00	113,544	113,563	113,311	113,355	21983	11.12.2017 - 08.00.00																		
9	11.12.2017	12:00:00	113,356	113,429	113,233	113,397	14050	11.12.2017 - 12.00.00																		
10	11.12.2017	16:00:00	113,399	113,436	113,267	113,426	16818	11.12.2017 - 16.00.00																		
11	11.12.2017	20:00:00	113,426	113,568	113,42	113,544	9258	11.12.2017 - 20.00.00																		
12	12.12.2017	0:00:00	113,534	113,569	113,434	113,444	9086	12.12.2017 - 00.00.00																		
13	12.12.2017	4:00:00	113,445	113,506	113,427	113,444	11252	12.12.2017 - 04.00.00																		
14	12.12.2017	8:00:00	113,445	113,487	113,362	113,443	14639	12.12.2017 - 08.00.00																		
15	12.12.2017	12:00:00	113,444	113,533	113,413	113,483	11746	12.12.2017 - 12.00.00																		
16	12.12.2017	16:00:00	113,485	113,741	113,364	113,617	18425	12.12.2017 - 16.00.00																		
17	12.12.2017	20:00:00	113,617	113,634	113,479	113,533	14693	12.12.2017 - 20.00.00																		
18	13.12.2017	0:00:00	113,495	113,565	113,407	113,476	14623	13.12.2017 - 00.00.00																		
19	13.12.2017	4:00:00	113,477	113,498	113,116	113,311	15536	13.12.2017 - 04.00.00																		
20	13.12.2017	8:00:00	113,309	113,443	113,296	113,389	10978	13.12.2017 - 08.00.00																		
21	13.12.2017	12:00:00	113,39	113,414	112,944	113,051	15716	13.12.2017 - 12.00.00																		
22	13.12.2017	16:00:00	113,052	113,262	112,993	113,119	18842	13.12.2017 - 16.00.00																		
23	13.12.2017	20:00:00	113,119	113,122	112,45	112,526	25235	13.12.2017 - 20.00.00																		
24	14.12.2017	0:00:00	112,514	112,786	112,514	112,598	15129	14.12.2017 - 00.00.00																		
25	14.12.2017	4:00:00	112,597	112,68	112,546	112,561	13041	14.12.2017 - 04.00.00																		
26	14.12.2017	8:00:00	112,563	112,874	112,56	112,767	14574	14.12.2017 - 08.00.00																		
27	14.12.2017	12:00:00	112,767	112,825	112,571	112,752	18214	14.12.2017 - 12.00.00																		
28	14.12.2017	16:00:00	112,752	112,79	112,329	112,349	18316	14.12.2017 - 16.00.00																		
29	14.12.2017	20:00:00	112,349	112,416	112,056	112,384	20235	14.12.2017 - 20.00.00																		
30	15.12.2017	0:00:00	112,369	112,391	112,228	112,228	16319	15.12.2017 - 00.00.00																		
31	15.12.2017	4:00:00	112,231	112,381	112,103	112,243	15879	15.12.2017 - 04.00.00																		
32	15.12.2017	8:00:00	112,244	112,268	112,022	112,144	15543	15.12.2017 - 08.00.00																		
33	15.12.2017	12:00:00	112,144	112,251	112,108	112,216	16999	15.12.2017 - 12.00.00																		
34	15.12.2017	16:00:00	112,215	112,734	112,207	112,674	23971	15.12.2017 - 16.00.00																		
35	15.12.2017	20:00:00	112,679	112,728	112,542	112,57	19569	15.12.2017 - 20.00.00																		
36	18.12.2017	0:00:00	112,701	112,821	112,402	112,631	24253	18.12.2017 - 00.00.00																		
37	18.12.2017	4:00:00	112,632	112,685	112,584	112,652	15438	18.12.2017 - 04.00.00																		

Figure 5.4: Calculation process of EMA on USD/JPY data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1	Date	Hour	Open	High	Low	Close	Volume												TOTALS	TOTAL B	PROFIT	aver buy	aver sell	perc change	
2	08.12.2017	8:00:00	1,1764	1,1767	1,1732	1,1736	15239												210,099	210,113	-0,015	1,174	1,174	-0,007%	
3	08.12.2017	12:00:00	1,1736	1,1768	1,1729	1,1762	15596												179	179					
4	08.12.2017	16:00:00	1,1763	1,177	1,1746	1,1756	19686												179	179					
5	08.12.2017	20:00:00	1,1755	1,1773	1,1755	1,177	7104												179	179					
6	11.12.2017	0:00:00	1,1766	1,1777	1,1763	1,1776	6588												179	179					
7	11.12.2017	4:00:00	1,1776	1,1784	1,1775	1,178	4854												179	179					
8	11.12.2017	8:00:00	1,178	1,18	1,1775	1,1797	11246												179	179					
9	11.12.2017	12:00:00	1,1796	1,1803	1,1776	1,1778	11926												179	179					
10	11.12.2017	16:00:00	1,1778	1,1811	1,1777	1,1791	15783												179	179					
11	11.12.2017	20:00:00	1,1791	1,1794	1,1763	1,1768	8095												179	179					
12	12.12.2017	0:00:00	1,177	1,1779	1,1768	1,1769	5132												179	179					
13	12.12.2017	4:00:00	1,1769	1,1775	1,1764	1,1772	3307												179	179					
14	12.12.2017	8:00:00	1,1772	1,1792	1,1769	1,1783	11719												179	179					
15	12.12.2017	12:00:00	1,1783	1,1785	1,1749	1,175	13380												179	179					
16	12.12.2017	16:00:00	1,175	1,1751	1,1747	1,1723	18639												179	179					
17	12.12.2017	20:00:00	1,1723	1,1748	1,172	1,1741	9646												179	179					
18	13.12.2017	0:00:00	1,174	1,1748	1,1735	1,1742	4068												179	179					
19	13.12.2017	4:00:00	1,1742	1,1762	1,1742	1,1754	4561												179	179					
20	13.12.2017	8:00:00	1,1754	1,1762	1,1737	1,1749	8246												179	179					
21	13.12.2017	12:00:00	1,1749	1,177	1,1729	1,1757	14011												179	179					
22	13.12.2017	16:00:00	1,1757	1,177	1,1747	1,1762	17121												179	179					
23	13.12.2017	20:00:00	1,1762	1,1831	1,1762	1,1824	20809												179	179					
24	14.12.2017	0:00:00	1,1824	1,1843	1,1821	1,1842	9106												179	179					
25	14.12.2017	4:00:00	1,1842	1,1842	1,1825	1,1826	6013												179	179					
26	14.12.2017	8:00:00	1,1826	1,1837	1,181	1,1818	14068												179	179					
27	14.12.2017	12:00:00	1,1819	1,1862	1,1812	1,182	19941												179	179					
28	14.12.2017	16:00:00	1,182	1,1826	1,177	1,1787	21040												179	179					
29	14.12.2017	20:00:00	1,1787	1,1801	1,1774	1,1777	13369												179	179					
30	15.12.2017	0:00:00	1,1777	1,1789	1,1764	1,1784	8362												179	179					
31	15.12.2017	4:00:00	1,1784	1,179	1,1778	1,1783	6267												179	179					
32	15.12.2017	8:00:00	1,1783	1,1798	1,1779	1,1796	12708												179	179					
33	15.12.2017	12:00:00	1,1796	1,1812	1,179	1,1799	16807												179	179					
34	15.12.2017	16:00:00	1,1799	1,18	1,176	1,1765	21532												179	179					
35	15.12.2017	20:00:00	1,1765	1,1765	1,1747	1,1749	12161												179	179					
36	18.12.2017	0:00:00	1,1742	1,1757	1,1737	1,1756	9649												179	179					
37	18.12.2017	4:00:00	1,1756	1,1765	1,1755	1,176	5350												179	179					
38	18.12.2017	8:00:00	1,176	1,1794	1,176	1,1788	14042												179	179					
39	18.12.2017	12:00:00	1,1788	1,1799	1,1784	1,1793	14139												179	179					
40	18.12.2017	16:00:00	1,1793	1,1834	1,1787	1,179	18234												179	179					

Figure 5.5: Calculation process of EMA on EUR/USD data

CFM

CMF calculation begins by finding out the money flow multiplier where the value of MFV equals to close price minus low price then high price minus close price, the results are subtracted between each other and divided by high price minus low price. Next, the money flow volume must be computed. MFV_N value is defined by multiplication of the money flow multiplier and volume. Final computing step is the value of CMF, where the SUM of the money flow volume in N period is divided by SUM of volume in N period. The value of N has been defined as 21, other usage than this particular value is an aspect to change. The figures 5.6 and 5.7 below, describe the calculation process of CMF applied on EUR/USD, USD/JPY historical data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	Date	Hour	Open	High	Low	Close	Volume										21SUM (V)	21SUM (MFV)		CMF21													
2	08.12.2017	8:00:00	1.1764	1.1767	1.1732	1.1781	18239																										
3	08.12.2017	12:00:00	1.1736	1.1768	1.1729	1.1762	15596																										
4	08.12.2017	16:00:00	1.1763	1.177	1.1746	1.1756	19666																										
5	08.12.2017	20:00:00	1.1755	1.1775	1.1755	1.1762	7104																										
6	11.12.2017	0:00:00	1.1766	1.1777	1.1763	1.1762	6588																										
7	11.12.2017	4:00:00	1.1776	1.1784	1.1775	1.1796	4854																										
8	11.12.2017	8:00:00	1.178	1.18	1.1775	1.1796	11246																										
9	11.12.2017	12:00:00	1.1796	1.1803	1.1776	1.1776	11926																										
10	11.12.2017	16:00:00	1.1778	1.1811	1.1777	1.1791	15783																										
11	11.12.2017	20:00:00	1.1791	1.1794	1.1763	1.1763	8095																										
12	12.12.2017	0:00:00	1.177	1.1779	1.1768	1.1767	5132																										
13	12.12.2017	4:00:00	1.1769	1.1775	1.1764	1.1773	3307																										
14	12.12.2017	8:00:00	1.1772	1.1792	1.1769	1.1782	11719																										
15	12.12.2017	12:00:00	1.1783	1.1785	1.1749	1.1749	13380																										
16	12.12.2017	16:00:00	1.175	1.1751	1.1717	1.1729	18639																										
17	12.12.2017	20:00:00	1.1723	1.1748	1.172	1.17407	9646																										
18	13.12.2017	0:00:00	1.174	1.1748	1.1735	1.17424	4068																										
19	13.12.2017	4:00:00	1.1742	1.1762	1.1742	1.1754	4561																										
20	13.12.2017	8:00:00	1.1754	1.1762	1.1737	1.17486	8246																										
21	13.12.2017	12:00:00	1.1749	1.1779	1.1759	1.17569	14011																										
22	13.12.2017	16:00:00	1.1757	1.177	1.1747	1.1762	17121																										
23	13.12.2017	20:00:00	1.1762	1.1831	1.1762	1.18243	20809																										
24	14.12.2017	0:00:00	1.1824	1.1843	1.1821	1.1847	9106																										
25	14.12.2017	4:00:00	1.1824	1.1842	1.1825	1.1821	6013																										
26	14.12.2017	8:00:00	1.1826	1.1837	1.1811	1.1813	14068																										
27	14.12.2017	12:00:00	1.1819	1.1862	1.1812	1.182	19941																										
28	14.12.2017	16:00:00	1.182	1.1826	1.177	1.17872	21040																										
29	14.12.2017	20:00:00	1.1787	1.1801	1.1774	1.1766	13369																										
30	15.12.2017	0:00:00	1.1777	1.1789	1.1764	1.1784	8882																										
31	15.12.2017	4:00:00	1.1784	1.179	1.1778	1.17831	6267																										
32	15.12.2017	8:00:00	1.1783	1.1798	1.1779	1.17963	12708																										
33	15.12.2017	12:00:00	1.1796	1.1812	1.179	1.17987	18607																										
34	15.12.2017	16:00:00	1.1795	1.1765	1.1747	1.17491	12161																										
35	15.12.2017	20:00:00	1.1765	1.1765	1.1747	1.17491	12161																										
36	18.12.2017	0:00:00	1.1742	1.1757	1.1737	1.17559	9649																										
37	18.12.2017	4:00:00	1.1756	1.1755	1.1755	1.17601	5350																										
38	18.12.2017	8:00:00	1.176	1.1794	1.176	1.17883	14042																										
39	18.12.2017	12:00:00	1.1788	1.1799	1.1784	1.1793	14139																										
40	18.12.2017	16:00:00	1.1793	1.1834	1.1787	1.17897	18234																										
41	18.12.2017	20:00:00	1.179	1.1797	1.1775	1.17806	9971																										
42	19.12.2017	0:00:00	1.178	1.1785	1.1776	1.17816	7030																										
43	19.12.2017	4:00:00	1.1782	1.1795	1.178	1.17918	5388																										
44	19.12.2017	8:00:00	1.1792	1.1818	1.179	1.18058	14786																										
45	19.12.2017	12:00:00	1.1806	1.1831	1.1799	1.1826	17290																										
46	19.12.2017	16:00:00	1.1826	1.183	1.1804	1.18281	21380																										
47	19.12.2017	20:00:00	1.1828	1.1848	1.1828	1.18394	12131																										
48	20.12.2017	0:00:00	1.1833	1.1846	1.1833	1.18413	5010																										
49	20.12.2017	4:00:00	1.1841	1.1846	1.184	1.18451	4003																										
50	20.12.2017	8:00:00	1.1845	1.1853	1.1828	1.18371	15324																										
51	20.12.2017	12:00:00	1.1837	1.1857	1.1833	1.18433	16178																										

Figure 5.7: Calculation process of CMF on EUR/USD data

6 Chosen strategies

This chapter will describe algorithmic trading strategies and how they function. To be able to compare the strategies a universal benchmark Buy & Hold is required. These strategies are based upon strictly defined trading rules, which can generate signals buy and sell. The strategies are set to firstly generate buy signal before entering the trade, then, in an appropriate time, it is followed by a sell signal. The sell signal can not be generated, when an investor does not actually own any unit yet. Although the strategies differ from each other as indicators on which they are based on have their proper set of rules and different calculation process, the strategies are constituted on the alternation of buy and sell signals. At the end of the process, a sell signal is generated, when it is not suggested by the strategy, the sell signal has to be enforced by the trader. The reason why these strategies were selected was to see if they will function with picked indicators and used historical data. Pre-research was done on the exercise data to see which set of strategies will be used in the research. The three selected strategies were the most promising from the initial set of strategies. Another reason for selecting these strategies was to achieve alternate buy and sell signals. The investors frequently use trading strategies that are very dynamic and active by nature, there are also other strategies associated with long-term investment.

6.1 Benchmark strategy - Buy & Hold

The Buy & Hold strategy is a long term passive investment strategy in which an investor, who buys stocks and continues to hold them for a long period of time, regardless of fluctuations in the market. An investor actively selects investments but has no concern for short-term price movements. The trader, who is following the buy & hold strategy relies on deep analysis and business perspective of a company. In case of a strategy buy & hold, the stocks will be held for the long term and then only once will be sold. This strategy is nevertheless criticized for not selling at optimal times so there is

no limit for the possible losses in case any negative event occurs with respect to market or stock. Still, for most traders, the buy & hold strategy is easy to adopt, this strategy requires only a one-time series. As the total number of transactions is lower in case of a strategy of buy and hold, so the brokerage, advisory fees, and sales commission are also low in this strategy.

6.2 First analyzed strategy

The first strategy will be based on the Stochastic indicator. The strategy is backtested on daily data from 08. 12. 2017 to 11. 04. 2019. It is necessary to evaluate this strategy on a larger time series to obtain more significative results. For determinating the lowest (L) and highest prices (H) of the stochastic indicator at a selected day I will consider the 14 previous days, in other words, $n = 14$. The buy signal is generated when the value of $K < 20$ and the sell signal is generated when $K > 80$. The following graphical interpretations demonstrate the performance of the selected strategy on the Stochastic K indicator for both currency pairs. The shown data for the USD/JPY currency pair are from 05. 11. 2018 to 09. 11. 2018 and for EUR/USD currency pair from 23. 07. 2018 to 27. 07. 2018.

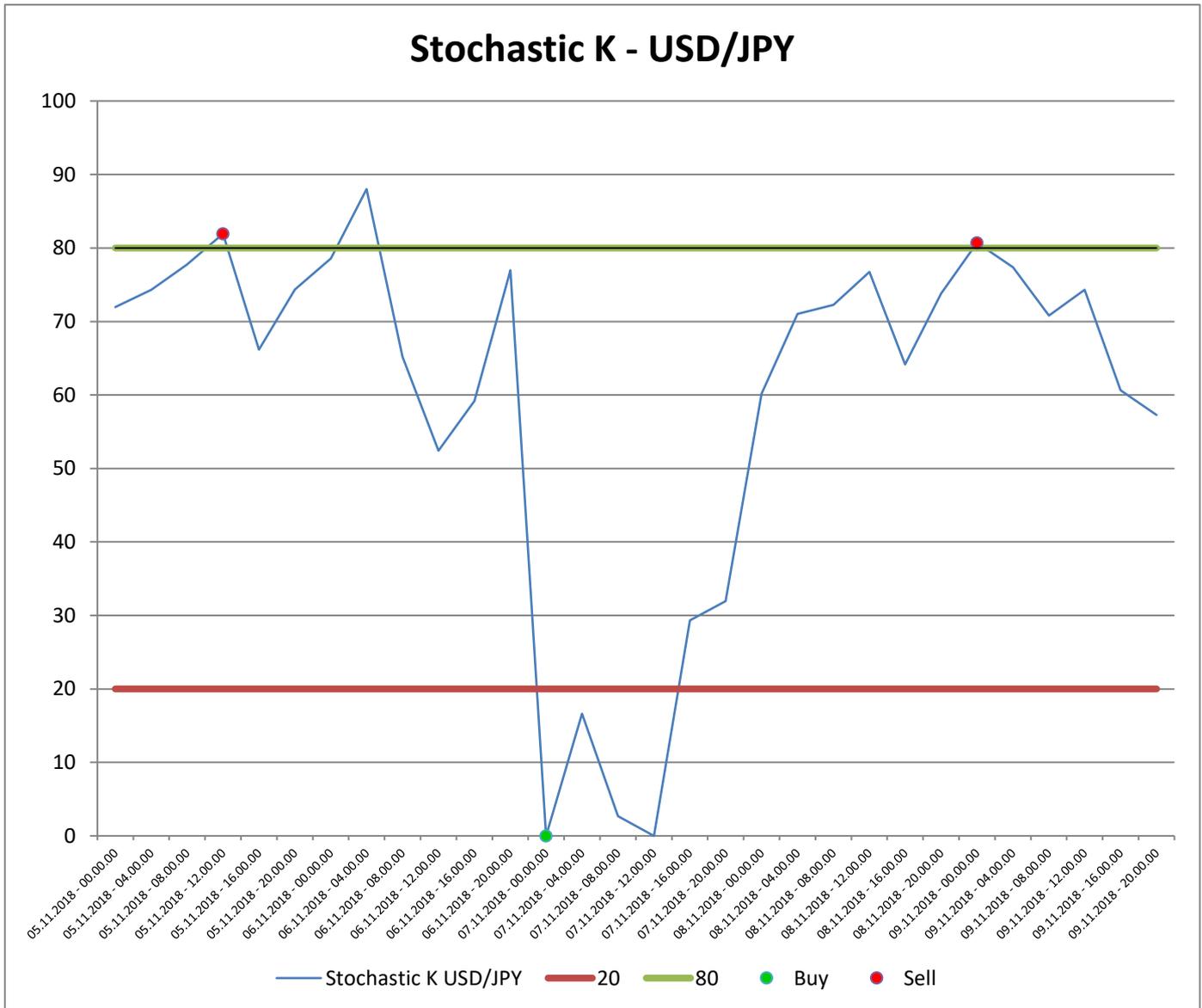


Figure 6.0: Stochastic K performance over the back-tested period for USD/JPY

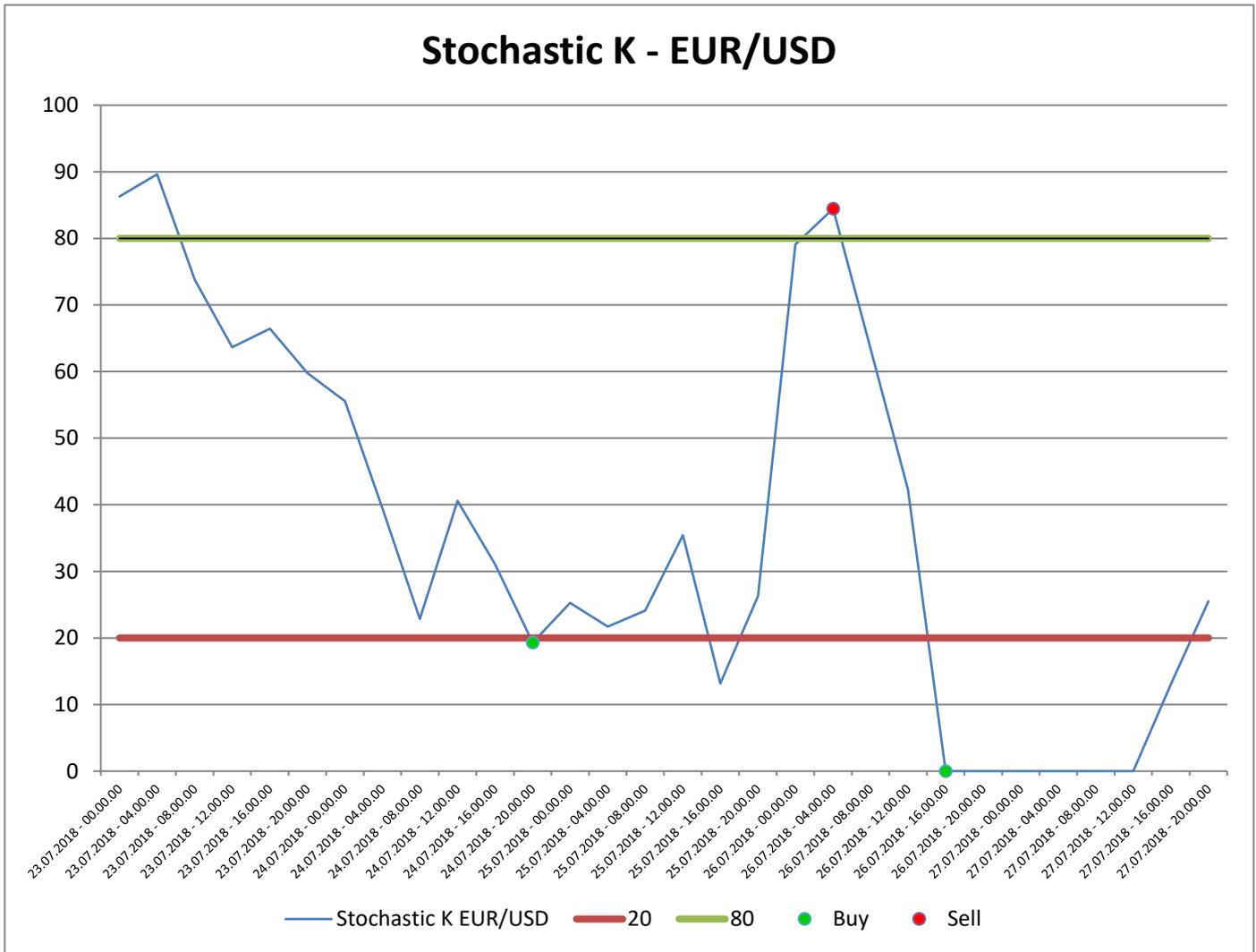


Figure 6.1: Stochastic K performance over the back-tested period for EUR/USD

6.3 Second analyzed strategy

This strategy is based on the CMF indicator. when the value of the indicator crosses above 0,05 a buy signal is generated, conversely when it crosses below $-0,05$, a sell signal is made. The last 21 time periods are considered in this strategy. The subsequent charts present how strategy performed on volume-based indicator CMF. It can be seen where the strategy generated buy and sell signals. The chart for the USD/JPY shows the strategy's performance on data from 18. 02. 2019 to 22. 02. 2019 and the EUR/USD graph displays the data from 19. 03. 2018 to 23. 03. 2018.

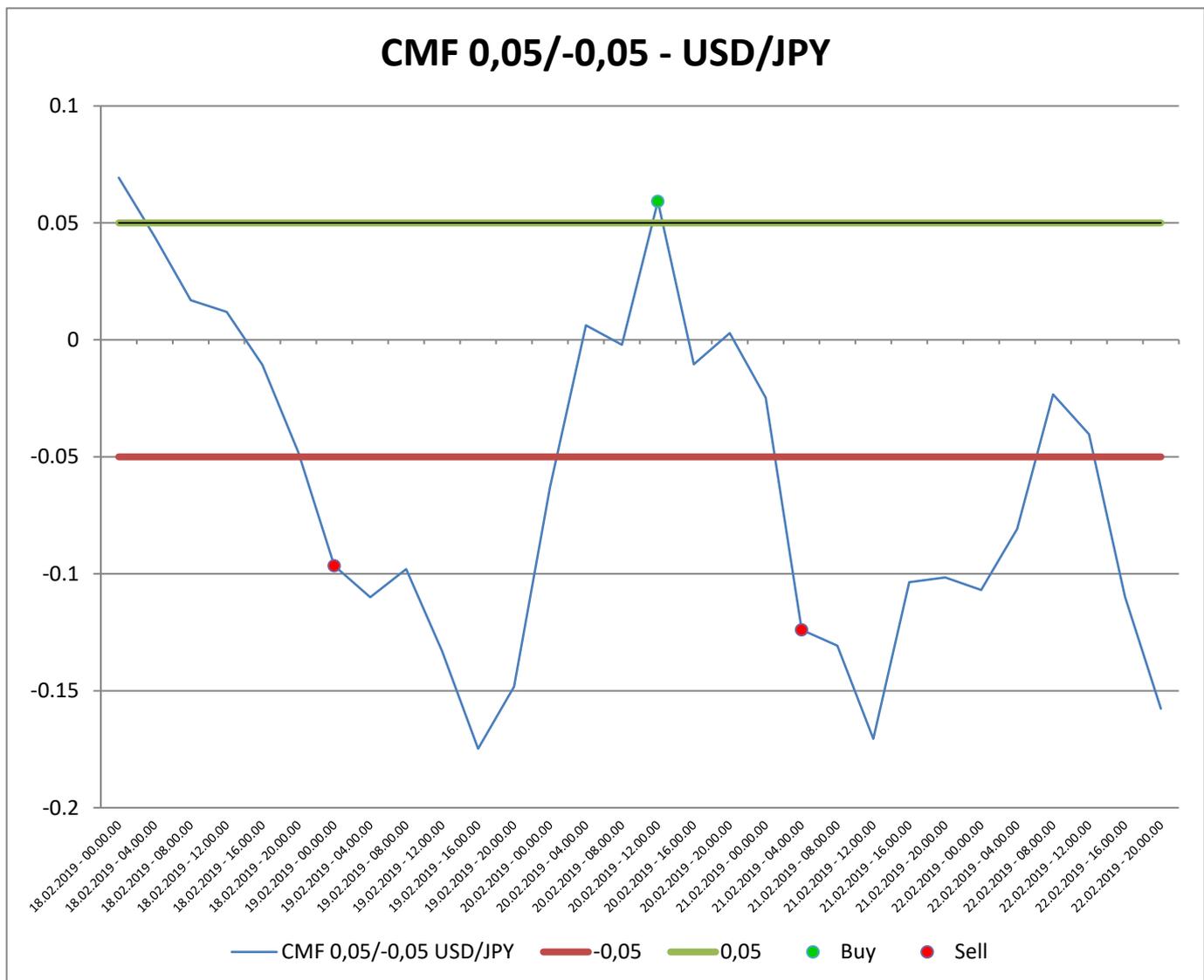


Figure 6.2: CMF performance over the back-tested period for USD/JPY

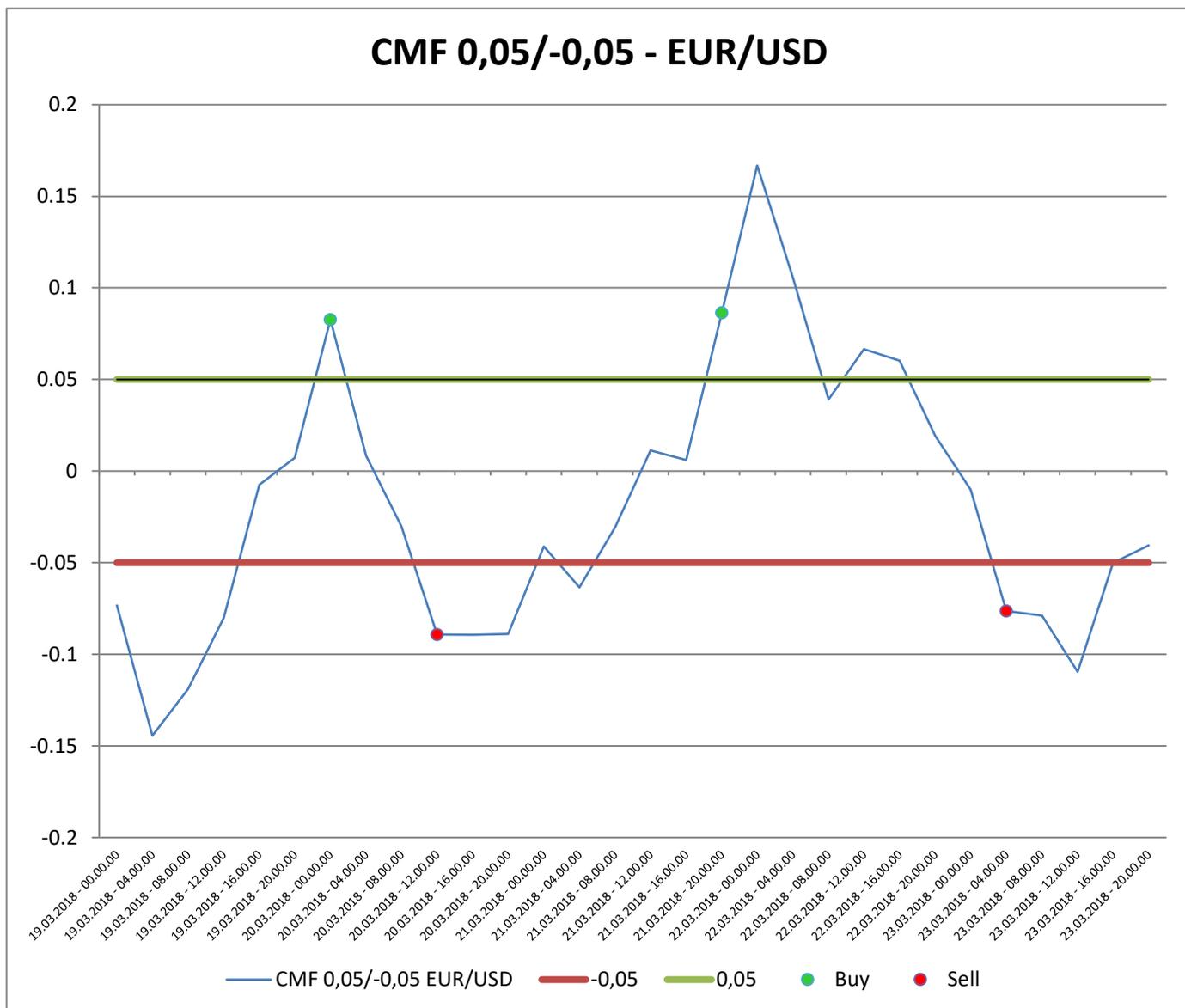


Figure 6.3: CMF performance over the back-tested period for EUR/USD

6.4 Third analyzed strategy

The last strategy is called Exponential Moving Average (EMA). This one is used by traders as an evaluation signal value buy, when EMA crosses above close price. In the case EMA crosses below the close price, a sell signal is generated. The following graphs show the performance of a selected strategy applied to EMA. The buy signals keep to generate above close price and sell signals are generated when EMA crosses below the close price. The graphical representation for the USD/JPY currency pair is measured from 11. 03. 2018 to 15. 03. 2018. The chart for the EUR/USD pair represents data taken from 23. 07. 2018 to 27. 07. 2019, to show the strong alternation of buy and sell signals.

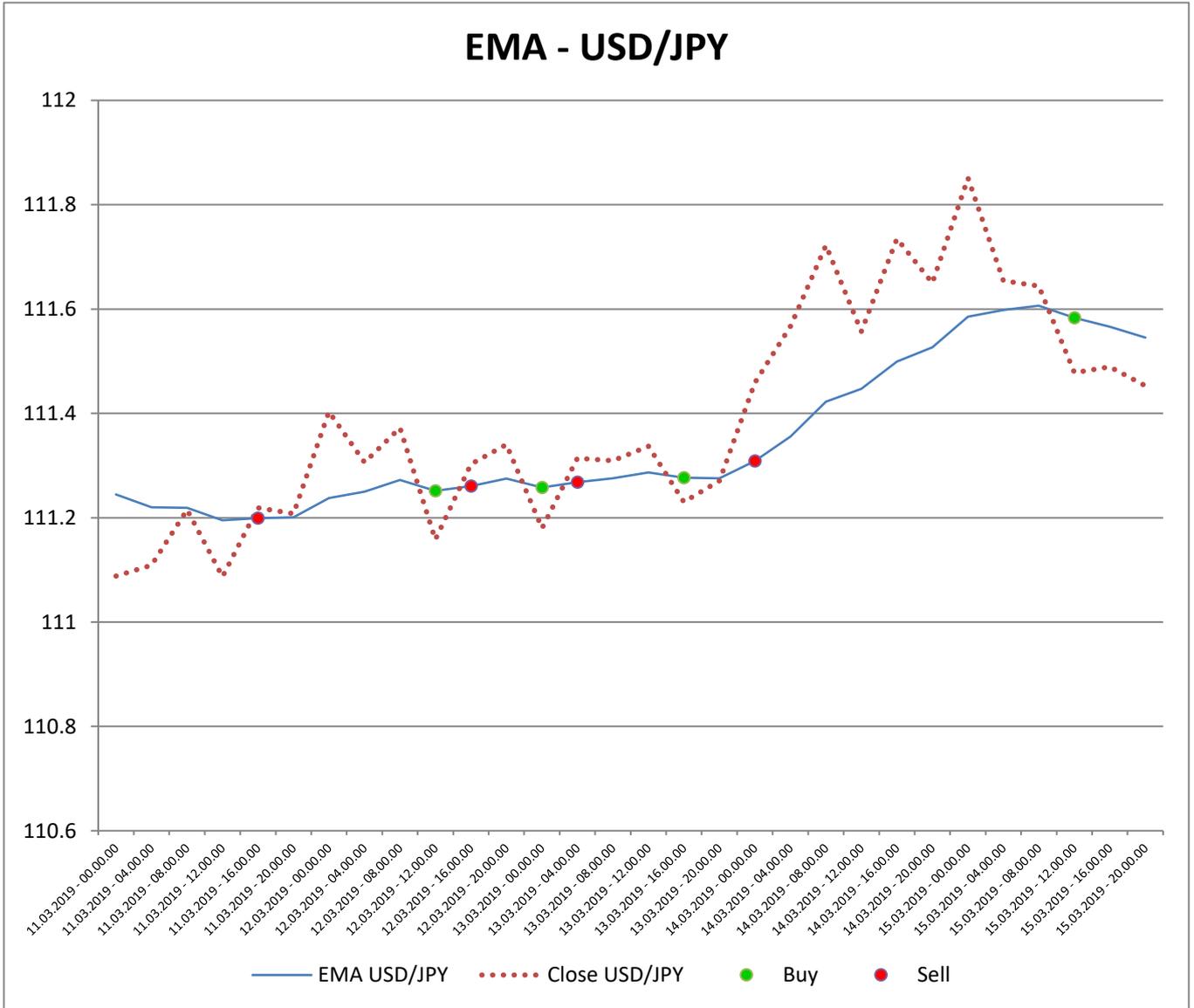


Figure 6.4: EMA performance over the back-tested period for USD/JPY

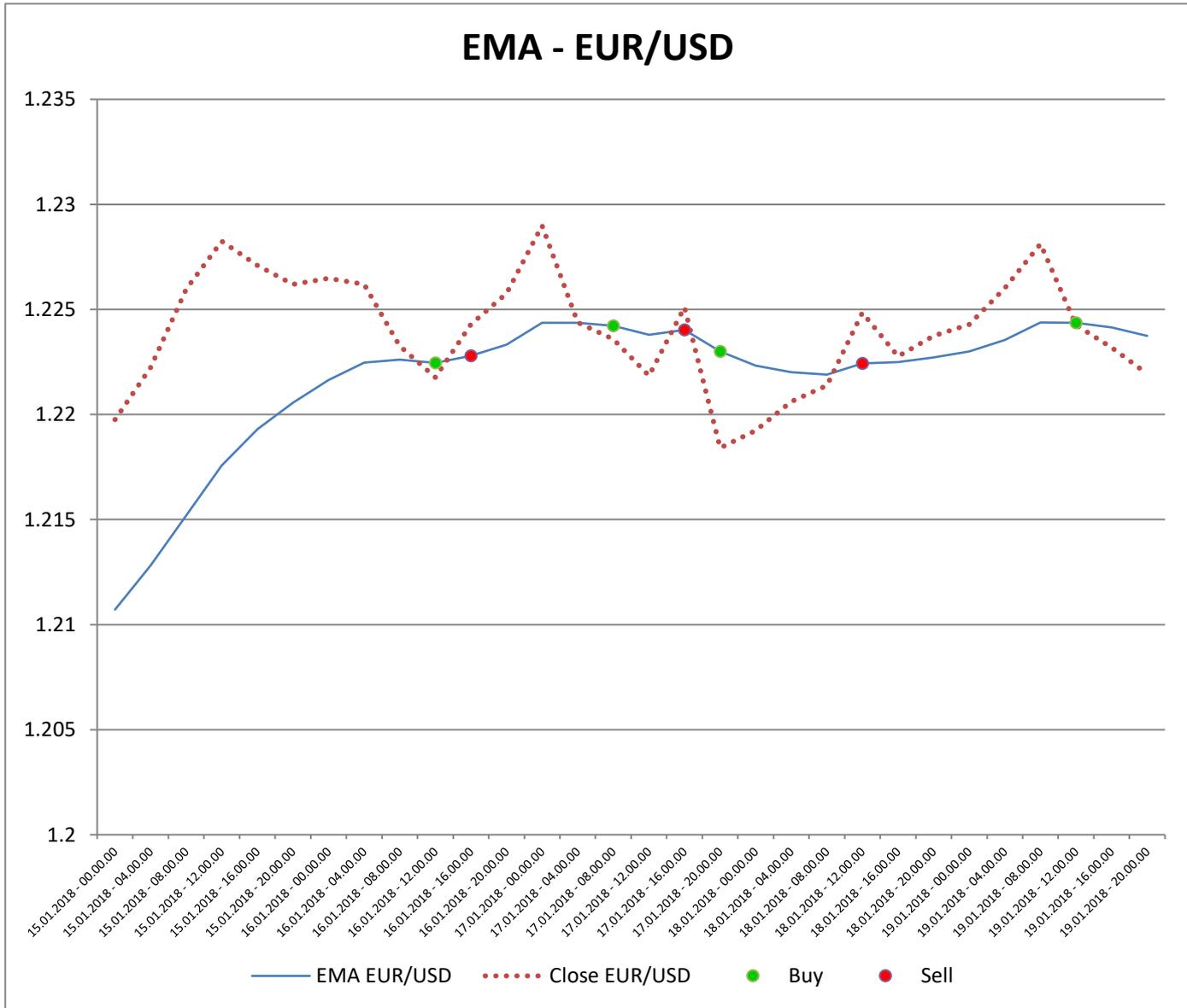


Figure 6.5: EMA performance over the back-tested period for EUR/USD

7 Results

This section will present the results obtained throughout the research, the overall rule of alternate buy and sell signals was achieved. The results may become affected, which can be caused when the last sell signal is not in consonance with the strategy. If the last sell signal is not suggested by the strategy it can create inequities in alternate buy and sell signals it can be fixed when on the last day the sell signal is enforced by the trader. The enforcement of the last sell signal settles the strategy and evens the number of buy and sell signals. The enforced sell signals in strategies are marked with "*".

7.1 Buy & Hold

The Buy and Hold strategy was implemented on the historical data from 08. 12. 2017 to 11. 04. 2019 for currency pairs EUR/USD and USD/JPY. In both cases, the strategy resulted in high losses. The buy and hold is a passive strategy and it is not very profitable and for a future a buy and hold investment, the prices could decline even more. The drawback of this strategy is that traders are tied up in a particular investment during this holding period and they can not sell the asset at most advantageous times.

7.2 The results of incorrect strategy on Stochastic Oscillator D

	USD/JPY	EUR/USD
Strategy	Stochastic D	Stochastic D
Number of sell signals	504	403
Number of buy signals	328	460
Sum of sell	55907,748	475,599
Sum of buy	36114,499	536,605
Average sell	110,928	1,180
Average buy	110,105	1,167
Profit/Loss	1979,249	-61,005

Table 7.0: Results of Stochastic Oscillator after incorrect strategy employment USD/JPY, EUR/USD

This trading strategy was applied on the historical data from 08. 12. 2017 to 11. 04. 2019 for both currency pairs EUR/USD and USD/JPY. This strategy for Stochastic Oscillator has proven to be unfortunately insufficient. The buy and sell signals

generated by this particular strategy for both currency pairs EUR/USD, USD/JPY were not alternate. The strategy did not take into account the condition when the trader has to buy one currency unit and after some time of consideration make a sell. In the case of USD/JPY, the strategy generated 176 more sell signals than buy signals, which caused inequities between values of sum sell and sum buy. The strategy was selling more currency units than buying, which had for a result that the final profit was too high to be true. The strategy was selling currency units that we did not own yet. As for the EUR/USD pair, the difference between buy and sell signals was not as high as in the previous case, but on the other hand, this time the strategy generated 57 more buy signals than sell signals. The strategy ended up with unsold currency units which resulted in -61,051 lost. The main issue of the strategies lied in the alternation of buy and sell signals.

7.3 The results of correct strategies on Stochastic Oscillator K, CMF, EMA

Moving on and learning from our failure, after trying and considering numerous other trading strategies whose proven to be also inefficient a new strategy was applied on the Stochastic Oscillator and unexcitingly it has brought positive results.

Currency	USD/JPY		
Strategy	CMF 0,05/-0,05	EMA	Stochastic K
Number of sell signals	38	191	40 *
Number of buy signals	38	191	40
Sum of sell	4193,528	21101,477	4437,504 *
Sum of buy	4192,566	21104,804	4439,472
Average sell	110,356	110,479	108,183
Average buy	110,331	110,496	110,987
Profit/Loss	0,962	-3,327	-1,968

*) Forced last sell signal (not suggested by particular strategy)

Table 7.1: Results of tested indicators after correct strategy employment USD/JPY

Currency	EUR/USD		
Strategy	CMF 0,05/-0,05	EMA	Stochastic K
Number of sell signals	47 *	179	39 *
Number of buy signals	47	179	39
Sum of sell	55,276 *	210,099	45,784 *
Sum of buy	55,400	210,113	45,803
Average sell	1,176	1,174	1,174
Average buy	1,179	1,174	1,174
Profit/Loss	-0,124	-0,015	-0,019

*) Forced last sell signal (not suggested by particular strategy)

Table 7.2: Results of tested indicators after correct strategy employment EUR/USD

1) Stochastic Oscillator K

The backtest for this strategy started from 08. 12. 2017 to 11. 04. 2019, the strategy was reformed to generate buy and sell signals alternatively. In the case of EUR/USD a slight loss was made -0,019, but the buy and sell signals were completely alternating, with the total number of 39 buy and sell signals. The last sell signal for the EUR/USD currency pair was enforced because it was not suggested by the strategy, the last enforced sell signal is marked with "*". The strategy has proven to be working in the calculation and has generated an alternate number of buy and sell signals considering the EUR/USD currency pair. As for the USD/JPY, the strategy also finished with a successful alternation of buy and sell signals. The strategy generated 40 buy signals and 40 sell signals. The strategy has proven to be slightly less profitable than in the case of EUR/USD, with a loss of -1.968. Because the strategy also did not evaluate into the process the last period's sell signal, that is why the last generated sell signal had to be enforced. The process has proven to be working with the strategy, the frequency of buy and sell signals is alternating.

2) CMF

The second strategy came out positively for USD/JPY currency pair but the EUR/USD resulted in a minor loss. The process of backtesting has begun 8th December 2017 at 8:00 am and ended 11th April 2019 at 12:00 pm. The strategy was set first to buy currency units and generate a buy signal, after adequate time the strategy came to sell

the units and generated a sell signal. For EUR/USD the strategy generated the same number of buy and sell signals, which is 47, with a total loss of -0.124. On the last day, the sell signal was not suggested by the strategy and had to be enforced. Although the strategy in the case of the USD/JPY pair has brought persuasive results. Considering that the strategy generated an equal amount of buy and sell signals, which is 38, the strategy can be defined as the most profitable. The strategy has proposed every generated signal and received 0.962 of profit. The strategy even did not require the enforced sell signal on the last day of the trade, all signals were successfully suggested by the strategy. In both cases, this strategy has carried out a successful alternation of buy and sell signals. For more profitable returns, further research and more precise data are necessary.

3) EMA

The last strategy after backtesting has brought some minor losses. The backtesting was firstly run from 08. 12. 2017 to 11. 04. 2019. The strategy for EUR/USD has brought a very small loss of -0.015 and the strategy has generated 179 buy signals and 179 sell signals. The frequency of buy and sell signals is alternating. The strategy comply with an overall rule where the strategies are firstly set to generate a buy signal and then it is followed by a sell signal. In the case of USD/JPY, the strategy generated 191 of buy and 191 sell signals. The strategy in the case of USD/JPY generated a loss of -3.327. The strategy in both currency pairs carried out a successful alternation of buy and sell signals and even the last sell signal was suggested by the strategy.

Conclusion

The bachelor thesis focused on Forex financial market, mainly targeted on algorithmic trading strategies. For the end, it is important to point out that currencies have low volatility. The results quite precisely reflected the theoretical foundations of algorithmic trading. For this research CMF, EMA and Stochastic Oscillator indicators were implemented into selected strategies. Each indicator is representing a different category of technical indicators: CMF uses volume, EMA is a trend-based indicator, and Stochastic Oscillator is part of momentum based indicators. The indicators were selected for being one of the most popular technical indicators in the public domain and they can be used on any security with historical trading data. The selected strategies were implemented and analyzed in MS Excel. The applied strategies were set to first generate a buy signal and in an appropriate time generate a sell signal. If the last sell signal was not suggested by the strategy, it had to be enforced. The absolute rule for the selected strategies is an alternation of buy and sell signals. The selected algorithmic strategies have made a minor profit in both currency pairs. The process of backtesting has initiated on 08. 12. 2017 and ended on 11. 04. 2019. At the beginning the backtest initiation the USD/JPY exchange rate was at 113.485 and after the backtest ended it was at 111.683. At the start of the backtest the EUR/USD initial price was 1.8622 and in the end it was 1.12983. The strategy with best performance is CMF strategy, applied on the USD/JPY currency pair, with a profit of 0.962 USD. The passive long-term Buy & Hold strategy can prove to be a very treacherous investment, for it generated high losses in EUR/USD also in USD/JPY. The Buy & Hold strategy generated significant losses comparing to the selected strategies. Thus the Buy & Hold strategy applied in the Forex market is not very ideal for investors who are not able to suppress behavioral biases and handle the impact of the downturns emotionally. The benefit of algorithmic trading lies in the ability to execute trades in a fraction of seconds. With always rotating currencies, where one can appreciate over another in second, with HFT would be possible for a trader to make a bigger profit. Further implementation and usage of algorithmic trading strategies requires more research.

Summary

This study aimed to implement algorithmic trading strategies on the two most popular currency pairs EUR/USD, USD/JPY using technical indicators. There exist a various number of technical indicators, which are helping in determinating the financial market's movement. The thesis also covers topics, Forex exchange market, characteristics and relationship between EUR/USD and USD/JPY and technical indicators. The historical data for selected currency pairs served as the base data for further computations. The MS Excel has proven to be surprisingly sufficient, the research has shown the capability of Excel in backtesting algorithmic trading strategies. For professional traders, Excel simply does not represent a perfect tool for testing strategies, but it is not counterproductive. The MS Exel is a publicly known platform with entrenched features more common to potential users. To summarize the topic, the algorithmic trading requires a lot of enhanced knowledge in computer programs and design of algorithms to gain potential profit.

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ACRONYMS

FX	Forex exchange
NYSE	New York stock exchange
OTC	Over the counter market
NASDAQ	National association of securities dealers automated quotations
LSE	London stock exchange
USD	American dollar
GBP	British pound
JPY	Japanese yen
AUD	Australian dollar
EUR	Euro
CHF	Swiss franc
CAD	Canadian dollar
NZD	New Zealand dollar
HFT	High frequency trading
FIX	Financial information exchange
MT5	Meta Trader 5
CMF	Chaikin money flow
EMA	Exponential moving average
MA	Moving average
SMA	Simple moving average
SUM	Sum
TEMA	Triple exponential moving average
ALD	Accumulation distribution line
MFM	Money flow multiplier
MFV	Money flow volume
RS	Relative strength
RSI	Relative strength index
AL	Average loss
AG	Average gain
ATR	Average true range
TR	True range
GPD	Gross domestic product
BoJ	Bank of Japan
FRS	Federal Reserve System
GMT	Greenwich Mean Time
\$	United States dollar
€	Euro
¥	Japanese yen

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