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Short-Term Stock Market Prediction Based on Candlestick Pattern Analysis

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Abstract

This study performs a comparative analysis and evaluates the impact of different Relative Strenght Index (RSI) and stop loss configurations on a trading algorithm based on candlesticks patterns. It is tested on both the Swedish OMXS30 market and the UK FTSE100 market.

By tweaking the configurations, RSI and stop loss was found to have a substantial impact on the performance of the algorithm. On both OMXS30 and FTSE100 markets the difference between configurations was shown to be significant.

Sammanfattning

Denna studie gör en jämförelse och analyserar olika Relative Strenght Index (RSI) och stop loss-konfigurationers påverkan på en tradingalgoritm som är baserad på candlestick patterns. Algoritmen är testad på svenska OMXS30 och brittiska FTSE100.

Genom att testa olika konfigurationer blev slutsatsen att RSI och stop loss hade en stor påverkar på algoritmens resultat. På både OMXS30 och FTSE100 var skillnaden mellan konfigurationerna signifikant.

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1 Introduction

The stock market is a fascinating phenomenon and it's movements has for a long time caught the interest of both banks, individual investors and scientists. Different strategies have been developed over time and is being used trying to predict future price movements in order to give maximum return on an investment. Investors and traders are constantly trying to find profitable patterns, because of this it's an area where very few have managed to create a stable prediction over time. This is usually recognized as a core principle of a free and open market. A solid price prediction would quickly be exploited by a large numbers of players on the market and therefore become ineffective [1].

The subject becomes even more interesting to research because of the wide range of ideas and opinions around the topic. Applied strategies in this area are divided into mainly two categories, fundamental analysis (FA) and technical analysis (TA). These different philosophies explain the markets movements and dynamics in different ways. While FA relies on studying the financial statements and analyzing revenues and costs, TA focuses on the data and statistics generated by previous action in the market. [2][3]

This report will compare different configurations of a trading algorithm based on candlestick patterns and analyze the impact of different RSI and stop loss configurations. RSI is a technical indicator used in trading and will be described more thoroughly below.

1.1 Problem statement

How does different RSI and stop loss configurations impact the results of market prediction techniques based on candlestick patterns?

1.2 Scope

The scope of this research will be limited to one algorithm with different stop loss and RSI configurations. The algorithm is based on ten different candlestick patterns and will be executed on the Swedish OMXS30 and the UK FTSE100. This research is going to compare the results from the different runs and analyze the difference in performance when the configurations are tweaked.

The time frame is going to be 100,000 ticks where 1 tick is equal to 1 hour. In terms of dates this time frame is from the 14th of January 2013 to the 12th of May 2017. The reason this time frame was chosen was because it was a limitation set by the ProRealtime software.

2 Background

2.1 Fundamental Analysis

In order to get a better idea of the trading strategies outlined in this report, it is crucial to understand the different methods that guide investors in their market decisions. One of these methods is fundamental analysis (FA).

Fundamental analysis is the idea that decisions should be based on an analysis of the intrinsic value of a company instead of its price history. Investors engaged in this philosophy will study both microeconomic and macroeconomic factors in order to value the company and reach a investment decision [4].

2.2 Technical Analysis

Technical analysis (TA) is another popular method among investors. It can almost be seen as the opposite of fundamental analysis, extracting information about the future from historical data instead of the intrinsic value of the company. Analysts and investors that use this method believe that a securities future price movements can be forecast using price and volume patterns from the past. [5].

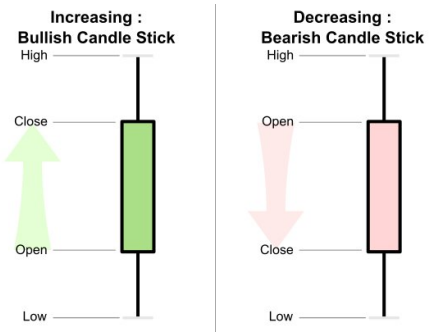
2.3 Candlesticks

A candlestick is a simple and popular way to visualize details about price movements over a set period of time. They will display open, close, high and low prices in a single graphical representation. One candlestick can symbolize the price movements during a period of for example 1 day, 1 hour or 5 minutes.

The wide part of the candlestick is called body and it's color will give the observer more details about the direction of movement. A red body indicates that the closing price was lower than the opening price and a green body that the closing price was higher than the opening price.

Investors can use the shapes of the candlesticks to get a quick understanding about the sentiment under that period of time. Multiple candlesticks in a chart can create patterns that will reoccur over time. Candlestick charts play an important role in TA [6].

Candlesticks have precise definitions and fixed time intervals which gives approaches based on candlesticks an advantage for research. They are easier to understand, analyze and work with [7].



Figur 1: Candlestick illustration [8]

2.4 Candlestick Patterns

A candlestick represents price movement in the market during some period of time. This period could vary as described above. A number of such candlesticks represent a candlestick pattern and represent price movement over a longer period of time.

2.5 The Effectiveness of Candlestick Patterns

In the past researchers have been able to show that such patterns have some kind predictive power. Both in the US but also in other markets around the globe. Below are some studies that concluded such results.

According to previous research traders are influenced by price behaviour [9]. In their study, Caginalp and Laurent managed to gain a 200% increase in value using candlestick patterns during a one-year holding period. Investigated all S&P 500 stocks between 1992-1996 and using candlestick patterns concluded that traders are influenced by price behaviour. The researchers managed to gain a 200% increase in value using candlestick patterns during a one-year holding period.

Other researchers have concluded that candlestick patterns can be used to predict price movements in market outside the US. Research done on markets in different parts of the world is of interest to us because our study will focus on Swedish OMX30 exchange and the UK FTSE100 exchange.

Lu and Chen investigated in 2013 if candlestick patterns, which are an old Japanese technique, are useful in Western markets [10]. They concluded that candlestick patterns do in fact have predictive power in three main European markets and that the patterns should be used somewhat differently in the different markets.

Another study conducted in 2013 researched sixteen candlestick patterns on the Brazilian stock market [11]. They found statistical evidence for predictive ability of some patterns. The researchers also concluded that the techniques must be adapted to different markets.

Goo, Chen and Chang researched daily candlesticks on the Taiwanese stock market from 1997 to 2006 [12]. Explored which candlesticks could possibly be used by investors. The interesting thing with this study is that it researched how many holding days should be used for each candlestick pattern. They also researched and concluded that a stop-loss strategy increased return. They say to have provided strong evidence that some candlestick trading strategies can create value for investors but they all need different holding periods.

The same researchers conducted another study where they investigated the predictive power of 2-day candlestick patterns and tried to determine how they can be improved. Here they researched securities on the Taiwan Stock Exchange between 1998 and 2007 and concluded that you could obtain information about future short term price movements [7].

Goo, Chen, and Wei link candlesticks to behavioural finance and suggest that candlesticks can reveal emotional and mental reactions. These reaction can then be used to predict future price movements.

Larsen conducted a research in Norway in 2010 where he researched how TA and AI could predict price movements [13]. Larsen complemented the strategy, which involved candlestick patterns, with a money management strategy and concluded that it outperformed the Oslo Benchmark Index. He tested 12 candlestick patterns with daily candles and concluded that they were able to outperform the Oslo Benchmark Index OSEBX.

The research done by Goswami, Bhensdadia, and Ganatra in 2009 concluded that Candlestick analysis is of value when predicting short term price fluctuations and market timing [14].

Mass psychology of the market is the reason TA and in particular candlesticks can be of value when predicting market movement. Using strategies based on candlesticks the trader tries to predict the

sentiment of the investors at the end of the day, meaning that the price of tomorrow will depend on what the investors think about a security, such as a stock, at the end of the day.

This puts approaches based on candlesticks in contrast to some other TA approaches which focus on finding statistical relations between the current price and the future price [15] [14].

2.6 Ten Candlestick Patterns used in this study

This study will focus on 10 different candlestick patterns, five bullish reversal pattern (end of negative trend) and five bearish (end of positive trend) reversal patterns. The bearish candlestick patterns are Evening Star, Bearish Harami, Bearish Engulfing, Gravestone Doji Top and Hanging Man. The bullish candlestick patterns are Morning Star, Bullish Harami, Bullish Engulfing, Gravestonr Doji Bottom and Hammer.

These patterns were chosen based on an assumption that these ten patterns are the most common in the market. This assumption is built on previous research mentioned in the background section, where these ten patterns were widely used and researched. Below are formulated mathematical definitions of these patterns. The definitions of the patterns below have been taken from Steve Nisons book Japanese Candlestick Charting Techniques [16]. There he defines them with words and pictures. For the purpose of this thesis they have been translated to formulas that can be used in an algorithm.

Values in the definitions are represented by the following syntax:

$$C_{x,p},$$

where C is a candlestick, x is a time index where the value t represents the latest index, p is a property of the candlestick, which can be either open, close, low, high, bodyBottom, bodyTop, shadowTop, shadowBottom.

p	**Explanation**
open	The opening price.
close	The closing price.
low	The lowest price.
high	The highest price.
bodyBottom	If the candle is positive this value will be the opening price and if the candle is negative this value will be the closing price.
bodyTop	If the candle is positive this value will be the closing price and if the candle is negative this value will be the opening price.
shadowTop	Absolute difference between high and bodyTop
shadowBottom	Absolute difference between low and bodyBottom

2.7 Bullish definitions

Bullish Harami
Downward trend
$C_{t-1,open} > C_{t-1,close}$
$C_{t,open} < C_{t,close}$
$C_{t-1,close} < C_{t,open}$
$C_{t-1,open} > C_{t,close}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,low} - C_{t-1,high}|} > 0.6$

Bullish Engulfing
Downward trend

$C_{t-1,open} > C_{t-1,close}$
$C_{t,open} < C_{t,close}$
$C_{t-1,close} > C_{t,open}$
$C_{t-1,open} < C_{t,close}$
$\frac{|C_{t,open} - C_{t,close}|}{|C_{t,low} - C_{t,high}|} > 0.6$

(Bullish) Doji
Downward trend
$C_{t-1,open} > C_{t-1,close}$
$C_{t-1,low} > C_{t,low}$
$C_{t,high} - C_{t,close} > 3 * |C_{t,open} - C_{t,close}|$
$C_{t,open} - C_{t,low} < \frac{C_{t,high} - C_{t,close}}{3}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,low} - C_{t-1,high}|} > 0.6$

Hammer
Downward trend
$C_{t-1,open} > C_{t-1,close}$
$C_{t-1,low} > C_{t,low}$
$(C_{t,bodyBottom} - C_{t,low}) > 2 * |C_{t,open} - C_{t,close}|$
$(C_{t,high} - C_{t,bodyTop}) < 0.3 * |C_{t,open} - C_{t,close}|$

Morningstar
Downward trend
$C_{t-2,open} > C_{t-2,close}$
$C_{t,open} < C_{t,close}$
$\frac{|C_{t-2,open} - C_{t-2,close}|}{|C_{t-2,low} - C_{t-2,high}|} > 0.6$
$C_{t-1,open} < C_{t-2,close}$
$C_{t,open} > C_{t-1,close}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,low} - C_{t-1,high}|} < 0.3$
$(C_{t-1,open} - C_{t-1,close}) < |C_{t-2,open} - C_{t-2,close}|$
$(C_{t-1,open} - C_{t-1,close}) < |C_{t,open} - C_{t,close}|$

$C_{t-1,low} < C_{t,low}$
$C_{t-1,low} < C_{t-2,low}$
$C_{t-1,high} < C_{t-2,open}$
$C_{t-1,high} < C_{t,close}$

2.8 Bearish definitions

Bearish Harami
Upward trend
$C_{t-1,open} < C_{t-1,close}$
$C_{t,open} > C_{t,close}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,high} - C_{t-1,low}|} > 0.6$
$C_{t,close} > C_{t-1,open}$
$C_{t,open} < C_{t-1,close}$

Hanging Man
Upward trend
$C_{t-1,open} < C_{t-1,close}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,low} - C_{t-1,high}|} > 0.6$
$C_{t,high} > C_{t-1,high}$
$C_{t,shadowBottom} > 2 * |C_{t-1,open} < C_{t-1,close}|$
$\mathbf{C}_{t,shadowTop} > 0.3 * |C_{t-1,open} < C_{t-1,close}|$

Bearish Engulfing
Upward trend
$C_{t-1,open} < C_{t-1,close}$
$C_{t,open} > C_{t,close}$
$C_{t,bodyBottom} < C_{t-1,bodyBottom}$
$C_{t,bodyTop} < C_{t-1,bodyTop}$
$\frac{|C_{t,open} - C_{t,close}|}{|C_{t,high} - C_{t,low}|} > 0.6$

Evening Star
Upward trend

$C_{t-2,open} < C_{t-2,close}$
$C_{t,open} > C_{t,close}$
$\frac{|C_{t-2,open} - C_{t-2,close}|}{|C_{t-2,low} - C_{t-2,high}|} > 0.6$
$C_{t-1,open} > C_{t-2,close}$
$C_{t,open} < C_{t-1,close}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,low} - C_{t-1,high}|} < 0.3$
$(C_{t-1,open} - C_{t-1,close}) < |C_{t-2,open} - C_{t-2,close}|$
$(C_{t-1,open} - C_{t-1,close}) < |C_{t,open} - C_{t,close}|$
$C_{t-1,high} > C_{t,high}$
$C_{t-1,high} > C_{t-2,high}$
$C_{t-1,low} > C_{t-2,open}$
$C_{t-1,low} > C_{t,close}$

Gravestone Doji
Upward trend
$C_{t-1,open} < C_{t-1,close}$
$\frac{|C_{t-1,open} - C_{t-1,close}|}{|C_{t-1,low} - C_{t-1,high}|} > 0.6$
$C_{t,high} > C_{t-1,high}$
$C_{t,high} - C_{t,close} > 3 * |C_{t,open} - C_{t,close}|$
$C_{t,open} - C_{t,low} < \frac{C_{t,high} - C_{t,close}}{3}$

2.9 ProRealtime

Pro Realtime is a software platform for trading different financial products such as stocks, futures, CFDs, commodities, bonds and options. Pro Realtime has a feature which allows users to create and backtest their own strategies. That is done with the ProBuilder programming language which is then run and executed by the Pro Realtime software [17].

2.10 Moving Average

Moving average (MA) is a simple indicator used within technical analysis and the motivation to use MA is to identify trends in the price by calculating an average price over a period of time. The period of time can vary depending on what time frame the person trading is interested in. By using MA the trader can view the development in price from a higher level without being distracted by small short-term variations in price and thus identify trends. [18]

2.11 Bollinger Bands

Bollinger Bands is an indicator consisting of two bands plotted N number of standard deviations above and below a simple moving average. Bollinger Bands is an indicator of whether the market is oversold or overbought. If the price is approaching the upper band it means that the market is overbought and if the price is approaching the lower band it means that the market is oversold. [19]

2.12 Spread

Spread is the difference between the market and the broker price.

2.13 Stop-Loss Order

A stop-loss order is placed in order to sell a security when it reaches a certain price. By using such stop-loss orders a trader can the loss if the price falls or rises rapidly. [20]

2.14 Relative Strength Index

Relative Strength Index, or RSI, is an indicator that is tracking the momentum of the price of a security. It is used to identify whether the security is overbought or oversold. [21]

2.15 Parabolic SAR

An indicator used to enter and exit a position based on the current trend. [22]

3 Method

3.1 The algorithm, entry and exit strategy

In this research we're going to develop a trading algorithm and compare six different runs on OMXS30 and FTSE100 exchanges. All six are going to be based on the same algorithm but have different stop loss and RSI configurations.

All of the algorithm configurations will look for candlestick patterns in the data and act depending on what pattern appears and what value the RSI indicator provides. The algorithm will close positions if the stop loss signal appears or if the price crosses the Bollinger Bands.

Because reversal patterns are quite common to appear, an algorithm that only uses candlestick patterns and trend recognition is likely to pick up false reversal signals. That is, a trigger for reversal that doesn't actually result in a reversal. RSI will be used as additional condition in some of the configurations as an attempt to combat this issue. RSI was chosen for this research based on the assumption that RSI will prevent an algorithm from acting on false reversal signals.

These parameters were tweaked in between each run of the algorithm, in order to try to improve the gain and optimize the algorithm. We assume that RSI and stop loss are the most important parameters we can tweak.

The tweaking resulted in six different configurations that from now on will be referred to as Algorithm configurations A, B, C, D, E and F.

- Algorithm configuration A: implements candlestick patterns + parabolic SAR + stop loss of 4 on OMXS30 and stop loss of 24 on FTSE100.
- Algorithm configuration B: implements candlestick patterns + parabolic SAR +stop loss of 6 on OMXS30 and stop loss of 32 on FTSE100.
- Algorithm configurationC: implements candlestick patterns + parabolic SAR +stop loss of 4 on OMXS30 and stop loss of 24 on FTSE100 + RSI with bounds 30 and 70.
- Algorithm configuration D: implements candlestick patterns + parabolic SAR +stop loss of 6 on OMXS30 and stop loss of 32 on FTSE100 + RSI with bounds 30 and 70.

- Algorithm configuration E: implements candlestick patterns + parabolic SAR +stop loss of 4 on OMXS30 and stop loss of 24 on FTSE100 + RSI with bounds 35 and 65.
- Algorithm configuration F: implements candlestick patterns + parabolic SAR +stop loss of 6 on OMXS30 and stop loss of 32 on FTSE100 + RSI with bounds 35 and 65.

All of the algorithm configurations will incorporate Paraolic SAR in order to keep track of the trend, this is because candlestick patterns only are relevant in the context of a trend. Bullish reversal patterns by definition need to lie within downward trend and bearish reversal patters need to lie within an upward trend.

The Parabolic SAR indicator will be used in order to identify if the security is in an upward or downward trend in all of the algorithms listed above. The algorithm configurations will use the standard Parabolic SAR configuration used in the Pro RealTime implementation of Parabolic SAR. This configuration has the following values:

- At = 0.02
- St = 0.02
- Lim = 0.2

The exit strategy for the all algorithm configurations will be based on Bollinger Bands. This choice is based on the assumption that the Bollinger Bands will accurately predict whether the market is oversold or overbought. If the closing price is above the Bollinger Band and the algorithm is holding a long position the algorithm will close its position. If the closing price is below the Bollinger Band and the algorithm is holding a short position the algorithm will close its position.

The algorithm configurations will use the default Bollinger Band configuration of 20 moving average days and 2 standard deviations.

The difference in the stop losses between the different markets is due to the difference in prices between the indices. For example a movement of 6 points may be seen as dramatic on the OMXS30 exchange while not at all significant on the FTSE100 exchange. Therefore we chose higher stop loss values for the FTSE100. We chose the stop loss values based on the assumption that the chosen values are reasonable for

the given markets. The stop loss will save the algorithms from drastic price movements in the losing direction.

The tick size that is going to be used is one hour and the time frame is going to be 100,000 hours. The tick size of one hour is beneficial to the method because the algorithm will have many data points compared to lower tick resolutions such as days or weeks. The time frame of 100,000 is the highest time frame the trading platform can provide (more about the choice of platform below). This way we have made sure that we're getting as many different data points as possible.

The spread for both markets was set to 0.5 points. This value was chosen based on the assumption that 0.5 points is a reasonable spread for the traded markets. In reality the spread differs depending on which broker one trades through.

The results from all the runs will be aggregated and compared to each other and to the index returns for the same period of time. Even if the algorithms would perform positively, a benchmark index is required to determine the profitability of each algorithm. This will be the same indices as the algorithms were run on, the OMXS30 and FTSE100.

Comparing trading strategies to index returns is a common practice, mostly because constructing a portfolio that mirrors an index is a simple and cheap investment strategy.[23] There is no reason to run a strategy that can't outperform the index it's currently trading.

3.2 Choice of platform

There are a lot of choices when it comes to a technical platform for building and executing algorithms and trading strategies. The most common stock brokers might offer their customers an API for constructing their own algorithms and executing orders through the brokers platform. This can be very time consuming and a lot of time could be spent just building the technical foundation for communicating with the broker.

Another choice would be to manually gather stock price data from an external source and then construct a standalone application that simply analyzes and collect statistics locally. The most difficult aspect with this approach is to get easy access to historical prices with intraday-level of detail.

The last approach considered in this study was to use an all-in-one solution for accessing data, creating the algorithm and executing

that algorithm on historical data. This was found to be the best fitting approach for this study.

That's why the strategy outlined in this report will be written in the ProBuilder language and tested on historical data through the ProRealTime trading platform. A popular choice of platform for trading and building automated trading strategies. ProRealTime ensures access to detailed market data and simplifies the process of creating and backtesting the algorithm.

4 Results

4.1 How the results were acquired

The raw data in the tables presented below was acquired by running our algorithms in Pro Realtime. For each algorithm the desired market and time frame were selected in the Pro Realtime software, the algorithm was then executed and after the algorithm terminated Pro Realtime exported the data which we present in the tables above.

4.2 Raw data

The following results were acquired by running the different algorithm configurations on the above mentioned data sets with an initial capital of 10000 SEK on OMXS30 and 10000£ on FTSE100.

4.3 Raw data for OMXS30 trading

	Algorithm config. A	Algorithm config. B	Algorithm config. C	Algorithm config. D	Algorithm config. E	Algorithm config. F
Gain	1950.4	1540.4	846.40	1962.4	3766.2	4454
Gain %	19.5	15.4	8.46	19.62	37.66	44.54
Trades	1458	1345	220	214	412	400
Winning trades	415	487	54	76	108	142
%winning trades	28.48	36.21	24.55	35.51	26.21	35.5
Losing trades	1042	858	166	138	304	258
Gain/Loss ratio	1.02	1.02	1.06	1.12	1.15	1.14
Avg gain/trade SEK	1.34	1.15	3.85	9.17	9.14	11.14
Avg gain/winning trade SEK	203.05	210.65	265.1	249.17	260	250.21
Avg loss/losing trade SEK	79	117.77	81.14	123.01	80.18	120.45
Time in the market	36.81%	45.2%	8.61%	11.44%	14.83%	18.96%

Table 1: OMXS30 trading results

4.4 OMXS30 index returns

	OMXS30
Gain SEK	5381.1
Gain %	53.81

Table 2: OMXS30 index results

4.5 Raw data for FTSE100

	Algorithm config. A	Algorithm config. B	Algorithm config. C	Algorithm config. D	Algorithm config. E	Algorithm config. F
Gain £	-1634	-3340	-423	-978	-4969	-6722
Gain %	-16.34	-33.4	-4.23	-9.78	-49.69	-67.22
Trades	1283	1198	159	155	315	310
Winning trades	444	477	49	59	96	118
%winning trades	34.63%	39.85%	30.82%	38.06%	30.48%	38.06%
Losing trades	838	720	110	96	219	192
Gain/Loss ratio	0.99	0.98	0.98	0.97	0.9	0.89
Avg gain/trade £	-1.27	-2.79	-2.66	-6.31	-15.77	-21.68
Avg gain/winning trade £	438.64	452.8	516.62	493.25	485.99	450.16
Avg loss/losing trade £	234.36	304.62	233.98	313.33	235.73	311.67
Time in the market %	47.24	52.46	8.6	10.3	15.07	18.01

Table 3: FTSE100 trading results

4.6 FTSE100 index returns

	FTSE100
Gain £	2612.9
Gain %	26.13

Table 4: FTSE100 index results

4.7 Explanation of the tables

The first two rows in the both tables above describe the gain of each algorithm configuration. The first row represents the absolute gain in

the currency of the market and the second row represents the relative gain in percent.

The following four rows represent the total number of trades,the number of winning trades, the percentage of winning trades compared to the total number of trades and the number of losing trades.

The next row represents the Gain/Loss Ratio. This number represents the ratio between the amount of money the algorithm gained on all winning trades compared to the amount of money the algorithm lost on all losing trades.

The following row represents the average gain per trade. This is how much money the algorithm gained or lost on average in each trade.

The next two rows represent the average gain of winning trades and average loss of losing trades. These amount represent how much money the algorithm won on average on each winning trade and how much money the algorithm lost on each losing trade.

The last row represents time in market for each algorithm. This represents the ratio between the total time our algorithm held any kind of position in the market compared to the entire time frame in which the algorithm was executed.

4.8 Explanation of the results

The first algorithm configuration that was run on the Swedish OMXS30 market was based on only candlestick patterns without any additional indicators and had stop loss of 4 points. This resulted in a gain of SEK 1950. Then a slightly modified configuration of the algorithm was run, this time with a stop loss of 6 points and gained SEK 1540.

In the following algorithm configuration the RSI indicator was added to indicate the trend of the market. Stop loss of 4 points and the standard RSI values were used, namely 30 for the lower and 70 for the upper bound. This algorithm gained SEK 846. The same algorithm but with a stop loss of 6 points gained SEK 1962.

Next we ran the two last configurations but now with 35 and 65 as RSI bounds. The version with a stop loss of 4 points gained SEK 3766 and the version with a stop loss of 6 points gained SEK 4454.

On the FTSE100, the algorithm configuration without RSI and a stop loss of 24 points lost £1634. With a stop loss of 32 points it lost £3340. The algorithm configuration with the standard RSI values and a

stop loss of 24 points lost £432. With a stop loss of 32 points it lost £978. When the RSI values was lowered to 35 and 65 the same algorithm with a stop loss of 24 points lost £4969. With a stop loss of 32 points it lost £6722.

5 Discussion

A discussion of the acquired results will follow below. This will first be discussed in regards to each individual market and this will be followed by a discussion of the overall effects of different RSI and stop loss configurations.

5.1 Analysis of OMXS30 results

After running algorithm configurations A and B on the OMXS30 exchange we noticed that A gained more compared to B. The difference between these two configurations is that A has a stop loss of 4 points and the B has a stop loss of 6 points. We noticed that these configurations produced many false reversal signals and tried to enter many short positions while the price was not near a reversal. This can be seen in the following figure where all the trades hit their stop loss.

Figur 2: Algorithm A OMXS30 example

The figure above and the following two figures in this chapter are interesting solely as examples of good and bad actions taken by the algorithm. They should only be viewed in that context. They show how the price develops and what effect this development has on the algorithms. The arrows in the figures mean that the algorithm is taking a position in the market. If the arrow is orange the position is long and if the arrow is black the position is short. The squares mean that the algorithm is exiting the position because of a stop loss. If the square is orange it means that the price has increased too much and the algorithm had to exit the position because it had a short position and if the square is black it means that the price has fallen too much while the algorithm had a long position.

Algorithm configurations C, D, E and F used the RSI indicator to combat this issue. E and F gained more compared to A and B while algorithm configuration C gained less than both A and B. D gained just a bit more than A. This shows that tweaking the stop loss and adding the RSI indicator with different configurations may alter the results drastically. In the majority of cases RSI improved the gains of the algorithm.

In the majority of cases the algorithm configurations with higher stop losses gained more compared to the configurations with lower stop losses. The majority of the configurations with the tweaked RSI values gained more than the ones with the standard RSI values.

The reason why the algorithm configurations A, C and E with lower stop loss performed worse compared to B, D and F is because they closed positions too early when the market went in the wrong direction. On the OMXS30 in our given time frame this turned out to be less beneficial compared to higher stop loss values.

The reason why the algorithm configurations E and F with tweaked RSI values performed better compared to C and D with standard RSI values is because the lower upper bound and the increased lower bound of RSI enabled configurations E and F to take more trades compared to C and D, as shown in the table. Because the percentage of winning trades is similar between all of the four configurations (C, D, E and F) the ones with more trades gained more because the average gain of a winning trade is significantly higher than the average loss of a losing trade as seen in the table for OMXS30 results.

Time in the market and number of trades is significantly higher for algorithm configurations A and B compared to C, D, E and F. This can

be explained by the fact that A and B don't use the RSI indicator at all. Because A and B don't have this extra constraint imposed by the RSI indicator, namely that the security needs to be overbought or oversold in order for a position to be taken, A and B take many positions based on false signals from the candlestick patterns. The trades in Figure 2 is an example of this.

Algorithm configurations C and D on the other hand have the lowest time in the market and the lowest number of trades because they have the strictest RSI constraints, namely that RSI needs to be above 70 for a security to be overbought and below 30 in order for a security to be oversold. Because of these constraints C and D don't take as many trades as A, B, E and F. Here is an example of a a trade with high precision taken just in the right time by this algorithm run.

Figur 3: Algorithm D OMXS30 example

Algorithm configurations E and F are in between when it comes to time in market and number of trades. Lower compared to A and B because E and F have the RSI constraint while A and B don't. They perform better compared to C and D because F and E don't have as strict RSI constraints as C and D.

The fact that E and F gain more than C and D could be explained by the fact that C and D miss many good trades because of their strict

RSI constraints and the fact that D, E and F gain more compared to A and B is because they act on less false candlestick signals.

Algorithm configuration C performed worse than all of the other algorithm configurations, which is somewhat unexpected because of the additional RSI condition. We assumed that this would increase the performance in result of reducing false signals, but this was not the case.

Generally speaking algorithm configurations that used RSI and higher stop losses gained more compared to algorithm configurations that didn't use RSI or used lower stop losses. This is because RSI eliminated some of the false signals and not closing positions too early when the market goes in the negative direction turned out to be more beneficial.

5.2 Analysis of FTSE100 results

Both algorithm configurations A and B had negative results on the London FTSE100 exchange. Algorithm configuration B performed worse compared to A. This can be explained by the fact that configuration A ended bad trades early, while B waited longer before closing bad trades due to the difference in stop loss.

Algorithm configurations C and D outperformed A and B and we can use the same reasoning as on the OMXS30 to explain why, namely the fact that by using the RSI indicator configurations C and D avoided many of the false signals produced by the candlestick patterns. In the figure below we can see a couple of trades taken by algorithm D on the FTSE100.

Figur 4: Algorithm D FTSE100 example

Algorithm configurations E and F performed worse than A, B, C and D which is interesting and in contrast with the results we received on the OMXS30 exchange where the standard RSI configuration performed worse compared to the weak one.

Generally it turned out that having a lower stop loss and exiting bad trades early is more beneficial on the FTSE100 compared to having a higher stop loss. This is in contrast to the results we received from OMXS30 where algorithms with higher stop losses gained more compared to algorithms with lower stop losses.

Having the standard RSI values used by C and D turned out to be more beneficial compared to the tweaked values used by E and F. This is also in contrast to the results we got from the OMXS30 exchange.

5.3 The effects of RSI, stop loss and other parameters

On both markets algorithm configurations with the same RSI configuration performed very similarly. This shows that RSI has a higher impact on the performance of the algorithms compared to stop loss. Stop loss has a slight effect, but far smaller compared to RSI.

While the exit strategy was more dynamic, the stop loss strategy was a just a fixed amount of index points. This served the purpose of a simple strategy that would eliminate big draw downs.

Because the average gain is higher compared to the average loss we can say that the exit strategy worked quite well in exiting position once a reversal had occurred and pierced one of the Bollinger bands. This strategy ensures that we continue to be in position until the price hit a level of overbought or oversold.

Another assumption that affected the results was the spread. This is something that was taken into consideration when developing the algorithms, in order to get a result that was closer to a real life scenario. An algorithm configuration with fewer amount of trades, like algorithm configurations using RSI C,D,E and F, will benefit from this and will have wasted less resources on what could be considered as a brokerage fee. However, this is a property that should be taken into consideration when evaluating efficiency because of it's inevitable impact on real life results.

In the method it was assumed that the ten chosen candlestick patterns are the most common patterns used by traders in the market. This is an assumption that is at the core of our algorithm and different candlesticks patterns could very well produce completely different result. For instance, it could be the case that our patterns produced false signals that would have been avoided with other patterns. More research is required in order to compare different candlestick patterns and evaluate to what extend different patterns produce false signals.

There are significant changes to the algorithm's performance when the RSI conditions were added and it is clear from our report that some additional conditions are required in order to consider trading on candlestick patterns. This also indicates that there are improvements to be made and that the algorithm might perform differently when more conditions are added.

As could be seen in the results chapter, both OMXS30 and FTSE100 returns were greater than the gain of any algorithm configuration in the same time frame. Since this was the benchmark used to determine efficiency, it becomes clear from the scope of this report that the algorithm configurations do not provide enough satisfactory results that would make them considerable as a solid investment strategy.

5.4 Limitations and Future Research

The choice of candlestick patterns in this research is one of the limitations. The ten patterns used in this research were chosen based on the assumption that they are the most common ones in the market today. Instead one could have conducted a study in order to decide which candlestick patterns are in fact the most common ones and only then perform this research.

The algorithm configurations in this research were run on a specific time frame due to the limitations of the ProRealtime software. The results of this research could have been different if another time frame was used. This is because if the general trend of the market could be in an opposite direction compared to the trend in the time frame used in this research. This is a limitation that could be solved by running the algorithm configurations on different time frames and choosing these time frames in such a way so that the market is trending in different directions across the time frames. Something that could be done in future research.

The third limitation of this research is the choice of indicator that were used in order to improve the performance of the candlestick patterns. RSI indicator was chosen based on the assumption that it will effectively prevent algorithm configurations C,D,E and F from acting on false reversal signals. Instead of basing this decision on an assumption one could have performed a study in order to have scientific proof for the assumption.

Another limitation of this research is the choice of the exit strategy. Bollinger Bands were chosen based on the assumption that Bollinger Bands would be a sufficient indicator and predict whether the security is overbought or oversold. In a future research one could run our algorithm configurations but with other indicators for predicting whether the market is oversold or overbought. It would be interesting to see how the results differ if one would replace Bollinger Band with another indicator.

6 Conclusion

In this research we've shown that different RSI and stop loss configurations has a substantial impact on the performance of a trading algorithm based on candlestick patterns. By looking at the result tables one can see that the algorithm configurations can be group into three pairs. Algorithm configurations A and B gained very similar results. The same can be said about the pairs C and D, E and F. The two algorithm configurations in each pair had the RSI configuration in common. Thus we conclude that RSI has a substantial impact on the performance of a trading algorithm based on candlestick patterns.

Tweaking the RSI parameters can either improve or worsen the performance of the algorithm depending on which market the algorithm is executed on.

On both markets the majority of the algorithm configurations with lower stop loss outperformed algorithm configurations with higher stop loss, meaning that the stop loss has in fact an effect on the outcome. However the differences between the different RSI configurations is larger compared to the differences between the different stop loss configurations.

As described in the section about the limitations there are a number of variables that were chosen based on assumptions in this research. Therefore the conclusions presented in this section should be viewed in the context of our assumptions.

Referenser

[1] Allan Timmermann and Clive W J Granger. Efficient market hypothesis and forecasting. *Int. J. Forecast.*, 20(1):15–27, 2004.

[2] Wing-Keung Wong, Meher Manzur, and Boon-Kiat Chew. How rewarding is technical analysis? evidence from singapore stock market. *Applied Financial Economics*, 13(7):543–551, 2003.

[3] Jane A Ou and Stephen H Penman. Financial statement analysis and the prediction of stock returns. *J. Account. Econ.*, 11(4):295–329, 1989.

[4] Baruch Lev and S Ramu Thiagarajan. Fundamental information analysis. *Journal of Accounting Research*, 31(2):190, 1993.

[5] Lawrence Blume, David Easley, and Maureen O'Hara. Market statistics and technical analysis: The role of volume. *J. Finance*, 49(1):153, 1994.

[6] Ben R Marshall, Martin R Young, and Lawrence C Rose. Candlestick technical trading strategies: Can they create value for investors? *Journal of Banking & Finance*, 30(8):2303–2323, 2006.

[7] Yeong-Jia Goo, Dar-Hsin Chen, and Yi Wei, Chang. Pinpoint and synergistic trading strategies of candlesticks. *International Journal of Economics and Finance*, 3(1), 2011.

[8] Probe-meteo. Probe-meteo.com, cc by-sa 3.0. [Online; accessed May 14, 2017].

[9] G Caginalp and H Laurent. The predictive power of price patterns. *Appl. Math. Finance*, 5(3-4):181–205, 1998.

[10] Tsung-Hsun Lu and Jinji Chen. Candlestick charting in european stock markets. *JASSA The Finsia Journal of Applied Finance*, (2), 2013.

[11] Hércules A do Prado, Hércules A do Prado, Edilson Ferneda, Luis C R Morais, Alfredo J B Luiz, and Eduardo Matsura. On the effectiveness of candlestick chart analysis for the brazilian stock market. *Procedia Comput. Sci.*, 22:1136–1145, 2013.

[12] Yeong-Jia Goo, Dar-Hsin Chen, and Yi-Wei Chang. THE APPLICATION OF JAPANESE CANDLESTICK TRADING STRATEGIES IN TAIWAN. *Investment Management and Financial Innovations, Volume 4, Issue 4*, 2007.

[13] Jan Ivar Larsen. *Predicting Stock Prices Using Technical Analysis and Machine Learning*. PhD thesis, Norwegian University of Science and Technology, June 2010.

[14] M M Goswami, C K Bhensdadia, and A P Ganatra. Candlestick analysis based short term prediction of stock price fluctuation using SOM-CBR. In *2009 IEEE International Advance Computing Conference*, 2009.

[15] Milad Jasemi, Ali M.Kimiagari, and A.Memariani. A CONCEPTUAL MODEL FOR PORTFOLIO MANAGEMENT SENSITIVE TO MASS PSYCHOLOGY OF MARKET. *Int. J. Ind. Eng.: Theory Appl. Pract.*, 19(1):1–15, 2011.

[16] Steve Nison. *Japanese Candlestick Charting Techniques*. 1991.

[17] Pro Realtime. [Online; accessed Feb 23, 2017].

[18] Marcus Christian Toms and University of Newcastle upon Tyne. School of Electrical, Electronic and Computer Engineering. *The Technical Analysis Method of Moving Average Trading: Rules that Reduce the Number of Losing Trades*. 2011.

[19] Xin Xie. *Full View Integrated Technical Analysis: A Systematic Approach to Active Stock Market Investing*. 2011.

[20] Jawwad Ahmed Farid. *Risk Frameworks and Applications - 2nd Edition*. 2006.

[21] Deron Wagner. *Advanced Technical Analysis of ETFs: Strategies and Market Psychology for Serious Traders*. 2012.

[22] Frank K. Reilly E. K. Brown. *Investment Analysis and Portfolio Management*. 1979.

[23] Honghui Chen, Gregory Noronha, and Vijay Singal. Index changes and losses to index fund investors. *Financial Analysts Journal*, 62(4):31–47, 2006.