Valter Frade

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Technical Indicators. A Comparative Study

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Orientador: Pedro Mota Ph.D, Assistant Professor,
NOVA University of Lisbon

Júri

FACULDADE DE
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UNIVERSIDADE NOVA DE LISBOA

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Abstract

In the financial markets context, the ability of taking fast decisions represents an competitive advantage. Therefore, implementing methodologies that can be automatized by computers becomes a primary need. The technical analysis, and the tools that come from it (technical indicators) are an answer to this problem. Having this in mind, trading strategies based on the most used technical indicators (MA, MACD and RSI) were implemented.

So, the purpose of this thesis was try to understand (through a comparative analysis) which one of these technical indicators generates more reliable/profitable trading signals, aiming to design trading strategies that can outperform the market returns (Buy and Hold strategy). In this study were considered 352 stocks of US market from 01/01/2015 to 31/12/2018.

Through the quantiles analysis of trading points, we show that RSI is the technical indicator that generates more reliable trading signals, however this indicator is not the most profitable.

At last, optimized trading strategies consisting into combinations of the RSI indicator with each one of the other indicators lead to the maximization of average returns, but the average returns are still lower than those that were obtained through Buy and Hold strategy. However, for the most part of considered companies the optimized trading strategies have generated higher returns than the Buy and Hold strategy.

Keywords: Financial Markets; MACD; Moving Averages; Quantile Analysis; RSI; Technical Analysis; Technical Indicators; Trading Strategies.

Resumo

Num contexto de mercados financeiros, no qual a capacidade de tomar decisões rapidamente representa uma vantagem competitiva, surge a necessidade de implementar metodologias que possam ser automatizadas e implementadas por computadores. A análise técnica, e os métodos que dela advêm (Indicadores técnicos) são uma resposta para este problema. Tendo isto em mente, ao longo desta tese foram implementadas estratégias de compra e venda de ações baseadas naqueles que são os indicadores técnicos tipicamente mais usados: médias móveis, RSI e MACD.

Assim o propósito desta tese foi perceber (através de um estudo comparativo) qual destes indicadores técnicos gera sinais de compra e venda mais confiáveis/rentáveis (quer isoladamente, quer combinados com outros indicadores) tendo em vista o desenho e implementação de estratégias de troca que possam *bater* o mercado. Neste estudo foram tidos em consideração os dados de 352 ações do mercado dos Estado Unidos, compreendendo o período temporal de 01/01/2015 até 31/12/2018.

Através de uma análise de quantis dos pontos de troca, chegamos à conclusão que o RSI é o indicador que gera sinais mais confiáveis, apesar de não ser o indicador que apresenta retornos médios superiores.

Por fim, foram implementadas estratégias otimizadas de compra e venda de ativos que consistiram em combinar o RSI com cada um dos outros indicadores técnicos, o que levou à maximização dos retornos médios, contudo estes não ultrapassaram os retornos médios de mercado, apesar de se ter observados que para a maioria das empresas em consideração as estratégias otimizadas tiveram retornos superiores aos que foram obtidos pelo mercado.

Palavras-chave: Análise de Quantis; Análise Técnica; Estratégias de Troca; Indicadores Técnicos; MACD; Médias Móveis; Mercados Financeiros; RSI.

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Introduction and Objectives

1.1 Introduction

To every one that works in the financial markets context, it is of crucial importance the ability to take buying or selling decisions in a fast and efficient way. That ability represents a competitive advantage when comparing with the other market players and therefore the implementation of automatized computer methodologies to buy or sell (or eventually stay put) is a primary need for everyone that works in trading. The technical analysis approach, and the mathematical tools that are at the technical analyst disposal, usually known as technical indicators, provides a framework to build strategies and give answers to the questions of when to buy and sell the financial products.

Having this in mind, in this thesis several trading strategies based on the some of the most used technical indicators as the Moving Average (MA), Moving Average Convergence Divergence (MACD) and Relative Strength Index (RSI), were implemented.

The purpose of this thesis is to try to better understand, through a comparative analysis, which one of these technical indicators can be used to generates more reliable/profitable trading orders (buy or sell), aiming to design trading strategies that can outperform the traditional market returns, based in the Buy and Hold strategy (Buy and Hold is a strategy consisting in buying the financial asset in the beginning of the period and selling at the end of the period).

In this thesis we also provide a quantiles analysis of trading points, that is, we will compare the prices of each buy or sell with the prices of the last 65 preceding days in order to understand if the trading prices are high or low when comparing with the more

recent market prices. In this context, we show that RSI is the technical indicator that generates more reliable trading signals in the sense that usually the order to buy is given at lower prices and the order to sell is given at higher prices, even so this indicator is not the most profitable in terms of capital returns.

At last, we purpose some optimized trading strategies consisting into combinations of the RSI indicator with each one of the other indicators. We show that this combination of technical indicators can lead to a strategy with higher average returns, but these are still lower than the average of the Buy and Hold returns strategy. In spite of it, for more than half of the considered companies the optimized trading strategies have higher returns than the Buy and Hold strategy.

This thesis is organized as follow:

- Chapter one, in the rest of this first chapter we discuss a little more the main objectives of this work;
- Chapter two, in this chapter we introduce and explain in more detail what is the Technical Analysis and the Technical Indicators that are used;
- In Chapter three, is explained the nature of the data we used and the methodology that is followed in the study;
- Chapter four, the results obtained from the different strategies implementation are provided and the subsequent discussion is presented;
- Chapter five, finally, in this last chapter some concluding remarks and future work is presented.

1.2 Objectives

In a context of trading in financial markets, regardless of an investor adopt a technical, or fundamental approach it's clear that technical analysis and the methods that come from it (technical indicators) gives an important insight about the market's state as well as the moments which corresponds to a trade.

Since there is a wide diversity of available technical indicators, stands out the need to understand which kind of information each technical indicator gives and how reliable it is. Because, if we blindly follow the information/insight that was given by each technical indicators (in a trading context), this approach could lead us to substantial losses.

Therefore, one of the main objectives of this work was to conduct a study in which we blindly follow a given technical indicators (in this case the technical indicator's in

consideration were MA, MACD and RSI) and dissect the respective results, taking into account the resulting returns and trading prices analysis.

One of the purposes of this study was to try to understand the relation between each technical indicator's insight and the respective generated returns, as well as, the relation between the technical indicator's insight and the price's reality (quantile analysis).

Through the results obtained in a first phase, the final purpose of this thesis was to design optimized trading strategies, based on the combination of different technical indicators, that could lead us to the maximization of the previous results.

Chapter 2

Technical Analysis and Technical Indicators

In this chapter we introduce and explain what is technical analysis and what are the technical indicators that we use in this work.

2.1 Technical Analysis

What will happen to the next price? (Will it rise or will it decrease?)

The question above is the main problem of any investor before he, or she takes the final decision, buy, sell or do nothing about any stock (or other asset). In order to obtain gains, consistently, the investor has to his disposal a set of tools that will able him to make profitable calls. Traditionally, this set of tools are based in two different approaches: Technical and Fundamental Analysis ([1]).

By using technical analysis approach, the "technical investor" believes that all relevant information to understand the price market, lies in the price market itself ([1], [2]). On the other hand, by using fundamental analysis the " fundamental investor" tries to understand the intrisic value of a given stock (it's not necessarily equal or similar to market price), by examining macro and microeconomic factors, such as revenues, earnings, future growth or profit margin, etc. So, while the fundamental trader studies the causes that lead to market fluctuations, the technical one studies the effect that market fluctuations have in price itself as in other investor's expectations see also [1] and [2].

In particular, Technical Analysis approach is based in three principles:

1. *Market action discounts everything*;

2. *Prices move in trends*;

3. *History repeats itself*.

"*Market action discounts everything*"... If we believe that all fundamental aspects will reflect themselves in market price, in final analysis the study of the market price is the only necessary element to understand the market price itself. Therefore, through the technical indicators support, the trader let the market (past prices) tell him which way is most likely to go ([1] or [3]).

"*Prices move in trends*"... Identify trends in early stages, or following the ones that exist already, its the main objective of many techniques used through Technical Analysis approach. So, accept that market price moves in trends is essential if we want to accept Technical Analysis approach as valid. This idea can be easily confirmed by several charts (stocks, index, petroleum, gold, etc) where its possible to observe price rises and/or price decreases for a given time period ([1], [3]).

"*History repeats itself*"... This idea arises from the human instinct that "what it happened before will happen again in the future". Thus, the study of chart patterns is crucial in technical analysis approach. Over decades, several patterns were identified and categorized, since they have been associated, consistently, as preceding critical moments of the market (turn overs from bullish to bearish market, and vice-versa, bubles, etc) (again [1], [3]).

Figure 2.1: Financial market *State-of-Mind*

For example, the figure above describes what happens in a bubble situation ("Greed Phase"). We can find something very similar when we look to the Bitcoin crash at the beginning of 2018 (Figure 2.2).

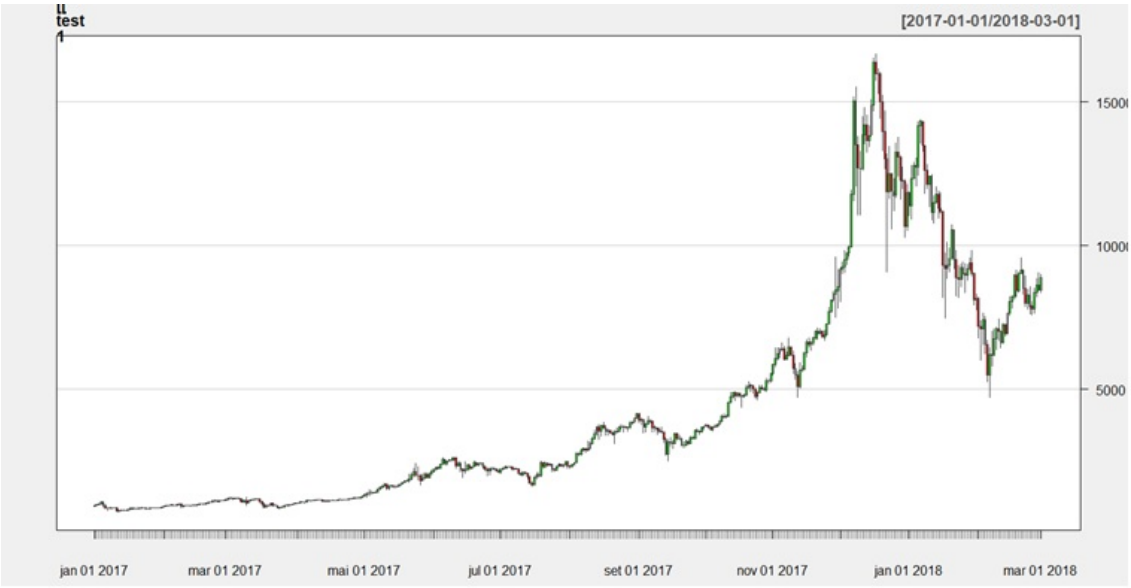

Figure 2.2: Illustration of Bitcoin bubble at the end of 2017

Having this in mind, over this thesis several technical analysis will be used in defining trading strategies, with the main objective of obtain gains consistently.

2.2 Technical Indicators

2.2.1 Moving Averages

One of the most fundamental principles by which the technical analysis experts are ruled by, it's that price fluctuations occur by trends. Therefore, if it 's possible to identify a trend, timely, it would be possible to maximize gains and limit losses. The Moving Average approach is one of the most used methods in technical analysis, whose the main purposes are: indentifying trends and data smoothing ([4]). Basically, a moving average is the average of a price time serie's subset (with a given size, time window) that moves across the price series over time. In other words, for each moment, there is a moving average value. There are different ways by which moving averages can be computed, depending of the analysts considerations. Below will be explained how some moving average types are computed.

2.2.1.1 Simple Moving Average (SMA)

$$SMA = \frac{P_t + P_{t-1} + ... + P_{t-(n-1)}}{n} \tag{2.1}$$

P_t is the price value at the t period, and n is the number of values used to make the calculation of SMA (time window), considerating the price values between t and $t-(n-1)$ periods, see Figure 2.3. All prices values considered to the SMA calculation for period t, have the same weight, independently of the price value and respective time period ([4], [5]).

> ***Note:*** *SMA(10) means that a given simple moving average has a time window that considers* 10 *periods (the last* 10 *stock prices known). This approach is also applied to other moving average types.*

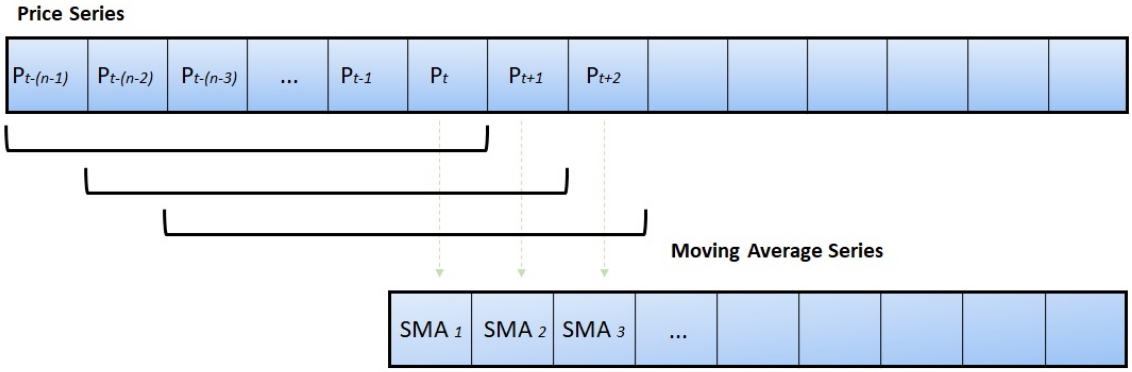

Figure 2.3: Moving Average calculation scheme

2.2.1.2 Weighted Moving Average (WMA)

$$WMA = \frac{nP_t + (n-1)P_{t-1} + ... + 2P_{t-(n-2)} + P_{t-(n-1)}}{n + (n-1) + ... + 2 + 1} \tag{2.2}$$

Differently from SMA, in WMA calculation, each price value has a weight, accordingly with respective time period. So, recent price values have higher weights, and, the older ones have lower weights, see Figure 2.4. By the equation above, weight factors values are applied to the price values between n and 1 periods ([6]).

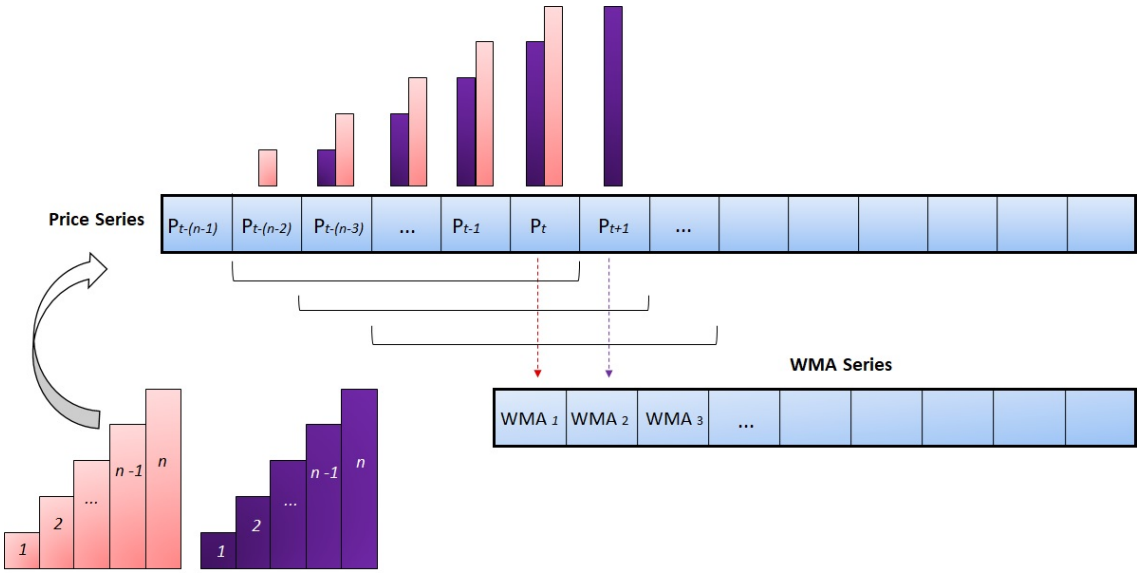

Figure 2.4: Weighted Moving Average calculation scheme. The color bars illustrate the weight factors that are applied to each element of the price series.

2.2.1.3 Exponential Moving Average (EMA)

In this case, EMA is calculated recursively, in other words, to calculate the next EMA value, the previous one is necessary. For a given time window, with n time periods, the first EMA value is equal to the first SMA value.

$$EMA_1 = SMA_1 \tag{2.3}$$

The following EMA values are calculated recursively, using the previous EMA value, as it follows:

$$EMA_{t-(n-1)} = \alpha P_t + (1-\alpha) * EMA_{(t-(n-1))-1} \tag{2.4}$$

P_t is the stock value at the time t and $EMA_{(t-(n-1))-1}$ is the previously calculated EMA value.
The α value is a decreasing factor, calculated as follows:

$$\alpha = \frac{2}{n+1} \tag{2.5}$$

2.2.2 Relative Strength Index (RSI)

Introduced by J. Weller Wilder, RSI is one of the most popular technical indicators used in financial markets analysis. Through this indicator it's possible to observe the historical weakness/strength of a given stock (or another asset) by using it closing prices ([7]).

Since RSI is a "momentum oscilator", it measures the velocity and magnitude change of price values. In particular, RSI indicator considers "momentum" as the relation between the gains and losses that occur in a set of price values, in a given time window n ([7]).

RSI takes values between 0 and 100, typically (by convention), RSI is considered high when is equal to 70 or higher, and low when it's value is equal or lower to 30. Next, will be explained the procedure to compute RSI ([7]).

RSI Computation:

1. Firstly are obtained two series, G (Gain series) and L (Loss series). For each moment of time t, G and L series are calculated as follows ([8]):

   - if $P_t - P_{t-1} > 0$, $G_t = P_t - P_{t-1}$ and $L_t = 0$;
   - if $P_t - P_{t-1} < 0$, $G_t = 0$ and $L_t = P_{t-1} - P_t$;
   - if $P_t - P_{t-1} = 0$ both G_t and L_t will be equal to 0.

2. Next, Relative Strength ratio RS, is calculated by the ratio between the exponential moving average of G and L series ([8]):

$$RS = \frac{EMA(G,n)}{EMA(L,n)} \tag{2.6}$$

3. Finally, the RSI final value is obtained through:

$$RSI = 100 - \frac{100}{1 + RS} \tag{2.7}$$

If $EMA(L,n)$ is equal to zero the RSI value is 100.

2.2.3 Moving Average Convergence Divergence (MACD)

Developed in 1979 by Gerald Appel, MACD is a technical indicator used to identify momentum, trends, trends direction and trends reversal moment. MACD is a set of values that are defined as the difference between two exponential moving averages (one faster, and another one slower). Once MACD is calculated, the next step is to compute the "signal", which is defined as an exponential moving average (EMA) of MACD, obtained previously ([9], [10]).

MACD Computation:

1. Lets consider a price series P, two EMA's (with a different time window) are calculated: $EMA(P,n)$ (slower) and $EMA(P,m)$ (faster), with $n > m$.
   Then:

$$MACD = EMA(P,m) - EMA(P,n) \tag{2.8}$$

2. Next, the signal line is calculated as follow:

$$signal = EMA(MACD, s) \tag{2.9}$$

s is the time window (lag factor) defined to calculate the $signal$;

3. Finally, the histogram is obtained through:

$$histogram = MACD - signal \tag{2.10}$$

Figure 2.5: MACD indicator applied to Amazon daily closing prices from *01/05/2018* to *24/01/2019*. A: red line, that corresponds to EMA with 12 period length ("fast EMA"); B: blue line, that corresponds to EMA with 26 period length ("slow EMA"); C: grey line, MACD line; D: red dashed line, Signal line (EMA of MACD with 9 period length); E: Histogram; F: Amazon canddlestick price chart.

Chapter 3

Methodology

This chapter describes the steps that were taken in order to acquire and compute the stock prices used in this thesis. This work was performed in a computer with a windows 10 64 bits operative system; processor i7-4700HQ CPU 2.40GHz; 8GB of RAM Memory. The R version used in this work was 3.3.2.

3.1 Select/Acquire/Save Data

In this thesis were considered the daily closing prices of 352 stocks (Appendix 2), downloaded from yahoo finance. All stocks are included in National Market System from US and can be founded at the annex section. In order to download data from yahoo finance, a method from quantmod library was used, through R software.
The trading period for each stock considers the time period between 01-01-2015 and 31-12-2018, 1005 observations. After the download process, the data for each stock was saved in a csv file.

Listing 3.1: Code section that was used to perform the download and save data in csv files

```
1  ######################################
2  ## Acquire_data_stocks ###############
3  library(quantmod)
4  library(xts)
5  library(xlsx)
6
7  ticker <- (Lista_de_empresas$Ticker)
8
9  for(i in 1:length(ticker)){
10  try({
```

```
11
12  ## Obtain data ##----------------------------
13
14  test <- list()
15  test[[1]] <- getSymbols(ticker[i], from ="2014-01-01",
16  to = "2018-12-31", periodicity = "daily",
17  return.class = "xts", auto.assign = FALSE)
18
19  ## Create/Save files .csv ##
20
21  write.table(test[[1]],file = paste('D:/Dados_stocks_tese/',ticker[i],'.csv'),
22  row.names = FALSE, sep=",")
23  })
24 }
```

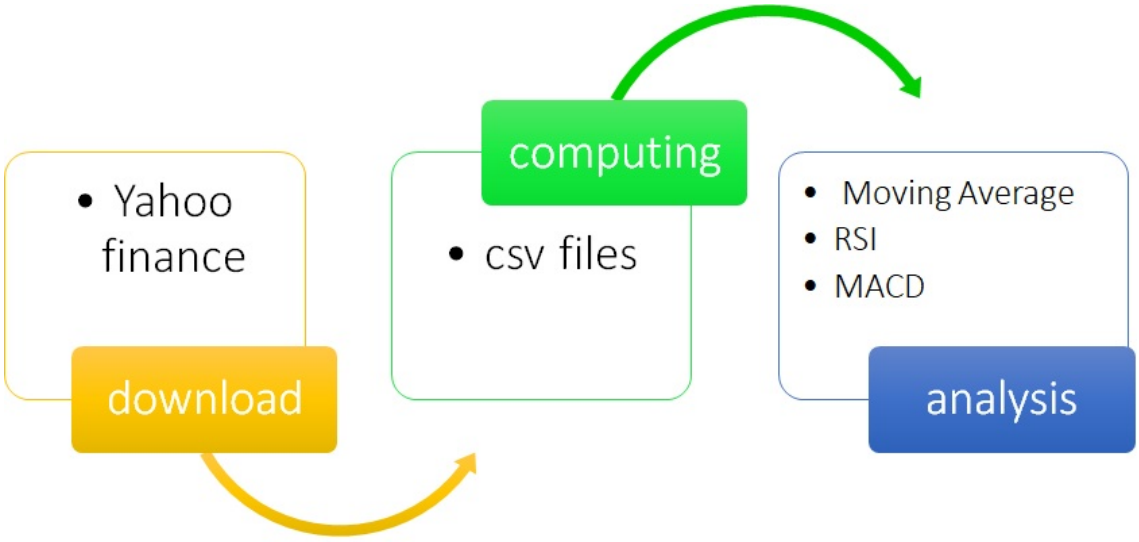

Figure 3.1: Scheme of work phases

3.2 Trading Strategies

In this section will be explained how each technical indicator (Moving Average; RSI; MACD) is translated into a trading strategy for each stock. It's important to refer that in trading simulations it wasn't considered trading costs.

3.2.1 Moving Average Strategy

This trading strategy is based on the dual cross-over moving average. Firstly, two moving averages with different lag values are computed, one shorter (fast moving average), and the other one longer (slow moving average), see [11].
According with this strategy, the buy signal is generated when the shorter MA crosses the longer one from bellow, see Figure 3.2. On the other hand, the sell signal occurs when

the shorter MA crosses the longer one from above ([11]). In this work were applied two different strategies based on moving average technical indicator:

- MA(12; 26), fast moving average with lag value equal to 12, and slow moving average with lag value equal to 26. This trading strategy from now on will be defined as MA_1;
- MA(10; 66), fast moving average with lag value equal to 10, and slow moving average with lag value equal to 66. This trading strategy from now on will be defined as MA_2;

Figure 3.2: Representation of trading moments through Dual Moving Average indicator. Red line- fast moving average n=10; Blue line- slow moving average n=66; Yellow circle - buy signals; Red circle - sell signals

3.2.2 MACD Strategy

The MACD technical indicator generates Buy and Sell signals in more than one situation, see Figure 3.3. In this work, buy signal is generated when signal line crosses MACD line from below, and sell signal is generated when signal line crosses MACD line from above ([12], [13]). MACD parameters considered in this thesis were 12, 26 and 9 ([12], [13] and [14]):

- 12 corresponds to lag value of fast EMA;
- 26 corresponds to lag value of slow EMA;
- 9 corresponds to lag value of signal line.

Figure 3.3: Representation of trading moments through MACD indicator. Yellow circle - buy signals and respective buying prices; Red circle - sell signals and respective selling prices

3.2.3 RSI Strategy

As it was said before, the RSI takes values between 0 and 100. The trading moments generated by this indicator happens when RSI is equal or lower than 30 (buy signal), or RSI is equal or higher than 70 (sell signal), see Figure 3.4.

Figure 3.4: Representation of trading moments through RSI indicator. Blue line - RSI indicator with n parameter equal to 14; Yellow circle - buy signals and respective buying prices; Red circle - sell signals and respective selling prices

The RSI's lag parameter (time window) considered in this work is equal to 14 ([8], [15]).
At the appendix 1 are available the code sections that were used to implement the trading strategies based on technical indicators.

3.3 Quantile Analysis

In order to get a different view about the moment when a trade happens (buy or sell), it was performed a quantile analysis. Firstly, this quantile analysis consisted into dividing the trading prices into two groups: buying prices, and selling prices.
Secondly, for each price, of each group, it was calculated the respective quantile taking into account the price itself and the prices of last quarter (previous 65 periods).

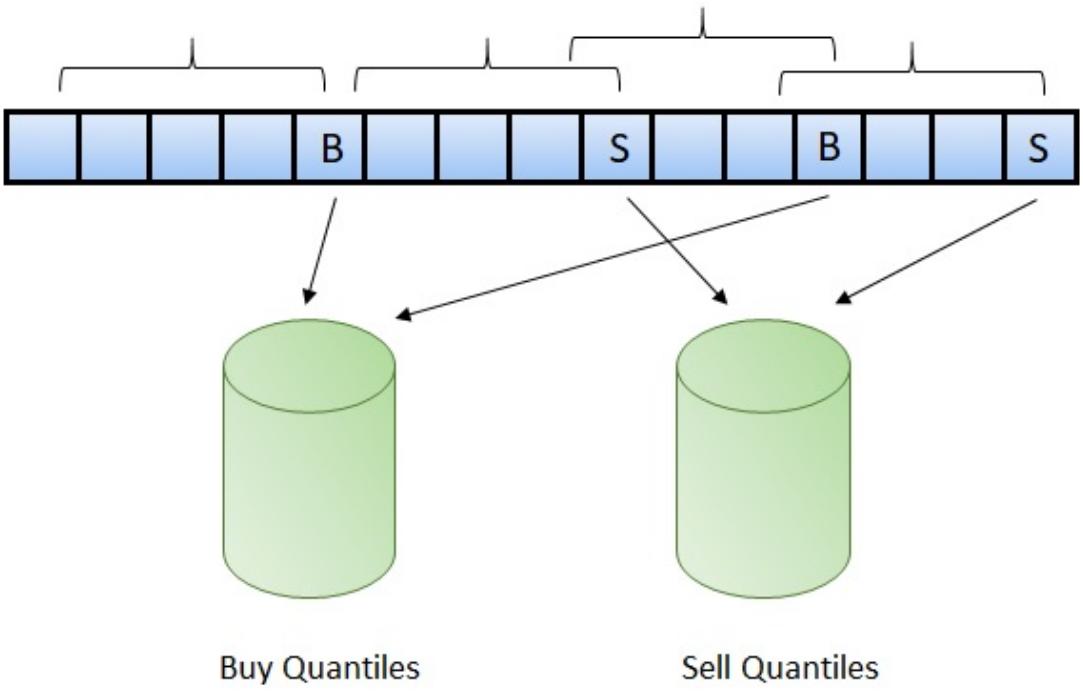

Figure 3.5: Illustration of how quantile's analysis is performed. The buying trades are defined by B letter. The selling trades are defined by S letter. The brackets meaning refers to the values that are considered in quantile analysis.

Listing 3.2: Code section that was used to perform quantile analysis

```
## "Buy" Quantile
quantis_buy <- c() ## "Buy" Quantile

for(i in 1:length(t_buy)){
  percentil <- ecdf(data_stock_prices_3_months[t_buy[i]:(quantil_3_months+t_buy[i]-1)])
  quantis_buy[i] = percentil(data_stock_prices_3_months[(quantil_3_months+t_buy[i]-1)])
}
Quant_Buy <- c(Quant_Buy,quantis_buy)

## "Sell" Quantile
quantis_sell <- c() ## "Sell" Quantile

for(i in 1:length(t_sell)){
percentil <- ecdf(data_stock_prices_3_months[t_sell[i]:(quantil_3_months+t_sell[i]-1)])
quantis_sell[i] = percentil(data_stock_prices_3_months[(quantil_3_months+t_sell[i]-1)])
}
Quant_Sell <- c(Quant_Sell,quantis_sell)
```

Chapter 4

Results and Discussion

In this Chapter, the results obtained for each trading strategy (based on one technical indicator, or more) will be presented and discussed. The main results to focused on, over this chapter, are:

- the returns for each trading strategy;
- the comparison between each trading strategy and "buy and hold"strategy;
- the returns obtained for the "Optimized Strategies".

4.1 Moving Average

4.1.1 Moving Average (26; 12)

In order to analyse the profits of MA_1 trading strategy, the respective histogram of the returns is presented in Figure 4.1. To read this histogram correctly, we should note, for instance, when we see 0 return, that means the final profit is equal to 0%, in relation to initial capital (no gains, no losses). If we read 20 return, that means initial capital raised by 20%. On the other hand, if we read −20, that means initial capital decreased by 20%, from the start.

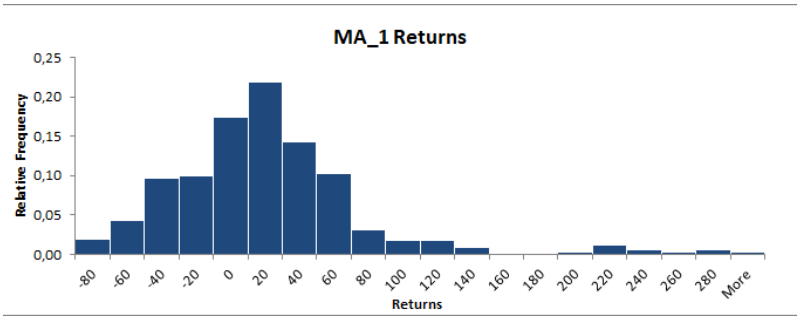

Figure 4.1: Returns Histogram of MA_1 trading strategy

According with the histogram presented above, we conclude that by chosing MA_1 trading strategy there is 57% probability to generate positive returns, and the average return is between 0 – 20%.
To understand the advantage that each indicator brings (or doesn't) to a trading strategy, the comparison between the results of each one technical indicator trading strategy and "Buy and Hold" strategy was made. Below, Buy and Hold return's histogram will be presented in Figure 4.2.

Figure 4.2: Returns Histogram of Buy and Hold trading strategy

From the Figure 4.2, it's possible to observe that Buy and Hold approach has 67% of probability to generate positive returns. The average return using Buy and Hold strategy is between 20 – 40%

In order to understand if MA_1 strategy add value to the typical "Buy and Hold" strategy, the differences between the returns of these two strategies were calculated, for each considered stock. Then, the differences were sorted, from the smallest to the largest corresponding "Buy and Hold" returns values. This plot can be observed in Figure 4.3.

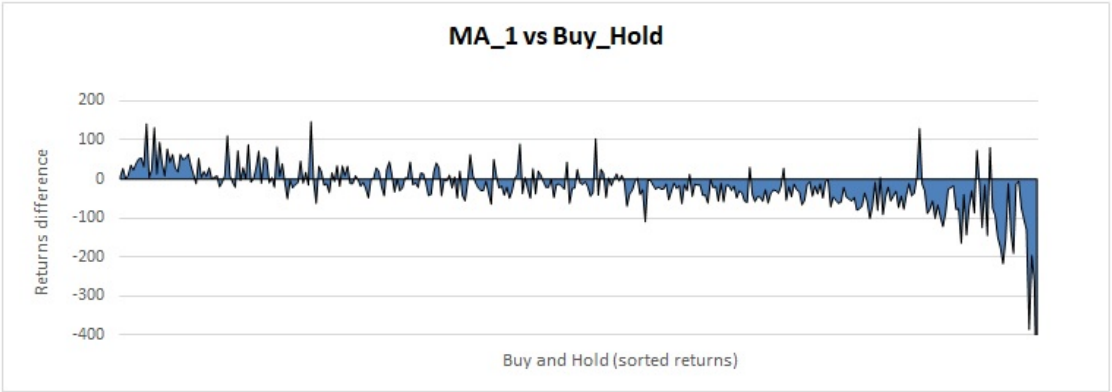

Figure 4.3: Difference between MA_1 and Buy and Hold strategy sorted by smallest to largest corresponding "Buy and Hold"returns values

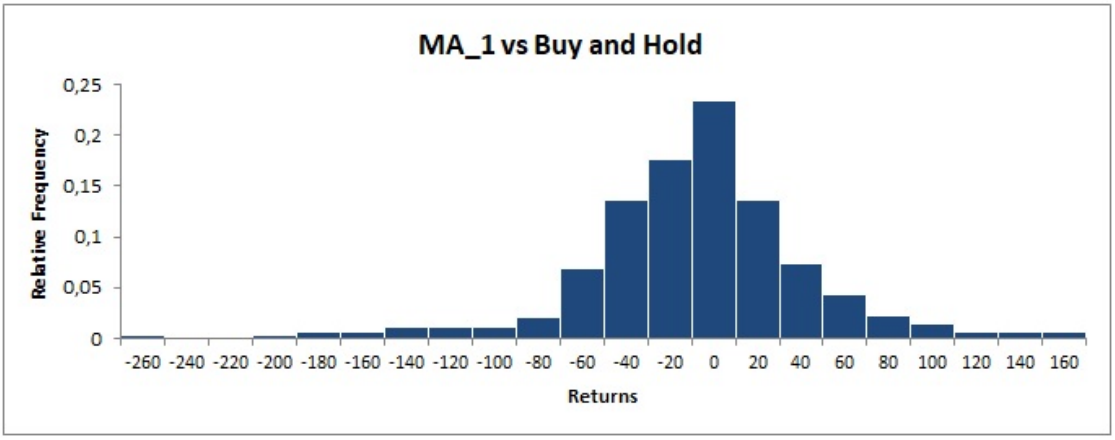

Figure 4.4: Histogram of returns'difference between MA_1 and Buy and Hold strategy

According with the results above, it becomes clear that "Buy and Hold" surpasses the MA_1 trading strategy. However, it should be noted that for "Buy and Hold" lowest return's values, MA_1 strategy has a superior performance than the "Buy and Hold" strategy. Like it was said at 2.3 section, for each trading strategy, it was performed a quantile analysis to the corresponding buy and sell prices. Those results are presented in Figure 4.5.

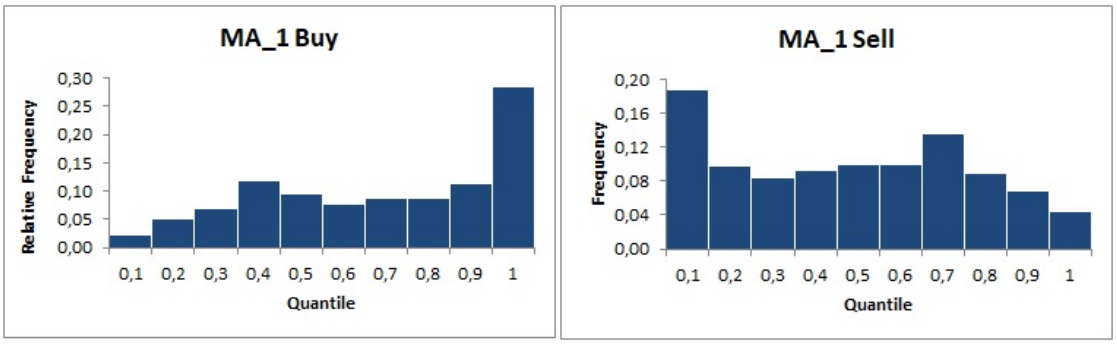

Figure 4.5: Histograms of buy (left) and sell (right) prices'quantiles of MA_1 trading strategy

Trough the analysis of Sell and Buy quantile histograms, we observe that 65% of the buying prices, using MA_1 strategy, are in $0,6-1$ quantiles, considering the last quarter's prices. On the other hand, 57% of the selling prices are in $0,1-0,5$ quantiles of the last quarter's prices.

This is not an intuitive result, however, since MA follows trends, the signals generated by this indicator will be triggered some periods after the trend begins. So, if the price starts to rise (up trend), the buy signal will be generated later, therefore when we buy, there is an huge chance that the respective buying price is higher than the recently past prices. The same principle is applied to sell signals as well, so, this can explain why that most of the sell prices coincide with the last quarter's minimum values. We can observe

very clearly this idea in the Figure 4.6.

Figure 4.6: Representation of trading moments through Dual Moving Average indicator. Red line- fast moving average n=10; Blue line- slow moving average n=66; Yellow circle - buy signals; Red circle - sell signals

Observing Figure 4.6, if we look to the first sell signal (May-2016), it's clear that the respective selling price corresponds to the lowest prices of the last quarter (3 months). For instance, if we pay attention the last buy signal, it's also clear that this one corresponds to the highest prices of last 3 months.
From a purely financial point of view, these results represent a failure, because in order to generate profit, the basis idea is: "buy when the price is low, and sell when the price is high", and according with the obtained results, this idea is not being accomplished.

4.1.2 Moving Average (66; 10)

A second Moving Average strategy (MA_2) is considered with the shorter (faster) of lag order 10 (two weeks of daily prices), and the other one longer (slower) of lag order 66 (corresponding to one quarter of daily prices).
At the next figure (Figure 4.7), the return's histogram, obtained through MA_2 strategy is presented.

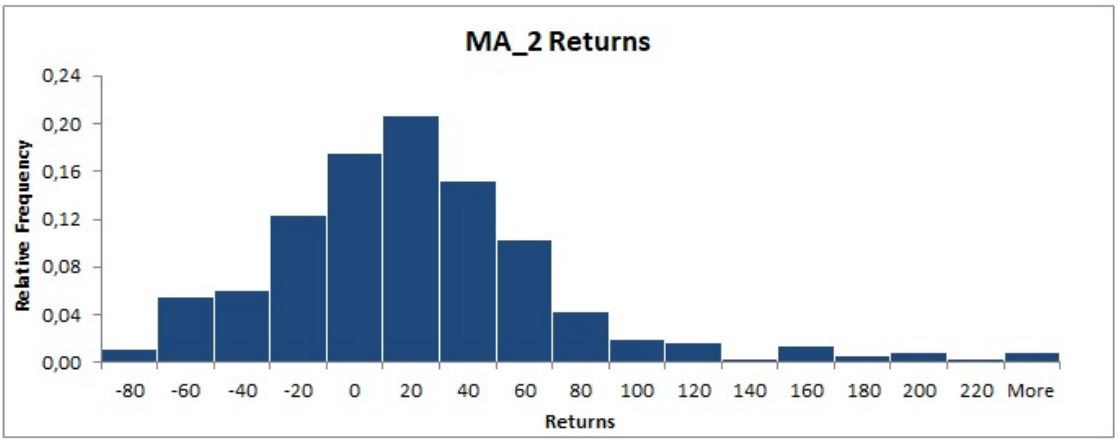

Figure 4.7: Returns Histogram of MA_2 trading strategy

Similarly to MA_1 strategy, the MA_2 also reproduces average returns between 0 – 20%. But, the MA_2 strategy has 59% probability to generate profit, and the higher returns produced by this strategy are higher than those generated by the MA_1 strategy.

Again the differences between the returns of MA_2 and Buy and Hold strategies were computed, the differences were sorted, from the smallest to the largest corresponding "Buy and Hold" returns values and the plot can be observed in Figure 4.8 and in histogram form in 4.9.

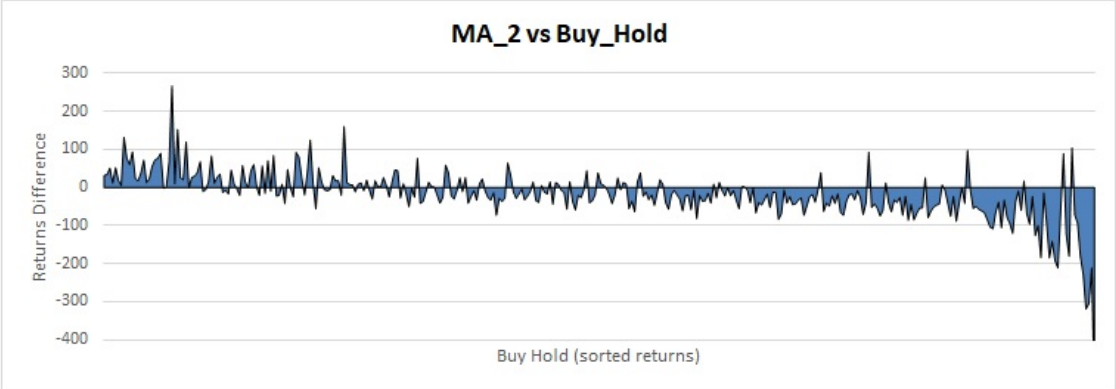

Figure 4.8: Difference between MA_2 and Buy and Hold strategy sorted by smallest to largest corresponding "Buy and Hold"returns values

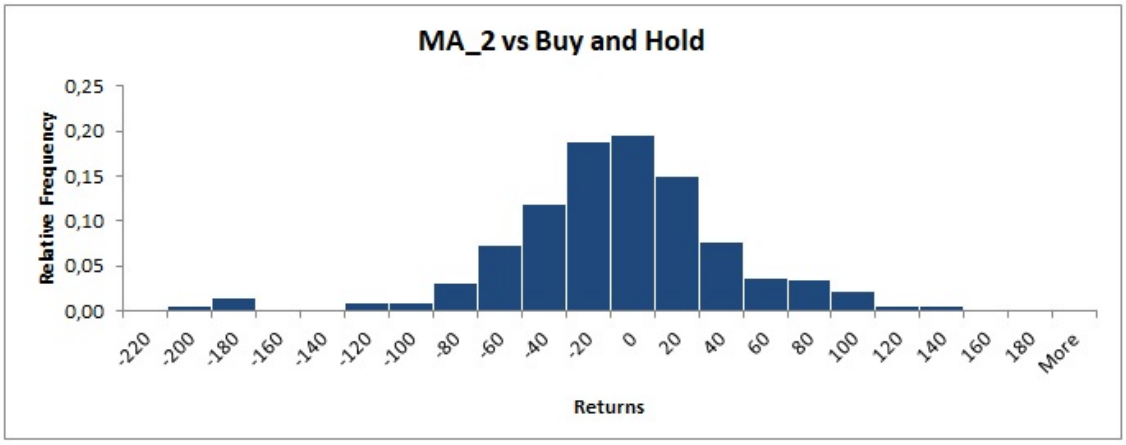

Figure 4.9: Histogram of returns'difference between MA_2 and Buy and Hold strategy

Like happened with MA_1 strategy, when MA_2 trading strategy is applied, for the "Buy and Hold", lowest returns, MA_2 strategy has a superior performance than the Buy and Hold strategy.

The Buy and Sell quantiles were again computed and the result are presented in Figure 4.10.

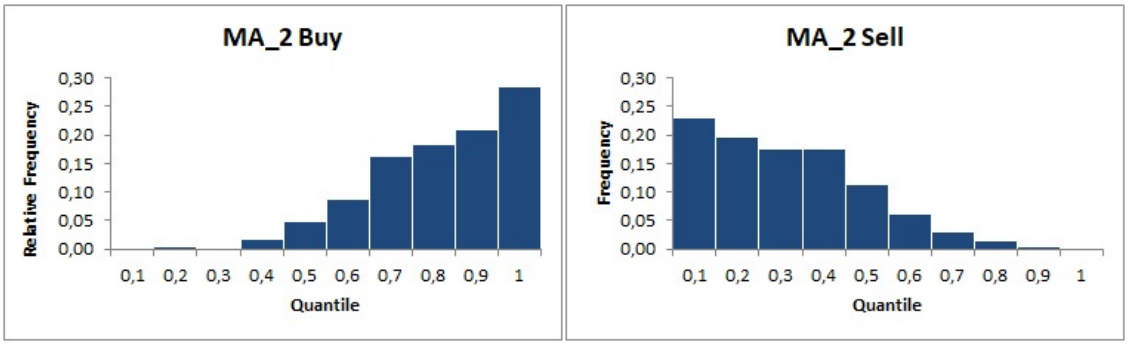

Figure 4.10: Histograms of buy (left) and sell (right) prices'quantiles of MA_2 trading strategy

Looking at the two histograms above (Figure 4.10), it's clear that Buy and Sell quantile histograms for MA_2 strategy are very similar to those that were obtained through MA_1 trading strategy. In this case, we observe that 93% of buying prices are between $0,6-1$ quantiles of last quarter's prices. On the other hand, with MA_2 strategy 89% of the selling prices are between $0,1-0,5$ quantiles of last quarter's prices.

For, MA_1 and MA_2 strategies, the buying prices and the selling prices are at the high and the low range prices of the last quarter, respectively.

4.2 MACD

In this section we present the results from the application of MACD trading strategy, as described in section 2.2.2. Below, in Figure 4.11, is presented the histogram of return's results of MACD trading strategy, described at 2.2.2 section.

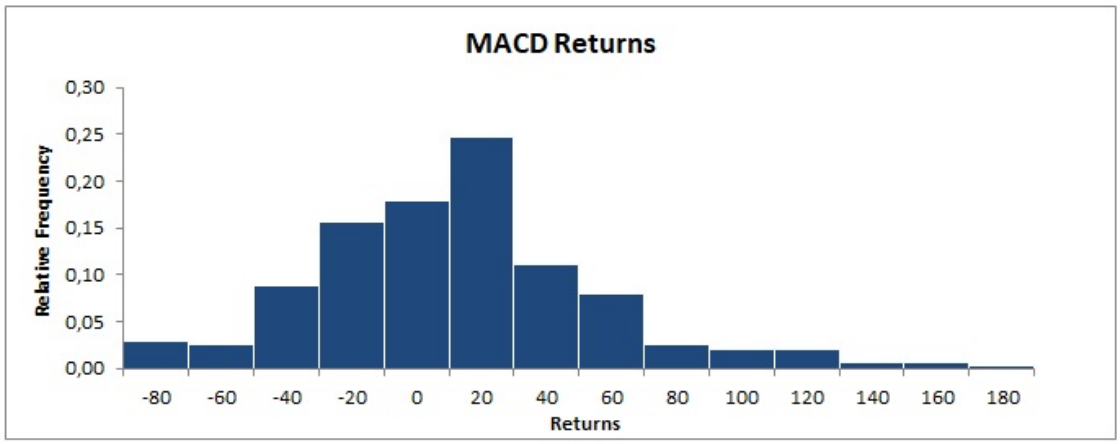

Figure 4.11: Returns Histogram of MACD trading strategy

According with the histogram above, the MACD trading strategy generates average returns between 0 – 20%. With MACD strategy there is about 52% probability to generate positive returns. As before, we also plot in Figure 4.12 the result for the difference between MACD and "Buy and Hold"returns (ordered by the "Buy and Hold" returns), and the histogram for the differences is presented in Figure 4.13.

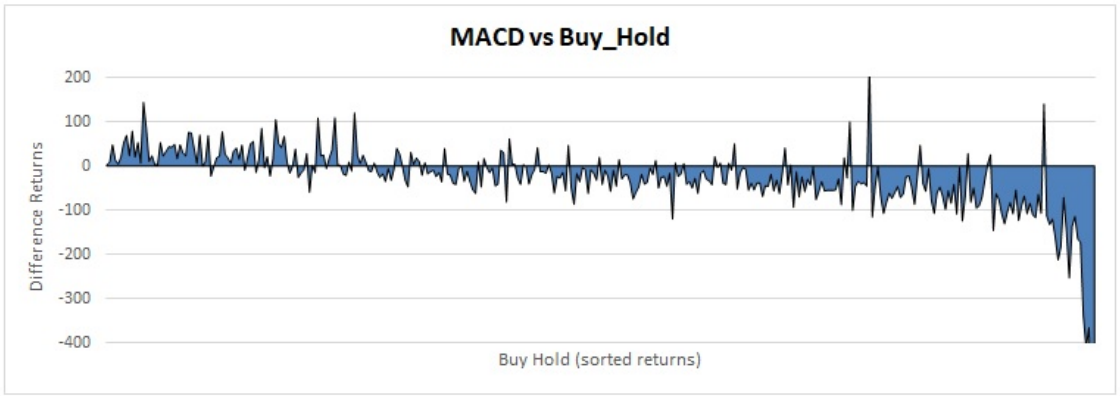

Figure 4.12: Difference between MACD and Buy and Hold strategy sorted by smallest to largest corresponding "Buy and Hold"returns values

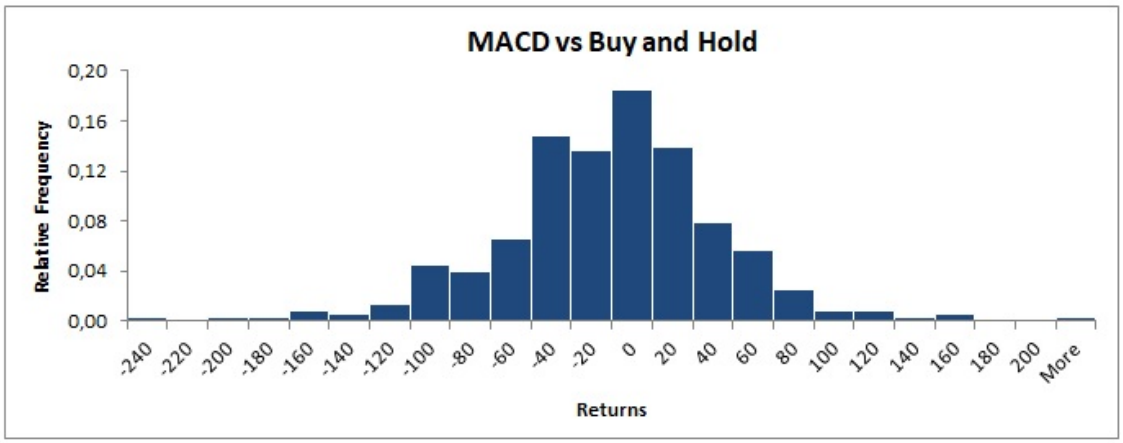

Figure 4.13: Histogram of returns'difference between MACD and Buy and Hold strategy

Looking to "Buy and Hold" lowest returns, the respective MACD returns have an higher performance. However, it's very clear that Buy and Hold approach exceeds by far the MACD strategy, similar results were also obtained in [**16**].

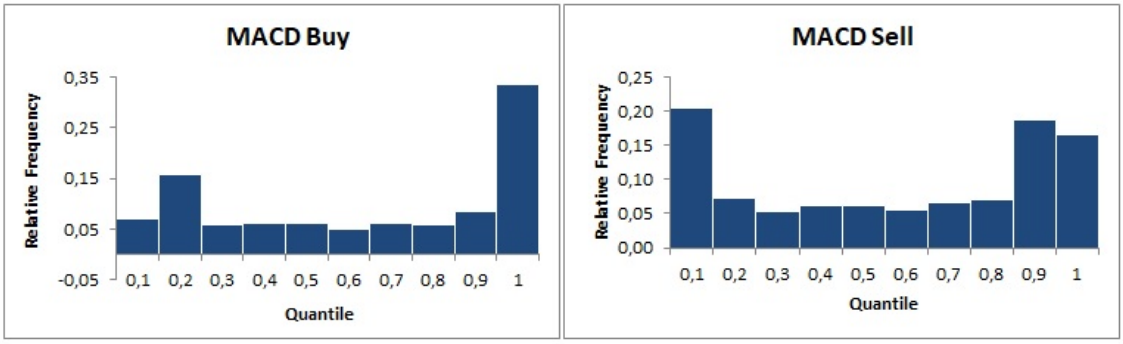

Figure 4.14: Histograms of buy (left) and sell (right) prices'quantiles of MACD trading strategy

The Buy quantile's histogram (Figure 4.14) for MACD trading strategy keep similar results to the trading strategies presented before. For MACD strategy, it's observed that 59% of buying prices are between $0,6 - 1$ quantiles of last quarter's prices. In relation to the selling prices 45% of these are between $0,1 - 0,5$.

4.3 RSI

Finally, the results for the RSI trading strategy (described at 2.2.3 section) will be presented next. First, the histogram for the returns in Figure 4.15 and the plot of the differences between RSI and "Buy and Hold" returns (ordered by the "Buy and Hold" returns) in Figure 4.16.

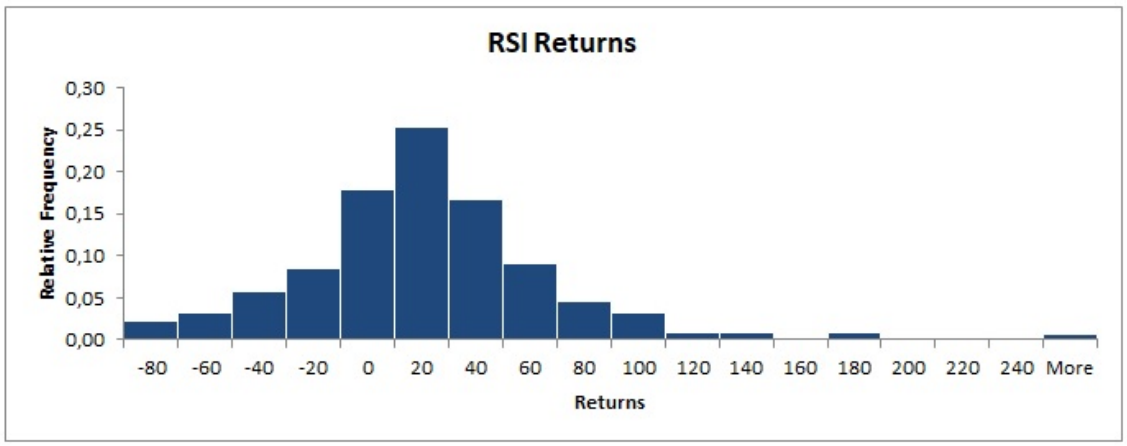

Figure 4.15: Returns Histogram of RSI trading strategy

Like all previous strategies, the RSI trading strategy generates average returns between 0 – 20%. Using RSI trading strategy there is about 63% probability of profit.

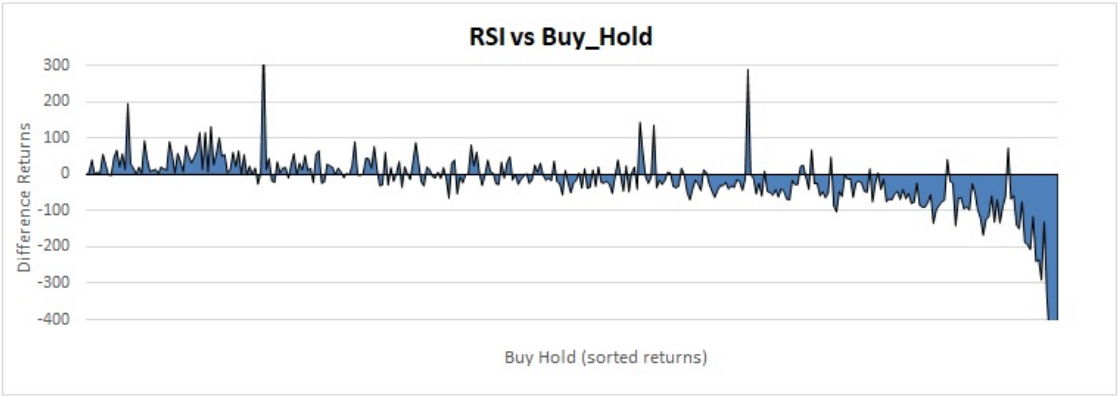

Figure 4.16: Difference between RSI and Buy and Hold strategy sorted by smallest to largest corresponding "Buy and Hold"returns values

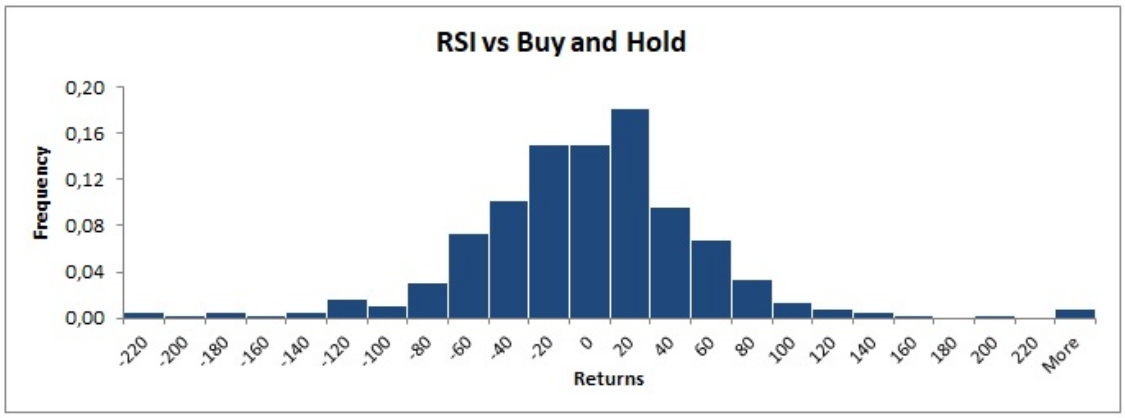

Figure 4.17: Histogram of returns'difference between RSI and Buy and Hold strategy

Comparing the "Buy and Hold" lowest returns with the respective RSI returns, it can be concluded that RSI strategy exceeds the "Buy and Hold"performance.

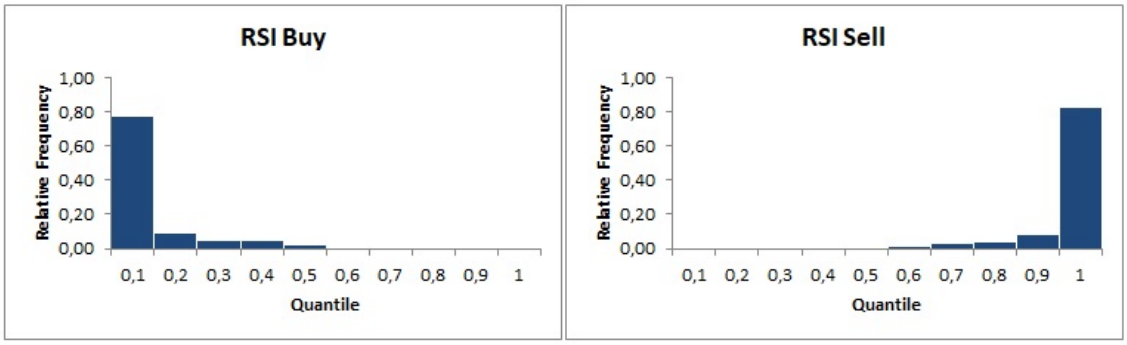

Figure 4.18: Histograms of buy (left) and sell (right) prices'quantiles of RSI trading strategy

This time, the Buy and Sell quantile's histograms for RSI trading strategy are totally different from those that were obtained before. For RSI strategy, it's observed that 93% of buying prices are between $0,1 - 0,3$ quantiles of last quarter's prices. In relation to the selling prices, 95% of these are between $0,8 - 1$.

Regardless the previous results, according with the quantile analysis presented above, the basis idea "buying when price is low, and selling when price is high" is accomplished. However the average returns generated by RSI strategy is not much different in relation to other strategies, and the question now is why (this question will be discussed in next section).

4.4 Comparing Technical Indicators

In this section it will performed the comparison between the trading strategies that were applied until now. And it will be explained the results that were obtained through each strategy.

In Table4.1 a summary regarding the descriptive statistics for the returns for the different trading strategies.

Table 4.1: Summary of trading strategies returns

Returns %	MA_1	MA_2	RSI	MACD	Buy and Hold
Average Return	10,59	13,58	12,85	3,85	31,46
Min	-97,65	-89,83	-99,61	-97,21	-99,76
Max	324,29	377,39	337,79	298,44	735,59
Median	6,68	6,70	8,57	1,04	26,90
1_st Quartile	-23,54	-19,61	-13,05	-26,36	-19,45
3_rd Quartile	30,25	35,73	34,71	24,11	59,16
percentile 5	-63,04	-64,34	-61,69	-61,77	-84,00
percentile 95	103,51	117,48	92,20	86,81	164,56

In Table4.2 we have some information regarding the total number of trades for the all set of the 352 stocks considered.

Table 4.2: Number of trades for each strategy (352 stocks)

Trades	MA_1	MA_2	RSI	MACD
Sell	7513	3885	1294	14380
Buy	7174	3561	1408	14239
Total	14687	7446	2702	28619

Observing Table4.1, it becomes obvious that the MA_2 trading strategy exceeds by far MA_1. However, when we pay attention to the results of quantile's histogram of these strategies, a question comes up: "If buy quantiles are higher in MA_2 than in MA_1 and sell quantiles are lower in MA_2 than in MA_1, how MA_2 generates higher returns?"

Since MA_2 long moving average (66) is slower than MA_1 long moving average (26), the signals generated by the first one will be later than the signals generated by the MA_1 strategy. So, if an up trend starts, this one will be identified, firstly, by MA_1 (buy signal), but, at moment when MA_2 identifies this same trend, the respective buying price will be higher than the buying price of MA_1.

However, in a price series there are "small trends" which doesn't reflect the real price's trend, in last analysis, these "small trends" can lead to false signals. For example, a false

signal happens when a price is rising, but it decreases just for a few sessions, and then, it starts to rising again. In this example, would be generated a false selling signal. The probability to generate a false signal is higher as the lower moving average parameter. In this case, MA_1 has lower parameter values than MA_2, which leads to more signals (Table 4.2), but there are more false signals in MA_1 than in MA_2, therefore, MA_2 has an higher performance. A similar result can be found when we look to the results of quantile's histogram obtained through MACD trading strategy. In this case the returns are the lowest when compared with the other strategies.

Also, looking to the results of Table 4.1 we observe similar average returns that were calculated in [16] (however this returns were obtained for a different period). Examining the results of this table and the quantile's histogram of RSI trading prices (Figure 4.18) it's not logical that the buying and selling prices (trough this strategy) corresponds to the lowest and highest prices of the last quarter, respectively, and still the average returns are very similar to those that were generated by MA_1 and MA_2 strategies. Like it was said before, we will explain why this happens.

It's important to remember that the resulting value of RSI indicator can be seen as a balance between gains and losses for a given time period. If a price series decreases, consistently, for a given time period, the RSI value will be low (buying moment), on the other hand, if price series increases for a long time, RSI value will be high (selling moment). The RSI's problem is, if a price series, for instance, increases for a really long time, after the sell signal, the price will continue to rise, and then we conclude that we sell to early. On Figure 4.19, we can observe an example of the described situation.

Figure 4.19: Example of trading moments through RSI indicator in a highly Bullish stock. Blue line - RSI indicator with n parameter equal to 14; Yellow circle - buy signals and respective buying prices; Red circle - sell signals and respective selling prices

In fact and according with Figure 4.19 we realize that after the selling signal (red circle), the price continues rising up, in this kind of situation, RSI fails because it doesn't allow a new buying. So, through this example we illustrate how in spite of the RSI gives very accurate signals, it doesn't imply higher profits.

Another way to compare each trading strategy performance to the others is examining the returns obtained through each indicator for the same company stock. This analysis can be performed by determining the Median of the difference between trading strategies returns and Buy and Hold returns. The results of this analysis are presented at Table 4.3.

Table 4.3: Median of differences returns

Median Returns	**MA_1**	**MA_2**	**MACD**	**RSI**
Buy and Hold	-15,91	-16,96	-18,64	-10,29

Examining the results of Table 4.3 we conclude that for the most part of the companies that were considered in this study, the trading strategy that generates higher returns, among the trading strategies based in technical indicators, is RSI. On the other hand, once that for all trading strategies the Median of the difference between trading strategie's returns and Buy and Hold returns is negative, it means that for the most part of the companies that were considered Buy and Hold strategy generates higher returns, when compared with the other strategies

To finish, making the comparison between Buy and Hold strategy and the strategies based on technical indicators, we conclude that the keen advantage of strategies based on technical indicators is to reduce losses, or even generate positive returns when any stock, or market are in a Bear phase. However, when the market, or a given stock are in a Bull phase, Buy and Hold strategy generates higher returns.

4.5 Optimized Strategies

After looking to RSI results, we realize that this indicator is highly effective in determining the buying moments, but since the considered trading period corresponds to a Bull phase, by the reason described before, the RSI indicator is not so effective determining the selling moments, because it don't capture the up trend.

In order to design a trading strategy that brings the positive aspects of each technical indicator, in this thesis the RSI indicator was mixed with each one of the indicators presented before (moving averages, and MACD).

More specifically, buy signal is generated when RSI is equals or lower than 30. The sell signal is generated when RSI takes values between 70 and 100 intersected with the MA or MACD selling moment. Having this idea in mind, were designed 3 optimized strategies:

- RSI_MA_26_12 (RSI indicator combined with MA_26_12);
- RSI_MA_66_10 (RSI indicator combined with MA_66_10);
- RSI_MACD (RSI indicator combined with MACD).

In Table 4.4 a descriptive statistics summary for the returns for the optimized strategies is presented.

Table 4.4: Summary of trading strategies results

Returns %	MA_1	MA_2	RSI	MACD	RSI_MA_1	RSI_MACD	RSI_MA_2	B/H
Average Return	10,59	13,58	12,85	3,85	23,81	20,45	25,57	31,46
Min	-97,65	-89,83	-99,61	-97,21	-99,65	-99,69	-99,65	-99,76
Max	324,29	377,39	337,79	298,44	398,53	604,55	493,10	735,59
Median	6,68	6,70	8,57	1,04	19,47	15,45	18,19	26,90
1_st Quartile	-23,54	-19,61	-13,05	-26,36	-18,08	-14,67	-12,97	-19,45
3_rd Quartile	30,25	35,73	34,71	24,11	54,36	44,55	55,57	59,16
percentile 5	-63,04	-64,34	-61,69	-61,77	-77,10	-76,08	-72,48	-84,00
percentile 95	103,51	117,48	92,20	86,81	146,30	138,00	149,85	164,56

Histograms for the returns for each optimized strategy and for the difference from the optimized strategy for the Buy and Hold strategy are presented in Figure 4.20.

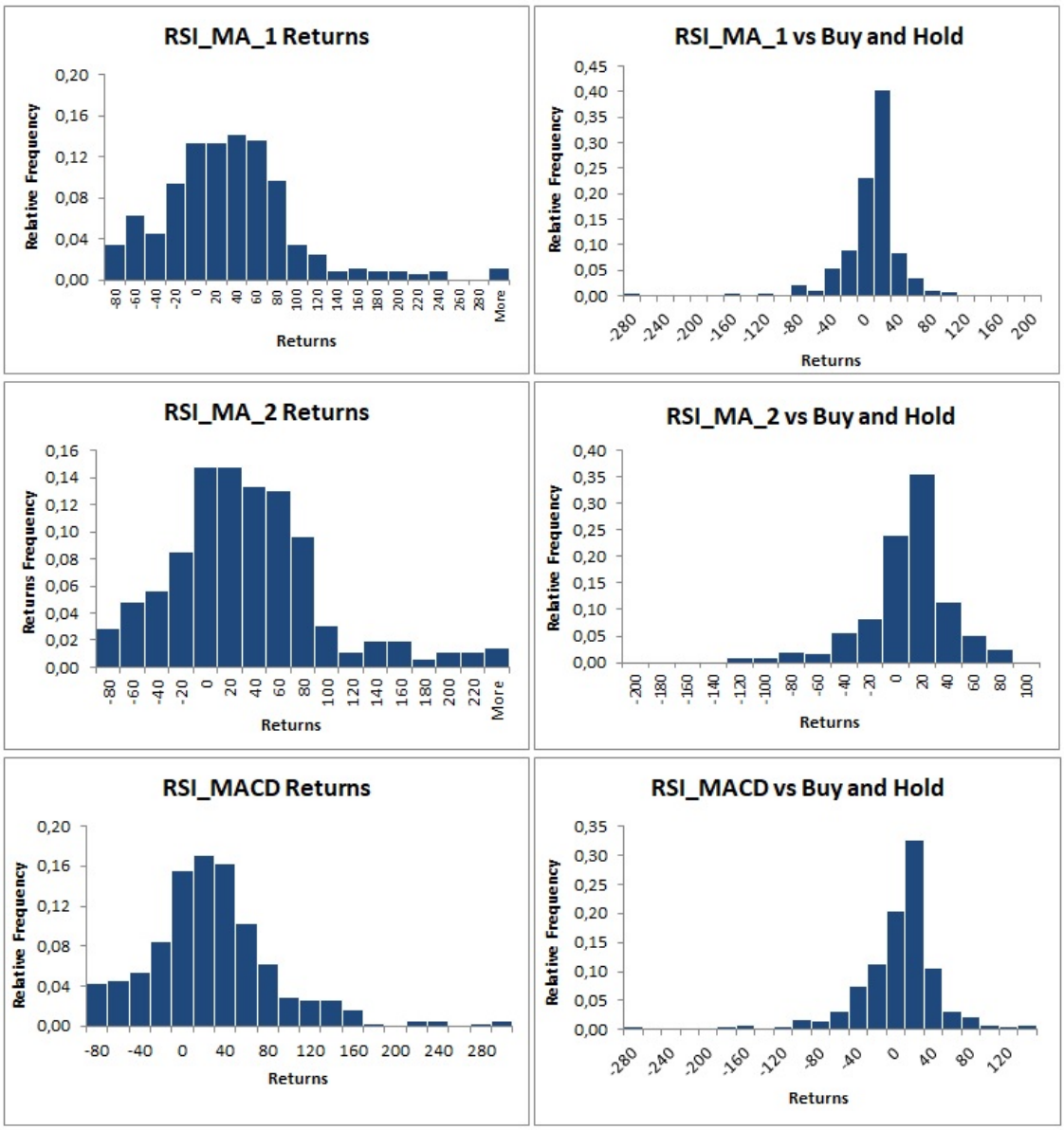

Figure 4.20: On left side are represented the returns histograms of each optimized strategy. On the right side are the histograms of returns'difference between each optimized strategy and Buy and Hold strategy

Observing the Figure 4.20 and Table 4.4, we conclude (by respective returns histogram) that average returns has raised (in relation to average returns obtained by trading strategies that only consider one technical indicator), so in a general way, through optimized strategies the returns are improved.

On the other hand, for Buy and Hold strategy lowest returns, the respective optimized strategies returns have become lower, in relation to those that were obtained by trading strategies that only consider one technical indicator. Looking at Table 4.5 it becomes clear why. Since the number of trades decreases, significantly, the time period between trades

are wider, therefore these optimized strategies adopt a profile that is similar to Buy and Hold strategy.

Finally, it's important to refer that in spite of the optimized strategies generate better results than the original ones, Buy and Hold strategy is still (taking into account the average returns) the most profitable trading strategy. However, Table 4.6 gives us another perspective.

Table 4.5: Number of trades for each optimized strategy (352 stocks)

Trades	RSI_MA_1	RSI_MA_2	RSI_MACD
Sell	212	307	503
Buy	539	631	765
Total	751	938	1268

Another advantage in decreasing the number of trades is the reduction of transactions costs. Looking to optimized trading strategies results, we observe that RSI_MA_1 should be considered the most profitable approach.

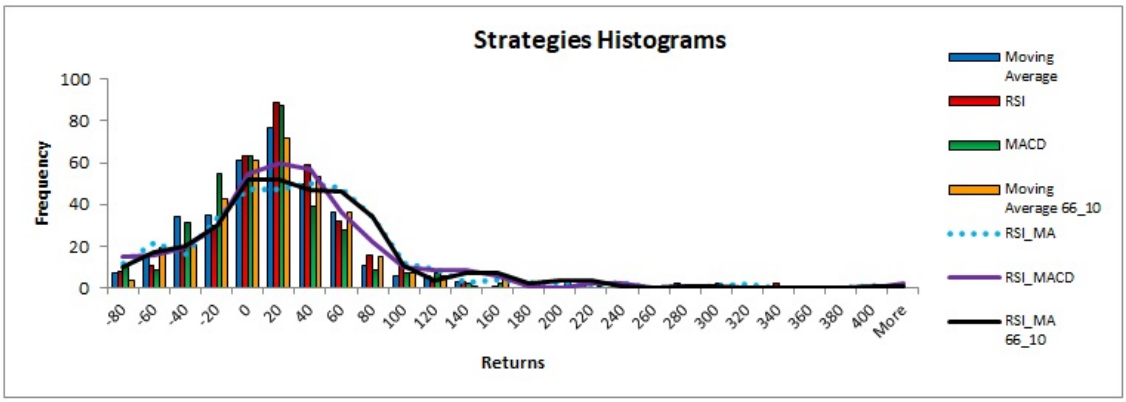

Figure 4.21: Returns'histogram of all trading strategies based in technical indicators

For the optimized strategies, it was also determined the median of the difference between trading strategies returns and Buy and Hold returns. This results are presented in Table 4.6.

Table 4.6: Median of differences returns for optimized strategies

Median Returns	RSI_MA_1	RSI_MA_2	RSI_MACD
Buy and Hold	1,94	1,85	0,26

Like it was said before, Table 4.6 gives us a different perspective, besides the average returns. Notice that when we compute and obtain a positive median for the difference between the returns of any strategy and the Buy and Hold strategy, that means that more than 50% of the observations are positive meaning that for more than half of the stocks the considered strategy delivered higher returns than the Buy and Hold strategy.

According with the table above we realize that for the most part of the companies that were considered in this study, the trading strategy that generates higher returns is RSI_MA_1. This table also adds a new insight about the comparison between trading strategies based in technical indicators and Buy and Hold strategy, because, in spite of Buy and Hold strategy generates higher average returns, the optimized strategies generates higher returns than Buy and Hold for more than 50% of the considered stocks.

Chapter 5

Conclusion

Through the study conducted over this thesis, in a first phase, we conclude that trading strategies based on technical indicators do not outperform the market, since the average returns of Buy and Hold strategy exceeds by far the average returns of other strategies. However, it was observed that for Buy and Hold lowest returns, the corresponding technical indicators returns are higher (this idea is confirmed for all technicals).

Comparing the technical indicators results with themselves we realize two different things: at the returns level, MA_2 trading strategy generates higher returns, however through the quantiles analysis results RSI is the indicator that gives us a more reliable information about the trading points.

Lastly, when we combine the RSI indicator with other technical indicator, it was possible to design an optimized strategy that highlight the advantages of each one technical indicator, resulting into the maximization of returns.

In spite of returns' maximization, the optimized strategies, still, do not outperform the Buy and Hold strategy at the average returns level. But, through a deepier analysis, we observe that for the most part of considered companies, all optimized strategies generated higher returns than Buy and Hold strategy (Table 4.6). It should be pointed out, that these results were obtained for these companies and for this time period. So, results such as average returns could acquire different values if we apply this same approach to other data set.

In a more general note, we agree that technical analysis is valuable tool to follow and understand the market, however defining a trading strategy using only technical

indicators without consider other factors (stocks's selection, macroeconomy), or other methods (risk management or Markov Chains) would be a unresponsible approach.

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Appendix 1

A.1 Trading Strategies' Scripts

Listing A.1: Code section that was used to perform MA's trading strategies

```
tryCatch({
-- Processo de Venda
for(i in 2:length(data_stock_prices_present)){
if(B[i-1]>A[i-1] && B[i]<A[i]){
vector_ordens[i]= "sell"
c_Sell = c_Sell + 1
t_sell[c_Sell]= i
}
else{
vector_ordens[i]= "withdraw"
nada = nada + 1}
}

-- Processo de Compra
for(i in 2:length(data_stock_prices_present)){
if(B[i-1]<A[i-1] && B[i]>A[i]){
vector_ordens[i]= "buy"
c_Buy = c_Buy + 1
t_buy[c_Buy] = i}
}

for(i in 2:length(vector_ordens)){
if(vector_ordens[i]=="sell"){
Conta_cash[i] = Conta_cash[i-1]+Conta_activos[i-1]*data_stock_prices_present[i]
Conta_activos[i] = 0
}
if(vector_ordens[i]=="buy"){
```

```
Conta_cash[i] = Conta_cash[i-1] - 1*Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]+floor(1*Conta_cash[i-1]/data_stock_prices_present[i])
}
if(vector_ordens[i]=="withdraw"){
Conta_cash[i] = Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]}
}
```

Listing A.2: Code section that was used to perform MACD trading strategy

```
tryCatch({

for(i in (length(data_stock_prices_present)-Signal_line_length+2):
length(data_stock_prices_present)){
if(MACD_obtido[i-1]>Signal_line[i-1] && MACD_obtido[i]<Signal_line[i]){
vector_ordens[i]= "sell"
c_Sell = c_Sell + 1
t_sell[c_Sell]= i
}
else{
vector_ordens[i]= "withdraw"
nada = nada + 1}
}

for(i in (length(data_stock_prices_present)-Signal_line_length+2):
length(data_stock_prices_present)){
if(MACD_obtido[i-1]<Signal_line[i-1] && MACD_obtido[i]>Signal_line[i]){
vector_ordens[i]= "buy"
c_Buy = c_Buy + 1
t_buy[c_Buy] = i}
}
for(i in 2:length(vector_ordens)){
if(vector_ordens[i]=="sell"){
Conta_cash[i] = Conta_cash[i-1] + Conta_activos[i-1]*data_stock_prices_present[i]
Conta_activos[i] = 0
}
if(vector_ordens[i]=="buy"){
Conta_cash[i] = Conta_cash[i-1] - 1*Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]+floor(1*Conta_cash[i-1]/data_stock_prices_present[i])
}
if(vector_ordens[i]=="withdraw"){
Conta_cash[i] = Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]}
}
```

Listing A.3: Code section that was used to perform RSI trading strategy

```
Estados_possiveis <- c("sold","bought","neutral") -- Conjunto de Estados possiveis
State <- Estados_possiveis[3] -- Estado inicial (Neste caso comprado)

tryCatch({
for(i in (T_media+1):length(A)){

if(A[i]>=70 && (State=="bought"||State=="neutral")){
vector_ordens[i]= "sell"
State = "sold"
c_Sell = c_Sell + 1
t_sell[c_Sell]= i
}
else{

if(A[i]<=30 && (State=="sold"||State=="neutral")){
vector_ordens[i]= "buy"
State = "bought"
c_Buy = c_Buy + 1
t_buy[c_Buy] = i
}

else{
vector_ordens[i]= "withdraw"
nada = nada + 1}
}
}

for(i in 2:length(vector_ordens)){
if(vector_ordens[i]=="sell"){
Conta_cash[i] = Conta_cash[i-1] + Conta_activos[i-1]*data_stock_prices_present[i]
Conta_activos[i] = 0
}
if(vector_ordens[i]=="buy"){
Conta_cash[i] = Conta_cash[i-1] - 1*Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]+ floor(1*Conta_cash[i-1]/data_stock_prices_present[i])
}
if(vector_ordens[i]=="withdraw"){
Conta_cash[i] = Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]}
}
```

Listing A.4: Code section that was used to perform RSI_MA's trading strategy

```
Estados_possiveis <- c("sold","bought","neutral") -- Conjunto de Estados possiveis
State <- Estados_possiveis[3] -- Estado inicial (Neste caso comprado)

tryCatch({
for(i in (T_media+1):length(A)){
- Processo de Venda
if(A[i]>=70 && (State=="bought"||State=="neutral") && (MovA_Slow[i]>MovB_Fast[i])){
vector_ordens[i]= "sell"
State = "sold"
c_Sell = c_Sell + 1
t_sell[c_Sell]= i}

else{
if(A[i]<=30 && (State=="sold"||State=="neutral")){
vector_ordens[i]= "buy"
State = "bought"
c_Buy = c_Buy + 1
t_buy[c_Buy] = i}

else{
vector_ordens[i]= "withdraw"
nada = nada + 1}
}
}

for(i in 2:length(vector_ordens)){
if(vector_ordens[i]=="sell"){
Conta_cash[i] = Conta_cash[i-1] + Conta_activos[i-1]*data_stock_prices_present[i]
Conta_activos[i] = 0
}
if(vector_ordens[i]=="buy"){
Conta_cash[i] = Conta_cash[i-1] - 1*Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]+ floor(1*Conta_cash[i-1]/data_stock_prices_present[i])
}
if(vector_ordens[i]=="withdraw"){
Conta_cash[i] = Conta_cash[i-1]
Conta_activos[i] = Conta_activos[i-1]}
}
```

A.2 Returns Calculation Script

Listing A.5: Code section that was used to perform RSI_MA's trading strategy

```
Valor_inicial = Conta_cash[1]+(Conta_activos[1]*data_stock_prices_present[1])

Valor_final = Conta_activos[length(Conta_activos)]*
data_stock_prices_present[length(data_stock_prices_present)]+Conta_cash[length(Conta_cash)]

Serie_retornos[j]= (Valor_final/Valor_inicial)*100

Buy_hold[j]= 100*(floor(1*Conta_cash[1]/(data_stock_prices_present[1]))*
data_stock_prices_present[length(data_stock_prices_present)])/(1*Conta_cash[1])
}
```

APPENDIX B

Appendix 2

B.1 List of Stocks

Table B.1: List of Stocks

Ticker	Name	Ticker	Name
AAPL	Apple Inc.	AMKR	Amkor Technology, Inc.
AMZN	Amazon.com, Inc.	AEIS	Advanced Energy Industries, Inc.
GOOG	Alphabet Inc.	CENX	Century Aluminum Company
AMAT	Applied Materials, Inc.	ASPS	Altisource Portfolio Solutions S.A.
MBWM	Mercantile Bank Corporation	BPOPM	Popular Capital Trust II
INDB	Independent Bank Corp.	OPB	Opus Bank
GBCI	Glacier Bancorp, Inc.	SBBP	Strongbridge Biopharma plc
FBIZ	First Business Financial Services, Inc.	OSBCP	Old Second Capital Trust I
EPAY	Bottomline Technologies (de), Inc.	EQBK	Equity Bancshares, Inc.
TCBIP	Texas Capital Bancshares, Inc.	CTBI	Community Trust Bancorp, Inc.
TBBK	The Bancorp, Inc.	BANFP	BFC Capital Trust II
RCKY	Rocky Brands, Inc.	HBANO	Huntington Bancshares Incorporated
MCBC	Macatawa Bank Corporation	MSFT	Microsoft Corporation
GBNK	Guaranty Bancorp	INTC	Intel Corporation
DCOM	Dime Community Bancshares, Inc.	CSCO	Cisco Systems, Inc.
BANX	StoneCastle Financial Corp.	CMCSA	Comcast Corporation
UBSI	United Bankshares, Inc.	SBUX	Starbucks Corporation
TBK	Triumph Bancorp, Inc.	COST	Costco Wholesale Corporation
RBCAA	Republic Bancorp, Inc.	CATM	Cardtronics plc
MRLN	Marlin Business Services Corp.	NVDA	NVIDIA Corporation
FFIN	First Financial Bankshares, Inc.	FTR	Frontier Communications Corporation
COLB	Columbia Banking System, Inc.	CELG	Celgene Corporation
PWOD	Penns Woods Bancorp, Inc.	ETFC	E*TRADE Financial Corporation
PMBC	Pacific Mercantile Bancorp	SYMC	Symantec Corporation
PACW	PacWest Bancorp	DISH	DISH Network Corporation

Table B.2: List of Stocks (continuation)

Ticker	Name	Ticker	Name
ESSA	ESSA Bancorp, Inc.	CERN	Cerner Corporation
AMGN	Amgen Inc.	AMAG	AMAG Pharmaceuticals, Inc.
AAL	American Airlines Group Inc.	ALKS	Alkermes plc
ADBE	Adobe Systems Incorporated	AAON	AAON, Inc.
GOOGL	Alphabet Inc.	VRSK	Verisk Analytics, Inc.
ADP	Automatic Data Processing, Inc.	ALSK	Alaska Communications Systems Group, Inc.
AKAM	Akamai Technologies, Inc.	ACTG	Acacia Research Corporation
ATVI	Activision Blizzard, Inc.	ATHN	athenahealth, Inc.
ADSK	Autodesk, Inc.	ARWR	Arrowhead Pharmaceuticals, Inc.
WBA	Walgreens Boots Alliance, Inc.	ANGI	Angie's List, Inc.
ARNA	Arena Pharmaceuticals, Inc.	ALGN	Align Technology, Inc.
ACAD	ACADIA Pharmaceuticals Inc.	GLPI	Gaming and Leisure Properties, Inc.
ALXN	Alexion Pharmaceuticals, Inc.	ARRS	ARRIS International plc
AVGO	Broadcom Limited	AMCX	AMC Networks Inc.
EA	Electronic Arts Inc.	PAAS	Pan American Silver Corp.
AMBA	Ambarella, Inc.	APOG	Apogee Enterprises, Inc.
LULU	Lululemon Athletica Inc.	ANDE	The Andersons, Inc.
AGNC	AGNC Investment Corp.	AMSC	American Superconductor Corporation
JBLU	JetBlue Airways Corporation	AMRS	Amyris, Inc.
ORLY	O'Reilly Automotive, Inc.	AMED	Amedisys, Inc.
ACOR	Acorda Therapeutics, Inc.	ALCO	Alico, Inc.
ADI	Analog Devices, Inc.	ADUS	Addus HomeCare Corporation
ACIW	ACI Worldwide, Inc.	AAWW	Atlas Air Worldwide Holdings, Inc.
AMTD	TD Ameritrade Holding Corporation	MDRX	Allscripts Healthcare Solutions, Inc.
ARCC	Ares Capital Corporation	KLIC	Kulicke and Soffa Industries, Inc.
AGIO	Agios Pharmaceuticals, Inc.	AZPN	Aspen Technology, Inc.
ARLP	Alliance Resource Partners, L.P.	GIII	G-III Apparel Group, Ltd.
ALNY	Alnylam Pharmaceuticals, Inc.	DAVE	Famous Dave's of America, Inc.
AINV	Apollo Investment Corporation	AREX	Approach Resources, Inc.
ACHN	Achillion Pharmaceuticals, Inc.	ANSS	Ansys, Inc.
ACET	Aceto Corporation	AMNB	American National Bankshares Inc.
ABMD	ABIOMED, Inc.	ADTN	ADTRAN, Inc.
LIFE	aTyr Pharma, Inc.	ACLS	Axcelis Technologies, Inc.
ADXS	Advaxis, Inc.	HOLI	HollySys Automation Technologies, Ltd.
SAVE	Spirit Airlines, Inc.	ATAX	America First Multifamily Investors, L.P.
AKRX	Akorn, Inc.	DOX	Amdocs Limited
ASML	ASML Holding N.V.	AVID	Avid Technology, Inc.
CAR	Avis Budget Group, Inc.	ASNA	Ascena Retail Group, Inc.
JKHY	Jack Henry & Associates, Inc.	ARAY	Accuray Incorporated
AVAV	AeroVironment, Inc.	AMBC	Ambac Financial Group, Inc.
ALGT	Allegiant Travel Company	AIMC	Altra Industrial Motion Corp.
ACHC	Acadia Healthcare Company, Inc.	ATRA	Atara Biotherapeutics, Inc.
TA	TravelCenters of America LLC	ATEC	Alphatec Holdings, Inc.
MANH	Manhattan Associates, Inc.	ARII	American Railcar Industries, Inc.
LAMR	Lamar Advertising Company	ANAT	American National Insurance Company
ATRO	Astronics Corporation	ACRS	Aclaris Therapeutics, Inc.
ATNI	ATN International, Inc.	ABDC	Alcentra Capital Corporation
APEI	American Public Education, Inc.	GABC	German American Bancorp, Inc.
ANIK	Anika Therapeutics, Inc.	ASFI	Asta Funding, Inc.
ANGO	AngioDynamics, Inc.	ASCMA	Ascent Capital Group, Inc.
AEGN	Aegion Corporation	TEAM	Atlassian Corporation Plc
WRLD	World Acceptance Corporation	FWP	Forward Pharma A/S
UHAL	AMERCO	CHY	Calamos Convertible and High Income Fund
CACC	Credit Acceptance Corporation	ADAP	Adaptimmune Therapeutics plc

Table B.3: List of Stocks (continuation)

Ticker	Name	Ticker	Name
ATSG	Air Transport Services Group, Inc.	PRTS	U.S. Auto Parts Network, Inc.
AROW	Arrow Financial Corporation	BRKS	Brooks Automation, Inc.
ARCB	ArcBest Corporation	ASYS	Amtech Systems, Inc.
AMRK	A-Mark Precious Metals, Inc.	AMPH	Amphastar Pharmaceuticals, Inc.
ALRM	Alarm.Com Holdings, Inc.	ABUS	Arbutus Biopharma Corporation
USAP	Universal Stainless Alloy Products Inc	FWRD	Forward Air Corporation
STFC	State Auto Financial Corporation	AGFS	AgroFresh Solutions, Inc.
SEED	Origin Agritech Limited	ACBI	Atlantic Capital Bancshares, Inc.
BREW	Craft Brew Alliance, Inc.	MPAA	Motorcar Parts of America, Inc.
AUDC	AudioCodes Ltd.	AXTI	AXT, Inc.
ATRI	Atrion Corporation	ASTE	Astec Industries, Inc.
AOSL	Alpha and Omega Semiconductor Limited	ASND	Ascendis Pharma A/S
AMWD	American Woodmark Corporation	CHI	Calamos Opportunities and Income Fund
ACGL	Arch Capital Group Ltd.	AGNCB	AGNC Investment Corp.
ABCB	Ameris Bancorp	AIMT	Aimmune Therapeutics, Inc.
RAIL	FreightCar America, Inc.	NBRV	Nabriva Therapeutics plc
ARTNA	Artesian Resources Corporation	FSAM	Fifth Street Asset Management Inc.
ADRO	Aduro BioTech, Inc.	BIDU	Baidu, Inc.
KALU	Kaiser Aluminum Corporation	BIIB	Biogen Inc.
HOMB	Home Bancshares, Inc. (Conway, AR)	BBBY	Bed Bath & Beyond Inc.
ATLC	Atlanticus Holdings Corporation	MNST	Monster Beverage Corporation
AMSWA	American Software, Inc.	FITB	Fifth Third Bancorp
AMSF	Amerisafe, Inc.	CNBKA	Century Bancorp, Inc.
ALLT	Allot Communications Ltd.	CBRL	Cracker Barrel Old Country Store, Inc.
AGYS	Agilysys, Inc.	BMRN	BioMarin Pharmaceutical Inc.
CCD	Calamos Dynamic Convertible and Income Fund	HBAN	Huntington Bancshares Incorporated
AVNW	Aviat Networks, Inc.	PDLI	PDL BioPharma, Inc.
AMCN	AirMedia Group Inc.	BGCP	BGC Partners, Inc.
OMAB	Grupo Aeroportuario del Centro Norte, S. A. B. de C. V.	EGLE	Eagle Bulk Shipping Inc.
CRMT	America's Car-Mart, Inc.	PACB	Pacific Biosciences of California, Inc.
CRESY	Cresud Sociedad Comercial, Inmobiliaria	BKCC	BlackRock Capital Investment Corporation
DNKN	Dunkin' Brands Group, Inc.	SBCF	Seacoast Banking Corporation of Florida
BPOP	Popular, Inc.	ROLL	RBC Bearings Incorporated
PBYI	Puma Biotechnology, Inc.	HTBI	HomeTrust Bancshares, Inc.
BLUE	bluebird bio, Inc.	GBDC	Golub Capital BDC, Inc.
ICON	Iconix Brand Group, Inc.	FIZZ	National Beverage Corp.
FIBK	First Interstate BancSystem, Inc.	FCNCA	First Citizens BancShares, Inc.
EWBC	East West Bancorp, Inc.	BMTC	Bryn Mawr Bank Corporation
BCRX	BioCryst Pharmaceuticals, Inc.	BLKB	Blackbaud, Inc.
BCPC	Balchem Corporation	BBSI	Barrett Business Services, Inc.
SBGI	Sinclair Broadcast Group, Inc.	BABY	Natus Medical Incorporated
BRKR	Bruker Corporation	CBSH	Commerce Bancshares, Inc.
BOKF	BOK Financial Corporation	BUSE	First Busey Corporation
VIVO	Meridian Bioscience, Inc.	BRKL	Brookline Bancorp, Inc.
ONB	Old National Bancorp	BOJA	Bojangles', Inc.
COKE	Coca-Cola Bottling Co. Consolidated	BEAT	BioTelemetry, Inc.
BJRI	BJ's Restaurants, Inc.	WASH	Washington Trust Bancorp, Inc.
BCOR	Blucora, Inc.	WABC	Westamerica Bancorporation
UBSH	Union Bankshares Corporation	UCBI	United Community Banks, Inc.
TCBI	Texas Capital Bancshares, Inc.	PPBI	Pacific Premier Bancorp, Inc.
SGMO	Sangamo Therapeutics, Inc.	NBTB	NBT Bancorp Inc.
RRGB	Red Robin Gourmet Burgers, Inc.	INBK	First Internet Bancorp
LCUT	Lifetime Brands, Inc.	CSFL	CenterState Banks, Inc.
IBTX	Independent Bank Group, Inc.	CATY	Cathay General Bancorp
FFBC	First Financial Bancorp.	BLMN	Bloomin' Brands, Inc.
BZUN	Baozun Inc.	WIFI	Boingo Wireless, Inc.
BGFV	Big 5 Sporting Goods Corporation	LOB	Live Oak Bancshares, Inc.
SASR	Sandy Spring Bancorp, Inc.	IBCP	Independent Bank Corporation
NXST	Nexstar Media Group, Inc.	FARM	Farmer Bros. Co.
ZION	Zions Bancorporation	EBSB	Meridian Bancorp, Inc.
VRA	Vera Bradley, Inc.	CCBG	Capital City Bank Group, Inc.
SFBS	ServisFirst Bancshares, Inc.	BELFB	Bel Fuse Inc.

Table B.4: List of Stocks (continuation)

Ticker	Name	Ticker	Name
SBNY	Signature Bank	UBNK	United Financial Bancorp, Inc.
JBSS	John B. Sanfilippo & Son, Inc.	TRST	TrustCo Bank Corp NY
JACK	Jack in the Box Inc.	TOWN	TowneBank
BBOX	Black Box Corporation	TBNK	Territorial Bancorp Inc.
TECH	Bio-Techne Corporation	NWBI	Northwest Bancshares, Inc.
NRIM	Northrim BanCorp, Inc.	NFBK	Northfield Bancorp, Inc. (Staten Island, NY)
IBKR	Interactive Brokers Group, Inc.	MNRO	Monro Muffler Brake, Inc.
NBIX	Neurocrine Biosciences, Inc.	LBAI	Lakeland Bancorp, Inc.
FMBI	First Midwest Bancorp, Inc.	CBPO	China Biologic Products Holdings, Inc.
FIVE	Five Below, Inc.	BSRR	Sierra Bancorp
CNOB	ConnectOne Bancorp, Inc.	BPFH	Boston Private Financial Holdings, Inc.
CALA	Calithera Biosciences, Inc.	BLDR	Builders FirstSource, Inc.
SBLK	Star Bulk Carriers Corp.	BIOS	BioScrip, Inc.
BDGE	Bridge Bancorp, Inc.	BPMC	Blueprint Medicines Corporation
BCOM	B Communications Ltd	UBFO	United Security Bancshares
BANF	BancFirst Corporation	RVSB	Riverview Bancorp, Inc.
TRIB	Trinity Biotech plc	PEBO	Peoples Bancorp Inc.
SVA	Sinovac Biotech Ltd.	HWBK	Hawthorn Bancshares, Inc.
PFBC	Preferred Bank	HBCP	Home Bancorp, Inc.
IBOC	International Bancshares Corporation	GNBC	Green Bancorp, Inc.
GSBC	Great Southern Bancorp, Inc.	FCBC	First Community Bancshares, Inc.
STBA	S&T Bancorp, Inc.	EBTC	Enterprise Bancorp, Inc.
SBSI	Southside Bancshares, Inc.	BFIN	BankFinancial Corporation
PLAY	Dave & Buster's Entertainment, Inc.	BECN	Beacon Roofing Supply, Inc.
OSBC	Old Second Bancorp, Inc.	WTBA	West Bancorporation, Inc.
LBRDA	Liberty Broadband Corporation	TCBIL	Texas Capital Bancshares, Inc.
ISBC	Investors Bancorp, Inc.	SYBT	Stock Yards Bancorp, Inc.
FNLC	The First Bancorp, Inc.	CBSHP	Commerce Bancshares, Inc.
BSET	Bassett Furniture Industries, Incorporated	BNCL	Beneficial Bancorp, Inc.
BOOM	DMC Global Inc.	BGNE	BeiGene, Ltd.
BHBK	Blue Hills Bancorp, Inc.	BELFA	Bel Fuse Inc.
BCOV	Brightcove Inc.	LBRDK	Liberty Broadband Corporation
BANR	Banner Corporation	HBNC	Horizon Bancorp
TCBK	TriCo Bancshares	FITBI	Fifth Third Bancorp
SHBI	Shore Bancshares, Inc.	FBNC	First Bancorp