Algorithmic Trading & Market Micro-structure

Group Project

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Three Moving Average Crossover (MAC) and On-Balance-Volume (OBV) Algorithms Analysis

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1. Introduction

This report was elaborated in the Algorithm Trading and Market Microstructure curricular unit of the post-graduation in Data Science for Finance at Nova Information Management School. The aim of this project is to use two Algorithm trading strategies, Three Moving Average Crossover Algorithm and On-Balance Volume (OBV) Stock Trading Strategy to determine when to buy and sell stock and analyze the performance of these strategies, in a simulation, using the information of 10 stock prices data during 1 year.

This report starts by presenting a description of the Algorithms and the strategy behind them. Subsquently the model assumptions and dataset are clarified as well as the methodology used. Afterwards, the results and its analasys are presented and lastly, conclusions on the algorihms efficacy are drawn.

Apart from this report, this project contains three other documents that were developed:

- Algo_Project_Code.ipynb – Python document with the two algorithm demonstration code for Tesla, Inc. (TSLA)
- Dataset.xlsx – Excel document containing the market data on the 10 stocks necessary to run the code in Python for both algorithms;
- Results.xlsx – Excel document with the detailed results summary and detailed results per stock and per strategy.

2. Algorithms Presentation

2.1 Three Moving Average Crossover (MAC)

2.1.1 Moving Average Indicator

Moving averages are an indicator used in technical analysis that provides traders and investors with historical information on the price movements of a security. By computing the average, we are able to cancel out the noise from volatility fluctuation and obtain a smoothed and more easily interpretable trend. Moving averages are said to be lagging indicators because they analyze the trailing performance of a security and the trends obtained by plotting moving averages provide signals on future performance and can be used as a basis for buy or sell decisions (Mitchell, 2021).

There are two types of moving averages widely used in technical analysis: simple moving average (SMA) and exponential moving average (EMA) for data points such as the open, close, high or low prices (Mitchell, 2021).

The SMA is a moving average simply based on obtaining the sum of data points over a given period and dividing it by the number of points. On the other hand, the EMA is based on giving weights to each price points, with the most recent ones being given the highest weights. This

method gives more sensitivity to the latest observations in order to be more responsive to the most recent changes in the market or in the performance of the security. Its computation is based on obtaining the SMA and computing the weight (or multiplier) for each period as follows (Mitchell, 2021) :

Multiplier = [2 / (N + 1)] where **N** refers to the number of periods to be included in the EMA

Current EMA = [Closing Price – EMA (Previous Time Period)] x Multiplier + EMA (Previous Time Period)

Moving averages are important indicators that can allow traders to visualize the direction towards which the price of a stock is heading and to draw strategies in order to take decisions regarding buy or sell decisions, entering or leaving a certain market or taking advantage of momentum. Strategies based on moving averages mainly consist in comparing the current price of a security and its movements with their historical moving averages (Woods, 2021).

The direction of the trend is an important point of comparison. When the current price movement follows the trend up or down, the market is said to be trending in a bullish or bearish way. Otherwise, if the current movement opposed the trend, the market is known to be reversing (Woods, 2021).

The slope of the MA trend is also to be kept in mind when analyzing MA indicators. Usually, when the slope of the trend is steep, it signals the end of a bearish or bullish trend, meanwhile a flat slope could suggest a sideways market where no clear pattern is clear, or the beginning of a bullish or bearish trend (Woods, 2021).

The distance between the current prices and the trend line also give indications on the state of the market. When prices cross the threshold up or down, it signals traders to either buy or sell the security. Moreover, moving averages can act as support or resistance thresholds during upward and downward trends. During upward trends, traders may expect prices to bounce off the support level and resume climbing and vice-versa for downward trends and resistance levels (Woods, 2021).

There exhists many trading strategies based on moving averages. In this study, we chose to take a closer look at the Three Moving Average Crossover (TMAC) Trading Strategy and its algorithmic and numerical implementation.

2.1.2 Three Moving Average Crossover

The TMAC, as its name suggests, is based on three moving averages; short, medium and long term. The moving average can be either simple or exponential and the time frames for the three MA can be chosen at the discretion of the trader and are usually modified based on the results obtained from the strategy. The strategy consist of comparing the short, medium and long term trends of historical performance and base buy or sell decisions on these trends.

As mentioned previously, observing the three MA can give indications on the state of the market. The following scenarios are examples of how MA indicators can give signals to traders (Burns, 2020):

- if the short term MA pulls away from the two other indicators, it could signal short term momentum, while if the long term MA is above the others, we are losing momentum,
- If the price movement falls below the long term trend, we are probably observing a market downturn,
- If price falls below all three MA trends, then the market is both becoming bearish and losing short term momentum,
- when the three MA are aligned, the market is strongly trending in a bearish or bullish way.

2.1.3 Three Moving Average Crossover Use

The comparison between the three trends can lead to buy or sell strategies as seen through the following (Burns, 2020):

- If the short term MA crosses over the medium term MA, both above the long-term trend, we can expect an strongly upward trading market which signals long entry potential.
- If the short term MA crosses below the medium term MA, both below the long-term trend, we can expect an strongly downward trading market which signals short selling potential.
- If the short term MA crosses above the medium term MA, both below the long-term trend, we can expect the trend to resume an upward trend after a downside period which signals long buy potential.
- If the short term MA crosses below the medium term MA, both above the long-term trend, we can expect the trend to resume a downward trend after an upside period which signals short selling potential.
- A price crossover of all three MA is a strong signal of a bullish market, while a price cross under shows a strongly bearish market.

These three averages are therefore reliable indicators of current momentum, as the short term trend gives indications on whether the historical trends are set to be maintained or if we are observing a shift in the market. By plotting charts of their trends, traders and investors can highlight points of entry into or exit of the market or value regions where trades could be reverted for a profit. In the next parts of this report, we will perform a numerical analysis of this strategy and compare its performance to the On-Balance Volume (OBV) Stock Trading Strategy, described next.

2.2 On-Balance-Volume (OBV)

In the world of trading, technical analysis traders have a lot of indicators to choose from. In the indicator’s category, there is a momentum subcategory with several indicators inside; one of the popular options here is called the "On-Balanced Volume" indicator or OBV for short. It uses volume flow information to and retail investors are present on the market and to distinguish the volume generated by either one of those groups. If, for instance, the volume increases, but the price remains relatively flat, at first, it is considered a sign that pension and mutual funds might be buying instruments that retail help the trader make better predictions of stock price or asset changes. Another way to look at the OBV indicator is in the perspective of a tool that reflects how the crowd sentiment predicts the bullish or bearish market outcomes. Alternatively, we can call it a measure of the buying and selling pressure that is currently being employed on the market.

The indicator was introduced by Joseph Granville back in 1963. Joseph published the concept in his book "New Kye to Stock Market Profits". The concept behind the indicator is based on the idea that an increase in trading volume, even if it does not affect the price at first, at some point, it will. The price will then go up or down, depending on what types of orders prevail. This indicator is widely popular, despite the market manipulation attacks felt on volume-based indicators, towards the later portion of market development. Nowadays, traders still use the OBV as a tool to help them find out when institutional investors are selling. Once the price follows and the volume goes up, institutional investors might start selling, while retail investors start buying, for example.

2.2.1 How On-Balanced Volume works

To understand the OBV indicator, we must take a deep look at it. Let's start by saying that the OBV is a cumulative indicator which means that whenever a change in the instrument's price exists, the volume is adjusted in the cumulative OBV total. For example, if the price increases, the volume is added to the OBV, while, if the price drops, the volume is subtracted. There is also a third scenario where the price remains stable, and no volume is added or subtracted. Depending on the market status, the value of the OBV can be either positive or negative. Positive values are recorded when today's price exceeds the previous day's closing price, while negative values appear when today's price is below yesterday's closing price. The OBV indicator can also be seen as an oscillator around the zero line. However, because of the way this indicator works, traders, usually, don’t care much about its numerical value, on the other hand, they look at the nature of the indicator's movement and the slope of the line itself.

Figure 1 - OBV indicator (source: Wikipedia)

The image above, shows the OBV line oscillating back and forth between its numerical values. The line goes up and down innumerable times, but traders are generally focusing on the degree of the slope of the line, instead of an exact numerical value.

2.2.2 Calculation

The formula used to calculate the On Balanced Volume indicator is given by the following equation:

$$OBV = OBVprev \pm trading\ volume$$

Where the current level for the on-balance volume indicator is given by the level for the on-balance volume indicator for the previous day aggregated with the latest trading volume that can be positive, negative or zero.

2.2.3 Using On-Balance Volume

The most common usages of the OBV indicator in today's trading markets is to use it as a tool to help identify trend conformations, trend reversals and oversold or overbought scenarios in the market. These are the most common purposes that traders try to achieve with the OBV indicator. Traders using OBV try to spot the institutional and small investors presence; in practical terms, we can see how we might, theoretically, be able to capitalize on this. If divergences are spotted between the price of an asset and the volume, this divergence can help technical traders potentially recognize two upcoming market movements:

1. Spot price decreases – when the trading volume goes down without a simultaneous price decrease.
2. Spot price increases – when the trading volume goes up without a simultaneous price increase.

If such situations are observed, we can potentially take this as a sign of an opportunity to buy or sell against incorrect prevailing trends. One of the most basic ways that we could, in theory, capi-

talize on these, would be by looking to sell when we see the volume going down without being followed by an immediate drop in price or the other way around, to buy when we see the trading volume going up without a follow-up price jump.

3. Assumptions

To test the capacity of delivering excess returns by each algorithm, several assumptions were made to homogenize the conditions so that it becomes possible to perform an unbiased analysis.

The first assumption is related with the time frame. In fact, it was considered one year as the interval used to test the algorithms performance.

This one year period begins on the 1st June 2020 and ends on the 28th May 2021. At the latter date mentioned, the long positions must be closed if not already closed. This strong assumption was made to set a clear investment period in order to create equal conditions and to bring the model closer to reality in which usually individuals and companies have liquidity constraints and need liquid money to fund their activities.

The second assumption is concerned with the trading costs to perform a buy or a sell operation in the market. Those were considered to be 0.001 (0.1%) of the invested capital.

The following assumption states that the invested capital which was considered to be 100% of the available capital at each moment considering capital appreciated and losses, being the initial capital USD 1 000 000.

The last assumption clarifies that short selling is not allowed and thus the first trading order must be on buy side and the last one on sell side. Actually the algorithms designed intercalate buy and sell positions, meaning after a buy position the next market order will be on sell side.

4. Dataset

The dataset used is possible to be visualized in the attached Excel document named “Dataset.xlsx”. It comprises the daily spot values and traded volume observed during the period that goes from the 1st June 2020 to the 28th May 2021 of the ten selected companies.

The selected companies were:

- Tesla, Inc. (TSLA)
- Amazon.com, Inc. (AMZN)
- The Walt Disney Company (DIS)
- Walmart Inc. (WMT)
- Pfizer Inc. (PFE)
- GameStop Corp. (GME)

- JPMorgan Chase & Co. (JPM)
- Carnival Corporation & plc (CCL)
- NextEra Energy, Inc. (NEE)
- Caterpillar Inc. (CAT)

The criteria used to choose the companies which integrate the data set had three conditions.

The first was the company stock being traded in USD and in US Exchanges to try to guarantee that the daily price fluctuations are business related and not currency related.

The second condition was the selection of companies that operate in different industries to test the adaptability of the algorithms.

The last condition was choosing an outlier with an extreme volatility to check how the algorithms would perform under stress conditions. The company chosen that meet this criterion was GameStop Corp. (GME), a meme stock that has been subjected to intense speculative trading volume by the Wall Street Bets Reddit community that registered an annual realized volatility of 240.3% over the mentioned period.

The data was extracted from Yahoo Finance.

5. Methodology

The first step was the definition of the two algorithms used for trading which as mentioned are hereby named as Three Moving Average Crossover (MAC) and On-Balance-Volume (OBV).

Afterwards code was developed in python for each algorithm enabling it to be adaptable for any stock.

The attached Python document named “Algo_Project_Code. ipynb” is meant to be a demonstration code for Tesla, Inc (TSLA) data but separately the algorithm code was also applied to the remaining stocks as well.

Moreover, code was developed for data extraction from Python to Excel. However, the data extraction Python document was not included as a project attachment because it was not considered interesting given the final results are better presented in the attached Excel file named “Results.xlsx”.

The next phase was results presenting and analysis followed with a conclusion chapter in which figures a discussion about the best trading strategy as well as some suggestion for further research are included.

6. Results

As previously mentioned, 3 trading strategies were adopted to test which one would bring better one year returns.

The first trading strategy is simple buy and hold strategy where the buy order is given on 1st June 2020 and the sell order given on 28th May 2021. The return on investment was computed by dividing the profits or losses deducted by the trading costs with the initial amount invested of USD 1 000 000.

The second makes use of the Three Moving Average Crossover (MAC) algorithm and the third trading strategy resorts on On-Balance-Volume (OBV) algorithm. In both cases the final return on investment is obtained by the overall compound profits and losses deducted by the trading costs registered over the period divided by the initial amount invested of USD 1 000 000.

For a better visualization of the individual results by security and strategy as well as the buy and sell points it is suggested an observation of the attached Excel file named “Results.xlsx”. Actually, in addition to present the final results summary in the tab “Results_summary”, it also contains two tabs by security (one for MAC and another for OBV) with the full historical profits, losses and costs observed as well as a graphical charts of the algorithm behavior to generate buy and sell orders.

To summarize the results, the below table table shows the return on investment obtained by the 3 trading strategies.

Stock	B&H	MAC	OBV
TSLA	247,63%	182,37%	125,22%
AMZN	30,20%	11,98%	7,92%
DIS	50,17%	39,45%	27,68%
WMT	14,36%	2,54%	-1,82%
PFE	14,90%	13,77%	12,08%
GME	5269,83%	1646,25%	2428,25%
JPM	66,31%	45,80%	7,77%
CCL	75,68%	61,59%	5,22%
NEE	14,35%	-1,05%	-6,70%
CAT	99,77%	50,95%	55,74%
Average	**588,32%**	**205,37%**	**266,14%**
Avg. w/o GME	**68,15%**	**45,27%**	**25,90%**

Table 1 – Return on investment results

The following two bar plots help on the results visualization being the first a graph containing all the securities’ return on investment and its average and the second a graph excluding the return on GameStop Corp. (GME).

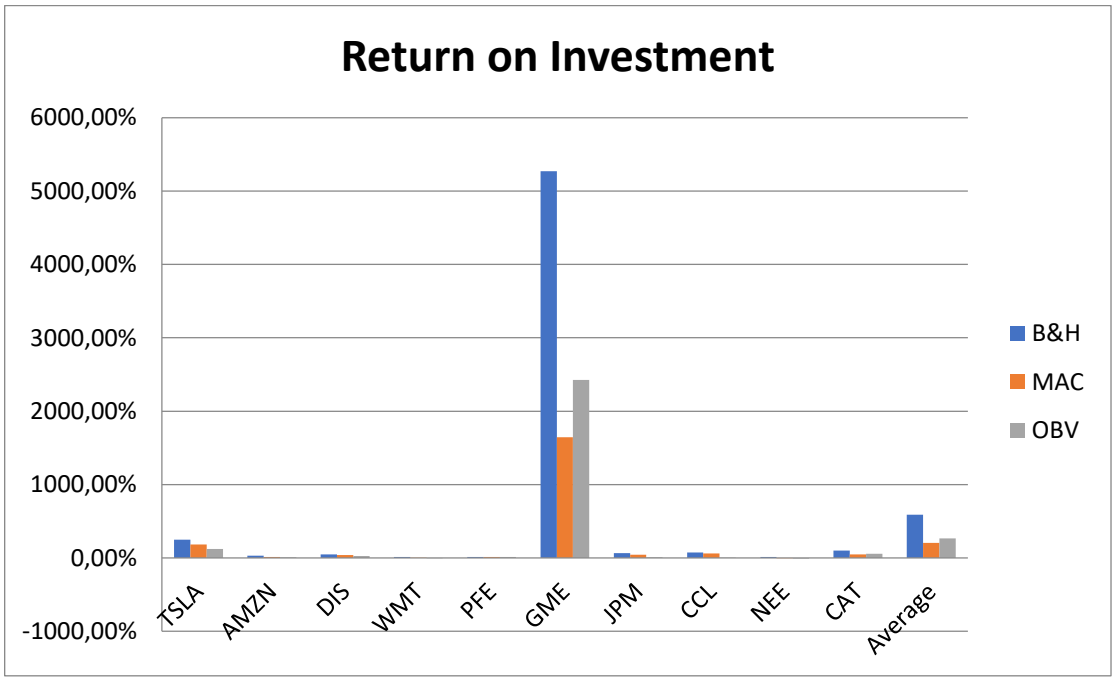

Figure 2 - Return on investment bar plot

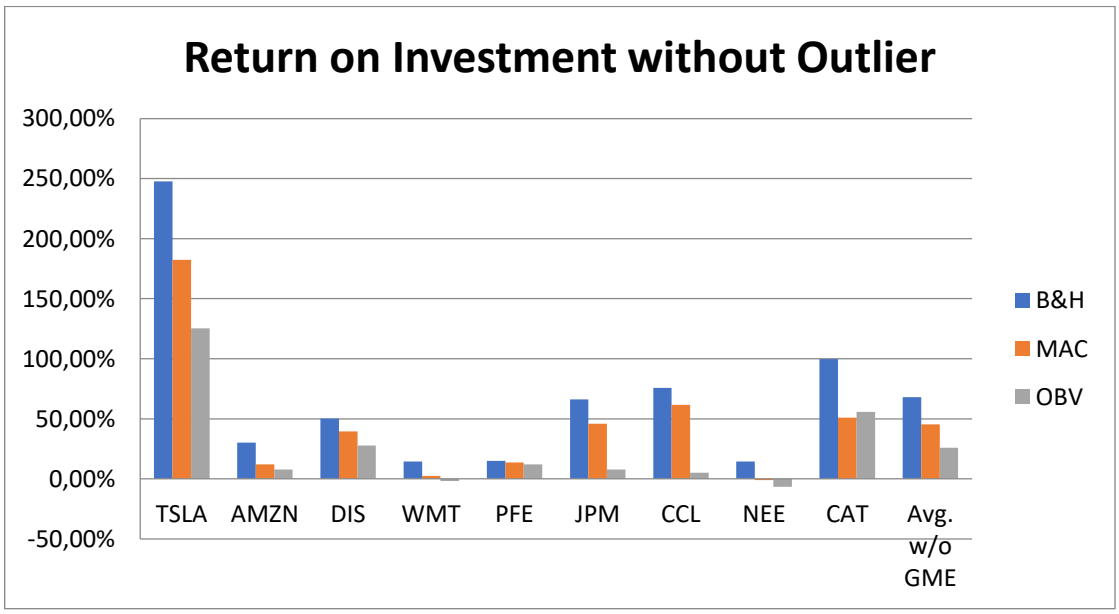

Figure 3 - Return on investment without outlier bar plot

7. Analysis of the Results

7.1 Dominant Strategy

The strategy that brings better returns is the simple buy and hold method, followed by the Three Moving Average Crossover being the On-Balance-Volume the worst performer in general with the exception of GameStop Corp. and Caterpillar Inc. in which OBV strategy beat MAC one.

To better understand the extent of the differences in the performance of the 3 mentioned strategies, the below table shows the excess returns between each other.

Stock	B&H	MAC	OBV	B&H - MAC	B&H - OBV	MAC - OBV
TSLA	247,63%	182,37%	125,22%	65,26%	122,41%	57,16%
AMZN	30,20%	11,98%	7,92%	18,23%	22,28%	4,05%
DIS	50,17%	39,45%	27,68%	10,72%	22,48%	11,76%
WMT	14,36%	2,54%	-1,82%	11,82%	16,18%	4,36%
PFE	14,90%	13,77%	12,08%	1,14%	2,83%	1,69%
GME	5269,83%	1646,25%	2428,25%	3623,57%	2841,58%	-781,99%
JPM	66,31%	45,80%	7,77%	20,51%	58,54%	38,03%
CCL	75,68%	61,59%	5,22%	14,09%	70,46%	56,37%
NEE	14,35%	-1,05%	-6,70%	15,40%	21,05%	5,65%
CAT	99,77%	50,95%	55,74%	48,81%	44,03%	-4,79%
Average	**588,32%**	**205,37%**	**266,14%**	**382,95%**	**322,18%**	**-60,77%**
Avg. w/o GME	**68,15%**	**45,27%**	**25,90%**	**22,89%**	**42,25%**	**19,37%**
Volatility	**1646,39%**	**509,03%**	**760,70%**	**1138,80%**	**885,91%**	**254,45%**
Vlt. w/o GME	**73,87%**	**56,13%**	**41,62%**	**20,53%**	**37,02%**	**24,36%**

Table 2 - Excess returns

Additionally and using the dominant buy and hold strategy as the base 1 for performances, the below table and graphs establish a quantitative relationship between the 3 strategies.

Stock	B&H as Base	B&H vs MAC	B&H vs OBV
TSLA	100,00%	73,65%	50,57%
AMZN	100,00%	39,65%	26,23%
DIS	100,00%	78,63%	55,18%
WMT	100,00%	17,71%	-12,68%
PFE	100,00%	92,36%	81,04%
GME	100,00%	31,24%	46,08%
JPM	100,00%	69,07%	11,72%
CCL	100,00%	81,39%	6,90%
NEE	100,00%	-7,30%	-46,71%
CAT	100,00%	51,07%	55,87%
Average	**100,00%**	**52,75%**	**27,42%**
Avg. w/o GME	**100,00%**	**55,14%**	**25,35%**
Volatility	**0,00%**	**32,03%**	**38,17%**
Vlt. w/o GME	**0,00%**	**33,01%**	**39,88%**

Table 3 - Quantitative relationship of returns

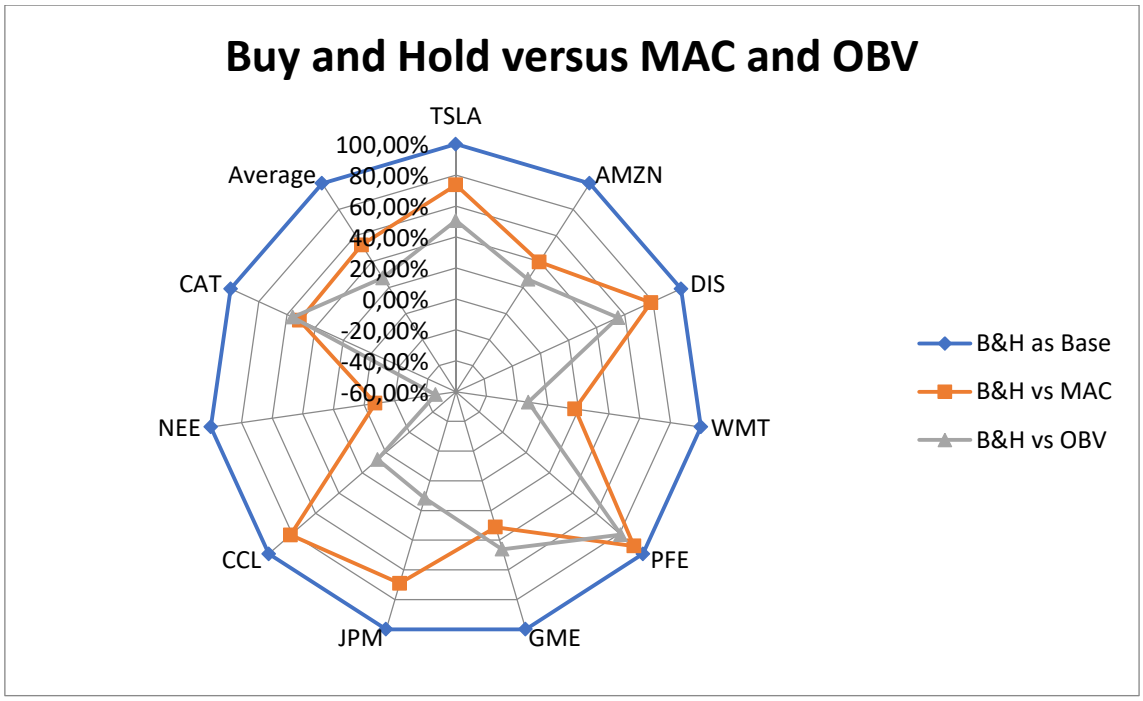

Figure 4 - Buy and hold strategy vs algorithms strategies spyder plot

As it is possible to observe the results clearly show that the buy and hold strategy brings consistently higher returns. This can be explained not only by the reduced trading costs this strategy bear but also by the nature of the algorithms themselves.

It is very difficult to beat the market but it is fair to state that both MAC and OBV strategies do not add extra value in terms of returns since on average MAC only brings a little more than half of the returns of B&H and OBV a little higher than 25%.

With the available data it is not possible to establish a clear causality between what price, volume and company features brings better results within MAC and OBV but further analysis is conducted below focusing on the differences between MAC and OBV results.

7.2 MAC versus OBV

Taking a closer look on the Three Moving Average Crossover and the On-Balance-Volume, it is important to understand why MAC seems generically better than OBV since on average it brings better results being more effective than OBV is 80% of the observation in the dataset.

The following two tables present summarize the number of combined buy and sell orders, the number of profitable closing position operations, the success rate of profitable closing position operations as well as the annualized volatility in terms of returns (applicable for MAC) and the annualized volatility in terms of volume (applicable for OBV).

Stock	Nº Orders MAC	Profitable Bets	Success Rate	Annual Returns Volatility
TSLA	9	6	67%	72,70%
AMZN	14	5	36%	31,38%
DIS	11	7	64%	33,21%
WMT	12	6	50%	20,60%
PFE	10	7	70%	24,15%
GME	8	7	88%	240,30%
JPM	11	7	64%	31,38%
CCL	12	7	58%	81,06%
NEE	14	5	36%	25,46%
CAT	7	6	86%	30,53%
Average	**11**	**6**	**62%**	**59,08%**
Avg. w/o GME	**11**	**6**	**59%**	**40,96%**
Volatility	**2**	**1**	**18%**	**66,97%**
Vlt. w/o GME	**2**	**1**	**16%**	**21,99%**

Table 4 - MAC market orders summary

Stock	Nº Orders OBV	Profitable Bets	Success Rate	Annual Volume Volatility
TSLA	15	5	33%	532%
AMZN	30	10	33%	471%
DIS	19	9	47%	696%
WMT	14	5	36%	604%
PFE	17	6	35%	595%
GME	13	4	31%	1074%
JPM	35	11	31%	527%
CCL	25	7	28%	683%
NEE	25	5	20%	577%
CAT	16	9	56%	620%
Average	**21**	**7**	**35%**	**638%**
Avg. w/o GME	**22**	**7**	**36%**	**594,37%**
Volatility	**7**	**2**	**10%**	**167,92%**
Vlt. w/o GME	**7**	**2**	**11%**	**73,02%**

Table 5 - OBV market orders summary

It is possible to see that the number of orders is significantly higher in OBV strategy (approximately the double of operation). This characteristic seems to be explained by the considerable difference in terms of annual realized volatility on returns and annual realized volatility on volumes being the latter much greater.

The success rate of the operations is consistently better in MAC and, on average, is much higher than OBV (62% vs 35%) which makes it a more sustainable strategy given the algorithm allows both reducing the trading costs and provide a better return per operation.

The volatility of the success rate is higher in MAC than in OBV suggesting a higher risk higher return pattern but OBV strategy seems to react better in stress conditions given the performance in GameStop Corp. (GME) is greater in OBV when compared to MAC.

However, it is necessary to state that with the used dataset it is not possible to establish a clear causality between the characteristics of price changes, volume and company features brings better results within MAC and OBV.

8. Conclusions

Creating algorithms that can beat the market performance is task that although achievable is very complex and costly.

In fact, not only does the algorithm need to be carefully tested with a sufficient amount of historical data but it also needs to be dynamically tested in real time. Moreover, it is of the upmost importance that the algorithm is constantly checked and updated according to the current market conditions.

This academic project tested two existent algorithms on ten selected stocks that under the market circumstances of the period between 1st June 2020 and 28th May 2021 failed to deliver better returns than the market returns.

Passive management portfolio defenders would say this study would once again prove the good old buy and hold method of a stock with good fundamentals is the most appropriate to adopt given it is almost impossible to statically beat the market with active trading strategies.

On the other side, active management portfolio defenders would argue the study is too naïve, the algorithms are not the best fit for the market conditions analyzed and the methodology used is not consistent.

Although this study has no intention to prove that either passive or active investment performs better than the other, it is reasonable to state that both theories have its own merits and drawbacks.

It is also fair to state that the methodology used could be improved. Actually, the quantity of data for this study is extremely small and do not represent a statically significant dataset. The assumptions used are a bit strict and could be relaxed for example by allowing short selling and the

period in study could be larger than 1 year or it could even contain 1 year periods in different years.

In conclusion, this study suggest buy and hold method is better than MAC and OBV under the analyzed market circumstances but further research and analysis should be performed.

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