

ABSTRACT

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MARK

ONE:

EXPERIMENTAL INVESTIGATION

☒

DESIGN INVESTIGATION

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NAME OF
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GRADE

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* If this project is awarded a monetary prize, the check will be written in this scientist's name, and it will be his/her responsibility to distribute the prize money equally among all participating scientists.

PROJECT

TITLE

Alpha of Various Technical Indicator Based Strategies

Purpose: The use of technical indicators is very common in the trading of securities and often can help to predict trends into the future. For trading stocks based on technical indicators to be considered worth the effort, they must outperform the wider stock market in general. The purpose of this project is to determine the difference in return between the Dow Jones Industrial Average and indicator-based strategies.

Procedure: In this study, five popular technical indicators were evaluated, including Relative Strength Index, Money Flow Index, Bollinger Bands, Moving Average Convergence/Divergence, and Moving Averages. The performance of each indicator was investigated using a simulated portfolio starting with \$10,000 that was equally invested into a mixture of stocks in Dow Jones. Each portfolio was traded between January 1, 2001 to January 1, 2021 based on Buy/Sell signals generated from each indicator. The annual percent yield of each indicator-based strategy was compared with the yield from Dow Jones Index

Conclusion: Ultimately, none of the indicators outperformed the Dow Jones Industrial Average over the 20 years tested ($p < 0.05$). The indicators ranked by performance were the Moving Average Convergence Diagram, Money Flow Index, Bollinger Bands, Relative Strength Index, and Moving Averages. Overall, the annual returns of the Dow over the course of the 20 years were far more variable than those under the indicator-based strategies. Furthermore, the indicator-based strategies outperformed the Dow Jones Index in the years 2000, 2008-2009, and 2018, suggesting that technical indicators are useful in predicting stock prices in such volatile markets.

Alpha of Various Technical Indicator
Based Strategies

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Purpose

The use of technical indicators is very common in the trading of securities and often can help to predict trends into the future. For technical indicator-based trading to be considered beneficial, it must outperform the wider stock market in general. The purpose of this project is to determine the alpha (excess return) of five popular stock trading strategies, which sell and buy a stock based on the market trend predictions of respective technical indicators, in comparison with the wider market based on Dow Jones Industrial Average. The outcome of this analysis can inform the accuracy of market prediction by each of the selected technical indicator-based strategies.

Hypothesis

Based on Efficient Market Hypothesis, no technical indicator-based strategy can drive greater return compared with the wider market. The strategies to be tested in this study include Relative Strength Index (RSI), Money Flow Index (MFI), Bollinger Bands (BB), Moving Average Convergence/Divergence (MACD), and Moving Averages (MA).

Variables/Critical Components

The RSI formula used the closing price over rolling 14-day period to compute average gain and loss. The MFI formula was based on closing price and volume over rolling 14 day period. The BB calculation was based on 2 standard deviations over rolling 20 day period. The MACD calculated the 26 and 12 day exponential moving average from closing prices. MAs were calculated with closing price.

The performance of a simulated account utilizing a given indicator was compared with the performance of the Dow Jones Industrial Average over 20 years. The simulated account was initiated with the same weighted portfolio of stocks in the Dow Jones Industrial Average across all technical indicators. The performance was recorded at the end of each year, when each portfolio was reset to equal weight.

All indicators were tested across 20 years. The portfolio in the simulate account consists of only the stocks currently in the Dow Jones that have been continuously traded during the past 20 years. The same portfolio was used in computing all indicators.

Review Of Literature

Introduction:

The profit from investing in financial assets relies on the ability to predict future changes in the prices of assets. Technical indicators are formulas which transform market data into buy or sell signals. Many indicators have been created to help predict the price changes of assets. These technical indicators rely on data such as historic price and volume, i.e. the amount a certain asset has been traded in a given period of time, rather than fundamental aspects of a business such as revenue or profit margins. The idea behind technical analysis is that prices can move in patterns which can be detected and profited upon, and that certain indicators transform market data in a way which may reveal these patterns (Nazário, et al. 2017).

The efficacy of technical analysis is a frequent subject of contention. The Efficient Market Hypothesis (EMH) states that prices of traded assets reflect all available information available regarding the security (Malkiel, 2003; Bouattour, 2019). If the EMH is true, however, creating a model which can create a risk-adjusted return greater than the market average should be impossible. However, existing literature on the profitability of technical analysis is not definitive.

RSI, MFI, BB, MACD, and MA

The RSI measures the historical weakness or strength of a stock. It is a momentum oscillator because it depends on the change in price of the underlying security. It is built on the idea that when the price of any asset changes very rapidly, regardless of what reason drives it, others will view it as overbought or oversold and

react towards it. This will result in a price change in the opposite direction which the RSI aims to predict beforehand. The indicator fluctuates between 0 and 100, with >70 considered overbought, and therefore a sell signal and <30 considered oversold, and therefore a buy signal. Typically the RSI is used on a 14-day time period, which is the time period that will be used in this experiment. The RSI across past n periods is calculated through the following formulas:

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

Where:

$$RS = \frac{\text{Average Price Gain Over } n \text{ Periods Where close } > \text{ open}}{\text{Average Price Decrease over } n \text{ Periods Where close } < \text{ open}}$$

The MFI is similar in function and idea to the RSI, also fluctuating between 0 and 100 with the same overbought and oversold territory. However, it is calculated by taking volume into account. MFI across past n periods is calculated with the following formulas:

$$MFI = 100 - \frac{100}{1+MFR}$$

Where:

$$MFR = \frac{\text{Total Positive Money Flow across 14 Periods}}{\text{Total Negative Money Flow across 14 Periods}}$$

$$RMF = \text{Closing Price} * \text{Volume}$$

A MA is the average price across a certain time period, and different types of moving averages may weigh each price differently. However, a simple moving average is just the average across certain distances of time. Typically multiple moving averages are used together to determine price trends in a stock. When a shorter time period moving average moves below a longer term one, it can be an indication that the price is

ready to trend down. This is because as the shorter time period moving average is more reactive to changes in the price, the shorter term average moving below the long term moving average indicates current buying pressure is falling below the historical average. The opposite scenario where a shorter term moving average moves above a longer term one should also hold true. Two moving averages, a 20-day and a 50-day, were used in this study. MA is calculated across x periods with the following formula:

$$MA = \frac{\sum_{n=1}^x \text{Price } X \text{ Periods Before}}{x}$$

The BB are formed with 2 lines, often 2 standard deviations above and below a MA, which is often a 20-day period. The price of a stock often should stay within the upper and lower bounds of the Bollinger bands, as the bands move along with the MA. Therefore, a move outside of the Bollinger bands requires a large percentage move up or down in a short period of time, which indicates an asset is overbought if it is above the upper bound of the Bollinger band and oversold if below. The Bollinger bands used in this experiment will be 2 standard deviations from a 20-day MA.

The MACD diagram consists of the MACD line, Signal Line, and divergence series. Both the MACD and Signal Line are exponential moving averages across a distance of time, with the MACD line being a shorter time period and Signal Line being a longer time. The divergence series is calculated from the difference between the MACD and Signal Line. The idea of the MACD indicator is that the fast moving average will begin to change in response to changes in a stock earlier than the slow moving average. Therefore, by comparing them with the divergence series, trends in a stock's price can be revealed before they occur. If the MACD line crosses below the Signal Line, signified by the divergence series becoming negative, it is considered a sell signal;

while if the MACD crosses above the signal line, it is considered a buy signal. The most commonly used values for time period in the MACD, Signal, and divergence are 12, 26, and 9 days respectively (denoted by MACD(12, 26, 9)), which will be used in this experiment.

In the current study, the percentage gain an account would achieve if it had bought and sold based solely on the indicator will be calculated annually. This percentage gain will be compared to the gain of a hypothetical account which had just held the stocks in an index. The stocks that will be used are the 26 stocks in the Dow Jones Industrial Average as of 2021 that have been listed for at least 20 years on the New York Stock Exchange (Journal, 2020). The Dow Jones Industrial Average is a group of stocks intended to be representative of the general U.S economy.

Previous Research:

A large amount of studies have been conducted on the performance of using computer models to predict stock prices, often neural networks or other machine learning algorithms (Jiang, 2021). In a study conducted by Atsalakis, et. al, an adaptive neuro fuzzy inference system was used to evaluate and predict future prices of a variety of stocks. (Atsalakis & Valavanis, 2009). The success of several models challenges the EMH as they demonstrate historical price data can be used to predict trends to a certain extent that is profitable.

Other studies have been conducted to determine the success rate of strategies based on a specific indicator such as the RSI (Marek & Sediva, 2017) (Bhargavi & Gumparthi, 2017), or multiple indicators (Viaz & Ramaswami, 2016). These studies also

found that using technical indicators to buy or sell a variety of stocks did often return a profit from the original investment, although returns often varied.

While the use of indicators was demonstrated to have a positive return, all studies had been conducted in foreign markets in emerging economies. Additionally, while returns were stated, some were not compared to the performance of the underlying stock. In other studies, the performance of the technical analysis based strategy was not compared to an index associated with the economy of the country, making it unclear whether the performance of the strategy was due to its efficacy or the high growth rate of the economy the study was conducted in.

In this experiment, the performance of strategies based on the RSI, MFI, BB, MACD, and MA will be measured across the last 20 years on the 30 Dow Jones stocks. The profitability of these strategies will be determined by the amount by which the strategy outperforms the index.

Materials

- MacBook Air (16GB RAM, 2TB SSD)
- Python with libraries of pandas, numpy, and scipy
- Price data from January 1, 2001-January 1, 2021 for each stock in the current Dow Jones Industrial Average which have had IPO before 2001
 - Data obtained will be opening, closing, high, and low price
- Price data for Dow Jones index futures will be used to determine returns of the index

Procedure

1. The stock price data from January 1, 2001 to January 1, 2021 was obtained from Yahoo finance.
2. The technical indicators were computed from the closing data and trading volume according to the formulas specified previously.
3. Simulated accounts with \$10000 started at the beginning of 2001 by having all money invested with equal weight into each of the 26 stocks. Stock trading was determined by the buy/sell signals of the technical indicator.
 - When an indicator produced a sell signal (ex: RSI goes over 70), the account would sell at the next opening price.
 - Similarly, when a buy signal was produced, the account would buy at the opening price on the next day using the amount sold at the sell signal
 - Accounts were simulated using python and libraries numpy and pandas were used
4. The percent yield of an account was calculated yearly from 2001-2020.
5. The percent annual yield was then compared to the yield over time of the Dow Jones index.
 - P-values were calculated using the non-parametric Mann-Whitney U-Test
6. The excess return was calculated by the percent difference between the annual yield from the indicator-based trading account and the annual yield from the Dow Jones Industrial Average.

Results

Table 1. Cumulative Return of \$10,000 based on various technical indicators and Dow Jones Industrial Average from the end of 2000 to the end of 2020

Year	MA	BB	MFI	RSI	MACD	Dow
2000	10000	10000	10000	10000	10000	10000
2001	10936.33	9577.45	9813.17	9974.43	10457.81	9129.7
2002	9393.83	8604.46	8766.03	9442.21	10042.34	7910.38
2003	10693.77	9622.4	10375.79	10751.42	11586.02	9759.85
2004	11309.55	10660.42	11672.31	11710.65	12931.06	11549.1
2005	11204.05	10528.08	11487.72	11540.18	13274.13	12002.21
2006	12147.2	11427.17	12559.5	12463.5	14607.71	14042.48
2007	12575.54	12293.91	13283.97	12870.74	15266.92	16331.61
2008	13227.85	13065.95	14209.91	13307.51	16164.05	18178.23
2009	11947.01	11170.38	12102.77	11167.29	15578.1	13992.86
2010	12260.77	12205.3	13468.49	12059.17	16114.94	16418.46
2011	13189.46	13289.41	14401.71	13035.42	16978.86	18418.59
2012	13855.41	14035.97	15247.81	13810.23	18228.24	20323.84
2013	14972.99	15855.78	16316.06	14948.55	19529.68	23894.2
2014	15663.85	15903.92	16312.79	15456.41	20436.45	26431.24
2015	16483.16	17668.59	18356.91	16688.05	21688.55	30969.26
2016	17679.43	19707.18	20428.58	18340.25	24516.7	36561.68
2017	17886.29	20200.02	20682.26	19219.26	24065.72	37087.36
2018	19015.39	21420.76	21651.39	20198.77	24840.75	39016.36
2019	19185.97	21349.66	21757.11	21181.97	25741.66	42988.67
2020	19945.17	22587.82	23353.6	22194.41	27895.55	49904.08

Return of Various Indicator Based Strategies

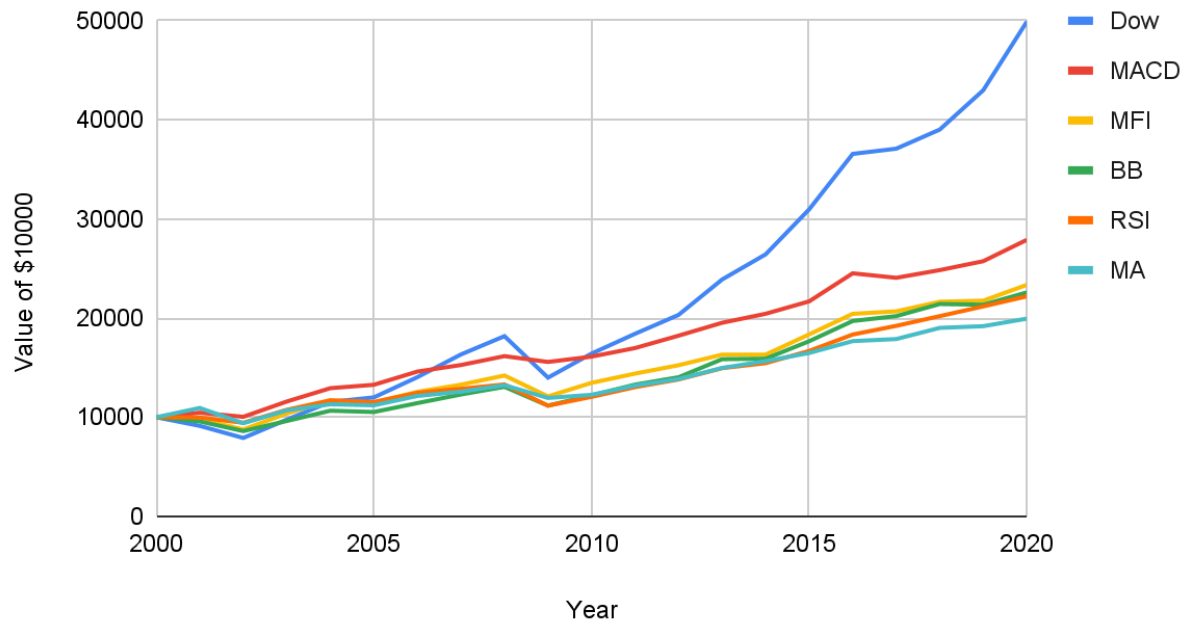


Figure 1. Cumulative return across 2000-2020 from technical indicators and Dow Jones Industrial Average

Table 2. Stock annual returns (%) based on various technical indicators and Dow Jones Industrial Average between 2000 and 2020

Year	MA	BB	MFI	RSI	MACD	Dow
2001	9.36	-4.23	-1.87	-0.26	4.58	-8.7
2002	-14.1	-10.16	-10.67	-5.34	-3.97	-13.36
2003	13.84	11.83	18.36	13.87	15.37	23.38
2004	5.76	10.79	12.5	8.92	11.61	18.33
2005	-0.93	-1.24	-1.58	-1.46	2.65	3.92
2006	8.42	8.54	9.33	8	10.05	17
2007	3.53	7.58	5.77	3.27	4.51	16.3

2008	5.19	6.28	6.97	3.39	5.88	11.31
2009	-9.68	-14.51	-14.83	-16.08	-3.63	-23.02
2010	2.63	9.26	11.28	7.99	3.45	17.33
2011	7.57	8.88	6.93	8.1	5.36	12.18
2012	5.05	5.62	5.88	5.94	7.36	10.34
2013	8.07	12.97	7.01	8.24	7.14	17.57
2014	4.61	0.3	-0.02	3.4	4.64	10.62
2015	5.23	11.1	12.53	7.97	6.13	17.17
2016	7.26	11.54	11.29	9.9	13.04	18.06
2017	1.17	2.5	1.24	4.79	-1.84	1.44
2018	6.31	6.04	4.69	5.1	3.22	5.2
2019	0.9	-0.33	0.49	4.87	3.63	10.18
2020	3.96	5.8	7.34	4.78	8.37	16.09

Table 3. Comparison of stock annual returns (%) from technical indicators with Dow Jones Industrial Average

Statistics	MA	BB	MFI	RSI	MACD	Dow
Mean	3.71	4.43	4.63	4.27	5.38	9.07
Median	5.12	6.16	6.40	4.98	5.00	11.74
Min	-14.10	-14.51	-14.83	-16.08	-3.97	-23.02
Max	13.34	12.97	18.36	13.87	15.37	23.38
Range	27.94	27.47	33.19	29.95	19.34	46.40
P-Value*	0.006	0.023	0.04	0.007	0.02	N/A

* The statistical significance between annual returns from a technical indicator and Dow Jones Industrial Averages were evaluated using Mann-Whitney U test.

Annual Returns From Various Indicators Across 2001-2020

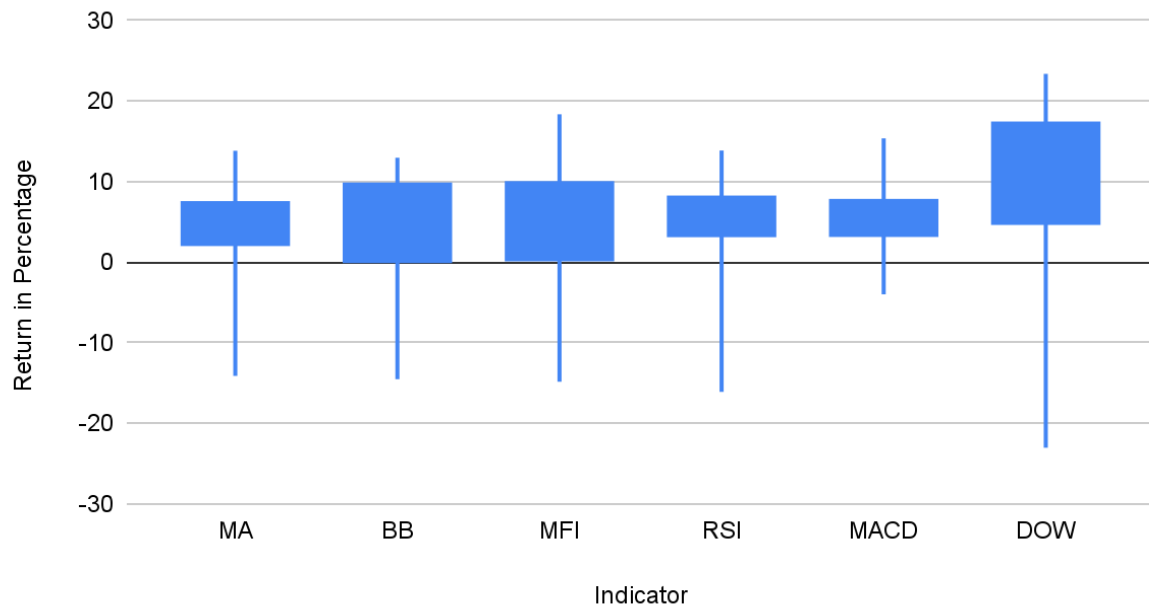


Figure 2. Annual returns (%) from various technical indicators across 2001-2020.

Table 4. Excess Returns (%) by Year based on various technical indicators between 2001 and 2020

Year	MA	BB	MFI	RSI	MACD
2001	18.07	4.48	6.83	8.45	13.28
2002	-0.75	3.2	2.68	8.02	9.38
2003	-9.54	-11.55	-5.02	-9.51	-8.01
2004	-12.57	-7.55	-5.84	-9.41	-6.72
2005	-4.86	-5.16	-5.5	-5.38	-1.27
2006	-8.58	-8.46	-7.67	-9	-6.95
2007	-12.78	-8.72	-10.53	-13.03	-11.79
2008	-6.12	-5.03	-4.34	-7.91	-5.43

2009	13.34	8.52	8.2	6.94	19.4
2010	-14.71	-8.07	-6.05	-9.35	-13.89
2011	-4.61	-3.3	-5.25	-4.09	-6.82
2012	-5.3	-4.73	-4.47	-4.4	-2.99
2013	-9.5	-4.6	-10.56	-9.32	-10.43
2014	-6	-10.31	-10.64	-7.22	-5.97
2015	-11.94	-6.07	-4.64	-9.2	-11.04
2016	-10.8	-6.52	-6.77	-8.16	-5.02
2017	-0.27	1.06	-0.2	3.35	-3.28
2018	1.11	0.84	-0.52	-0.1	-1.98
2019	-9.28	-10.51	-9.69	-5.31	-6.55
2020	-12.13	-10.29	-8.75	-11.31	-7.72

Difference in Return Between Various Strategies and Dow

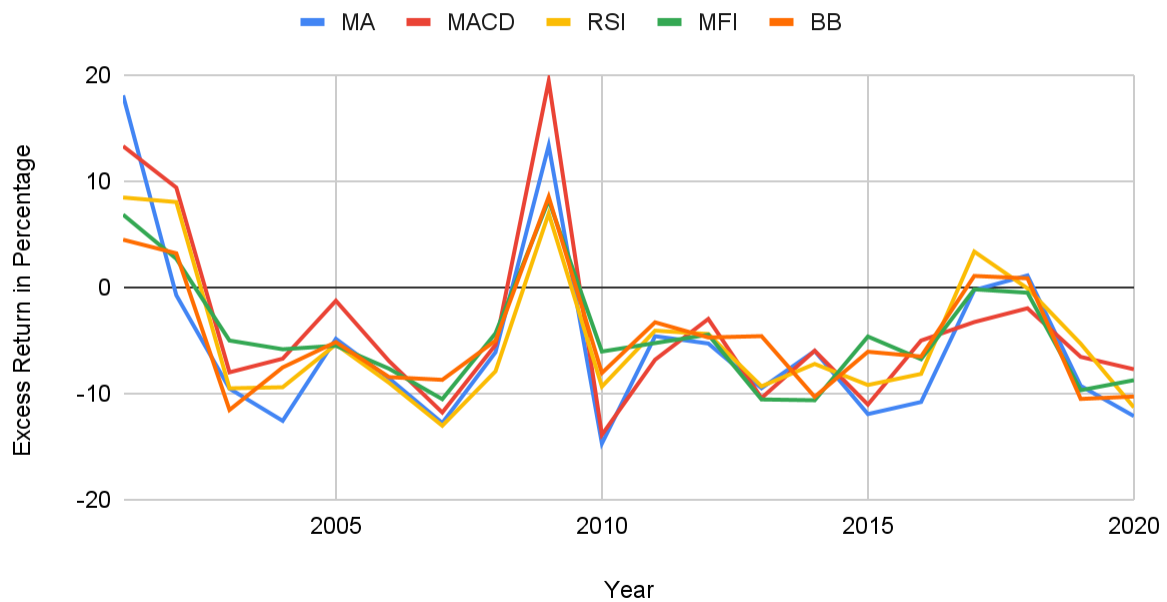


Figure 3. Excess returns from Dow Jones Industrial Average by various technical indicators across 2001-2020.

Discussion

Over the course of 20 years, while the most successful of the technical indicator based strategies, the MACD, returned 178%, the Dow Jones Industrial Average returned close to 400%. From this data it is clear that strategies solely based on technical indicators are incapable of outperforming the general market over long periods of time, ultimately supporting the Efficient Market Hypothesis. The indicators listed by return were the MACD, MFI, BB, RSI, and MA. Of the final returns of each indicator, the MFI, BB, and RSI, all produced very similar returns, although the MA underperformed significantly and MACD outperformed the other indexes by a large margin. Although both the MA and MACD are indicators related to the moving average, the better performance of the MACD may indicate that the use of shorter term, exponential moving averages may be more accurate in predicting the movement of an asset's price.

Additionally, it is worth noting that the annual returns of the Dow over the course of the 20 years were far more variable than those under the indicator based strategies. The return of the Dow varied 46% points ranging from -23.04% to 23.38%. Meanwhile, the returns on indicator based strategies varied on average 27.58% points. These differences indicate that while the strategies based on technical indicators do not produce greater returns than the Dow Jones, they are able to noticeably reduce variability in returns.

The periods of time in which the indicator based strategies are able to outperform the indexes also reveal notable trends. The most prominent periods of outperformance are between 2000-2001 and 2009, with a smaller period of outperformance in 2018. The periods of outperforming by the active strategies used in this study coincided with recessions in 2000-2001 and 2008 or volatile markets in 2018. This trend indicates that these technical indicators can, with some degree of accuracy, predict the direction of a stock price in more volatile periods.

Conclusion

The purpose of this experiment was to determine whether using strategies based on popular technical indicators would be capable of outperforming the market. The hypothesis that no indicator-based strategy would outperform the Dow Jones was supported in this experiment. The strategies involving MA, BB, MFI, RSI, and MACD underperformed the Dow on average by 5.36, 4.63, 4.44, 4.80, and 3.69 percentage points ($p = 0.006, 0.023, 0.04, 0.007, 0.02$), respectively. The accumulated return of the strategies in the same order was 199%, 226%, 234%, 222%, and 279%, while during the same period the Dow Jones returned 499%.

Across the 7343 days of data used in the study, 194 did not contain price data. These rows were replaced with the average values of the previous day and the day after. Throughout any year, sharp changes in stock price may occur due to events such as earnings. By filling in the missing data with averages, the new data may have not accurately reflected the speed of the change. However, because a very small proportion of the data was unknown (2.64%), it is unlikely to affect the interpretation of the data. In future studies, one could utilize multiple dataset to obtain the missing value.

This experiment has supported the idea that in the aim of superior returns to the general market, technical indicators are not very effective. However, the strong performance of indicator based strategies during volatile markets provides a possible case where the use of technical indicators may be beneficial.

There is room for further expansion on the findings of this experiment. Experiments regarding the phenomenon of outperformance by indicator based strategies in the years 2000, 2008-2009, and 2018 could be done to understand the results found in this study. The unique market conditions of high volatility during these periods suggests that technical indicators are useful in predicting stock prices in such volatile markets. Such hypotheses can be evaluated by introduction of additional volatility in a dataset by expanding to additional periods of volatility, such as 1990-1991 and 2020-2021. Additionally, this study was performed in a 20 year period

with specific market conditions found in U.S stocks. One may want to investigate if the same conclusion would apply in other markets with different market behaviors, such as those in different countries or assets.

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