Mirza Aydemir

217401167

MATH 6914 – Take-home Final

1. Introduction

The goal of this assignment is to evaluate whether a simple technical trading rule based on MACD can improve a passive investment approach in MSFT. To do this, our analysis begins with a MACD strategy and then compares its performance against a buy and hold benchmark. This gives a clear way to see whether the signal can generate better trading outcomes than simply holding the stock through the full period in 1999.

The first strategy uses the difference between a 5-day and 10-day exponential moving average to construct the MACD signal. When the indicator is positive, the strategy takes a long position in MSFT, and when it is negative, the strategy takes a short position.

We extend this idea by introducing a second strategy that keeps the same MACD signal from MSFT but pairs it with an opposite position in SPY. This creates a simple long-short structure that is less tied to outright market direction and allows for a comparison between a directional trading rule and a more hedged version of the same signal. Looking at both strategies together makes it possible to study not only return differences, but also how the risk profile changes once the SPY leg is added.

The final comparison focuses on buy and hold, the standalone MSFT MACD strategy, and the paired MSFT-SPY strategy in order to assess their relative performance and risk characteristics.

2. Data and setup

This analysis is based on daily closing prices for MSFT and SPY over the 1999 sample period. To keep the calculations clean and easy to follow, the data is first reorganized into a price table with one column for Microsoft and one column for SPY, indexed by date. This creates the base table used for all later calculations in both strategies. Both assets have 261 observations in the sample, which is consistent with a full year of trading days.

The signal construction begins with the MSFT price series. From that series, a 5-day exponential moving average and a 10-day exponential moving average are calculated. The MACD variable is then defined as the difference between these two moving averages. Once the MACD series is available, it is converted into a trading position variable that determines whether the strategy is long or short. This position is then lagged by one day when computing strategy returns so that the implementation uses yesterday's signal to trade today.

Symbol Date	MSFT	SPY	EMA_5	EMA_10	MACD
1999-01-01	34.673	123.31	34.673000	34.673000	0.000000
1999-01-04	35.250	123.03	34.865333	34.777909	0.087424
1999-01-05	36.625	124.44	35.451889	35.113744	0.338145
1999-01-06	37.813	127.44	36.238926	35.604518	0.634408
1999-01-07	37.625	126.81	36.700951	35.971878	0.729073

3. Summary of Implementation Progress

The implementation follows a clear sequence that builds the trading strategies step by step from the raw price data. The first part of our implementation prepares the data and organizes the daily MSFT and SPY prices into a clean working table. From there, the daily return series is computed, since all later performance calculations depend on returns rather than raw price levels. This creates the basic structure needed for both the buy and hold benchmark and the active trading strategies.

After the return series is prepared, we construct the MACD signal for Microsoft. This is done by calculating the 5-day and 10-day exponential moving averages and then taking their difference. Once the MACD series is available, it is translated into a trading rule by assigning a long position when MACD is positive and a short position otherwise.

The next step is to turn the signal into realized strategy performance. To do that, the position variable is lagged by one day before being multiplied by the MSFT daily return. This is an important part of the implementation because it ensures that the strategy uses yesterday's signal to trade today, rather than using information from the same day. The first missing return created by the lag is then replaced with zero, and the buy and hold return series is created alongside it so that both approaches can be compared on the same basis.

Once Strategy 1 is fully defined, we then extend the same signal into Strategy 2. In this version, the MSFT signal is kept, but an opposite position is added in SPY with the same dollar amount. This creates a paired structure rather than a purely directional one. We then calculate daily returns of this paired strategy and checks the number of position changes, which helps show how active the strategy is over the sample period.

The later parts of the implementation focus on evaluation and visualization. For Strategy 1, we are creating three charts:
1. MSFT with EMA (5) and EMA (10)
2. MSFT with EMAs and position

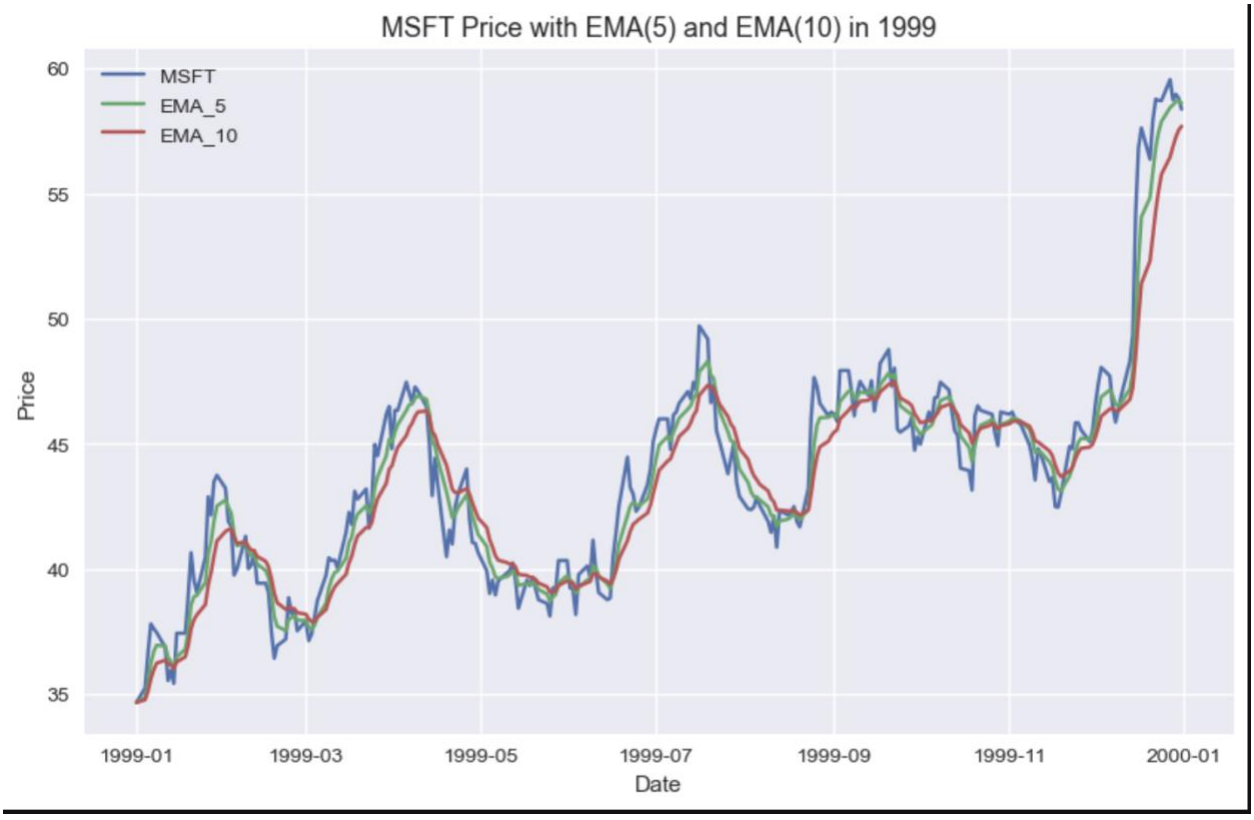
3. Buy-and-hold versus Strategy 1 cumulative performance.

For Strategy 2, we also add on cumulative performance, drawdown statistics, and recovery information.

4. Strategy 1

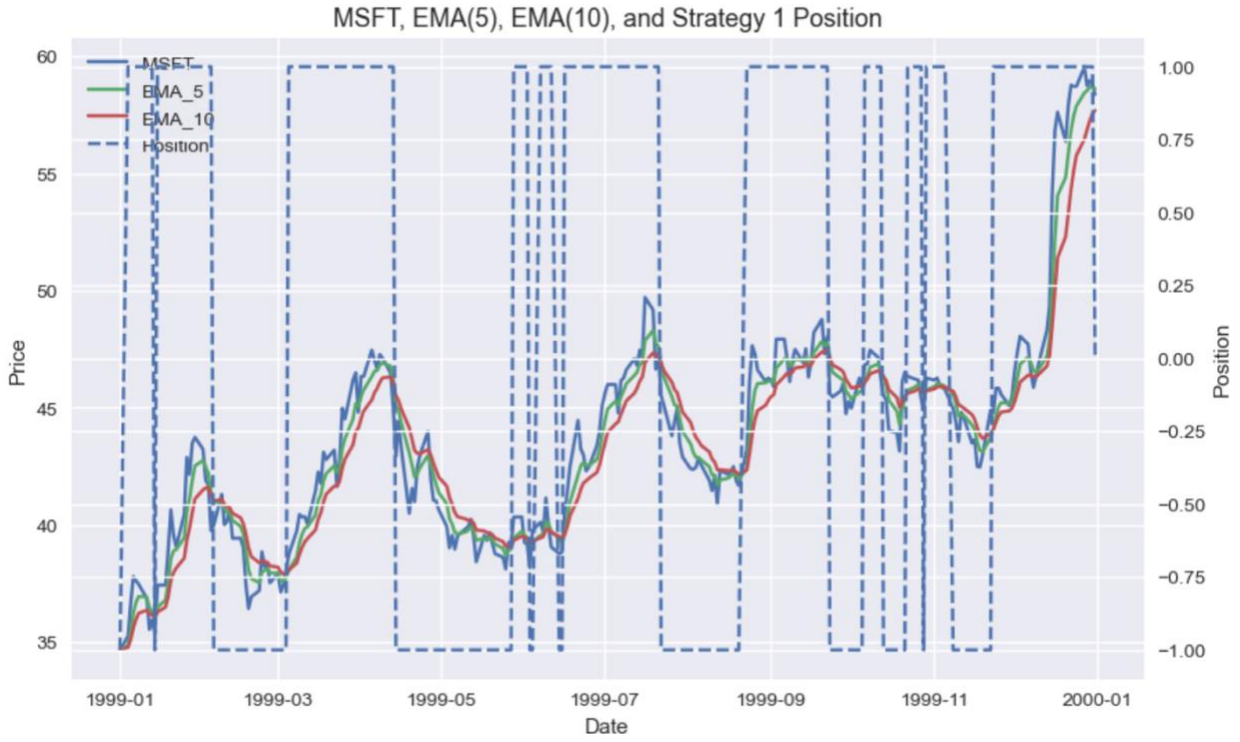
Our first strategy applies a simple MACD trading rule to Microsoft stock. The idea is to use the relationship between a short-term and a longer-term exponential moving average to decide whether the strategy should hold a long or a short position. We are creating the 5-day EMA, and the 10-day EMA are calculated from the MSFT price series, and the MACD variable is defined as the difference between them. When the short-term average is above the long-term average, the MACD becomes positive and suggests upward momentum. When the short-term average is below the long-term average, the MACD implies negative momentum.

Once the indicator is constructed, it is converted into an actual trading rule. We assign a position of +1 when MACD is greater than zero and a position of -1 otherwise. This means the strategy is always invested either long or short, except at the very end of the sample where the final position is closed out.



This figure shows the Microsoft price together with the two exponential moving averages that generate the signal. It serves as the raw visual foundation of the strategy because it shows how closely the short-term average reacts to price changes compared with the slower 10-day average.

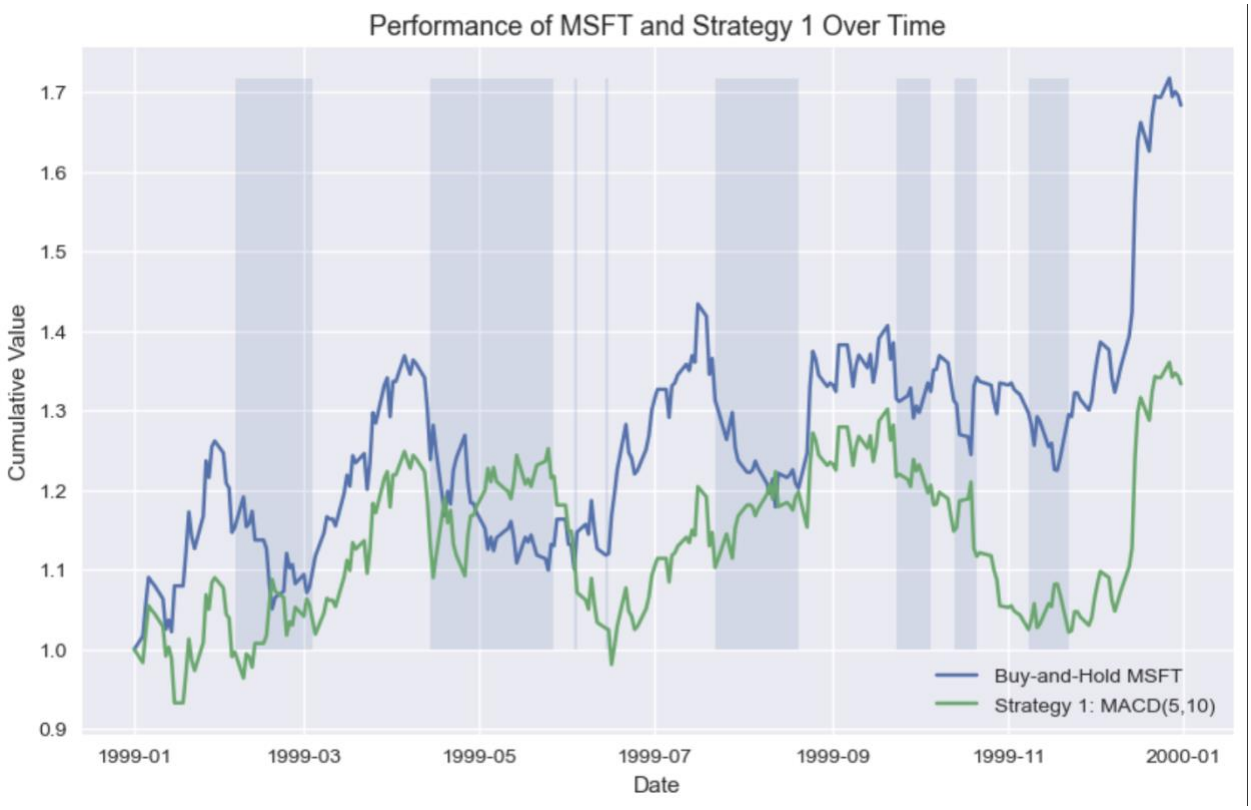
During stronger upward movements, the 5-day EMA stays above the 10-day EMA more often, while in weaker periods the two lines move closer together or reverse order.



We extend this above by showing not only the moving averages but also the position series implied by the rule. This is useful because it connects the trading signal to the actual changes in portfolio exposure. Instead of only seeing how the averages move, we can also see when the strategy switches from long to short and when it stays in the same position for a longer period.

After the signal is defined, the next step is to calculate realized returns from it. We do this by lagging the position by one day and then multiplying it by the MSFT daily return series. This is a very important part of the implementation because this ensures that we don't use future information. The strategy does not use the signal from the same day to earn that same day's return. Instead, it uses yesterday's signal to determine today's position. This makes the backtest more realistic and ensures that the reported performance comes from a feasible trading rule rather than from future information.

The performance of Strategy 1 is summarized in the plot "Performance of Strategy 1 vs buy and hold" below. This graph compares the value of one dollar invested in the MACD strategy against the value of one dollar invested in a passive buy and hold position in MSFT. Looking at both lines together makes it possible to see not only the final performance difference, but also how that difference developed through time. The short positions are shaded as well to see -1 positions easier. In this sample, the buy and hold strategy finishes at a higher final value than Strategy 1, which suggests that the MACD rule did not outperform a passive position over the full year.



The risk of Strategy 1 can also be examined through drawdown analysis. Drawdown measures the decline from a previous cumulative peak and is useful because it captures the depth of losses experienced by the strategy along the way. Based on our results, Strategy 1 shows a maximum drawdown of about -21.66%. and the worst point occurs on 1999-06-16. We conclude here that even though the strategy is active and changes direction frequently over time we experienced a loss from the previous peak. In other words, the trading rule did not fully protect the portfolio from downside risk during the weaker period in the middle of the sample.

5. Strategy 2

The second strategy extends the first one by keeping the same MACD signal on Microsoft but adding an opposite position in SPY. The idea here is not to create a completely new signal, but to change the portfolio structure built around that signal. In Strategy 1, the trading rule is purely directional because the entire position depends only on whether the model is long or short MSFT. In Strategy 2, that same view on Microsoft is paired with an opposite market position in SPY using the same dollar amount. This turns the strategy into a simple paired trade rather than a single asset directional trade.

The implementation is quite straightforward we set the MSFT position in Strategy 2 equal to the Strategy 1 signal and then assign the SPY position as the negative of that same signal. As a result, whenever the MACD rule indicates a long position in MSFT, the strategy also takes a short position in SPY. When the signal turns negative, the position flips to short MSFT and long SPY. On the final day of the sample, both positions are closed so that the strategy ends with no open exposure.

This extension matters because it can reduce the effect of broader market movements on the strategy's performance. In the first strategy, a wrong directional call on MSFT directly hurts the whole portfolio. In the second strategy, part of the market exposure is offset by the opposite SPY leg. That does not remove risk, but it changes the type of risk the portfolio is taking. The performance of Strategy 2 is then evaluated through its cumulative return. This allows the paired

strategy to be compared with the earlier strategies on the same basis. Strategy 2 ends with a lower final value than buy and hold.

The risk side of Strategy 2 is important because of the reasons mentioned above. We compute drawdown as the percentage fall below the running maximum and then summarize the worst drawdown episode in a separate table. According to our results, Strategy 2 has a maximum drawdown of about -8.93% and the worst point occurs on 1999-06-16. The drawdown begins on 1999-05-14 and it recovers in 1999-08-24, giving a drawdown duration of 72 days. We conclude here that the paired structure experienced a much smaller decline than Strategy 1. Even though Strategy 2 did not produce the highest terminal wealth, it behaved in a more controlled way during the main loss period.

	Metric	Value
0	Maximum Drawdown	-0.089347
1	Max Drawdown Date	1999-06-16 00:00:00
2	Drawdown Start Date	1999-05-14 00:00:00
3	Recovery Date	1999-08-24 00:00:00
4	Drawdown Duration (days)	72

This difference in drawdown behavior is one of the main findings of the strategy. Strategy 1 experienced a much deeper maximum drawdown, while Strategy 2 lost less from its earlier peak during the worst period of the year. That does not automatically make Strategy 2 better in every sense, since it also gives up some upside, but it does suggest that adding the opposite SPY position helped stabilize the path of returns.

6. Comparative Findings Across All Approaches

Here we bring together the three approaches studied in our implementation, buy and hold in MSFT, Strategy 1 based on MACD trading in MSFT alone, and Strategy 2 based on the same MACD signal combined with a negative SPY trade.

	Final Value	Total Return	Annualized Return	Annualized Volatility	Sharpe-like Ratio	Maximum Drawdown
Buy-and-Hold MSFT	1.6836	0.6836	0.6536	0.3741	1.5308	-0.1969
Strategy 1	1.3335	0.3335	0.3204	0.3752	0.9272	-0.2166
Strategy 2	1.2861	0.2861	0.2750	0.1522	1.6730	-0.0893

The first result that stands out is that buy and hold in MSFT delivers the highest final value and the highest total return over the sample period. The ending value of the passive strategy is 1.6836, which corresponds to a total return of 0.6836 and an annualized return of 0.6536 after conversion. This shows that simply holding Microsoft produced stronger cumulative growth than either of the

two active trading strategies. In other words, the MACD rules did not improve on the upside captured by a passive long position in a stock that performed strongly over the period.

Strategy 1 performs worse than buy-and-hold on return and does not offer an improvement in risk as well. Its final value is 1.3335 and an annualized return of 0.3204. At the same time, its annualized volatility is 0.3752, which almost the same as the buy and hold volatility of 0.3741. This is a crucial finding because it shows that Strategy 1 gives up a large amount of return without meaningfully reducing overall risk. Its Sharpe-like ratio is also lower, at 0.9272 compared with 1.5308 for buy and hold. So even before considering drawdowns, Strategy 1 appears weaker on a risk adjusted basis.

When we consider the drawdown analysis, buy and hold has a maximum drawdown of 0.1969, while Strategy 1 reaches a larger maximum drawdown of -0.2166. This means the direct MACD strategy not only underperforms in cumulative return but also experiences a deeper peak to trough loss than simply holding the stock. That weakens the case for Strategy 1 further, because the strategy does not compensate for its lower return with better downside protection. In this sample, it ends up looking worse than the passive benchmark on both return and maximum drawdown.

Strategy 2 presents a different profile. Its final value is 1.2861, which is lower than both buy-and-hold and Strategy 1, and its total return of 0.2861 is the smallest of the three. Its annualized return is also lower at 0.2750. So, if the comparison is based only on terminal wealth, Strategy 2 is not the strongest performer. However, Strategy 2 achieves this outcome with much lower annualized volatility of 0.1522 and a much smaller maximum drawdown of -0.0893. This is a major improvement in risky behavior compared with the other two approaches.

This risk improvement is also reflected in the Sharpe-like ratio. Strategy 2 has the highest Sharpe-like ratio in the table, at 1.6730, compared with 1.5308 for buy and hold and 0.9272 for Strategy 1. This suggests that although the paired strategy does not produce the highest return, it delivers the most return per unit of risk among the three. That result fits the earlier discussion of the opposite SPY position. By combining the MSFT signal with a hedge-like market leg, Strategy 2 gives up some upside but gains a much more stable return path. So, the main value of Strategy 2 is not aggressive outperformance, but improved efficiency on a risk adjusted basis.

Looking at all three strategies together, the comparison shows that the choice of benchmark matters. If the goal is simply to maximize cumulative return over the sample, buy and hold seems the best option. If the goal is to use the MACD signal in its simplest direct form, Strategy 1 does not appear very attractive because it produces lower returns without clear benefits. If the goal is to improve downside behavior and reduce volatility while keeping a signal based trading structure, Strategy 2 is the strongest alternative. This is why the final table is useful: it shows that the best strategy depends on whether the focus is on raw return or on the balance between return and risk.

In this sample, the MACD rule by itself is not enough to beat a passive long investment in Microsoft. However, once the same signal is placed inside a paired MSFT-SPY structure, the results become more interesting. The strategy still does not win on total return, but it becomes much more attractive from a risk control point of view. This means the main contribution of the MACD signal in this assignment is not that it generates the highest absolute profit, but that it

becomes more useful when combined with a portfolio construction approach that reduces overall exposure and drawdown.

7. Interpretation of Results

The results of the three approaches show that the sample period matters a lot when evaluating a trading rule. In this case, buy and hold in MSFT delivers the strongest performance over the full year. One reason for this is that a passive strategy benefits fully when a stock experiences strong upward momentum. If the general direction of the stock is favorable, continuously holding the position can outperform an active rule that frequently enters and exits. In that kind of environment, a trend following indicator may not add much value because simply staying invested captures more of the upside. This can help explain why buy and hold finishes with the highest final value and total return in the summary table.

At the same time, the weaker performance of Strategy 1 also says something important about the limitations of MACD in a short horizon trading setting. Our MACD signal is built with moving averages, so it reacts with a delay. This means it may work reasonably well when price movements develop smoothly, but it may struggle when the market changes direction quickly. In those cases, the strategy may switch too late. It can also get confused in choppy periods, where the signal changes back and forth without a sustainable trend. That type of behavior reduces performance because the rule keeps responding to short term fluctuations without capturing enough of the big move. The results of Strategy 1 are consistent with this idea, since it underperforms staying invested while also showing a larger maximum drawdown.

Strategy 2 shows that the same signal can behave differently once the portfolio structure changes. By keeping the MSFT MACD signal but adding the opposite SPY position, the strategy reduces part of its systematic exposure. This does not eliminate risk completely, but it changes the nature of risk the portfolio is taking on. Instead of relying only on the absolute performance of Microsoft, the strategy becomes more of a relative position between MSFT and the market. That helps explain why Strategy 2 produces a much smaller maximum drawdown and much lower annualized volatility than the other two approaches. The hedge like SPY trade appears to make the returns more stable, especially during the main loss period.

In my view, this leads to the purpose of this assignment. Better risk control does not necessarily mean the highest return. Strategy 2 has the lowest total return of the three, so it is not the best performer if the only objective is terminal wealth. However, it offers the most defensive risk profile and the strongest Sharpe ratio, which shows that it delivers returns more efficiently relative to the amount of risk taken. A passive investor focused only on pure growth might prefer buy and hold strategy, while a more risk averse investor may find Strategy 2 more attractive because of its lower volatility and smaller drawdown.