Trend-Following Trading Algorithm

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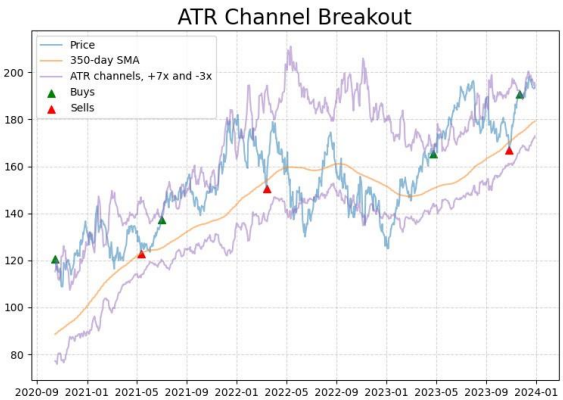
1 INTRODUCTION

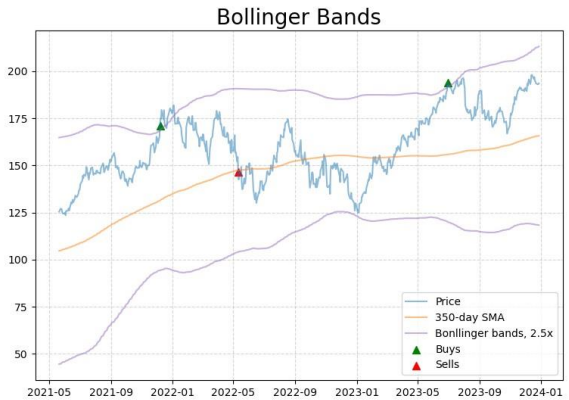
Trend-Following is a trading style that attempts to capture gains through the analysis of an asset's momentum in a particular direction. Trend trading strategies assume that a security will continue to move in the same direction as it is currently trending. To detect trend in one direction, there are a variety of indicators that can be used.

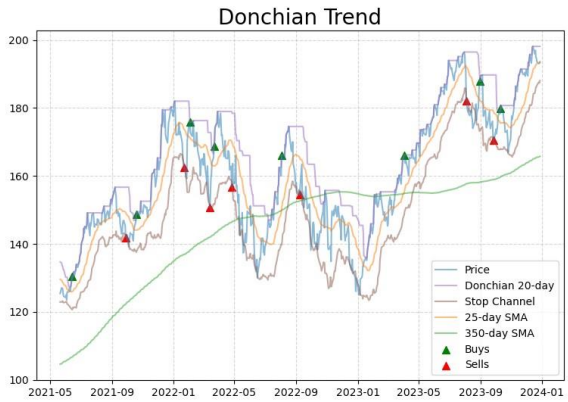
Curtis M. Faith did a backtest in "The way of the turtle" of some well-known strategies with different assets, such as currencies, commodities, and bonds, obtaining very good results. As first step, we are implementing and backtesting some of those strategies (described in the following link: https://www.quantifiedstrategies.com/trend-following-trading-strategy/) with AAPL shares data from the last 25 years. The strategies are described below:

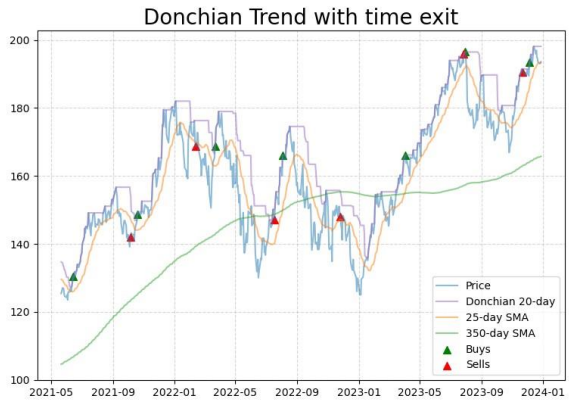
- **ATR channel breakout**: buy the asset when the price goes above an upper channel, which is calculated adding a certain amount of ATR (Average True Range is a volatility indicator) to a moving average of the price. The trade is closed when the price goes bellow the moving average.
- **Bollinger band**: this system is like the ATR channel breakout, but instead of ATR as volatility indicator, it uses standard deviation of prices.
- **Donchian trend**: buy the asset when the price is maximum compared to last days' prices (rolling max is the so called Donchian channel). Additionally, an uptrend filter is applied, which means that the following condition must be met to open a trade: short moving average > long moving average.
- **Donchian trend with time exit**: this system is the same as the previous one, but it sells the asset after a fixed number of days since the buy signal.
- **Dual Moving Average**: buy the asset when the short moving average is above the long moving average, and close the position when the condition is no longer met.
- **Triple Moving Average**: this system is like the previous one, but it uses three moving averages. The condition to be met is that the short moving average is above the mid moving average, and the mid moving average is above the long moving average.

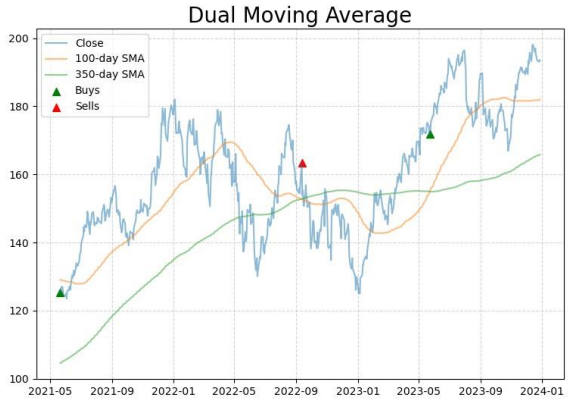
Below are some plots with the signals, and buys and sells of each strategy described above, to visualize how they work:

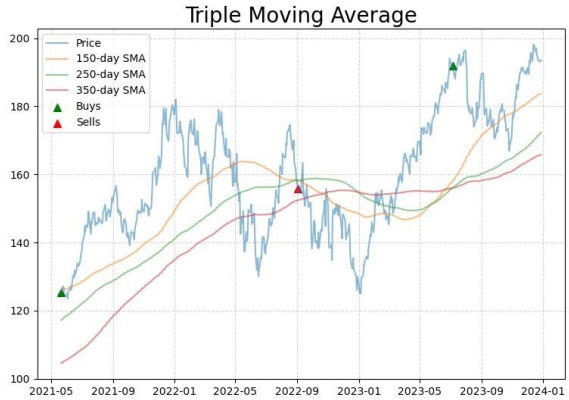












2 BACKTEST OF REFERENCE TREND-FOLLOWING STRATEGIES

To analyse the effectiveness of these strategies, a backtest of each was conducted using daily price data of AAPL from January 1, 2000, to January 1, 2024. This period included recessions, bullish, and sideways market phases, making it a sufficiently long timeframe to conduct the backtest and draw conclusions.

Each strategy starts with an Invested Capital of 100k$. When the strategy generates a buy signal, based on an indicator or combination of indicators, the entire cash balance is used to buy the stock. When the strategy generates a sell signal, the entire stock holding is sold. Transaction costs, such as broker fees or slippage, are neglected.

The goal of every investment strategy is to maximize returns, minimize risk or a combination of both (ideally, maximize the return per unit of risk). With that in mind, the following metrics have been calculated for each of the strategies:

- **Compound annual return (%)**:

$$\mathrm{CAR} = 100 * \left(\frac{\text{Final Capital}}{\text{Invested Capital}}^{\frac{1}{\mathrm{N}_{\text{years}}}} - 1 \right)$$

- **Maximum drawdown (%)**: the maximum loss from a peak to a trough of a portfolio.

- **Volatility (%)**: standard deviation of annualized returns.
- **Market exposure (%)**: percentage of time that the investor is holding the asset.
- **Risk adjusted compound annual return (%)**: the longer we keep an asset in our portfolio, the more time we are exposed to the market and the greater the risk.

$$\text{Risk Adjusted CAR} = \frac{\text{CAR}}{\text{Market Exposure}}$$

- **Sharpe ratio (-)**: this ratio measures the excess return per unit of volatility (volatility is measured as standard deviation of returns).

$$\text{Sharpe} = \frac{\text{mean(Annualized Returns)} - \text{Risk Free Rate}}{\text{std(Annualized Returns)}}$$

- **Sortino ratio (-)**: this ratio measures the excess return per unit of volatility of negative returns (volatility of negative returns is measured as standard deviation of negative returns).

$$\text{Sharpe} = \frac{\text{mean(Annualized Returns)} - \text{Risk Free Rate}}{\text{std(Negative Annualized Returns)}}$$

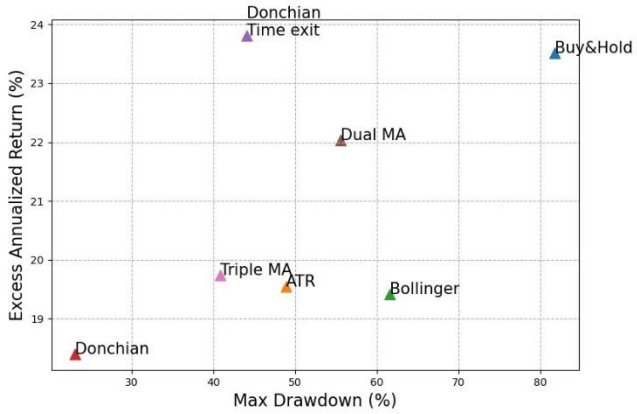
The following table summarizes results of the backtests. The strategy with the best result according to each metric is highlighted in green, and the strategy with the worst result is highlighted in red:

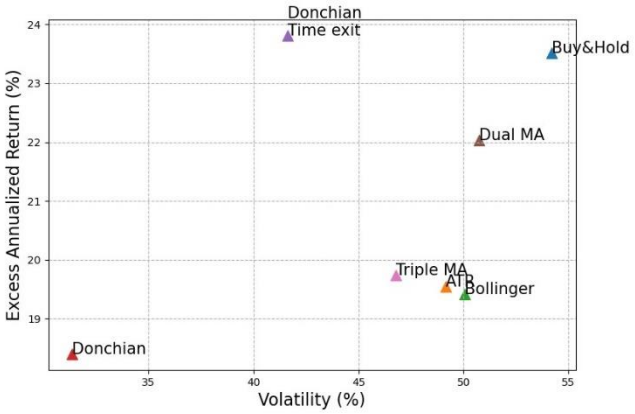
Strategy	Final Capital (M$)	Compound Annual Return (%)	Maximum Drawdown (%)	Volatility (%)	Market Exposure (%)	Risk Adjusted CAR (%)	Sharpe Ratio	Sortino Ratio	Number of trades
Buy and Hold	19.26	24.51	81.8	54.21	100	24.51	0.69	1.97	0
ATR	8.88	20.55	48.88	49.16	62.59	32.84	0.58	2.74	11
Bollinger	8.64	20.42	61.54	50.06	70.46	28.98	0.58	1.92	2
Donchian	7.05	19.4	23.04	31.36	39.15	49.56	0.77	5.35	106
Donchian, time exit	20.42	24.81	44.06	41.61	68.49	36.23	0.76	3.64	52
Dual MA	14.47	23.03	55.59	50.75	72.08	31.95	0.64	2.05	7
Triple MA	9.22	20.74	40.8	46.77	62.38	33.26	0.60	3.29	10

All the Trend Follow strategies significantly reduced the maximum drawdown and the volatility when compared to the Buy and Hold. In fact, most of the metrics that measure return per unit of risk have been improved.

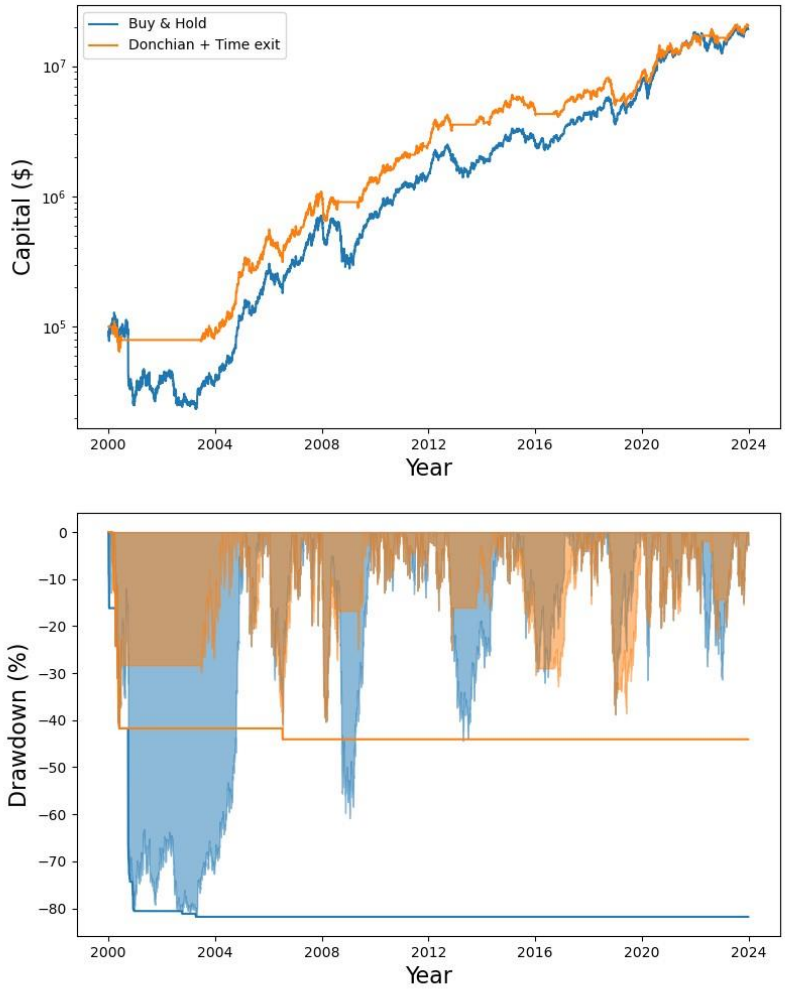
If we plot the excess return of each strategy against its maximum drawdown and volatility, it can be distinguished that there is a positive correlation between return and risk, which makes sense from a theoretical perspective. In general,

if the investor is willing to take on more risk, they can achieve higher returns in the long term. The baseline strategy, Buy and Hold, is the riskiest. It buys and holds the asset for the hole period, being constantly exposed to the market.





In this case, the Donchian Trend with time exit did the best. This strategy got better returns than the Buy and Hold, and reduced significantly the maximum drawdown and volatility. In the following plot of the Equity Curve the difference can be seen:



Trend Follow strategies protect investors during prolonged drawdowns. When markets are declining, Trend Follow trading signals sell assets and protect against future declines (in the picture above: 2000-2004, 2008-2010, 2022-2023). While this does not work during sudden crashes with quick recoveries, these drawdowns are not as detrimental to an investor.

3 VOLATILITY ANALYSIS

High volatility periods present both challenges and opportunities for Trend Follow strategies.

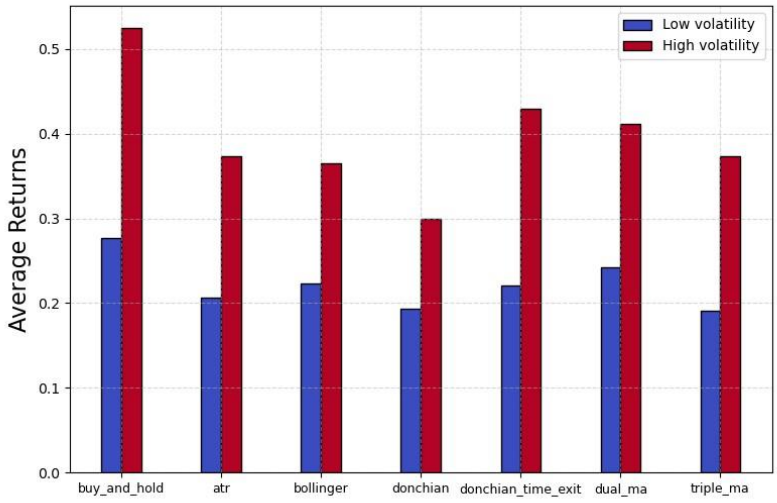
- Increased market noise makes prices less predictable. Price movements that appear to be the start of a new trend might quickly reverse.
- High volatility is often associated with market downturns or recessions. During such times, markets can experience sharp drops, which imply high risk.

- On the other hand, high volatility periods can be associated with strong price movements. Trend Follow strategies benefit from capitalizing those periods.

It has been analysed the performance of each strategy, in terms of Average Returns, in Low and High volatility periods. For that, the following steps have been followed:

1. Calculate asset price volatility of past days, using ATR indicator (Average True Range).
2. Calculate strategy Average Returns of next days.
3. Divide dataset in low and high volatility periods, using P50 quantile as boundary.
4. Compare mean Average Returns of the strategy in low and high volatility periods.

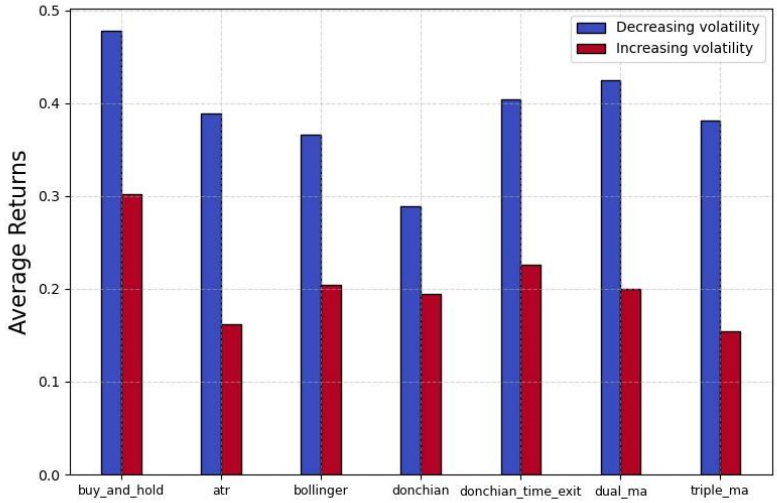
The results are the following:



Returns are higher in average after high volatility periods. This makes sense, as high volatility can be associated with strong market movements. However, those periods are also more risky, as high volatility is also associated with recessions. We don't want to increase strategy returns at any cost. Instead, we want to increase returns per unit of risk.

Another way to use volatility to improve Sharpe ratio is not by looking at its absolute value, but at how it changes. Decreasing volatility implies that price fluctuations are becoming less extreme. In the context of an upward trend, this can indicate stability and strengthening of the trend, making it a more reliable investment. Lower volatility is often associated with increased investor confidence and a more predictable market environment.

One way to check the change in volatility is to compare a Short Moving Average with a Long Moving Average of the ATR volatility indicator. If the volatility is decreasing, the short Moving Average will be below the long Moving Average.



Looking at this graph the pattern seems to be clear. Periods in which volatility decreases are associated with higher future returns, and do not imply higher risk. Therefore, this indicator could improve the Sharpe ratio of Trend Following strategies.

4 CUSTOMIZED STRATEGY

For now, it has been seen that some strategies outperformed the "Buy and Hold", at least in terms returns per unit of risk. The goal is to build a conservative Trend-Following strategy that minimizes drawdowns and volatility, while capitalizing on periods with high market uptrends.

The Donchian strategy with a time-based exit signal obtained the best results in the backtest. However, the final strategy is not being designed based merely on those results, as that would be overfitting. The analysis helped to understand that Trend-Following strategies reduce drawdowns during prolonged bearish markets, and are capable of detecting upward trends. On the other hand, the optimization of parameters based on a single backtest with an asset (AAPL in this case) would also lead to overfitting. It is preferable to use a simple, conservative logic, with fundamentals to support it.

In line with this argument, and based on the analysis conducted, the strategy will be based on several indicators, and a volatility filter to reduce risk. Using multiple indicators allows for some diversification of the strategy, as it requires confirmation from several signals to open a position.

- **Uptrend detection**: the Moving Average Crossover is probably the most used signal for detecting bullish trends, and although it is simple, it has proven to be effective. The condition to be met is the following:

  EMA (100-day) > EMA (350-day)

- **Momentum confirmation:** the Relative Strength Index (RSI) is a momentum indicator. It confirms the strength behind a price move. Therefore, we only enter a position if the RSI is in the normal range (no overbought or oversold conditions), and it is also increasing (which means that the uptrend strength is increasing). The conditions to be met are the following:

  RSI in normal range: 30 > RSI (30-day) > 70

  RSI increasing: RSI (5-day) > RSI (30-day)

- **Volatility filter:** decreasing volatility often indicates more stable and predictable market movements. In the context of an upward trend, this can suggest that the trend is more likely to be sustained without abrupt reversals, making it a more reliable signal for Trend Following strategies. The condition to be met is the following:

  ATR (25-days) < ATR (200-days)

- **Exit signal:** following a conservative approach, if the uptrend condition is no longer met, or the RSI indicates overbought market, we exit the long position. One of the following conditions must be met to exit a position.

  EMA (100-day) < EMA (350-day)

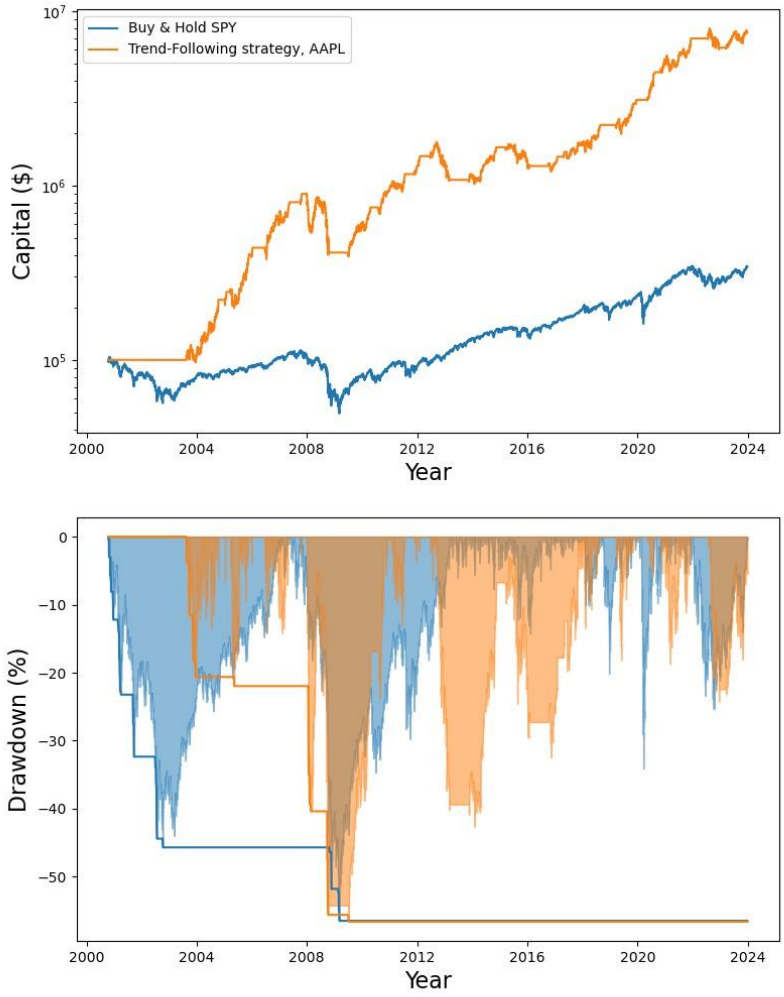
  RSI (30-day) > 70

5 BACKTEST AND RESULTS

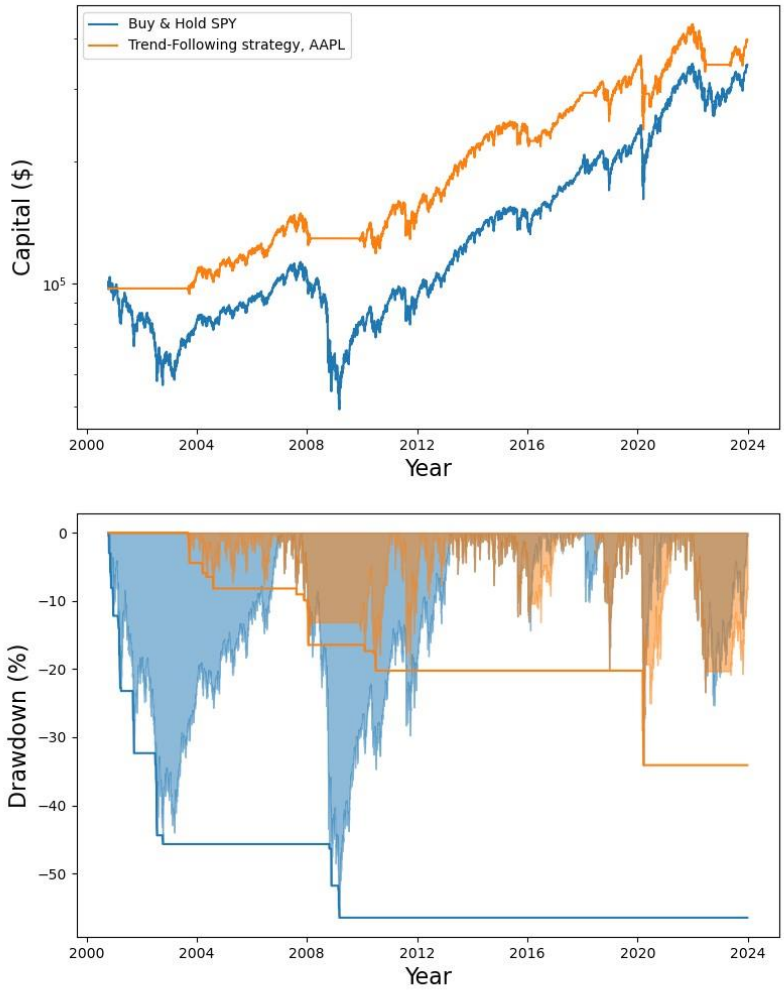
The benchmark for comparison of results is the S&P 500 index, which represents the market as a hole. The goal of every Hedge Fund is to get better results than the market on a consistent basis. The results from the backtest are the following:

Strategy	Final Capital (M$)	Compound Annual Return (%)	Maximum Drawdown (%)	Volatility (%)	Market Exposure (%)	Risk Adjusted CAR (%)	Sharpe Ratio	Sortino Ratio	Number of trades
Strategy, MCD	7.54	20.47	56.60	35.44	55.05	37.18	0.74	1.67	36
Buy and Hold, S&P 500	0.36	5.85	56.47	16.4	100	5.85	0.47	0.64	0

The difference can be visualized in the Equity Curve:



The goal is to beat the reference in terms of profitability, risk, or ideally profitability per unit of risk. It is easy to outperform SPY with a stock like AAPL, which has seen its price increase by 500x over the considered period, becoming the world's largest company by Market Cap. To evaluate the performance of the strategy, it would be reasonable to apply it directly to SPY, and compare the results with the index itself. In that case, the equity curve is as follows:



As expected, the strategy avoids being exposed to the market during sideways or prolonged bearish periods. It is capable of capitalizing on bullish trends. It limits the drawdown, reduces market exposure, and the annual return is practically the same. In other words, this strategy has been able to maintain returns while significantly reducing risk.

6 TREND-FOLLOWING PORTFOLIO

Trend-Following strategies are not designed to make predictions in specific markets, and they assume that prices already incorporate all available information. These strategies simply lay on the hypothesis that markets that have been moving in one direction are more likely to keep moving in that direction. As no predictions are made, diversification mitigates the risks associated with different economic cycles. In fact, professional trend-followers often participate in trading numerous futures markets spanning equities, bonds, currencies, commodities, and even more unconventional markets like carbon offsets.

In 1964, Bill Sharpe published a treatise titled "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," outlining a method for investors to attain higher returns while maintaining diversification. Investors willing to embrace higher risk in their pursuit of better returns would leverage their investments to acquire more units of this diversified portfolio. This means that a diversified portfolio is better to achieve higher returns per unit of risk, and if the investor is willing to take on more risk, they can use leverage.

6.1 Assets in the portfolio

The following tickers correspond to ETFs that represent different sectors of the stock market in the US:

- XLK: Technology Select Sector SPDR Fund (Technology)
- XLV: Health Care Select Sector SPDR Fund (Health Care)
- XLF: Financial Select Sector SPDR Fund (Financials)
- XLY: Consumer Discretionary Select Sector SPDR Fund (Consumer Discretionary)
- XLP: Consumer Staples Select Sector SPDR Fund (Consumer Staples)
- XLE: Energy Select Sector SPDR Fund (Energy)
- XLB: Materials Select Sector SPDR Fund (Materials)
- XLI: Industrial Select Sector SPDR Fund (Industrials)
- XLU: Utilities Select Sector SPDR Fund (Utilities)

Some advantages of appling a Trend-Following strategy to a portfolio of ETFs representing different sectors are the following:

- ETFs are less exposed to company-specific risks and are more resilient to negative developments in any single sector.
- ETFs reflect broader economic trends.
- ETFs are typically more liquid than individual stocks.

6.2 Buy/Sell signals

The Trend-Following strategy presented in the previous section will be applied to this portfolio. Buy signals are generated on each ETF based on the following indicators:

- **Uptrend indicator**: in this case a triple moving average crossover system is being used. This is slightly more conservative when it comes to identifying an uptrend than the dual moving average system, as there are more investment opportunities. The conditions to be met are the following:

  EMA (20-day) > EMA (100-day)

  EMA (100-day) > EMA (500-day)

- **Momentum confirmation:** the RSI must be in the normal range, and with increasing value (increasing uptrend strength). The conditions to be met are the following:

  RSI in normal range: 30 > RSI (30-day) > 70

  RSI increasing: RSI (5-day) > RSI (30-day)

- **Volatility filter**: decreasing volatility often indicates more stable and predictable market movements. The condition to be met is the following:

  ATR (25-days) < ATR (200-days)

- **Exit signal:** this strategy is supposed to be slightly more conservative than the one designed to trade singles stocks, as tracking multiple assets provides more investment opportunities. Therefore, if the closing price falls below the longer moving average, it stops holding the respective ETF. The condition to be met is the following:

  Close < EMA (500-day)

6.3 Asset allocation

The weights assigned to each asset in the portfolio are proportional to the inverse of volatility. For example, if on a given day there are 3 assets with a LONG signal, the weight of each asset is calculated proportionally to the inverse of volatility, always having 100% of the capital invested (unless hold signals of every asset are in False).

Volatility is calculated as the standard deviation of annualized returns over the last year. Meaning, each day the return of the asset is calculated relative to its price one year ago, and the standard deviation of these returns is calculated in a rolling window over the past year.

Volatility = 1year_rolling_std(annualized returns)

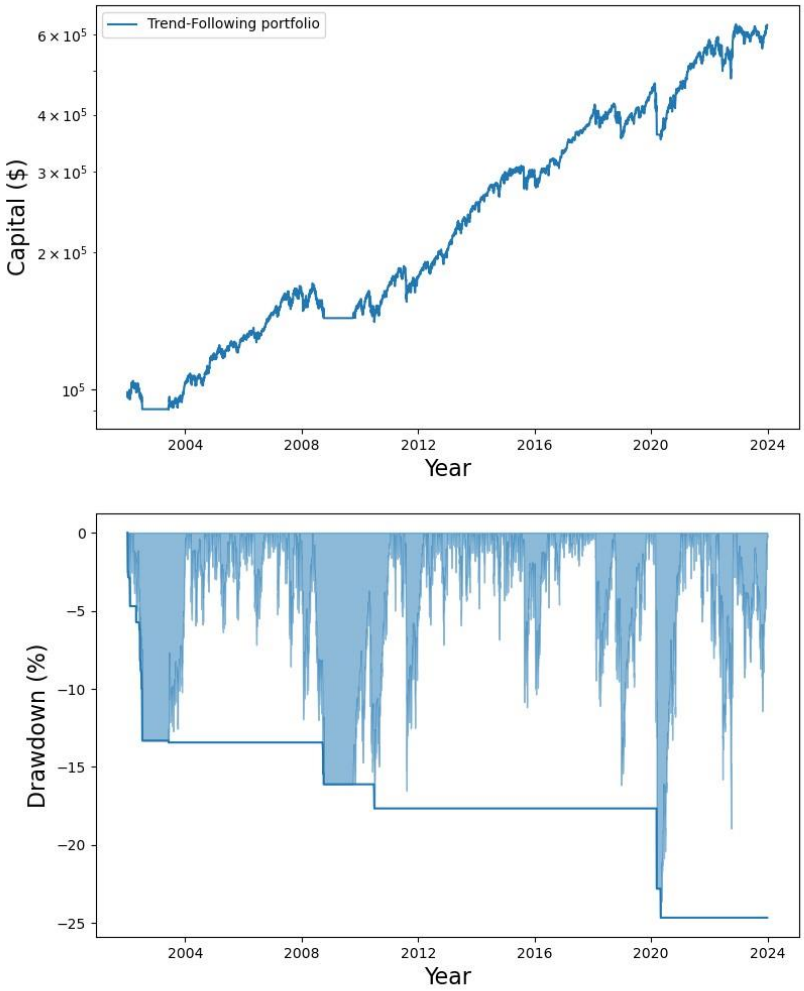
Asset weight $\propto$ 1/Volatility

6.4 Backtest and results

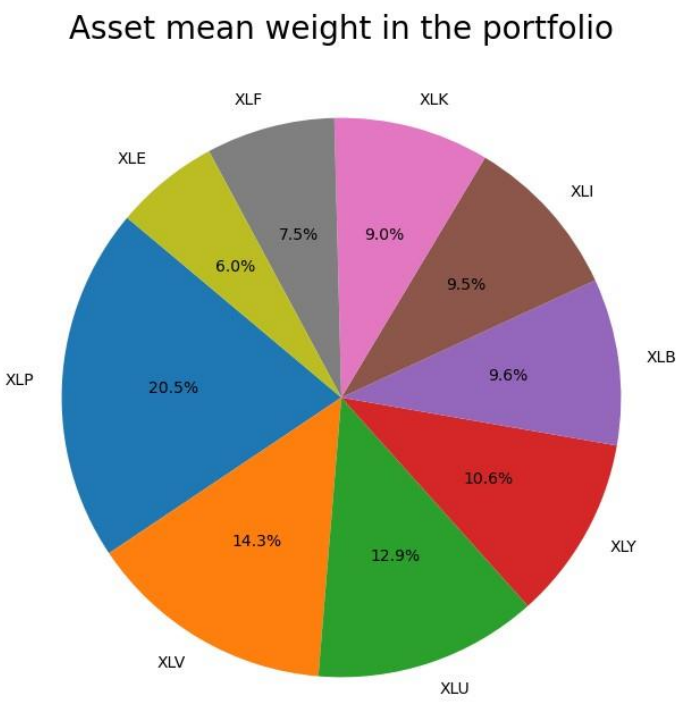
A backtest has been conducted with an invested capital of $100k in the period from January 1, 2000, to January 1, 2024. Below are certain metrics of interest related to the backtest results:

KPI	Result from backtest	Units
Invested capital	100	k$
Final capital	629.10	k$
Compound annual return	8.72	%
Best year return	45.14	%
Worst year return	-16.11	%
Maximum drawdown	24.64	%
Volatility	10.21	%
Sharpe Ratio	0.85	-
Sortino Ratio	2.12	-

The following plot represents the Equity Curve:



The following values correspond to mean weight of every ETF on the portfolio:



This strategy has significantly reduced the drawdown compared to the strategy applied with a single stock. Other aspects that could be considered are the following:

- Trade other type of assets that performs differently through economic cycles (economic growth, recession, inflationary, deflationary). For example, a Trend-Following portfolio can be made of stocks, bonds, gold and commodities.
- Try to design a strategy that maximizes Sharpe ratio, reducing volatility and drawdowns. And then, add some leverage to adjust the strategy to the desired risk.
- Add uncorrelated assets to the portfolio. The amount of diversification is not proportional to the number of assets. Adding uncorrelated assets busts the diversification, and thus reduces the risk.
- Take LONG and SHORT positions trading Index futures. This can make the portfolio profitable in both bullish and bearish market periods, increasing the Sharpe ratio.