Quantitative Trading

Signals, Strategies, and Market Microstructure

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Outline

- Trend and Momentum Strategies using Moving Averages

Course Reference:
Futuretesting Quantitative Strategies
`http://ssrn.com/abstract=4647103`

Trend and Momentum Strategies using Moving Averages

Moving Averages: Smoothing Price Dynamics

- **Objective of Moving Averages (MAs):**
  - Filter out short-term noise in prices
  - Extract the underlying trend component
  - Transform raw prices into tradable signals
- **Speed and Responsiveness:**
  - **Fast MA (short lookback):** low lag, reacts quickly, sensitive to noise
  - **Slow MA (long lookback):** higher lag, smoother, captures long-term trends
- **Common Types of Moving Averages:**
  - **Simple Moving Average (SMA):** equal weight on all observations
  - **Exponential Moving Average (EMA):** higher weight on recent prices $\Rightarrow$ faster reaction
  - **Weighted Moving Average (WMA):** linearly increasing weights, compromise between SMA and EMA

Key idea: moving averages convert noisy price series into structured signals suitable for systematic trading.

Simple Moving Averages at Different Speeds

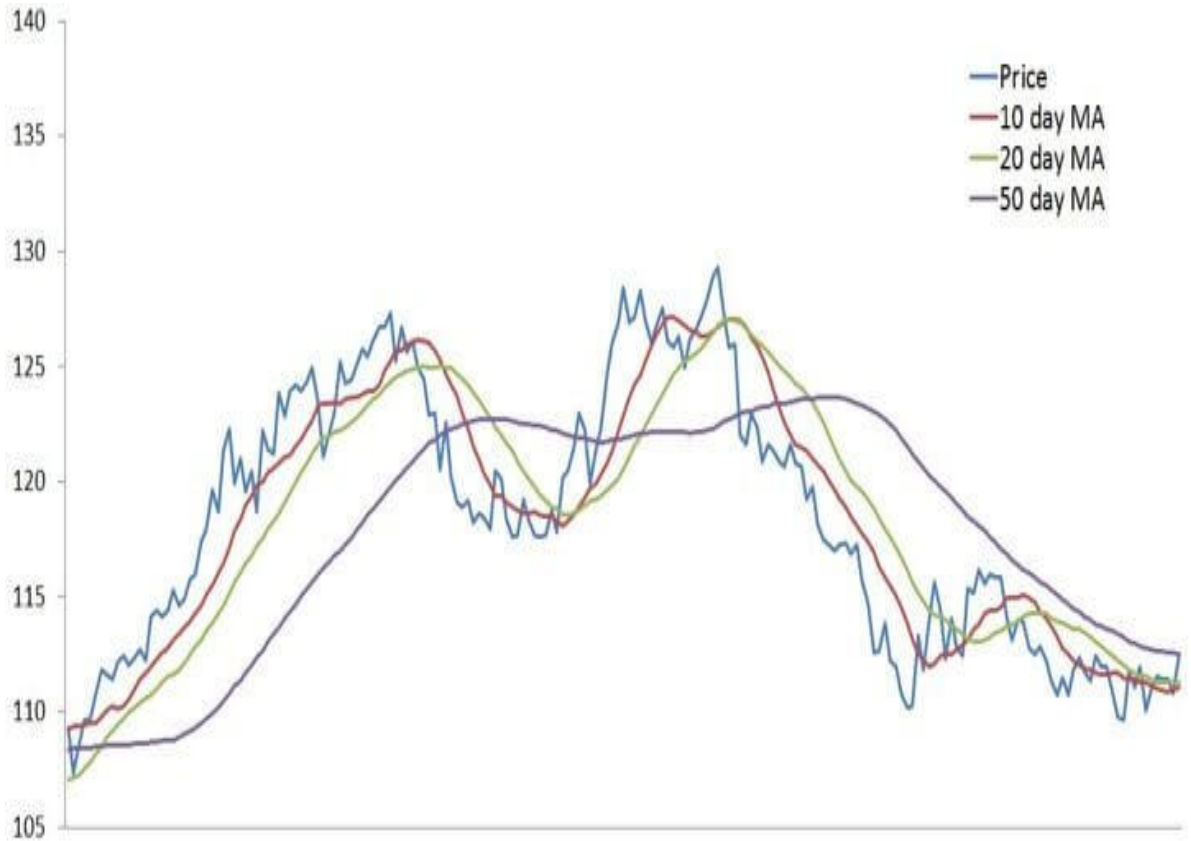

Figure 1: Simple Moving Averages (SMA) with different lookback windows.

Simple Moving Averages at Different Speeds

- Short lookback SMA:
  - Closely tracks price movements
  - Reacts quickly to trend changes
  - High sensitivity to noise and false signals
- Long lookback SMA:
  - Smooths short-term fluctuations
  - Captures persistent trends
  - Introduces lag in signal generation

Trade-off: responsiveness versus stability — a central theme in trend-following strategies.

Moving-Average-Based Trading Strategies

Moving averages form the foundation of many systematic trading rules. Common strategies can be grouped by their trading logic:

- **Trend-following strategies**
  - **Double Moving Average Crossover (DMAC):** fast MA crossing slow MA generates buy/sell signals
  - **Triple Moving Average Crossover (TMAC):** adds a medium-term MA to reduce false signals
- **Momentum indicators derived from MAs**
  - **Moving Average Convergence Divergence (MACD):** difference between fast and slow EMAs captures trend strength
  - **Relative Strength Index (RSI):** oscillator measuring persistence of gains versus losses
- **Volatility-aware MA strategies**
  - **Bollinger Bands (BB):** MA combined with volatility bands to identify extremes and breakouts

Unifying idea: prices, trends, momentum, and volatility are all filtered through moving averages.

The Bollinger band

Figure 2: Bollinger bands.

The Double Moving Average Crossover (DMAC)

- Uses two moving averages with different lookback horizons:
  - **Fast MA (short-term):** reacts quickly to recent price changes
  - **Slow MA (long-term):** captures the persistent trend
- Trading signals:
  - **Buy signal (Golden Cross):** fast MA crosses above slow MA
  - **Sell signal (Death Cross):** fast MA crosses below slow MA
- Interpretation:
  - Crossing indicates a change in trend dominance
  - Acts as a low-frequency momentum filter
- Limitations:
  - Performs poorly in range-bound or sideways markets
  - Generates whipsaws due to lag and noise

Key insight: DMAC trades trend persistence, not price levels.

The Triple Moving Average Crossover (TMAC)

- Uses three moving averages:
  - **Fast MA:** short-term market reaction
  - **Medium MA:** intermediate trend confirmation
  - **Slow MA:** long-term market regime
- Entry signals:
  - **Buy:** fast MA crosses above both medium and slow MAs
  - **Sell:** fast MA crosses below both medium and slow MAs
- Signal confirmation:
  - Medium MA acts as a filter against short-term noise
  - Reduces false breakouts relative to DMAC
- Trade management:
  - Exit when fast MA crosses back through medium MA
  - Or when MA ordering breaks down

Key trade-off: fewer trades, but higher signal reliability.

Moving Average Convergence Divergence (MACD)

- The MACD is a momentum indicator derived from moving averages.
- It measures the **distance** between a fast and a slow EMA:
  - Large positive values $\Rightarrow$ strong upward momentum
  - Large negative values $\Rightarrow$ strong downward momentum
- Unlike simple MA crossovers:
  - MACD provides a *continuous* measure of trend strength
  - Signals can be anticipated before actual MA crossovers
- MACD generates signals through:
  - Crossings with a signal line (smoothed MACD)
  - Zero crossings (trend confirmation)
  - Divergences between price and momentum

Interpretation: MACD combines trend-following and momentum in a single indicator.

The MACD Line: Definition

- The **MACD line** measures momentum as the difference between two exponential moving averages (EMAs).

MACD Line

$$DIFF_t = EMA(n_S)_t - EMA(n_L)_t$$

- n_S: short-term lookback window (fast EMA)
- n_L: long-term lookback window (slow EMA)
- Standard choice: $n_S = 12$, $n_L = 26$
- Interpretation:
  - $DIFF_t > 0$: short-term momentum exceeds long-term trend (bullish)
  - $DIFF_t < 0$: downward momentum dominates (bearish)

Remark: MACD is equivalent to a *double EMA crossover expressed in difference form*.

The MACD Signal Line

- The MACD line is smoothed using an exponential moving average, called the **signal line**.

Signal Line

$$SL_t = EMA_{DIFF}(n)$$

- Standard choice: $n = 9$
- The signal line filters noise from the raw MACD line
- Trading interpretation:
  - **Buy signal:** MACD line crosses above the signal line
  - **Sell signal:** MACD line crosses below the signal line

Key insight: the MACD-signal interaction is equivalent to a *triple EMA crossover* expressed in compact form.

The MACD Histogram

- The MACD histogram measures the distance between the MACD line and the signal line.

MACD Histogram

$$Hist_t = DIFF_t - SL_t$$

- Interpretation:
  - $Hist_t > 0$: MACD above signal line (bullish momentum)
  - $Hist_t < 0$: MACD below signal line (bearish momentum)
- Dynamics:
  - Increasing histogram $\Rightarrow$ momentum strengthening
  - Decreasing histogram $\Rightarrow$ momentum weakening
  - Zero crossing anticipates MA crossover

Key advantage: the histogram reduces lag by signalling changes in momentum before crossover events.

MACD Lines and Histogram

Figure 3: MACD line, signal line, and histogram.

MACD Lines and Histogram

- MACD line (blue): difference between fast and slow EMAs
- Signal line (orange): smoothed MACD (EMA of MACD)
- Histogram: distance between MACD and signal line

Reading the chart: histogram turning points often precede signal-line crossovers.

MACD: Trading Strategy

- The MACD line ($DIFF_t$) and the signal line ($MACD(n; n_S, n_L)_t$) provide entry and exit signals.
- Simplified trading rules:
  - **Go long:** MACD line crosses above the signal line, or histogram turns up below zero ($Hist_t > \epsilon$)
  - **Go short:** MACD line crosses below the signal line, or histogram turns down above zero ($Hist_t < \epsilon$)
  - **No trade:** Otherwise
- Histogram anticipates crossovers and reduces lag inherent in moving-average systems.
- Works best in trending markets; may give false signals in sideways markets.

Tip: Use this slide to visually relate MACD lines, signal lines, and histogram to trading decisions.

MACD: Entry Rule Algorithm

Algorithm 1 Set Entry Rule for MACD

Require: Current time t_j, stock price S_{t_j}
Require: MACD line $DIFF_{t_j}$, Signal line $MACD(n; n_S, n_L)_{t_j}$
Require: Histogram $Hist_{t_j}$, threshold ϵ

1: **if** $Hist_{t_j} > \epsilon$ **then**
2: Enter **long position**: $BoolLong \leftarrow$ True, $BoolTrade \leftarrow$ True
3: **else if** $Hist_{t_j} < \epsilon$ **then**
4: Enter **short position**: $BoolLong \leftarrow$ False, $BoolTrade \leftarrow$ True
5: **else**
6: **No trade**: $BoolTrade \leftarrow$ False
7: **end if**
8: **return** $BoolTrade, BoolLong$

Note: Histogram provides early signals before actual MACD crossover, helping to reduce lag

MACD: Exit Rule Algorithm

Algorithm 2 Set Exit Rule for MACD

Require: Current time t_j, stock price S_{t_j}
Require: MACD line $DIFF_{t_j}$, Signal line $MACD(n; n_S, n_L)_{t_j}$
Require: Histogram $Hist_{t_j}$, threshold ϵ
Require: Current trade status: *BoolTrade*, *BoolLong*

1: **if** *BoolLong* **and** $Hist_{t_j} < \epsilon$ **then**
2: Exit long position: *BoolTrade* $\leftarrow$ False
3: **else if** $\neg$*BoolLong* **and** $Hist_{t_j} > \epsilon$ **then**
4: Exit short position: *BoolTrade* $\leftarrow$ False
5: **end if**
6: **return** *BoolTrade*

Note: The exit logic mirrors the entry signal, using the histogram to minimize lag and lock in gains.

Bollinger Bands: Calculation Formula

1. **Typical Price:**

$$M_t = \frac{H_t + L_t + C_t}{3}$$

Average of high, low, and close prices.

2. **Simple Moving Average (SMA):**

$$SM_t(n) = \frac{1}{n} \sum_{i=1}^{n} M_{t-i+1}$$

Computes the mean of last n Typical Prices.

3. **Standard Deviation:**

$$SD_t(n) = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(M_{t-i+1} - SM_t(n)\right)^2}$$

Measures recent volatility.

Bollinger Bands: Calculation Formula

1. **Upper Band:**

$$\text{TopBand} = SM_t(n) + \alpha \times SD_t(n), \quad \alpha = 2$$

2. **Middle Band:**

$$\text{MidBand} = SM_t(n)$$

3. **Lower Band:**

$$\text{BotBand} = SM_t(n) - \alpha \times SD_t(n)$$

Tip: Bands expand with volatility and contract during calm periods, providing dynamic support/resistance.

Bollinger Bands: Interpretation and Use

- Bollinger Bands define a **dynamic price channel** around a moving average.
- The middle band represents the short-term trend, while the upper and lower bands adapt to volatility.
- **Band expansion** signals rising volatility, often following news or regime changes.
- **Band contraction** ("volatility squeeze") often precedes large price moves.
- Prices touching or exceeding the bands are *not* automatic buy/sell signals:
  - In trending markets, prices may "walk the band"
  - In range-bound markets, bands act as support and resistance

Key insight: Bollinger Bands measure relative price extremes conditional on recent volatility, not absolute overvaluation or undervaluation.

Bollinger Bands: Trading Strategy

- Bollinger Bands can be used to design **mean-reversion** or **breakout** strategies.
- **Mean-reversion strategy (range-bound markets):**
  - Go **long** when price touches or crosses the lower band
  - Go **short** when price touches or crosses the upper band
  - Exit near the middle band
- **Breakout strategy (trending markets):**
  - Enter positions when price breaks out after a volatility squeeze
  - Trade in the direction of the breakout
- Bands should be combined with momentum or trend indicators (e.g., MACD, RSI).

Warning: Using Bollinger Bands mechanically without regime detection leads to frequent false signals.

Limitations of Technical Indicators

- Most technical indicators are **backward-looking**, relying on past prices and volumes.
- Signals are often **lagged**, especially during rapid market regime changes.
- Indicators assume **stationarity** over the estimation window, which is frequently violated.
- Performance degrades in the presence of:
  - Structural breaks
  - Volatility regime shifts
  - Changes in market microstructure
- Parameter choices (window length, thresholds) introduce **model risk** and overfitting.

Key takeaway: Technical indicators are best viewed as *feature extractors*, not standalone trading systems.

From Stylised Facts to Models

- Financial time series exhibit stylised facts:
  - Heavy tails and non-Gaussian returns
  - Volatility clustering and persistence
  - Jumps, asymmetry, and regime changes
- Classical models (e.g. Brownian motion with constant volatility) fail to capture these features.
- This motivates progressively richer modelling frameworks:
  - Stochastic volatility models
  - Jump-diffusion processes
  - Regime-switching models
  - Nonlinear and data-driven models
- Model choice should be driven by the **stylised facts** relevant to the problem at hand.

Core principle: Models are approximations—use the simplest model that captures the dominant empirical features.

Summary and Outlook

- Financial time series exhibit rich dynamics that deviate strongly from classical assumptions.
- Key empirical characteristics include:
  - Heavy tails and extreme events
  - Volatility clustering and persistence
  - Jumps, asymmetries, and nonlinearity
  - Regime changes and cross-asset dependence
- These stylised facts challenge traditional econometric tools.
- Modern financial modelling integrates:
  - Stochastic processes beyond Brownian motion
  - Risk-aware statistical methods
  - Machine learning with memory and regime sensitivity

Outlook: The next part of the course will focus on stochastic volatility, jump processes, and data-driven models that explicitly address these empirical realities.

The end

Thank You !

Introduction

Moving Averages: Smoothing Price Trends

- Purpose of Moving Averages (MAs):
  - Smooth short-term price fluctuations
  - Reveal underlying trend
- Speed of MAs:
  - Fast MA (short lookback): less lag, more responsive
  - Slow MA (long lookback): more lag, smoother trend
- Types of MAs:
  - SMA: equal weight to all data points
  - EMA: more weight on recent prices $\Longrightarrow$ more responsive
  - WMA: weights based on position, compromise between SMA & EMA

SMA with different speeds

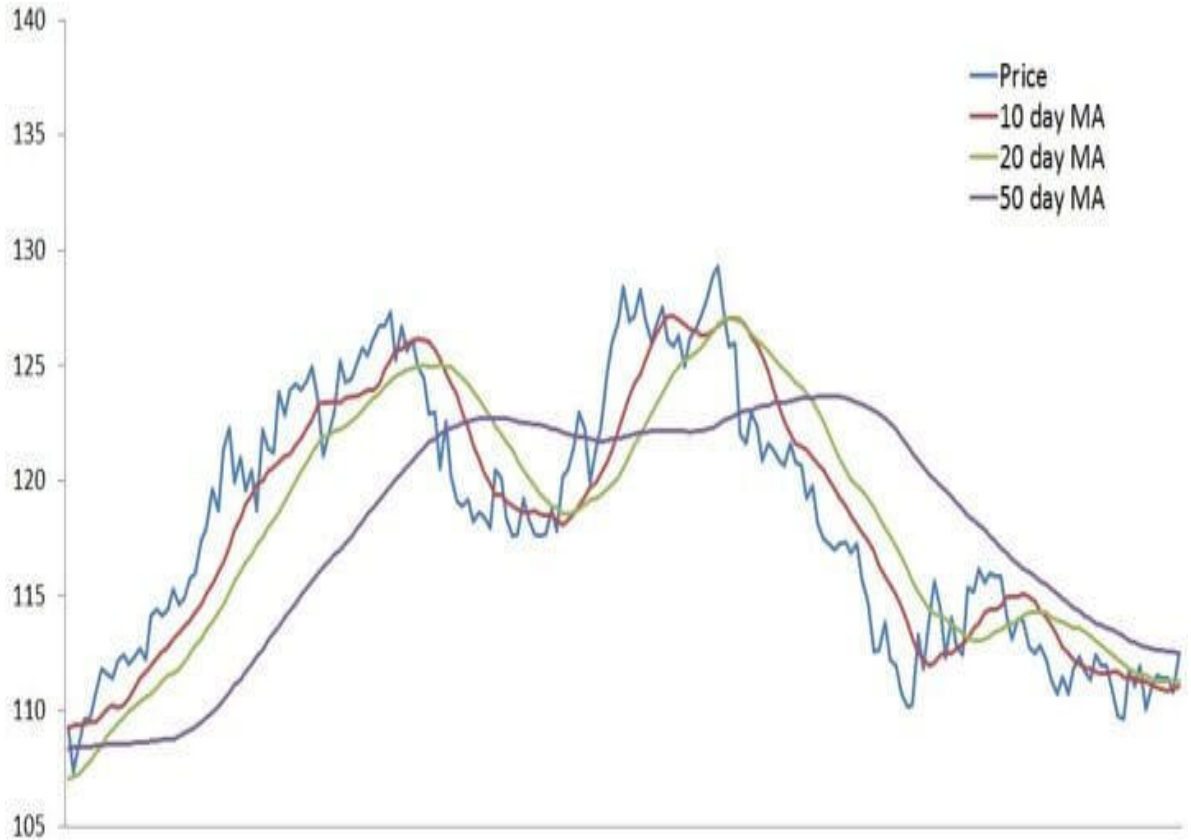

Figure 4: SMA with different speeds.

MA strategies

Some of the most common MA strategies include:

- Double Moving Average Crossover (DMAC): Generates buy/sell signals when a fast MA crosses a slow MA.
- The triple moving average crossover: Buy when the fast MA crosses above medium and slow MAs; sell when it crosses below.
- Moving Average Convergence Divergence (MACD): Measures momentum using the difference between fast and slow EMAs.
- Bollinger Bands (BB): Uses an MA with upper/lower bands to capture volatility and price extremes.
- Relative Strength Index (RSI): Momentum oscillator comparing recent gains and losses to detect overbought/oversold levels.

The Double Moving Average Crossover

- Uses two moving averages (MAs) with different lookback periods:
  - Shorter MA (fast) reacts quickly to price changes.
  - Longer MA (slow) smooths out longer-term trends.
- Buy signal (Golden Cross): fast MA crosses above slow MA.
- Sell signal (Death Cross): fast MA crosses below slow MA.
- Captures trend reversals but may produce false signals in sideways markets.

The Triple Moving Average Crossover

- Uses three MAs: fast (short-term), medium, and slow (long-term).
- Signal crossover:
  - Buy signal: fast MA crosses above both medium and slow MAs.
  - Sell signal: fast MA crosses below both medium and slow MAs.
- Medium MA crossing the slow MA confirms signals $\Longrightarrow$ reduces false trades.
- Captures early trend changes while filtering out noise better than DMAC.
- Exits when fast MA crosses below medium MA, or when MA relationships diverge.

The Moving Average Convergence Divergence

- Combines fast and slow EMAs to capture momentum and trend strength.
- Signal crossover:
  - Buy when MACD crosses signal line from below.
  - Sell when MACD crosses signal line from above.
- Zero crossover:
  - MACD changes sign $\Longrightarrow$ confirms trend shift (bullish if positive, bearish if negative).
  - Less reliable for entry/exit timing than signal crossover.
- Histogram divergence:
  - Rising histogram (lines diverging) $\Longrightarrow$ trend strengthening.
  - Falling histogram (lines converging) $\Longrightarrow$ trend weakening.

The Bollinger Bands

- Consist of a moving average (MA) with upper/lower bands ($\pm$ standard deviations).
- Bands act as dynamic 'support and resistance' levels.
- Main strategies:
  - Overbought/Oversold: Price near upper band $\Longrightarrow$ potential reversal down; Price near lower band $\Longrightarrow$ potential reversal up (mean reversion).
  - Trend Following: Trade only in the direction of the overall trend; e.g., short at upper band in downtrend.
  - Squeeze Strategy: Bands contract (low volatility) $\Longrightarrow$signals likely breakout. Break above/below bands $\Longrightarrow$ enter long/short accordingly.
- Versatile tool: works for both mean reversion and breakout trading.

The Relative Strength Index

- Momentum oscillator (0–100) used to identify trend strength, reversals, and overbought/oversold conditions.
- Main strategies:
  - Trend Following: RSI stays >30 in uptrend and <70 in downtrend.
  - Overbought/Oversold: RSI $>70 \rightarrow$ bearish setup; RSI $<30 \rightarrow$ bullish setup.
  - Trendline Breaks: Draw support/resistance on RSI; breaks often precede price reversals.
  - Divergences: RSI moves opposite price (bullish if higher lows vs. price lower lows; bearish if lower highs vs. price higher highs).
  - Positive/Negative Reversals: RSI low $<$ previous low but price low $>$ previous low $\Longrightarrow$ bullish; reverse for bearish.
  - Swing Rejections: Multi-step rejection pattern confirming reversals (bullish above 30, bearish below 70).
- Widely used as a leading indicator for timing entries and exits.

The SMA and DMAC: formulation & strategy

The SMA at time t given by

$$MA_t(N) = \frac{1}{N}\sum_{i=0}^{N-1} P(t-i) = \frac{1}{N}\sum_{i=1}^{N} P(t-(i-1))$$

where $P(t)$ the price at time t. In the DMAC, we let N_S be the number of observations in the short period, N_L be that in the long period, X_b is a percentage band. The MA rule is (N_S, N_L, X_b) and some popular ones are $(1, 50, 0)$, $(1, 100, 0)$. At time t, the buy signal is given by

$$MA_t(N_S) > MA_t(N_L) + X_b \rightarrow \text{ buy at time } t$$

and the sell signal is reversed, as follows:

$$MA_t(N_S) < MA_t(N_L) - X_b \rightarrow \text{ sell at time } t$$

The triple moving average crossover

Let N_S be the short period, N_M the medium period, N_L the long period. At time t, the long (buy) signal is given by

$MA_t(N_S) > MA_t(N_M) + X_b$ and $MA_t(N_M) > MA_t(N_L) + X_b \rightarrow$ buy at time t

and we unwind the long signal (we sell) when

$$MA_t(N_S) < MA_t(N_M) - X_b \tag{1}$$

The short (sell) signal is reversed, as follows:

$MA_t(N_S) < MA_t(N_M) - X_b$ and $MA_t(N_M) < MA_t(N_L) - X_b \rightarrow$ sell at time t

and we unwind the short signal (we buy) when

$$MA_t(N_S) > MA_t(N_M) + X_b \tag{2}$$

The MACD line

The **MACD line** is the difference between a fast (short term) EMA and a slow (long term) EMA of the closing price of a particular security. The formula is given by

$$DIFF_t = EMA(n_S)_t - EMA(n_L)_t \tag{3}$$

where n_S is the number of observations in the short period, n_L is that in the long period, and $EMA(k)_t$ is given in Equation (**??**). It is calculated by subtracting the value of a 26-period exponential moving average ($EMA(26)_t$) from a 12-period exponential MA $EMA(12)_t$. It corresponds to a Double Moving Average Crossover (DMAC) on EMA, where $EMA(12)_t$ is the fast average and $EMA(26)_t$ is the slow average.

The MACD

In general, it is compared with its 9-day exponential moving average, which is called **the signal line**

$$SL_t = EMA_{DIFF_t}(9) \tag{4}$$

In that case, it corresponds to a Triple Moving Average Crossover (DMAC) on EMA, where $EMA(9)_t$ is the fast average, $EMA(12)_t$ is the medium average, and $EMA(26)_t$ is the slow average. The intersection of these two signals indicates a buying signal if the MACD line comes from the bottom (below), and a selling signal if this line comes from the top (above). The formula is given by

$$MACD_t = DIFF_t - SL_t$$

We buy if $MACD_t > 0$ and sell if $MACD_t < 0$.

The MACD

It is plotted as two different lines, the first line (**the MACD line**) being the difference between the two MAs (long-term and short-term MAs), and the second line (**the signal or trigger line**) being an exponentially smoothed MA of the MACD line. The formula is given by

$$\begin{aligned} MACD(n; n_S, n_L)_t &= MACD(n; n_S, n_L)_{t-1} + \alpha\big(DIFF_t \\ &- MACD(n; n_S, n_L)_{t-1}\big) \end{aligned}$$

with smoothing factor $\alpha = \frac{2}{n+1}$.

The MACD histogram

The above formula can be rewritten as

$$MACD(n; n_S, n_L)_t = \alpha DIFF_t + (1 - \alpha) MACD(n; n_S, n_L)_{t-1}$$

Note, the difference (or divergence) at time t between the MACD line and the signal line, given by

$$Hist_t = \left(DIFF_t - MACD(n; n_S, n_L)_t\right) \tag{5}$$

is shown as a bar graph. It is called the MACD histogram. The purpose being to try to eliminate the lag associated with MA type systems. This is done by anticipating the MA crossover and taking action before the actual crossover. The system buys when the MACD line crosses the signal line from below and sells when the MACD line crosses the signal line from above.

MACD lines and its histogram

Figure 5: MACD lines and its histogram.

The MACD: strategy

The MACD line at time t, denoted $DIFF_t$, is given in Equation (3) and the signal line at time t, denoted $MACD(n; n_S, n_L)_t$, is given in Equation (5). We can use the MACD's histogram the same way that we use the MACD itself. See Figure (5).

For simplicity, we consider the case where we buy (long) the security when the MACD line crosses above the signal line, and sell (short) the security when the MACD line crosses below the signal line. That is, given some ϵ,

- Go long when MACD hist turns up below zero, $Hist_t > \epsilon$.
- Go short when MACD hist turns down above zero, $Hist_t < \epsilon$.
- Otherwise we don't trade.

Set entry rule for MACD

Algorithm 3 Set entry rule for MACD.

Require: The current time t_j, the stock price S_{t_j}, the window size.
Require: The MACD and signal lines $DIFF_{t_j}$ and $MACD(n; n_S, n_L)_{t_j}$
Require: The histogram $Hist_{t_j}$ given in Equation (**??**)

1: **if** $Hist_{t_j} > \epsilon$ **then**
2: Identify the trade as long: set $BoolLong =$ True and $BoolTrade =$ True .
3: **else if** $Hist_{t_j} < \epsilon$ **then**
4: Identify the trade as short: set $BoolLong =$ False and $BoolTrade =$ True .
5: **else**
6: Do not trade : set $BoolTrade =$ False .
7: **end if**
8: **return** BoolTrade, BoolLong

Set exit rule for MACD

Algorithm 4 Set exit rule for MACD.

Require: The current time t_j, the stock price S_{t_j}, the window size.
Require: The MACD and signal lines $DIFF_{t_j}$ and $MACD(n; n_S, n_L)_{t_j}$
Require: The histogram $Hist_{t_j}$ given in Equation (**??**)
Require: BoolTrade, BoolLong

1: **if** *BoolLong* And $Hist_{t_j} < \epsilon$ **then**
2: Identify the exit time of a long position: set *BoolTrade* = False .
3: **else if** !*BoolLong* And $Hist_{t_j} > \epsilon$ **then**
4: Identify the exit time of a short position: set *BoolTrade* = False .
5: **end if**
6: **return** BoolTrade

The Bollinger band: formula

1. Compute the Typical Price $M_t = \frac{H_t + L_t + C_t}{3}$
2. Compute the simple moving average (SMA) price of the last n Typical prices $SM_t(n) = \frac{1}{n}\sum_{i=1}^{n} M_{t-i+1}$
3. Compute the (daily) standard deviation of the last n Typical prices $SD_t(n) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(M_{t-i+1} - SM_t(n)\right)^2}$
4. Calculate the upper band: $\text{TopBand} = SM_t(n) + \alpha \times SD_t(n)$ where $\alpha = 2$ (two standard deviations).
5. Calculate the middle band: $\text{MidBand} = SM_t(n)$
6. Calculate the bottom band: $\text{BotBand} = SM_t(n) - \alpha \times SD_t(n)$

The Bollinger band

Figure 6: Bollinger bands.

The Bollinger band: market Signals

- Constructed using a 20-day MA with bands at ± 1 and ± 2 standard deviations.
- Provide insights into:
  - Trend – direction of the moving average.
  - Volatility – width of the bands.
  - Overbought/Oversold – position of price relative to the bands.
- Overbought signals:
  - Price above $+1\sigma \Longrightarrow$ overbought;
  - Price above $+2\sigma \Longrightarrow$ extremely overbought (likely pullback).
- Volatility trading:
  - Narrow bands $\Longrightarrow$ buy volatility (calls/puts).
  - Widening bands $\Longrightarrow$ sell volatility.

The Bollinger double bands (BDB)

It generates two sets of Bollinger bands, one set using the parameter of one standard deviation and the other using the typical setting of two standard deviations. Given the SMA $SM_t(n)$, the one-SD band is

$$\begin{aligned} \text{TopBand1} &= SM_t(n) + \alpha_1 \times SD_t(n) \\ \text{BotBand1} &= SM_t(n) - \alpha_1 \times SD_t(n) \end{aligned}$$

where α_1 is one-SD, and the two-SD band is

$$\begin{aligned} \text{TopBand2} &= SM_t(n) + \alpha_2 \times SD_t(n) \\ \text{BotBand2} &= SM_t(n) - \alpha_2 \times SD_t(n) \end{aligned}$$

where α_2 is two-SD. We can also use other types of moving averages, such as exponential moving averages (EMA) or weighted moving averages (WMA).

The Bollinger double bands: strategy

Consider a mix of trend following and mean-reverting strategy. The buy zone is given by

$$\text{Buy Zone } = \left[\text{ TopBand1 }, \text{ TopBand2 } \right] \tag{6}$$

and sell zone is given by

$$\text{Sell Zone } = \left[\text{ BotBand2 }, \text{ BotBand1 } \right] \tag{7}$$

The BDB strategy becomes

- Go long when the price enters the buy zone. Unwind when the price exit (from above or below) the buy zone.
- Go short when the price enters the sell zone. Unwind when the price exit (from below or above) the sell zone.
- Otherwise we don't trade.

Set entry rule for BDB

Algorithm 5 Set entry rule for BDB.

Require: The current time t_j, the stock price S_{t_j}, the window size.
Require: The Buy Zone given in Equation (6) and the Sell Zone given in Equation (7)

1: **if** S_{t_j} enters the Buy Zone **then**
2: Identify the trade as long: set $BoolLong =$ True and $BoolTrade =$ True .
3: **else if** S_{t_j} enters the Sell Zone **then**
4: Identify the trade as short: set $BoolLong =$ False and $BoolTrade =$ True .
5: **else**
6: Do not trade : set $BoolTrade =$ False .
7: **end if**
8: **return** BoolTrade, BoolLong

Set exit rule for BDB

Algorithm 6 Set exit rule for BDB.

Require: The current time t_j, the stock price S_{t_j}, the window size.
Require: The Buy Zone given in Equation (6) and the Sell Zone given in Equation (7)
Require: BoolTrade, BoolLong

1: **if** *BoolLong* And S_{t_j} exit the Buy Zone **then**
2: Identify the exit time of a long position: set *BoolTrade* = False .
3: **else if** !*BoolLong* And S_{t_j} exit the Sell Zone **then**
4: Identify the exit time of a short position: set *BoolTrade* = False .
5: **end if**
6: **return** BoolTrade

The RSI: formula

The formula is given by

$$RSI = \frac{AU(n)}{AU(n) + AD(n)} \times 100 \tag{8}$$

where

- $AU(n) = \frac{1}{n_u} \sum_{i=0}^{n_u - 1} UP_{t-i} = SMA(U, n)$ (UP_t is upward price changes) is the average of n_u days up closes. Up periods are characterised by the close being higher than the previous close. That is, $UP_t = C_t - C_{t-1} > 0$.
- $AD(n) = \frac{1}{n_d} \sum_{i=0}^{n_d - 1} DW_{t-i} = SMA(D, n)$ (DW_t is downward price changes) is the average of n_d days down closes. Down periods are characterised by the close being lower than the previous close. That is, $DW_t = C_{t-1} - C_t > 0$.

The ratio takes values in the range $[0, 100]$. When $AD = 0$ the RSI is 100 (only going up) and when $AU = 0$ the RSI is 0.

The RSI: formula

The formula is sometime written as

$$RSI = 100 - \frac{100}{(1 + RS(n))} \tag{9}$$

where

$$RS(n) = \frac{AU(n)}{AD(n)} = \frac{SMA(U, n)}{SMA(D, n)}$$

is the average gain over the average loss. If we choose the EMA as the average, we get

$$RS(n) = \frac{EMA(U, n)}{EMA(D, n)} \tag{10}$$

In general the formula will need at least 250 data points. A plot of RS looks exactly the same as a plot of RSI. The normalisation step makes it easier to identify extremes because RSI is range bound.

The RSI

Figure 7: RSI oscillator.

RSI: Overbought / Oversold Strategy

- The RSI oscillator identifies Overbought (> 70) and Oversold (< 30) price levels.
- Trading rules:
  - Buy (Long): when RSI rises back above 30 after being oversold. Exit if RSI later drops below 70.
  - Sell (Short): when RSI falls back below 70 after being overbought. Exit if RSI later rises above 30.
- Simple, widely used method for capturing reversals.

Set entry rule for RSI

Algorithm 7 Set entry rule for RSI.

Require: The current time t_j, the stock price S_{t_j}, the window size.
Require: The RSI indicator given in Equation (9)

1: **if** RSI line crosses the level 30 from above **then**
2: Identify the trade as long: set $BoolLong =$ True and $BoolTrade =$ True .
3: **else if** RSI line crosses the level 70 from below **then**
4: Identify the trade as short: set $BoolLong =$ False and $BoolTrade =$ True .
5: **else**
6: Do not trade : set $BoolTrade =$ False .
7: **end if**
8: **return** BoolTrade, BoolLong

Set exit rule for RSI

Algorithm 8 Set exit rule for RSI.

Require: The current time t_j, the stock price S_{t_j}, the window size.
Require: The RSI indicator given in Equation (9)
Require: BoolTrade, BoolLong

1: **if** *BoolLong* And RSI line crosses the level 70 from below **then**
2: Identify the exit time of a long position: set *BoolTrade* = False .
3: **else if** !*BoolLong* And RSI line crosses the level 30 from above **then**
4: Identify the exit time of a short position: set *BoolTrade* = False .
5: **end if**
6: **return** BoolTrade

The end

Thank You !