Quantitative Trading Module

Price Action and Volatility

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Outline

- **Foundations of Volatility and Range**
  - True Range (TR) and Average True Range (ATR)
  - Volatility-Adjusted Stops and Chandelier Exits
- **Market Sentiment and Synthetic Indicators**
  - Market Volatility Index (VIX) as a "Fear Gauge"
  - Williams Vix Fix (WVF) for Synthetic Volatility
- **Systematic Detection Strategies**
  - CM-WVF Framework for Bottom and Top Detection
  - MOPOI Strategy: Reversion after Overreaction
- **Regime Transitions and Breakouts**
  - Volatility Squeezes and Compression Regimes
  - Bollinger Oscillator (BOS) for Directional Confirmation

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

Volatility and Price Action Trading

Introduction to Volatility Trading

- **Volatility** measures the dispersion of returns around their mean.
- Expressed as a percentage; reported at various horizons (daily, weekly, annualised).
- **Historical volatility**: estimated from past prices; reflects realised market uncertainty.
- Key distinction in price action trading:
  - **Volatility** $\Rightarrow$ magnitude of price fluctuations (range width)
  - **Momentum** $\Rightarrow$ direction and strength of price trends
- **Volatility Indicators (VIs)** focus on price ranges, not direction:
  - High VI $\Rightarrow$ wide price ranges (unstable market)
  - Low VI $\Rightarrow$ narrow price ranges (compression / consolidation)
- Widely used indicators: ATR, Bollinger Bands, Keltner Channels, Williams Vix Fix (WVF).

Core idea: Volatility regimes govern when trends start, accelerate, or fail.

Price Range and True Range

Let O_t, H_t, L_t, C_t denote the open, high, low, and close prices at time t.

- **Range (intraday variability):**

$$R_t = H_t - L_t$$

  Measures the size of a single candlestick.

  - Large ranges indicate strong intraday participation.
  - Increasing ranges signal growing uncertainty or aggression.

- **True Range (gap-aware variability):**

$$TR_t = \max\big(H_t - L_t,\ |H_t - C_{t-1}|,\ |L_t - C_{t-1}|\big)$$

  - Captures overnight gaps and limit moves.
  - Provides a more realistic measure of price risk.

Key insight: True Range reflects the *maximum price excursion* faced by traders over one period.

Average True Range (ATR): Definition

The **Average True Range (ATR)** measures market volatility by averaging the True Range over a fixed window.

Given the True Range TR_t, define the n-period ATR as:

$$ATR_t(n) = \frac{1}{n} \sum_{i=0}^{n-1} TR_{t-i}$$

To avoid recomputing the full sum at each step, ATR is typically updated recursively:

$$ATR_t(n) = \frac{(n-1)\, ATR_{t-1}(n) + TR_t}{n}$$

- ATR is expressed in **price units** (e.g. dollars, points).
- Large ATR $\Rightarrow$ wide price swings and high uncertainty.
- Small ATR $\Rightarrow$ compressed ranges and quiet markets.

Interpretation: ATR approximates the *expected absolute price move* over one period.

ATR Indicator: Visual Interpretation

The ATR evolves with the size of price movements, independently of trend direction.

Figure 1: Average True Range (ATR) as a volatility indicator.

ATR Indicator: Visual Interpretation

- Rising ATR $\Rightarrow$ expanding price ranges and increasing uncertainty.
- Falling ATR $\Rightarrow$ contracting ranges and volatility compression.
- ATR does **not** predict direction — only the *magnitude* of future moves.
- Sudden ATR spikes often coincide with breakouts, news, or regime changes.

Key takeaway: ATR identifies *when* the market is active, not *where* it is going.

Average True Range (ATR) as a Volatility Indicator

- **True Range (TR)** captures the full price movement, including gaps:

$$TR_t = \max\{H_t - L_t,\ |H_t - C_{t-1}|,\ |L_t - C_{t-1}|\}$$

- **ATR** is the rolling average of TR over n periods:

$$ATR_t(n) = \frac{1}{n}\sum_{i=0}^{n-1} TR_{t-i}$$

- Interpreted in **price units** (e.g. dollars), not percentages.

Why ATR matters in trading

- Adjusts trading rules to current market conditions.
- Accounts for volatility caused by gaps and limit moves.
- Enables volatility-adjusted position sizing and stops.

Average True Range (ATR) as a Volatility Indicator

ATR-based trailing stop (Chandelier Exit)

$$SL_t = HH_t(n) - \alpha \cdot ATR_t(n), \qquad \alpha \in [1, 3]$$

- Stop widens in volatile markets and tightens in calm markets.
- Reduces premature exits during strong trends.

ATR Trailing Stop Indicator

ATR-based trailing stops adapt dynamically to market volatility.

Figure 2: ATR-based trailing stop adjusting to volatility changes.

ATR Trailing Stop Indicator

- Stop-loss moves in the direction of the trade as price advances.
- In high volatility regimes:
  - ATR increases $\Rightarrow$ stop moves further away.
  - Prevents exits due to normal price noise.
- In low volatility regimes:
  - ATR contracts $\Rightarrow$ stop tightens.
  - Locks in profits earlier when momentum weakens.
- Particularly effective in trend-following strategies.

Key insight: ATR trailing stops let *profits run* while cutting losses in a volatility-aware manner.

Choosing the ATR Window and Multiplier

The effectiveness of ATR-based indicators depends critically on parameter choices.

- **ATR window length (n):**
  - Short window (e.g. $n = 5$–10): very responsive, but noisy.
  - Medium window (e.g. $n = 14$): industry standard, balances stability and reactivity.
  - Long window (e.g. $n > 30$): smooth volatility, slower adaptation to regime changes.
- **ATR multiplier (k) for stops:**
  - Small k (e.g. 1–1.5): tight stops, frequent exits.
  - Moderate k (e.g. 2–3): robust to noise, trend-friendly.
  - Large k (e.g. > 4): wide stops, higher drawdowns tolerated.
- Parameters should be calibrated to:
  - Asset class (equities vs FX vs crypto)
  - Trading horizon (intraday vs swing vs long-term)
  - Strategy type (mean-reversion vs trend-following)

Key takeaway: ATR parameters encode a trade-off between *responsiveness* and *robustness to noise*.

Limitations of ATR-Based Indicators

While widely used, ATR-based indicators have important limitations.

- **Backward-looking measure:**
  - ATR is computed from historical price ranges.
  - It reacts to volatility changes but does not anticipate them.
- **No directional information:**
  - ATR measures magnitude, not trend direction.
  - Must be combined with directional signals (trend, momentum).
- **Regime dependence:**
  - Sudden regime shifts (crises, announcements) can invalidate recent ATR estimates.
  - Stops may widen *after* large losses have already occurred.
- **Parameter sensitivity:**
  - Poorly chosen windows or multipliers can lead to overtrading or excessive drawdowns.

Key insight: ATR is a powerful *volatility filter*, not a complete trading or risk model.

ATR in Risk Management and Position Sizing

Beyond indicators, ATR plays a central role in quantitative risk control.

- **Volatility-adjusted position sizing:**

$$\text{Position Size} \propto \frac{1}{\text{ATR}}$$

    - Higher volatility $\Rightarrow$ smaller positions.
    - Lower volatility $\Rightarrow$ larger positions.
- **Constant risk allocation:**
    - ATR allows capital to be distributed so that each trade contributes similar risk.
    - Widely used in CTA and trend-following strategies.
- **Portfolio-level benefits:**
    - Reduces volatility clustering at the portfolio level.
    - Improves drawdown control across regimes.
- **Link to theory:**
    - ATR acts as a nonparametric proxy for conditional volatility.
    - Complements GARCH and stochastic volatility models.

ATR in Risk Management and Position Sizing

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  - Complements GARCH and stochastic volatility models.

Key takeaway: ATR transforms volatility from a *threat* into a *control variable*.

Summary: ATR and Financial Time Series

ATR-based tools reflect several core properties of financial time series.

- **Time-varying volatility:**
  - ATR adapts to volatility clustering and persistence.
- **Non-Gaussian behaviour:**
  - Large price ranges occur more frequently than Gaussian models predict.
- **Regime awareness:**
  - ATR reacts to transitions between calm and turbulent markets.
- **Model-agnostic robustness:**
  - Does not rely on distributional or stationarity assumptions.

Big picture: ATR exemplifies how simple statistics, grounded in empirical facts, can outperform elegant but fragile theoretical models.

This motivates the next step: *explicit stochastic models of volatility*.

The VIX: Market Volatility Index

The **VIX** measures the market's expectation of future volatility.

- VIX = **30-day IV** extracted from S&P 500 option prices.
- Often called the *"fear gauge"*:
  - High VIX $\Rightarrow$ market stress, risk aversion, rising risk premia.
  - Low VIX $\Rightarrow$ calm markets, volatility compression, complacency.
- Constructed from a wide strip of **out-of-the-money puts and calls**, capturing the entire implied volatility surface.
- Continuous-time representation:

$$VIX = \sqrt{\frac{2e^{r\tau}}{\tau}\left(\int_0^F \frac{P(K,\tau)}{K^2}\,dK + \int_F^\infty \frac{C(K,\tau)}{K^2}\,dK\right)}$$

  where F is the forward index level.
- Strong **negative correlation with equity returns**: volatility spikes often coincide with market drawdowns.

Key insight: VIX is a forward-looking, option-implied measure of *systemic uncertainty*.

Daily VIX: Empirical Behaviour

The VIX exhibits pronounced spikes during periods of market stress.

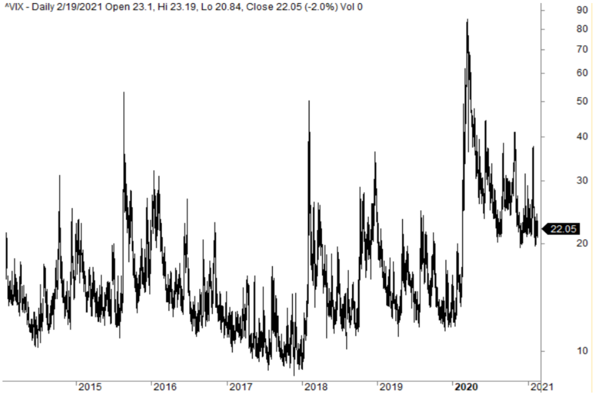

Figure 3: Daily VIX from 2014 to 2021.

Daily VIX: Empirical Behaviour

- Volatility is **mean-reverting** but experiences abrupt jumps.
- Spikes coincide with crises, policy shocks, or liquidity events.
- Calm regimes (low VIX) tend to persist, but end suddenly.
- Highlights the **asymmetry of volatility**: it rises fast, decays slowly.

Stylised fact: Volatility clusters in time and reacts nonlinearly to negative returns.

Williams Vix Fix (WVF) Indicator

The **Williams Vix Fix (WVF)** was designed as a *synthetic VIX* applicable to any asset.

- Motivation:
  - VIX is only available for major indices.
  - WVF replicates volatility spikes using **price data only**.
- Definition:

$$WVF_t = \frac{HC_t(m) - L_t}{HC_t(m)} \times 100$$

  where $HC_t(m)$ is the highest close over the last m periods (typically $m = 22$).
- Interpretation:
  - Large downward moves $\Rightarrow$ high WVF.
  - Captures downside-driven volatility surges.
  - Mimics VIX timing and spikes (though on a different scale).

Williams Vix Fix (WVF) Indicator

- Applications:
  - Synthetic volatility index for any stock or market.
  - Identification of volatility shocks and market stress.
  - Detection of potential market bottoms.

Key idea: WVF is a backward-looking, price-based proxy for implied volatility.

Daily WVF versus VIX

WVF reproduces the timing and clustering of VIX spikes using only price data.

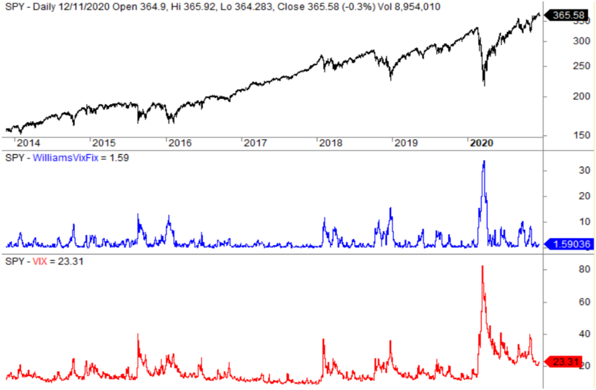

Figure 4: Daily WVF (blue) versus VIX (red).

Daily WVF versus VIX

- Strong co-movement during stress periods.
- Both indicators spike during market drawdowns.
- Differences in scale reflect construction:
  - VIX = option-implied, forward-looking.
  - WVF = price-based, backward-looking.
- WVF is especially useful when option markets are illiquid or unavailable.

Takeaway: Volatility is largely encoded in price dynamics themselves.

WVF and Market Bottom Detection

Volatility peaks often coincide with **market bottoms**.

- High VIX levels historically align with panic-driven sell-offs.
- WVF captures similar stress episodes via downside price pressure.
- WVF spikes indicate:
    - Capitulation selling.
    - Elevated risk aversion.
    - Potential exhaustion of downside momentum.
- WVF is **unbounded** (not an oscillator):
    - Absolute levels are not directly comparable over time.
    - Signals require smoothing or relative thresholds.
- Common enhancements:
    - Bollinger Bands on WVF (Williams, 2007).
    - Stochastic oscillator of WVF ($>$ 80% near bottoms).
    - Hybrid strategies (Moody, Hestla, MOPOI).

Caveat: High volatility indicates stress, not an immediate price reversal.

WVF with Bollinger Bands: Empirical Illustration

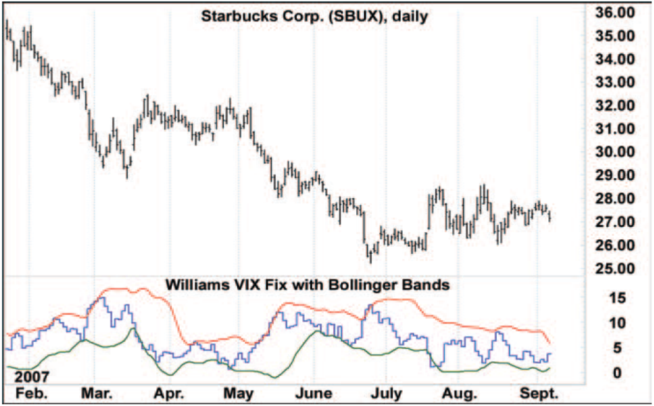

Figure 5: Starbucks: Williams Vix Fix (blue) with Bollinger Bands (red).

- WVF spikes coincide with sharp downside price moves.
- Bollinger Bands provide a **relative volatility threshold**.
- Interpretation:

Chris Moody's CM-WVF: Systematic Bottom Detection

- Chris Moody (2014) extended the **Williams Vix Fix (WVF)** into a **rule-based bottom-detection framework**.
- Objective: reduce discretionary interpretation of WVF spikes.
- Core components:
  - WVF level relative to **Bollinger Bands**.
  - Percentile-based volatility thresholds.
  - Time-frame specific calibration.
- Typical intraday timeframes:

$$\{5,\, 15,\, 30\} \text{ minutes}$$

- Visual representation:
  - Histogram format.
  - **Lime bars** $\Rightarrow$ volatility climax (potential bottom).
  - **Grey bars** $\Rightarrow$ neutral / no signal.
- Trading philosophy:
  - Volatility peaks before price reverses.
  - Entries are delayed until volatility **starts to contract**.

CM-WVF Extension: Market Top Detection

- Market tops can be detected by **mirroring the WVF logic**.
- Instead of downside pressure, we measure **upside exhaustion**.
- Define the **Top WVF** (WVFT):

$$WVFT_t = \frac{LC_t(m) - H_t}{LC_t(m)} \times 100$$

  where $LC_t(m)$ is the **lowest close** over the past m periods.
- Interpretation:
  - Strong upward extensions $\Rightarrow$ large negative WVFT.
  - Captures price surges relative to recent downside extremes.
- Statistical normalisation:

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

CM-WVF Extension: Market Top Detection

- Statistical normalisation:

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

- Bollinger-style thresholds:

$$MidBand_{Top} = SM_t(n), \quad BotBand_{Top} = SM_t(n) - \alpha SD_t(n), \alpha = 2$$

- Optional percentile filter to reduce false signals:

$$rangeLowTop_t = \alpha_L \cdot LWVFT_t(n)$$

CM-WVF Bottom Detection: Signal and Entry Logic

Figure 6: CM-WVF histogram: Lime bars indicate volatility spikes (bottom zones).

CM-WVF Bottom Detection: Signal and Entry Logic

- **Lime bar**: volatility spike $\Rightarrow$ bottom formation likely.
- **Grey bar**: volatility normalisation.
- **Core insight:** bottoms form when panic peaks, not when price reverses.
- **Entry rule:**
  - Enter **long** after the **first Grey bar following a Lime bar**.
  - Confirms volatility contraction after panic.
- Strengths:
  - Captures emotional extremes.
  - Works well across intraday timeframes.
- Limitation:
  - False positives during strong downtrends $\Rightarrow$ requires trend or momentum filter.

MOPOI Strategy: Mean Reversion After Volatility Overreaction

- MOPOI (2016) applies **Bollinger Bands directly to the WVF**.
- Core assumption: WVF behaves approximately as a **mean-reverting process**.
- Statistical intuition:

$$WVF(t, T) \approx \mu\Delta t \pm \alpha\sigma\sqrt{\Delta t}, \qquad \alpha = 2$$

- Overreaction occurs when WVF exceeds its upper statistical envelope.
- Define MOPOI bands over an n-day lookback:

$$SM_t(n) = \frac{1}{n}\sum_{i=1}^{n} WVF_{t-i+1}, \quad SD_t(n) = \mathrm{StdDev}(WVF)$$

$$TopBand_t = SM_t(n) + \alpha SD_t(n), \quad BotBand_t = SM_t(n) - \alpha SD_t(n)$$

MOPOI Strategy: Mean Reversion After Volatility Overreaction

- **Trading logic:**
  - WVF above *TopBand* $\Rightarrow$ panic / overreaction.
  - Entry occurs on **reversion** back inside the band.
- Empirically effective for $n \approx 10$ trading days.

MOPOI Trading Algorithm: Entry and Execution

- Objective: identify **mean-reversion entries** after volatility overreaction.
- **Long entry condition at time t:**

$$WVF_{t-2} > TopBand_{t-2}, \quad WVF_{t-1} < TopBand_{t-1}$$

- Interpretation:
  - $t-2$: panic / overreaction phase.
  - $t-1$: volatility contraction $\Rightarrow$ reversion signal.
- Empirical test:
  - Implemented in **TradingView**.
  - Tested on the $SP500$ (Aug–Dec 2014).
- Visual encoding:
  - Yellow WVF bars: overreaction.
  - Red WVF bars: normal volatility.
  - Green line: WVF moving average.
  - Blue line: MOPOI threshold ($TopBand$).

MOPOI Trading Algorithm: Entry and Execution

- Practical caveat:
  - Performs poorly in strong momentum regimes.
  - Requires trend or regime filter for robustness.

MOPOI Algorithm: Visual Illustration

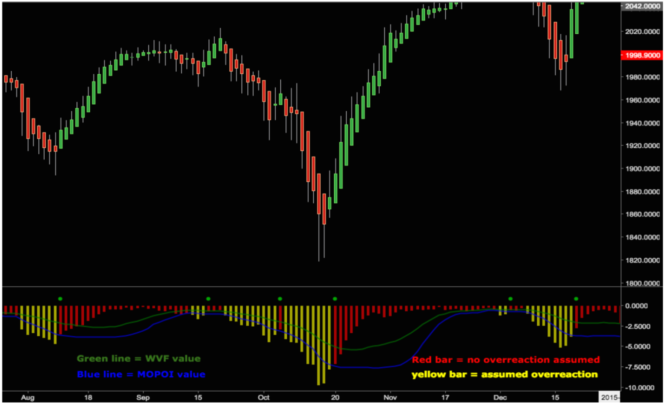

Figure 7: MOPOI strategy applied to the S&P 500 (Aug–Dec 2014).

MOPOI Algorithm: Visual Illustration

- All WVF values and MOPOI bands are multiplied by -1 for visual alignment with price.
- Yellow bars: volatility overreaction (panic phase).
- Red bars: normalised volatility.
- Buy signal occurs when:
  - WVF transitions from yellow $\rightarrow$ red,
  - while remaining above the long-term WVF mean.
- Illustrates the core MOPOI idea:
  - **Do not buy panic**.
  - **Buy the end of panic**.

Market Squeezes: Volatility Compression Regimes

- A **market squeeze** occurs when price pressure builds under constrained liquidity.
- Squeezes often precede **large, asymmetric price moves**.
- Main types:
  - **Long squeeze**: rapid price declines force long positions to liquidate.
  - **Short squeeze**: sharp upward moves force short sellers to cover.
  - **Volatility squeeze**: volatility falls to abnormally low levels while price consolidates.
- Volatility squeeze characteristics:
  - Narrow trading ranges.
  - Reduced realised volatility.
  - Market energy accumulates without clear direction.
- Key insight for traders:
  - Direction is uncertain during the squeeze.
  - **Magnitude** of the breakout is often predictable.

Bollinger Band Squeeze: Quantifying Volatility Compression

- Financial markets alternate between:
  - **Volatility contraction** (range-bound markets),
  - **Volatility expansion** (trending markets).
- Bollinger Bands (BBs) provide a natural volatility envelope.

$$S_t(n) = \frac{\text{TopBand}_t - \text{BotBand}_t}{SC_t(n)}$$

- $SC_t(n)$: simple moving average of closing prices.
- $S_t(n)$ measures **relative band width**.
- Interpretation:
  - Wide BBs $\Rightarrow$ high volatility.
  - Narrow BBs $\Rightarrow$ low volatility.
- A **squeeze condition** is triggered when:
  - $S_t(n)$ reaches a **multi-month minimum** (e.g. 6 months).
- Squeeze $\neq$ direction; it only signals **stored volatility**.

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Bollinger Oscillator (BOS): Risk-Adjusted Momentum

The **Bollinger Oscillator (BOS)** measures how far price deviates from its mean, scaled by current volatility.

$$BOS_t = \frac{M_t - SM_t(n)}{SD_t(n)}$$

- M_t: typical price (e.g. $(H_t + L_t + C_t)/3$).
- $SM_t(n)$: n-period simple moving average.
- $SD_t(n)$: rolling standard deviation.
- Interpretation:
  - Numerator $\Rightarrow$ trend deviation (direction).
  - Denominator $\Rightarrow$ volatility (risk).
- BOS is a **risk-adjusted trend indicator**.
- Large $|BOS|$ values:
  - Strong directional move,
  - Especially informative during low-volatility regimes.
- Complements BB squeeze:
  - Squeeze identifies **when** to trade,
  - BOS helps identify **which direction**.

Volatility Breakouts and Regime Transitions

Periods of low volatility are often followed by abrupt regime changes. Bollinger Bands provide a natural framework to detect such transitions.

- **Volatility compression**:
  - Narrow Boll-Bands indicate uncertainty and order-flow balance.
  - Market participants reduce risk and liquidity dries up.
- **Breakout phase**:
  - Price exits the band with expanding volatility.
  - Information arrival or positioning imbalance triggers repricing.
- **Directional confirmation**:
  - BOS > 0: upward regime shift.
  - BOS < 0: downward regime shift.
- **Interpretation**:
  - Breakouts are *regime transitions*, not isolated price moves.
  - Risk is asymmetric: losses are bounded during compression, gains can be large after release.

This mechanism underlies many trend-following and volatility-based strategies.

The end

Thank You !