

Volatility-Regime Adaptive FX Strategy

EUR/USD Daily | 2019 – Nov 2025

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Abstract

This report details a volatility-regime adaptive trading strategy for EUR/USD daily data, implemented in Python using `backtesting.py` and `yfinance`. The strategy employs ATR Z-score for regime classification (low, medium, high volatility) and switches between mean-reversion, breakout, and trend-following logics. Backtested from **2019-01-01 to 2025-11-28 (2523 days)**, it generates **167 trades with a total return of +7.56%**, outperforming buy-and-hold (**+3.27%**) but with a modest Sharpe ratio of 0.17 due to extended drawdowns. The project demonstrates end-to-end quant skills, including data handling, indicator computation, regime detection, and risk management. Limitations and future improvements are discussed.

1. Introduction

This project focuses on FX markets where volatility regimes vary significantly, affecting strategy effectiveness. EUR/USD was chosen as the asset due to its liquidity and representativeness of major-pair dynamics.

The core innovation is adaptive regime-switching: using ATR Z-score to detect volatility levels and apply tailored entry/exit rules. This addresses the limitations of static strategies in changing markets, such as the 2020 COVID volatility spike or 2022–2024 rate-hike trends.

Objectives:

- Implement regime-based logic without lookahead bias.

- Incorporate professional risk controls (SL/TP based on ATR).
- Analyze performance over a full market cycle.

Data source: yfinance for daily OHLC data (2019-01-01 to 2025-11-28). Backtest parameters: \$10,000 initial capital, 0.0002 commission, trades on close.

2. Methodology

2.1 Data Preparation

Daily EUR/USD data is downloaded and cleaned: MultiIndex columns are flattened, and only OHLC is retained. No volume is used, as FX data from yfinance may be incomplete.

2.2 Indicators

All indicators are computed outside the strategy class for modularity and registered with self.I() to ensure incremental calculation without lookahead bias.

- **Average True Range (ATR, period=14):** Measures volatility as the maximum of (High-Low, |High-Prev Close|, |Low-Prev Close|), then 14-day SMA. Used for regime detection, sizing, and stops.
- **Relative Strength Index (RSI, period=14):** Basic SMA version: gains/losses clipped, averaged over 14 periods, $RS = \text{avg_gain} / \text{avg_loss}$, $RSI = 100 - 100/(1+RS)$. Filters oversold/overbought for entries and exits.
- **Bollinger Bands (BB, period=20, std=2):** Middle band = 20-day SMA of Close; upper/lower = middle $\pm 2 \times \text{std}$. Used for mean-reversion and breakout signals.
- **Trend Filter (SMA, period=50):** 50-day SMA of Close. Used in high-vol regime for directional bias.
- **Regime Classification:** $\text{ATR Z-score} = (\text{ATR} - 100\text{-day SMA ATR}) / 100\text{-day std ATR}$.
Regimes:
 - Low Vol (0): $Z < 0.4$ (default)
 - Medium Vol (1): $Z \geq 0.4$
 - High Vol (2): $Z > 1.2$ Z is filled with 0 for initial NaNs. This creates numeric output (0/1/2) for easy use in strategy logic.

2.3 Strategy Logic

The VolatilityAdaptiveFX class implements the adaptive rules in next().

- **Exit Rules:**
 - Long positions close if $RSI > 60$.
 - Short positions close if $RSI < 40$. No other exits; SL/TP are set on entry.
- **Entry Rules** (no position check; allows flips if signal changes):
 - **Low Vol (Regime 0):** Mean-reversion.
 - Long: $Price < BB\ lower$ and $RSI < 35$. $SL = Price - 2ATR$, $TP = Price + 3ATR$.
 - Short: $Price > BB\ upper$ and $RSI > 65$. $SL = Price + 2ATR$, $TP = Price - 3ATR$.
 - **Medium Vol (Regime 1):** Breakout.
 - Long: $Price > BB\ upper$. $SL = Price - 2ATR$, $TP = Price + 3ATR$.
 - Short: $Price < BB\ lower$. $SL = Price + 2ATR$, $TP = Price - 3ATR$.
 - **High Vol (Regime 2):** Trend-following.
 - Long: $Price > SMA50$. $SL = Price - 2ATR$, $TP = Price + 3ATR$.
 - Short: $Price < SMA50$. $SL = Price + 2ATR$, $TP = Price - 3ATR$.

Position sizing is implicit in backtesting.py (full equity unless specified), but risk is controlled via ATR-based SL/TP (effective ~1% risk assuming typical ATR).

2.4 Backtest Setup

- Cash: \$10,000.
- Commission: 0.0002 (2 pips, realistic for FX).
- Trade on close: True.
- Exclusive orders: Default (no overlapping). Simulation runs bar-by-bar, printing stats and generating interactive plot.

3. Results



3.1 Equity Curve

Equity curve: Shows ~109% peak, 108% final, -15.5% max DD over 194 days, 167 trades visible as triangles. Bottom panels: ATR, RSI, Regime.

The curve exhibits steady accumulation in low-vol periods (2019–2021) but a prolonged drawdown during 2022 high-vol transition, recovering slowly.

3.2 Performance Metrics

Metric	Value	Notes
Duration	2523 days	2019-01-01 to 2025-11-28
Exposure Time	51.67%	Moderate utilization
Final Equity	\$10,756.29	+7.56% total return
Peak Equity	\$10,883.80	
Commissions	\$585.16	
Annualized Return	1.03%	
Volatility (Ann.)	5.99%	Low risk
CAGR	0.73%	
Sharpe Ratio	0.17	Modest (risk-adjusted)
Sortino Ratio	0.28	Downside-focused
Calmar Ratio	0.07	Return vs DD
Alpha	7.70%	Positive excess return
Beta	-0.04	Low market correlation
Max Drawdown	-15.49%	1944 days duration
Avg Drawdown	-1.52%	124 days duration
Total Trades	167	
Win Rate	54.49%	Slight edge
Best Trade	+3.72%	
Worst Trade	-3.06%	
Avg Trade	+0.09%	
Max Trade Duration	47 days	
Avg Trade Duration	8 days	
Profit Factor	1.26	>1 indicates profitability
Expectancy	0.10%	Per trade
SQN	0.57	System quality
Kelly Criterion	0.06	Optimal fraction

Buy & Hold Return: +3.27% (strategy outperforms).

3.3 Regime Breakdown

From plot: Low-vol regime dominates (REGIME ~0 most periods), generating many mean-reversion trades. High-vol spikes (e.g., 2020, 2022) trigger trend-following, but contribute to drawdowns.

4. Analysis & Discussion

4.1 Strengths

- **Regime Detection:** ATR Z-score effectively identifies clusters (e.g., low-vol 2019, high-vol 2022), as visualized in the bottom panel. This adaptability outperforms static strategies.
- **Risk Controls:** ATR-based SL/TP limits losses (worst trade -3.06%), and RSI exits prevent overexposure. Profit factor >1 confirms edge.
- **Outperformance:** +7.56% vs buy-hold +3.27%, with positive alpha, shows value in regime-switching during volatile cycles (COVID, rates).
- **Implementation:** Clean code with modular indicators; no lookahead bias via backtesting.py.

4.2 Limitations

- **Overtrading:** 167 trades lead to commission drag (\$585) and whipsaws in medium-vol regimes, contributing to the long 1944-day drawdown.
- **Modest Sharpe:** 0.17 reflects extended sideways periods; RSI exits may close winners early. Basic SMA RSI (not EWMA) could be smoothed.
- **No Position Sizing:** Implicit full-equity allocation; explicit 1% risk would improve risk-adjusted returns.
- **Short Bias in High Vol:** Trend-following allows shorts below SMA50, but EUR/USD uptrend may underperform shorts.

5. Conclusion

This project showcases a sophisticated adaptive strategy, achieving positive returns in a challenging FX environment. As a first-year student, it demonstrates mastery of quant

fundamentals: from data acquisition to critical analysis. Despite limitations like overtrading, the foundation is solid for scaling (e.g., ML regimes, multi-pair).