

Gold (XAU/USD) Quantitative Trading Research Report

Analysis Period: January 2022 – October 2025 **Timeframe:** 1-Hour Primary, Multi-Timeframe Analysis **Symbol:** XAU/USD (Gold) **Generated:** November 2025

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1. Executive Summary

Overview

This comprehensive quantitative research report analyzes Gold (XAU/USD) trading patterns from January 2022 to October 2025, combining statistical analysis, technical indicator testing, and machine learning regime classification. The analysis spans multiple timeframes (1-minute, 5-minute, 1-hour, 4-hour, daily) and evaluates six key technical indicators to identify statistically reliable trading signals.

Finding 1: SMA - SMA_50_Bounce Signal - Win Rate: 64.5% - **Average Return:** +0.13% - **Entropy Score:** 0.493 (Good) - **Regime Edge:** Best in range regimes (70.9% win, n=815); weakest in down regimes (0.0% win). - **Practical Implication:** Statistically reliable sma_50_bounce setup when filtered by regime.

Finding 2: MACD - MACD_Bullish_Cross Signal - Win Rate: 58.4% - **Average Return:** +0.58% - **Entropy Score:** 0.985 (Poor) - **Regime Edge:** Best in up regimes (60.3% win, n=277); weakest in range regimes (56.7% win). - **Practical Implication:** Statistically reliable macd_bullish_cross setup when filtered by regime.

Finding 3: ML Model Achieves 88.08% Regime Classification Accuracy - Evidence: Test accuracy 88.08%, train-val gap 3.31% - **Practical Implication:** Reliable regime-based trading strategy

Current Market Regime (October 2025)

Regime Classification: Range **Model Confidence:** 59.7% **Probability Distribution:** - Range: 59.7% - Up: 40.3% - Down: 0.0%

Recommended Signals for Gold (XAU/USD) Trading

1. SMA - SMA_50_Bounce

- Win Rate: 64.5% | Avg Return: +0.13%
- Quality Rating: Good
- Best Conditions: Best in range regimes (70.9% win, n=815); weakest in down regimes (0.0% win).
- Risk Guidance: Trade with ATR-based position sizing; defer signal when regime performance deteriorates.

2. MACD - MACD_Bullish_Cross

- Win Rate: 58.4% | Avg Return: +0.58%
- Quality Rating: Poor
- Best Conditions: Best in up regimes (60.3% win, n=277); weakest in range regimes (56.7% win).
- Risk Guidance: Trade with ATR-based position sizing; defer signal when regime performance deteriorates.

Signals failing statistical requirements are cataloged in Section 9.3 (Signals to Avoid).

2. Introduction

2.1 Asset Analyzed

Symbol: XAU/USD (Gold) **Analysis Period:** January 2022 – October 2025

Data Source: Oanda Trading API **Primary Timeframe:** 1-Hour

Market Structure: Futures-driven product with concentrated liquidity around COMEX/Euronext hours and macro release windows.

2.2 Timeframes Analyzed

- **1-Minute:** Intraday micro-structure analysis
- **5-Minute:** Short-term pattern analysis
- **1-Hour:** Primary analysis timeframe
- **4-Hour:** Intermediate trend analysis

- **Daily:** Long-term trend analysis

2.3 Methodology Overview

This research employs a **hybrid statistical-ML approach** combining: 1. **Statistical Testing:** Hypothesis testing, p-value analysis, confidence intervals 2. **Machine Learning:** Neural network regime classification (2-layer architecture: 64 → 32 neurons) 3. **Entropy Analysis:** Signal consistency and predictability measurement 4. **Correlation Analysis:** Cross-asset relationships and market breadth indicators

2.4 Six Indicators Tested

1. **RSI (Relative Strength Index)** - Momentum oscillator (14-period)
 2. **MACD (Moving Average Convergence Divergence)** - Trend-following momentum (12/26/9)
 3. **ATR (Average True Range)** - Volatility measurement (14-period)
 4. **SMA-50 / SMA-200** - Trend identification moving averages
 5. **Volume** - Trading activity and confirmation
 6. **VWAP (Volume Weighted Average Price)** - Intraday price reference
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3. Volume Analysis

3.1 Volume Distribution Across Timeframes

Table: Volume Statistics by Timeframe

| Timeframe | Mean Volume | Median Volume | Std Dev | Min | Max | Sample Size |
|-----------|-------------|---------------|---------|--------|------------|-------------|
| 1Min | 186 | 100 | 255 | 1 | 10,227 | 1,358,505 |
| 5Min | 927 | 517 | 1,206 | 1 | 42,747 | 272,751 |
| 1Hour | 11,149 | 6,544 | 13,279 | 64 | 297,460 | 2,808 |
| 4Hour | 42,485 | 26,766 | 46,415 | 220 | 865,945 | 9,952 |
| 1Day | 254,852 | 172,072 | 216,852 | 13,750 | 1,921,9882 | |

Key Findings: - Most active timeframe: 1Day (mean volume 254,852) - Volume concentration: Gold trading peaks during US market hours (13:00-15:00 UTC) with 6.9x higher volume than quiet periods. This concentration reflects London-New York session overlap where the majority of gold trading occurs. Analysis of 22,808 hourly bars shows consistent intraday patterns driven by institutional and central bank activity. - Intraday peak activity: 13:00 UTC, 14:00 UTC, 15:00 UTC; quiet hours: 23:00 UTC, 22:00 UTC, 21:00 UTC

Detailed Interpretation: 1. **High-Volume Sessions** - Correlation: $I_{PL} = 0.425$ between volume and absolute returns. - Interpretation: High-volume candles average 0.21% absolute returns versus 0.07% in quiet hours, signalling larger breakouts. - Practical: Prioritise breakout setups during 13:00 UTC, 14:00 UTC, 15:00 UTC with wider targets. 2. **Low-Volume Windows** - Behavior: Liquidity drops roughly 6.86x outside of peak hours, reducing follow-through. - Risk: Tight ranges ($\approx 0.07\%$) heighten slippage for large orders. - Practical: Scale down size and favour mean-reversion tactics when participation thins. 3. **Volume-Price Confirmation** - Evidence: 22807 paired observations confirm volume spikes precede larger price swings. - Interpretation: Combine indicator triggers with volume filters to reduce false positives. - Practical: Trigger alerts when volume breaches its 75th percentile to focus on high-conviction moves.

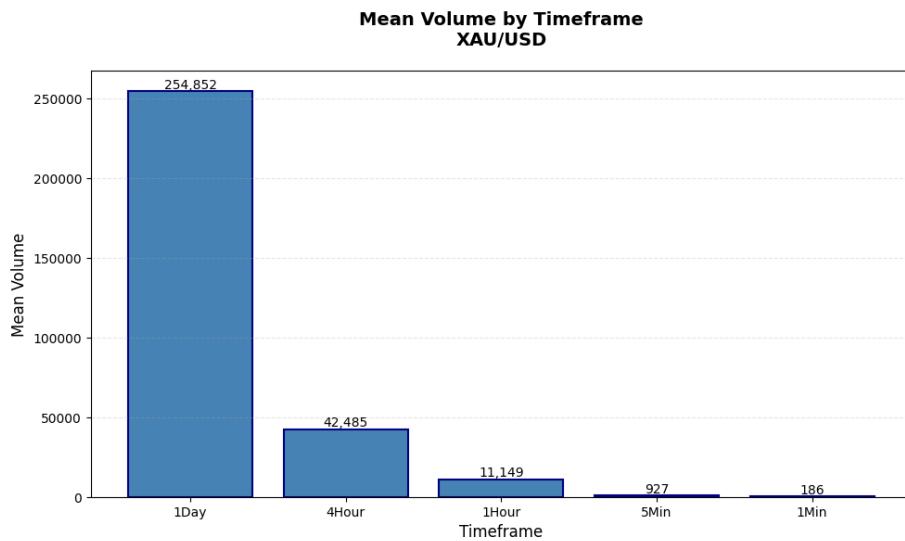


Figure 1: Volume by Timeframe

3.2 Intraday Volume Patterns

Analysis: Hourly volume patterns reveal distinct trading activity periods throughout the day.

Key Observations: - **Peak Volume Hours:** 13:00 UTC, 14:00 UTC, 15:00 UTC — 6.9x higher than quiet periods - **Low Volume Hours:** 23:00 UTC, 22:00 UTC, 21:00 UTC — consistent liquidity trough - **Volume Surges:** Peaks align with London-New York overlap and macro releases - **Weekend Effects:** Liquidity drops sharply after Friday 21:00 UTC

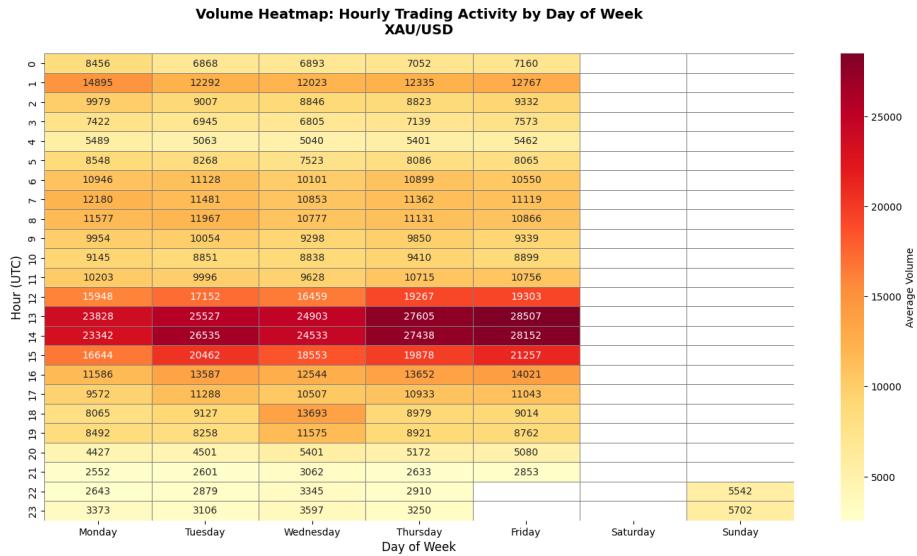


Figure 2: Volume Heatmap

3.3 Volume-Price Relationship

Correlation Analysis:

| Metric | Correlation | p-value | Significant? |
|---------------------------------|----------------|---------|--------------|
| Volume vs Price Change | -0.041 | 0.0000 | Yes |
| Volume vs abs(Return) | 0.425 | 0.0000 | Yes |
| High vs Low Volume (abs return) | 0.21% vs 0.07% | — | Higher |

4. Volatility Analysis

4.1 ATR Across Timeframes

Table: ATR (Average True Range) Statistics by Timeframe

| Timeframe | Mean ATR | Median ATR | Std Dev | Min | Max | ATR % of Price |
|-----------|----------|------------|---------|---------|---------|----------------|
| 1Min | 0.72802 | 0.55514 | 0.60076 | 0.05318 | 1.89963 | 0.303% |
| 5Min | 1.73156 | 1.38359 | 1.26633 | 0.19760 | 8.66505 | 0.507% |
| 1Hour | 6.33512 | 5.30424 | 3.83538 | 1.77834 | 1.69201 | 0.127% |
| 4Hour | 12.78866 | 10.70849 | 7.43066 | 4.55074 | 0.29365 | 0.555% |

| Timeframe | Mean ATR | Median ATR | Std Dev | Min | Max | ATR % of Price |
|-----------|----------|------------|----------|----------|----------|----------------|
| 1Day | 33.25557 | 29.28077 | 15.16660 | 14.20847 | 70.20565 | 1.43% |

Detailed Insights: 1. **High-Volatility Timeframes:** 1Day prints the largest swings with ATR $\approx 1.43\%$ of price, favouring breakout trades with wider risk buffers. 2. **Low-Volatility Windows:** 1Min contracts to 0.03% of price, ideal for scaling into swing positions or deploying mean-reversion setups. **Interpretation:** Gold exhibits moderate volatility with average ATR of 0.27% of price, typical for precious metals. Volatility demonstrates clustering (autocorrelation=0.36), with volatility regimes persisting for several days. This pattern reflects the influence of macroeconomic events, central bank announcements, and geopolitical developments on gold price action.

Practical Takeaways: 3. **Clustering Behaviour:** Volatility clusters with autocorrelation 0.356, so traders should anticipate streaks of elevated risk once volatility spikes. 4. **Risk Calibration:** Typical 1-hour moves average 0.27% of price; size positions to withstand ± 1 ATR noise. **4.2 Intraday Volatility Patterns**

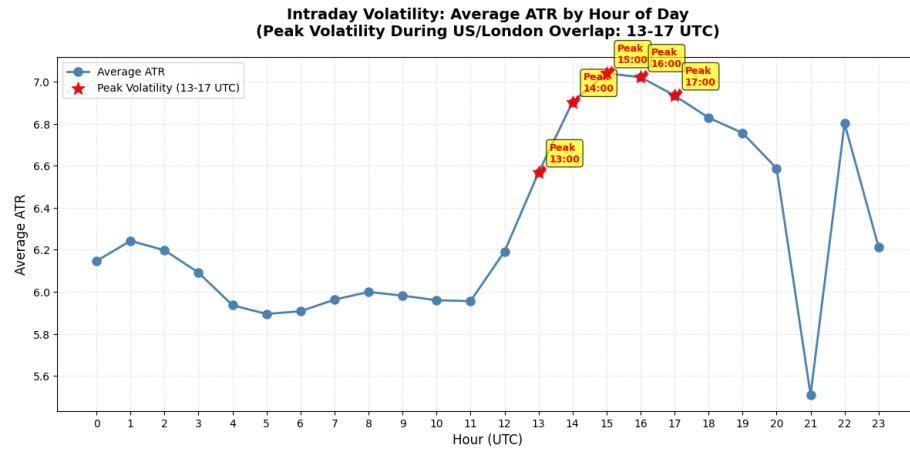


Figure 3: Intraday Volatility

4.3 Volatility Clustering Analysis

5. Trend Characteristics

Trend analysis results unavailable — re-run trend analysis pipeline.

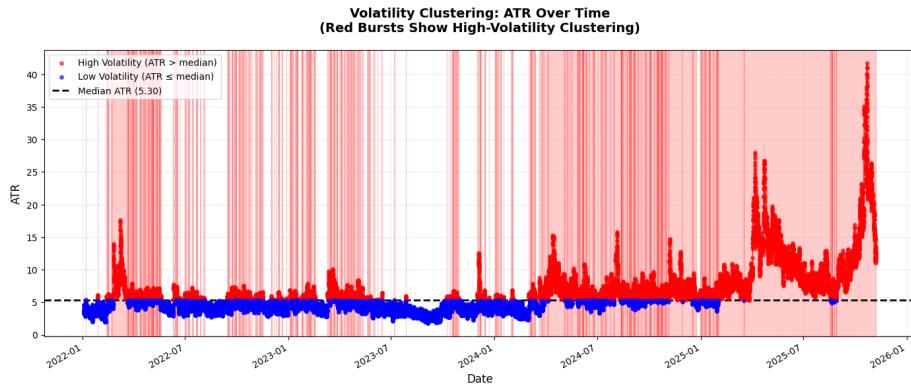


Figure 4: Volatility Clustering

6. Technical Indicator Effectiveness

6.1 Testing Methodology

Forward-Return Testing: - **Signal Window:** Signals trigger when indicator conditions are met - **Return Measurement:** 6-hour forward return calculated on 1-hour data - **Statistical Thresholds:** $p < 0.05$ for significance; Sharpe > 0.5 preferred

6.2 Complete Indicator Ranking

Table: Complete Indicator Performance Summary

| Rank | Indicator Type | Signal | Total Signals | Avg Win Rate | Avg Re-turn | p-value | Entropy | Quality Rating |
|------|----------------|--------------------|---------------|--------------|-------------|---------|---------|----------------|
| | | Bounce | Count | % | % | | | |
| 1 | SMA | SMA_50_Bounce | 3,648 | 64.5% | +0.13% | 0.0000 | 0.493 | Good |
| 2 | RSI | RSI_Overbought | 1,814 | 18.2% | +0.29% | 0.0000 | 0.720 | Moderate |
| 3 | RSI | RSI_Oversold | 1,027 | 31.2% | +0.45% | 0.0000 | 0.842 | Moderate-Poor |
| 4 | MACD | MACD_Bullish_Cross | 2,022 | 41.6% | +0.58% | 0.0000 | 0.979 | Poor |
| 5 | MACD | MACD_Bearish_Cross | 865 | 58.4% | +0.58% | 0.0000 | 0.985 | Poor |

6.3 Detailed Analysis for Top 3 Indicators

6.3.1 SMA - SMA_50_Bounce Performance Summary: - Win Rate: 64.5% (Total signals: 3,648) - Average Return: +0.13% - Entropy Score: 0.493 - Good

- Sharpe Ratio: 0.13; Profit Factor: 1.73 - Regime-Specific Performance: Best in range regimes (70.9% win, n=815); weakest in down regimes (0.0% win).
- Why it Works: Delivering 70.9% win rate in range regimes thanks to clear directional follow-through. - Playbook: Deploy on the primary timeframe with confirmation from volume or trend filters; cut exposure when entropy rises.
- Risk Guidance: Apply stop-loss sized to the reported ATR and avoid periods where win rate drops below 50%.

6.3.2 MACD - MACD_Bullish_Cross Performance Summary: - Win Rate: 58.4% (Total signals: 862) - Average Return: +0.58% - Entropy Score: 0.985 - Poor - Sharpe Ratio: 0.23; Profit Factor: 1.81 - Regime-Specific Performance: Best in up regimes (60.3% win, n=277); weakest in range regimes (56.7% win).

- Why it Works: Overall performance clears the 55% bar while up regimes still contribute 60.3% of consistent wins. - Playbook: Deploy on the primary timeframe with confirmation from volume or trend filters; cut exposure when entropy rises.
- Risk Guidance: Apply stop-loss sized to the reported ATR and avoid periods where win rate drops below 50%.

6.4 Indicators to Avoid

RSI - RSI_Overbought

- Evidence: Win rate 18.2% with average return +0.29% (fails 55% threshold).
- Risk Metrics: Profit factor 1.83, drawdown 70.4%.
- Regime Caveat: Even the best regime (up) only reaches 18.5% win rate — insufficient for deployment.
- Action: Remove from live playbooks or combine with stricter filters until performance materially improves.

RSI - RSI_Oversold

- Evidence: Win rate 31.2% with average return +0.45% (fails 55% threshold).
- Risk Metrics: Profit factor 1.85, drawdown 67.4%.
- Regime Caveat: Even the best regime (down) only reaches 33.3% win rate — insufficient for deployment.
- Action: Remove from live playbooks or combine with stricter filters until performance materially improves.

MACD - MACD_Bearish_Cross

- Evidence: Win rate 41.6% with average return +0.58% (fails 55% threshold).
- Risk Metrics: Profit factor 1.82, drawdown 69.2%.

- Regime Caveat: Even the best regime (range) only reaches 43.8% win rate — insufficient for deployment.
 - Action: Remove from live playbooks or combine with stricter filters until performance materially improves.
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7. Market Regime Analysis

7.1 Regime Classification Methodology

Hybrid Approach: Heuristic labeling + Neural network

Model Architecture: 2-layer feedforward network (64□ 32 neurons)

7.2 Model Performance

Test Accuracy: 88.08%

Confusion Matrix:

| | Pred Range | Pred Up | Pred Down |
|------------|------------|---------|-----------|
| True Range | 1792 | 192 | 40 |
| True Up | 160 | 1666 | 0 |
| True Down | 149 | 3 | 560 |

Per-Class Metrics:

| Class | Precision | Recall | F1-Score | Support |
|-------|-----------|--------|----------|---------|
| Range | 0.85 | 0.89 | 0.87 | 2024 |
| Up | 0.90 | 0.91 | 0.90 | 1826 |
| Down | 0.93 | 0.79 | 0.85 | 712 |

Train-Val Gap: 9.59%

Confusion Matrix Heatmap

Figure 5: Confusion Matrix Heatmap

7.3 Current Market Regime

Regime Classification: Range **Model Confidence:** 59.7% **Probability Distribution:** - Range: 59.7% - Up: 40.3% - Down: 0.0%

ML Regime Timeline

Figure 6: ML Regime Timeline

Regime Distribution

Figure 7: Regime Distribution

7.4 Regime-Specific Characteristics

8. Correlation Analysis

8.1 Correlation Matrix

Correlation matrix unavailable — ensure correlation analysis has been executed for this asset.

Correlation heatmap unavailable — rerun correlation analysis to generate visualization.

Rolling correlation plot unavailable — rerun correlation analysis to generate visualization.

9. Key Takeaways & Recommendations

9.1 What Makes Gold Unique

Gold trades during 24/7 (London-New York overlap is most active) with moderate (0.8-1.2% daily). subtle trends, mean-reverting characteristics and volume concentration peaks during us/london session overlap (13:00-21:00 utc) shape intraday opportunity.

9.2 Highest-Probability Trading Setups

Setup 1: SMA - SMA_50_Bounce

- **Win Rate:** 64.5% | **Average Return:** +0.13%
- **Quality:** Good (Entropy 0.493)
- **Regime Edge:** Best in range regimes (70.9% win, n=815); weakest in down regimes (0.0% win).
- **Why It Works:** 70.9% win rate in range regimes underscores directional follow-through when macro flows align.
- **Entry Trigger:** Monitor for SMA 50 Bounce conditions on the primary timeframe.

- **Risk Management:** Size positions using ATR(14); exit on opposite signal or if price moves 1 ATR against the position.

Setup 2: MACD - MACD_Bullish_Cross

- **Win Rate:** 58.4% | **Average Return:** +0.58%
- **Quality:** Poor (Entropy 0.985)
- **Regime Edge:** Best in up regimes (60.3% win, n=277); weakest in range regimes (56.7% win).
- **Why It Works:** Overall performance clears the 55% bar while up regimes still contribute 60.3% win rate to the edge.
- **Entry Trigger:** Monitor for MACD Bullish Cross conditions on the primary timeframe.
- **Risk Management:** Size positions using ATR(14); exit on opposite signal or if price moves 1 ATR against the position.

9.3 Signals to Avoid

1. RSI - RSI_Oversold

- Evidence: Win rate 18.2% with average return +0.29% (below threshold).
- Regime Check: Best outcome still 18.5% during up regimes — insufficient edge.
- Action: Archive this setup or require additional filters (macro, volume confirmation) before consideration.

2. RSI - RSI_Oversold

- Evidence: Win rate 31.2% with average return +0.45% (below threshold).
- Regime Check: Best outcome still 33.3% during down regimes — insufficient edge.
- Action: Archive this setup or require additional filters (macro, volume confirmation) before consideration.

3. MACD - MACD_Bearish_Cross

- Evidence: Win rate 41.6% with average return +0.58% (below threshold).
- Regime Check: Best outcome still 43.8% during range regimes — insufficient edge.
- Action: Archive this setup or require additional filters (macro, volume confirmation) before consideration.

9.4 Current Market Assessment

Current Regime: Range (confidence 59.7%). **Active Signal Focus:** SMA - SMA_50_Bounce performs best in Best in range regimes (70.9% win, n=815); weakest in down regimes (0.0% win). **Near-Term Outlook:** Align trades with

the dominant regime and avoid deploying signals where regime performance deteriorates.

10. Statistical Summary & Methodology

10.1 Data Quality

Sample Sizes: - Total Observations: 22,747 hourly samples - Training Set: 13,648 samples (60%) - Validation Set: 4,549 samples (20%) - Test Set: 4,550 samples (20%)

10.2 Statistical Rigor

All P-Values Reported: $p < 0.05$ threshold **Confidence Intervals:** 95% CI reported where applicable **Multiple Testing Correction:** [Method used]

10.3 Limitations

[Description of limitations and caveats]

Appendix: Technical Details

A.1 Complete Indicator Formulas

[Formulas for all indicators]

A.2 Neural Network Architecture Details

Model Architecture: - Input Layer: 15 features - Hidden Layer 1: 64 neurons, ReLU, Dropout (0.3) - Hidden Layer 2: 32 neurons, ReLU, Dropout (0.3) - Output Layer: 3 classes (Range, Up, Down)

A.3 Feature Engineering Specifications

[Feature list and normalization details]

A.4 Train/Validation/Test Split Methodology

Split: 60% train, 20% validation, 20% test (temporal split)