Quantitative Pairs Trading Strategy Development (Day 36–40)

This summary outlines the structured development of a **quantitative pairs trading system**, emphasizing **statistical validation**, **dynamic hedging**, and **robust adaptive backtesting**.

From Cointegration to Dynamic Hedging

Objective: Build a statistically sound framework to exploit mean-reverting relationships between asset pairs.

Approach: Progressed from Engle–Granger testing to advanced multivariate modeling (Johansen, VECM, Kalman Filter).

Deliverables:

- Cointegration detection tools
- Dynamic hedge ratio estimation
- Rolling backtest with risk controls
- Realistic PnL simulation including costs and slippage

Establishing Long-Run Equilibrium

Goal: Identify pairs with a stable equilibrium using the Engle–Granger two-step test.

Steps:

1. OLS regression to estimate hedge ratio (β).
2. ADF test on residuals to confirm stationarity.

Outcome: Pairs with stationary residuals are cointegrated and suitable for mean reversion.

Metric: Mean-reversion half-life guides holding periods.

Multivariate Cointegration Testing

Improvement: Overcomes Engle–Granger's bivariate limitation.

Method: VAR-based Johansen test with optimal lag selection (AIC/BIC).

Key Outputs:

- Cointegration rank (r) via trace and max-eigenvalue tests.
- Normalized cointegrating vector (β) for spread construction.

Result: Statistically robust pairs (e.g., GLD–HDFCBANK.NS).

Building the Mean-Reversion Model

Spread Definition: $S_t = \text{Stock A} - \beta \cdot \text{Stock B}$

Z-Score Normalization: Enables consistent entry/exit signals.

Trading Rules:

- Long when $Z < -2$; Short when $Z > 2$.
- Exit when $Z \to 0$.

Limitation: Static β becomes unreliable as relationships drift.

Adaptive Model and Trade Diagnostics

- **Rolling Backtest:** Continuously updates β, mean, and σ using a lookback window (e.g., 252 days).
- **Risk Parameters:**
  - Max holding days
  - Target PnL
  - Stop loss
- **Exit Logging:** Tracks Z-Exit, Hit Target, Stop Loss, or Time Limit.
- **Result:** Improved adaptability and trade-level transparency.

Time-Varying Hedge Ratio Estimation

Problem: Static OLS β fails under regime shifts.

Solution:

- **Rolling OLS**: Updates β periodically.
- **Kalman Filter**: Recursively estimates time-varying β via state-space modeling.

Benefit: Adapts to evolving market relationships, essential for intraday trading.

Joint Forecasting of Cointegrated Pairs

Model: Uses **VECM** when cointegration exists ($r \geq 1$); defaults to **VAR** otherwise.

Function: Models both short-run dynamics and long-run equilibrium corrections.

Advantage: Enables joint price forecasting and spread prediction.

Incorporating Market Realism

- **PnL Adjustments:** Includes transaction costs and proportional slippage.
- **Drawdown Enforcement:**
  - Halts trading if cumulative drawdown breaches a set threshold.
  - Prevents capital erosion and enforces discipline.

Robustness and Next Steps

Pre-Deployment Checks:

- Visual and statistical regime validation
- Sensitivity testing (lags, deterministic terms)
- Subsample stability analysis

Optimization: Tune parameters (lookback, Z-entry/exit) to maximize Sharpe or net PnL.

Future Focus:

- Volume-based slippage modeling, cooling-off mechanism post drawdown and portfolio-level optimization for multiple pairs