Quantitative Research Project - Volatility Pairs Trading: Bank Nifty & Nifty

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Introduction

In this project, we explored a **volatility pairs trading strategy** using Bank Nifty and Nifty implied volatilities. Since both indices share overlapping stocks and are influenced by similar market conditions, we hypothesized that the **volatility spread between these indices fluctuates around a mean**. Significant deviations from this mean are likely to revert over time, presenting potential trading opportunities.

To test this hypothesis, we implemented two trading strategies:

- Base Model - Dynamic Z-Score Strategy
- Improved Model - Kalman Residual Strategy

We compared these strategies based on **profit/loss, Sharpe ratio, drawdown, win rate, and the number of trades** to understand which method provides better **risk-adjusted performance**.

Dataset

We used **minute-level implied volatility (IV) data** for Bank Nifty and Nifty, along with **Time to Expiry (TTE)**. The dataset covers **standard Indian market hours (09:15 to 15:30)**. Missing values were appropriately handled.
The spread between the two indices was calculated as:

$$\text{Spread} = \text{Bank Nifty IV} - \text{Nifty IV}$$

The profit/loss for each trade was calculated using:

$$\text{P/L} = \text{Spread} \times (\text{TTE})^{0.7}$$

This formulation reflects both the **magnitude of the spread** and the **time to expiry**, providing a meaningful estimate of potential trade profits.

Base Model - Dynamic Z-Score Strategy

How the Strategy Works:
The Z-score model uses statistical methods to detect when the spread deviates significantly from its recent mean. Steps include:

- Compute a rolling mean and standard deviation of the spread.

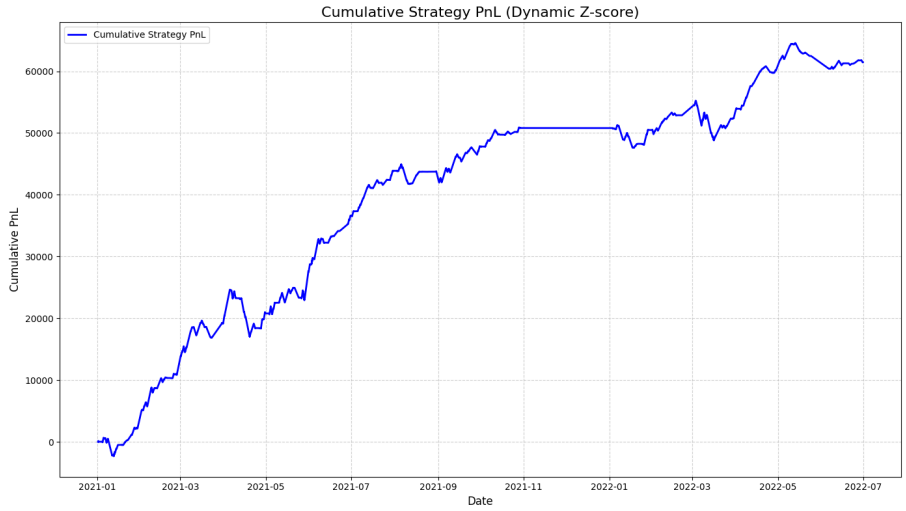
- Calculate Z-score to measure deviation in terms of standard deviations.
- Scale entry and exit thresholds dynamically based on short-term volatility.
- Generate trading positions:
  - Long spread when Bank Nifty volatility is unusually low (Z-score below negative threshold).
  - Short spread when Bank Nifty volatility is unusually high (Z-score above positive threshold).
- Exit trades when the spread moves back toward the mean or crosses exit thresholds.

Positions are **volatility-adjusted** to avoid oversized trades during high market swings.

Performance:

Metric	Value
Absolute Return	61,464
Annualized Sharpe	5.17
Max Drawdown	-7,621
Max Drawdown %	-11.8%
Win Rate	64.8%
Trade Count	4,368

The Z-score model effectively captures **mean reversion** between Bank Nifty and Nifty volatilities. It generates a large number of trades and achieves a **decent Sharpe ratio**, indicating good risk-adjusted performance. However, the **absolute return** is modest, and the **drawdown percentage** is noticeable, indicating limitations in adapting to changing market conditions.



Improved Model - Kalman Residual Strategy

How the Strategy Works:

The Kalman residual model improves upon the Z-score strategy by allowing the relationship between Bank Nifty and Nifty to change dynamically:

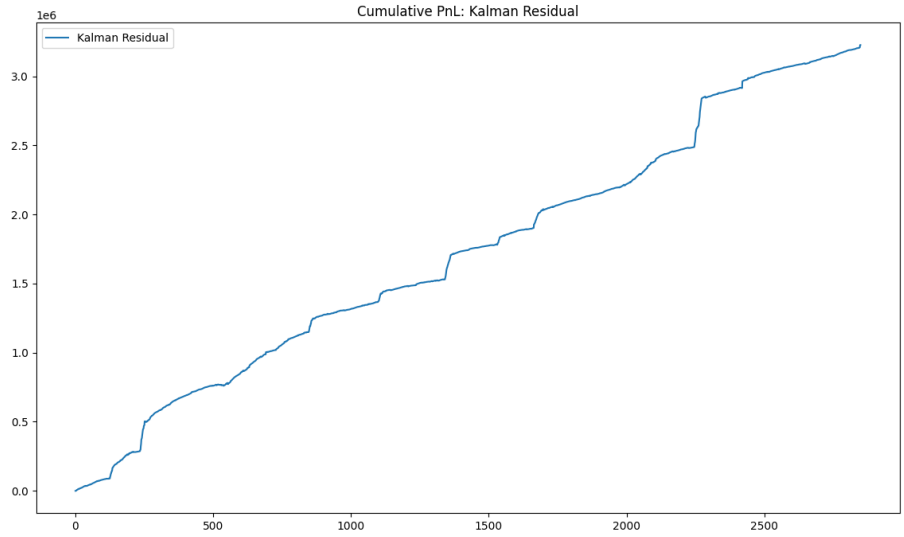
- Estimate a dynamic hedge ratio (beta) using a Kalman filter.
- Calculate residuals as the difference between actual Bank Nifty IV and beta-adjusted Nifty IV.
- Compute residual Z-scores to identify trade signals.
- Generate trades with adaptive thresholds, correlation checks, stop-losses, and maximum holding time.
- Track trade-level P/L and cumulative performance.

This approach allows the strategy to **adapt to changing market conditions**, making signals more accurate.

Performance:

Metric	Value
Absolute Return	3,226,235
Annualized Sharpe	6.02
Max Drawdown	9,965
Max Drawdown %	0.31%
Win Rate	89.5%
Trade Count	2,848

The Kalman residual model shows **exceptional performance**. By dynamically estimating the hedge ratio, it adapts to market conditions and identifies profitable trades more effectively. Absolute returns are much higher, drawdowns are minimal, and the win rate is high with fewer trades, capturing high-probability setups efficiently.



Model Comparison:

Metric	Dynamic Z-Score	Kalman Residual
Absolute Return	61,464	3,226,235
Annualized Sharpe	5.17	6.02
Max Drawdown	-7,621	9,965
Max Drawdown %	-11.8%	0.31%
Win Rate	64.8%	89.5%
Trade Count	4,368	2,848

- The Kalman residual model outperforms the Dynamic Z-Score model across all major metrics.
- It achieves **much higher returns** with **lower risk**, as seen from the minimal drawdown and higher Sharpe ratio.
- The Kalman model is **more selective**, producing fewer trades but achieving a **higher win rate**, indicating that it captures only high-probability setups.
- In contrast, the Z-Score model generates more trades but with **lower profitability** and **higher drawdowns**, reflecting its limitation in dynamic market conditions.
- Overall, the Kalman residual strategy provides **superior risk-adjusted performance**, combining high returns with low drawdowns and strong consistency.