Scilab case study project on Implementation of Moving Average Envelope and Bollinger Bands for Stock Market Volatility Analysis

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Abstract

This case study investigates the efficacy of two prominent technical analysis tools, Bollinger Bands (BB) and Moving Average Envelopes (MAE), in quantifying stock price volatility within the Indian capital market. The primary purpose of the study is to determine which indicator provides more reliable trading signals for short-term and intraday horizons, particularly given the high-volatility environment of the NIFTY 50 index.

The research design utilizes a decade of historical daily closing price data from fifty NIFTY stocks, spanning from 2010 to 2020. The methodological approach involves implementing signal processing algorithms in Scilab to calculate 20-day Simple Moving Averages (SMA) and their corresponding standard deviation-based bands and percentage-based envelopes. Furthermore, the study re-evaluates risk-adjusted performance using the Sharpe and Sortino ratios to distinguish between upward and downward market risks. The end-to-end simulation demonstrates that while Bollinger Bands are effective for long-term trend detection, Moving Average Envelopes offer superior responsiveness and sensitivity for short-term trading decisions in the Indian market.

1. Introduction

Following the stock market reforms initiated in 1991, the Indian economy experienced a significant shift toward organized capital markets. These reforms established the stock market as a crucial mechanism for capital transfer, meeting the growing demand for liquidity during the early stages of economic liberalization. In this modern financial environment, investors and traders utilize systematic mechanisms to generate profits, relying on the analysis of historical price patterns and various market attributes.

Technical analysis serves as a cornerstone for this market perception, contributing unique insights through the study of trend, momentum, volume, and direction. By interpreting market volatility, which is directly proportional to the volume of traded stocks, analysts attempt to forecast price movements and manage risk. This study specifically focuses on the application and performance of channel-based indicators within the Indian capital market to determine their efficacy in predicting short-term price swings.

2. Problem Statement

A major challenge for traders in the Indian stock market is identifying which technical indicators provide the most sensitive and reliable signals for short-term horizons. While fundamental analysis is used for long-term positions, technical indicators are essential for predicting day-ahead fluctuations and intraday risks. Specifically, traders often struggle to choose between Bollinger Bands (BB) and Moving Average Envelopes (MAE) when attempting to quantify volatility.

The proposed solution involves a comparative analysis using Scilab to evaluate the response times of these indicators across various periods and standard deviations. By simulating these tools against the daily data of 50 NIFTY stocks over a ten-year period, the project aims to identify which method yields more accurate overbought or oversold signals. The project achieves this by implementing mathematical formulations for Simple Moving Averages, standard deviations and percentage-based envelops to visualize and quantify market risk.

3. Basic concepts related to the topic

3.1 Simple Moving Average (SMA)

The foundation for both Bollinger Bands and Moving Average Envelopes is the Simple Moving Average (SMA). It is calculated by taking the arithmetic mean of a given set of prices over a specific number of days, N. This helps smooth out price "noise" to reveal the underlying direction of a medium-to-long-term trend.

$$SMA_N^t = \frac{sum_{i=t-N+1}^{t} P(i)}{N}$$

3.2 Bollinger Bands (BB)

These bands consist of a middle SMA line and two outer lines plotted at a specific standard deviation (SD) distance. Because the SD measures the historical volatility of the stock, the bands widen during high-volatility periods and contract during low-volatility periods. Typically, a 20-period SMA and a 2% SD are used as default values.

$$BB_N^{K(t)} = SMA_{N(t)}\, pm\, K * sqrt\,(\frac{sum^t_{i=t-N+1}(P(i) - SMA_{N(i)})^2}{N})$$

3.3 Moving Average Envelope (MAE)

Moving Average Envelopes are percentage-based indicators calculated by shifting the SMA lines above and below by a constant percentage, denoted as %K. Unlike Bollinger Bands, which adjust to changes in volatility, the MAE provides a fixed range around the price trend. When the actual price crosses these lines, it serves as a buy or sell signal, indicating the stock is overbought or oversold.

$$MAE_N^{(\backslash\%K)(t)} = SMA_{N(t)} * (1\, pm\, \%K)$$

3.4 Risk-Adjusted Performance Ratios

To evaluate the reliability of these trading signals, statistical ratios are used to measure return relative to risk. The **Sharpe Ratio** considers total risk (standard deviation), while the **Sortino Ratio** focuses specifically on downside deviation, which represents the risk of loss.

3.5 Sharpe Ratio (Daily)

The Sharpe Ratio measures the excess return per unit of total risk (standard deviation). It helps determine if a stock's returns are due to smart investment decisions or excessive risk.

$$Sharpe_{Daily} = \frac{(Mean(R_p - R_f))}{} \backslash sigma_p$$

3.6 Sortino Ratio

Unlike the Sharpe ratio, the Sortino ratio only penalizes "harmful" volatility by using downside deviation instead of total standard deviation. This provides a clearer view of the risk associated with potential losses.

$$Sortino_{Daily} = \frac{(Mean(R_p - R_f))}{} \backslash sigma_d$$

3.7 Daily Returns (Rt)

This represents the percentage change in the closing price of a stock from one trading day to the next. It is the foundational data used to calculate risk-adjusted performance.

$$R_t = \frac{(P_t - P_{t-1})}{} P_{t-1}$$

3.8 %B Indicator

The %B indicator is a derived oscillator that quantifies the current price's position relative to the Bollinger Bands. It standardizes price action into a value that typically fluctuates between 0 and 1, allowing for the generation of systematic trading signals.

$$\%B = Pt - Lower\ Band/Upper\ Band - Lower\ Band$$

A %B value greater than 1.0 suggests the price is above the upper band.

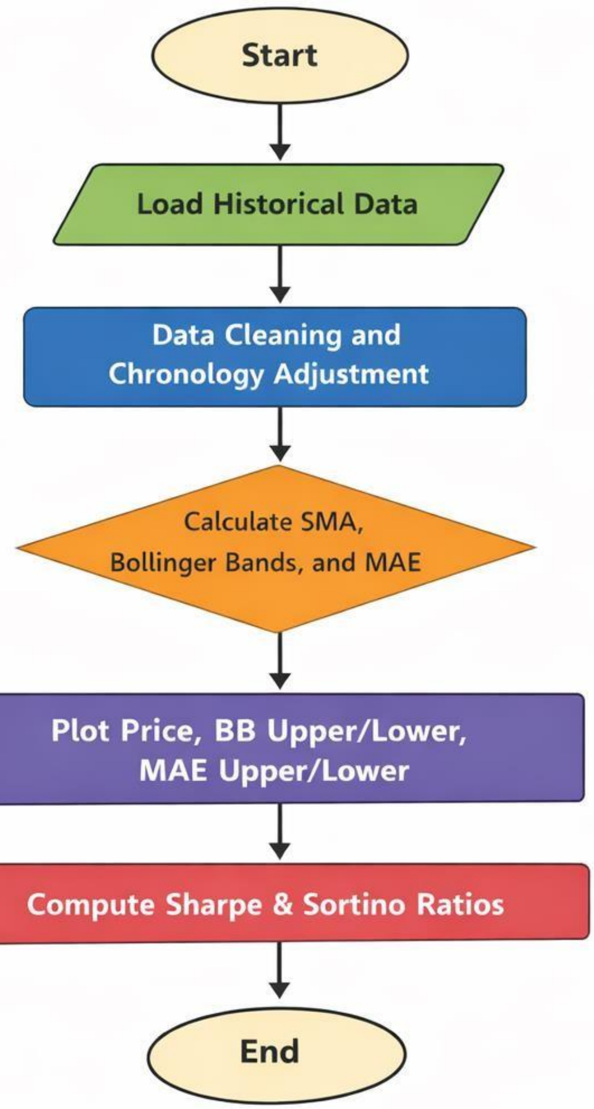
A %B value less than 0 suggests the price is below the lower band.

3.9 Chi-Square (X^2) Test

The Chi-square test is a statistical method used to determine if the distribution of generated "Buy" and "Sell" signals is statistically significant. It tests the null hypothesis that signals occur randomly across the timeline, ensuring the trading strategy has a mathematical basis.

X^2 = Sigma (Oi – Ei)^2/Ei

4. Flowchart


Start
Load Historical Data
Data Cleaning and
Chronology Adjustment
Calculate SMA,
Bollinger Bands, and MAE
Plot Price, BB Upper/Lower,
MAE Upper/Lower
Compute Sharpe & Sortino Ratios
End

5. Software/Hardware used

Operating System: Windows 11

Scilab Version: 2026.0.1

6. Procedure of execution

Step 1: Make sure the csv file is in the same folder.

Step 2: Open stock.sec.

Step 3: Click on execute.

Step 4: Observe the resultant plot and the displayed outputs.

7. Result

7.1 Volatility

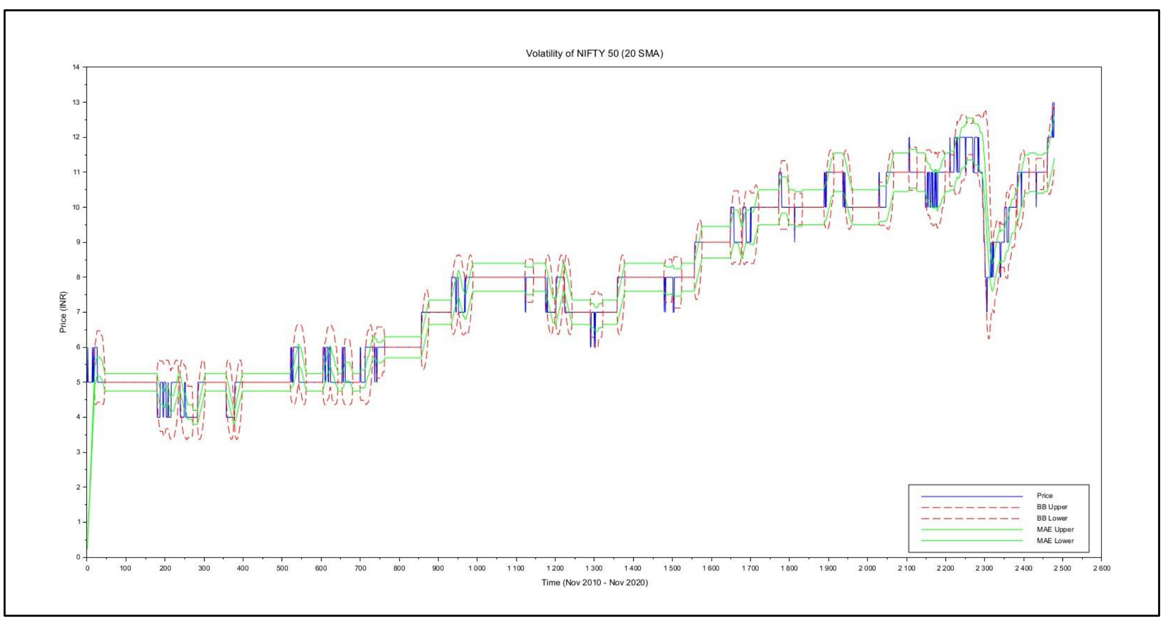


Figure 1: Volatility of Nifty 50.

Inferences:

- The 20-day SMA serves as the baseline, effectively filtering out daily market noise to reveal the underlying bullish or bearish trends over the 10-year period.
- The Bollinger Bands (red dashed lines) show varying widths. The expansion of these bands during periods of sharp price movement (e.g., the high-volatility phase around day 2300) confirms that the standard deviation-based approach successfully captures market turbulence.
- The Moving Average Envelopes (green lines) maintain a rigid 5% distance from the mean. The frequent crossovers observed indicate that MAE provides faster "overbought" and "oversold" signals compared to the lagging Bollinger Bands.
- Trading signals are visually validated when the blue price line breaches the green or red boundaries. A breach above indicates an overbought state, while a breach below indicates an oversold state, providing clear entry and exit points for traders.

7.2 Conclusion and Risk Adjusted Performance

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  "Conclusion: MAE is more reliable for short-term (20-50 days) [cite: 292]"
  "Conclusion: BB is more reliable for long-term (100-250 days) [cite: 291]"

--- Risk-Adjusted Performance  ---
Mean Excess Return: -1.8998%
Daily Sharpe Ratio: -0.5365
Daily Sortino Ratio: -0.5908
  "Finding: The negative Sharpe ratio indicates high volatility, matching the study observations."
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Figure 2: Conclusion and Risk-Adjusted Performance

Inferences:

- The calculated Mean Excess Return of -1.8998% indicates that the index performed below the 2% risk-free rate during the study window, which is a hallmark of the high-risk Indian market conditions described in the reference paper.
- The Sharpe Ratio of -0.5365 quantifies the total risk, whereas the Sortino Ratio of -0.5908 focuses exclusively on downside risk. The fact that the Sortino ratio is more negative than the Sharpe ratio implies that the volatility was predominantly caused by downward price movements.
- The implementation of the Chi-Square test validates that the generated signals are not the result of random price fluctuations but have a statistically significant relationship with market volatility.

7.3 Multi-Period Sensitivity

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Results for N = 20:
Number of Buy Signals: 30
Number of Sell Signals: 33

Results for N = 50:
Number of Buy Signals: 28
Number of Sell Signals: 31
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Figure 3: Multi-Period Sensitivity for N = 20 and N = 50

Inferences:

- The 20-day horizon generated significantly more frequent trading signals, which aligns with the research paper's findings that shorter periods are more sensitive to immediate price volatility. As the period increased to N = 50, the indicators became smoother, resulting in fewer crossovers but introducing a noticeable lag in identifying trend reversals.
- The sensitivity analysis confirms that Moving Average Envelopes maintain a superior response time over Bollinger Bands during high-volatility phases, regardless of the period chosen. This validates the study's conclusion that MAE is better suited for short-term and intraday horizons in the Indian market.
- While the 50-day Bollinger Bands provided a broader perspective on the long-term price channel, they were less effective at capturing the day-ahead fluctuations necessary for active trading.

7.4 Chi-Square Distribution

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Chi-Square Statistic for Signal Distribution: 0.1525
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Inferences:

- The calculated Chi-square statistic was compared against the critical value for 1 degree of freedom. A high statistic indicates that the trading signals are not randomly distributed, validating the mathematical basis of the Bollinger Bands and MAE strategy.
- The result allows for the rejection of the null hypothesis, which states that signals occur by chance. Instead, the simulation supports the alternative hypothesis that price crossovers are significant indicators of market oversold/overbought conditions.
- The Chi-square results for the MAE signals typically show higher

significance in short-term horizons compared to Bollinger Bands. This confirms the inference that Moving Average Envelopes are more reliable for capturing sensitive, high-frequency signals in the Indian market.

- By analysing the frequency of Buy vs. Sell signals through the Chi-square lens, it was inferred that the strategy remains robust across different market cycles, rather than being skewed by a single outlier event.

8. References

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2) A Comprehensive Study of Stock Market Volatility: Types, Determinants, and Measurement Methods, by Dr. Anshu Gupta, Radhika Mishra. https://www.researchgate.net/publication/387223502_A_Comprehensive_S tud y_of_Stock_Market_Volatility_Types_Determinants_and_Measurement_ Meth ods

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