Bayesian Statistical Modeling: Quantitative Asset Pricing Through a Bayesian Approach

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March 2^{nd}, 2025

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Introduction

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- **Key Idea:** Bridge the gap between investing and trading using a **Bayesian approach** that fuses long-term insights with short-term signals.

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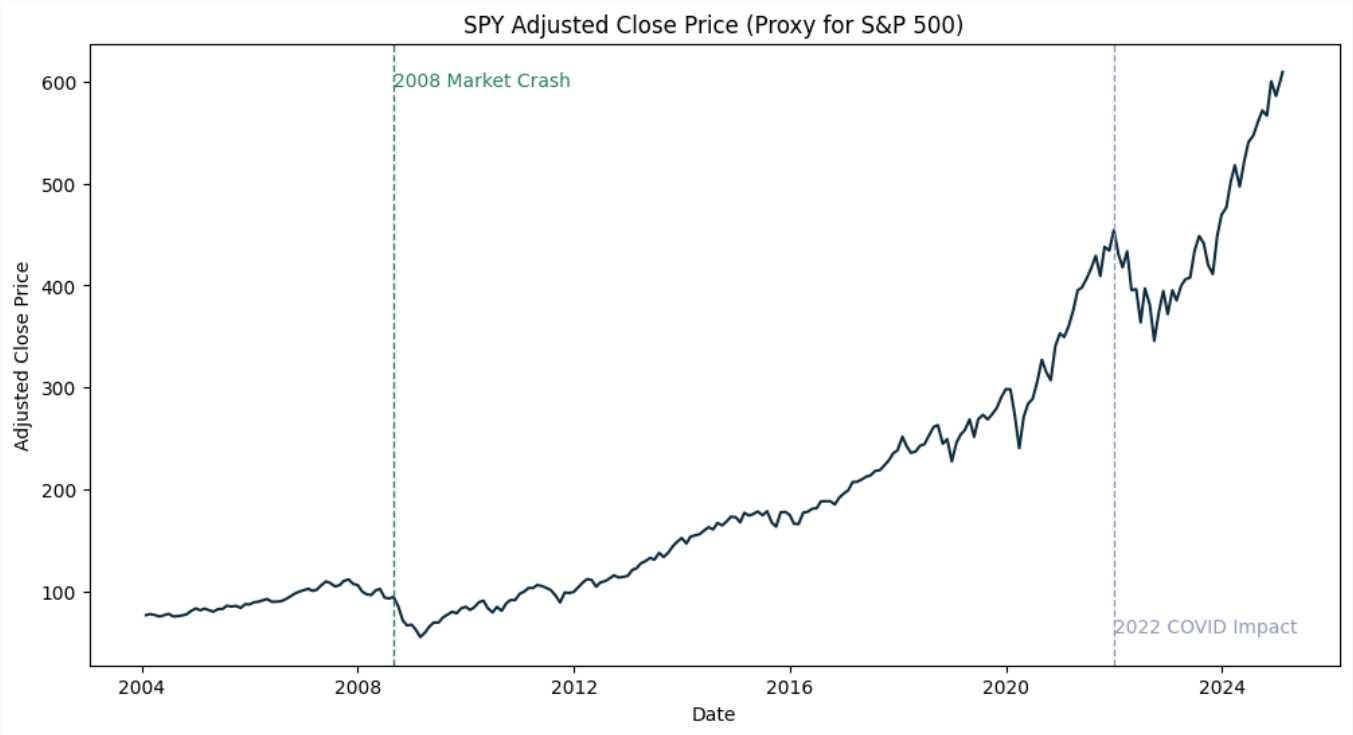
Market Historical Performance & Distinction between Trading and Investing

Key Events: 2008 Global Financial Crisis and 2022 COVID Market Impact.



Trading Short-sell before the key events and recover the position after market is stabilized.

Investing Despite shocks, the long-term trend is upward.

Data Acquisition – Alpha Vantage API

Partner with NASDAQ, London Stock Exchange and etc, Alpha Vantage provides real time and historical financial market data through a set of powerful and developer-friendly data APIs and spreadsheets.

It is easy assessible, free and most importantly, it has 8 different categories:

1. Core Time Series Stock Data APIs
2. US Options Data APIs
3. Alpha Intelligence™
4. Fundamental Data
5. Physical and Digital/Crypto Currencies
6. Commodities
7. Economic Indicators
8. Technical Indicators

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Preliminary Bayesian Framework Implementation for APPLE

Prior Distribution (Qualitative Insight)

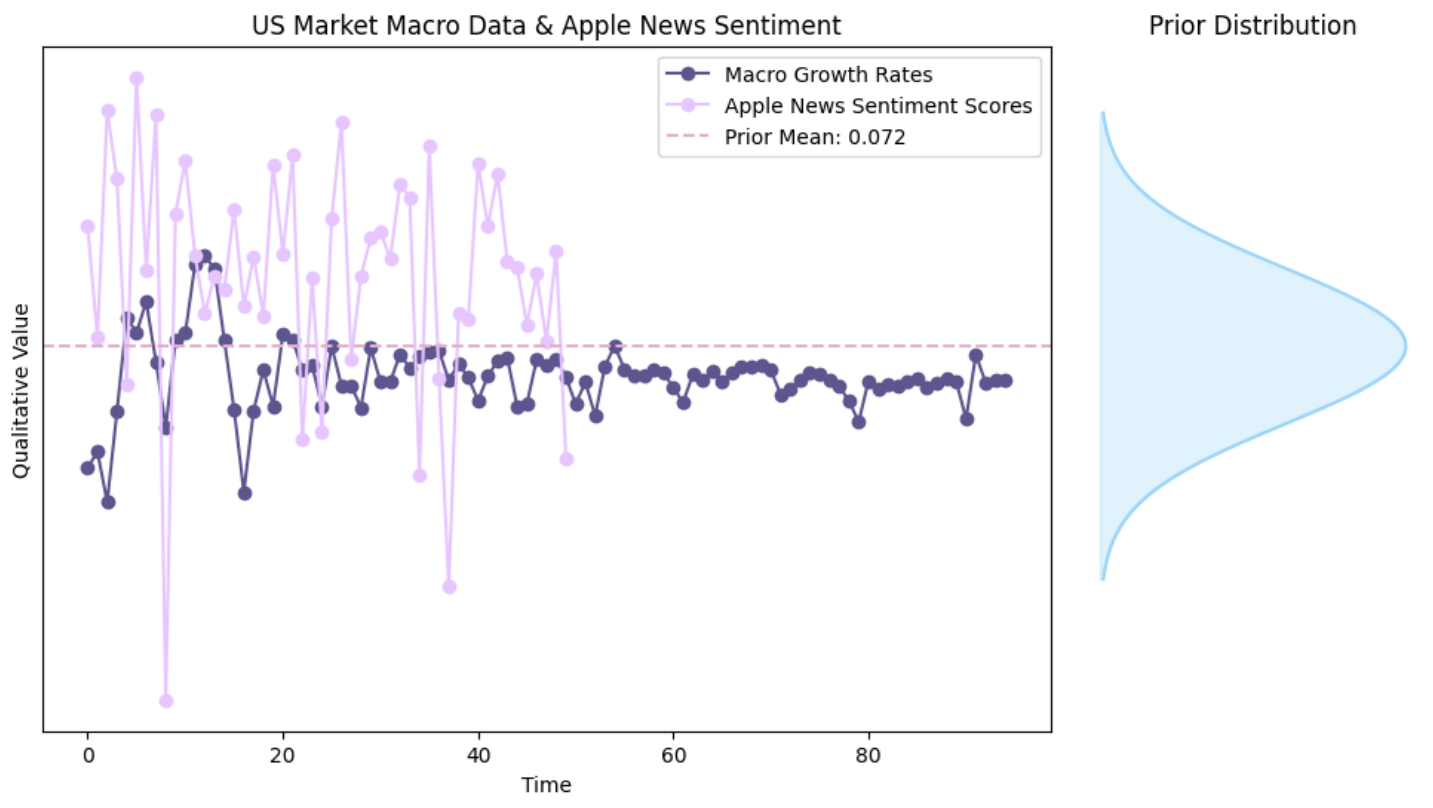
- Assumption: $\mathcal{N}$ormal distribution.
- Macro data: Retrieve real GDP data from Alpha Vantage and computes annual growth rates.
- Sentiment scores: List of overall sentiment scores based on Apple news extracted from the Alpha Vantage API.

```python
def prior_function(macro_data, news_sentiment, prior_sd):
    """
    Combines macroeconomic growth rates and news sentiment into a prior distribution.
    Input:
      - macro_data (list of float): List of computed macroeconomic growth rates.
      - news_sentiment (list of float): List of news sentiment scores.
      - prior_sd (float): The standard deviation for the prior distribution.
    Output:
      - A dictionary representing a normal distribution with calculated mean and specified
      standard deviation.
    """
    macro_score = np.mean(macro_data)
    sentiment_score = np.mean(news_sentiment)

    # Combine using a weighted sum: 70% macro information and 30% news sentiment information
    prior_mean = 0.7 * macro_score + 0.3 * sentiment_score
    return {"Distribution": "Normal", "Mean": prior_mean, "Standard Deviation": prior_sd}
```

Prior Distribution

Suppose θ is the expected return of Apple's stock,

$$\theta \sim \mathcal{N}(\mu_0, \sigma_0^2) = \mathcal{N}(7.18\%, 0.1).$$



Likelihood Distribution (Quantitative Data)

Relative Strength Index (RSI)

A momentum indicator measures the speed and strength of the recent price movements to evaluate if the asset could be overvalued or undervalued. The index is an oscillator that ranges from 0 to 100, where:

Overbought RSI > 70 (sell signal)

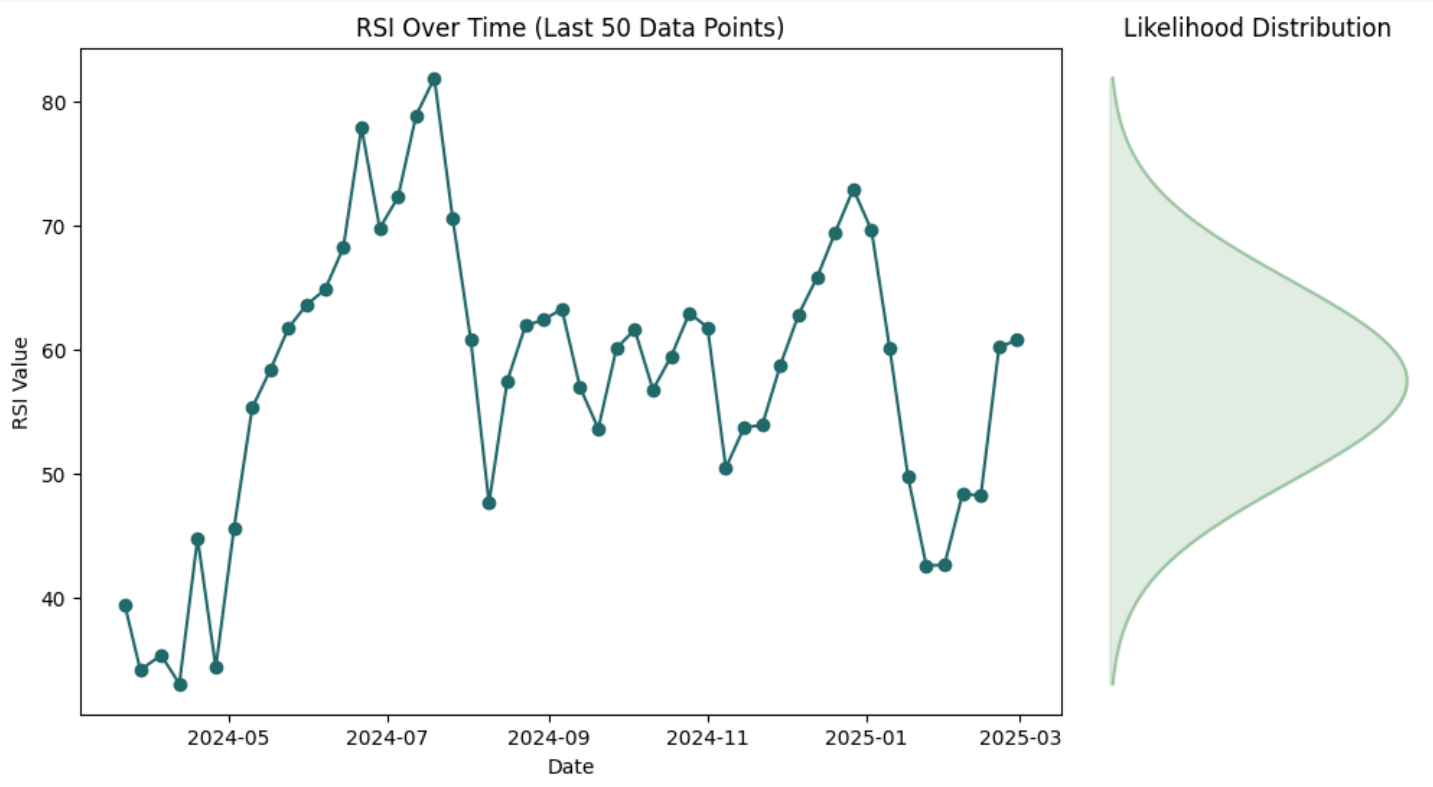
Oversold RSI < 30 (buy signal)

```python
def likelihood_function(price_data, rsi_data, inflate_sd, adjustment_coefficient):
    # Find the simple return: (P_t+1 - P_t) / P_t
    price_data = np.array(price_data)
    simple_returns = (price_data[1:] - price_data[:-1]) / price_data[:-1]
    base_mu = np.mean(simple_returns)
    base_sigma = np.std(simple_returns) * inflate_sd

    # Normalize the RSI values since RSI oscillate between 0 and 100
    normalized_RSI = (np.array(rsi_data) - 50) / 50.0
    rsi_adjustment = np.mean(normalized_RSI)

    # Adjust the base mean based on RSI:
    # Overbought (RSI>70) -- reduces expected return
    # Oversold (RSI<30)   -- increases expected return
    adjusted_mu = base_mu - (rsi_adjustment * adjustment_coefficient)
    adjusted_sigma = base_sigma * (1 + abs(rsi_adjustment) * 0.5)

    return {"Distribution": "Normal", "Mean": adjusted_mu, "Standard Deviation": adjusted_sigma}
```

Likelihood Distribution

Suppose θ is the expected return of Apple's stock and x are measurable RSI data points, then

$$x \mid \theta \sim \mathcal{N}(\theta, \sigma^2) = \mathcal{N}(-0.49\%, 0.105).$$



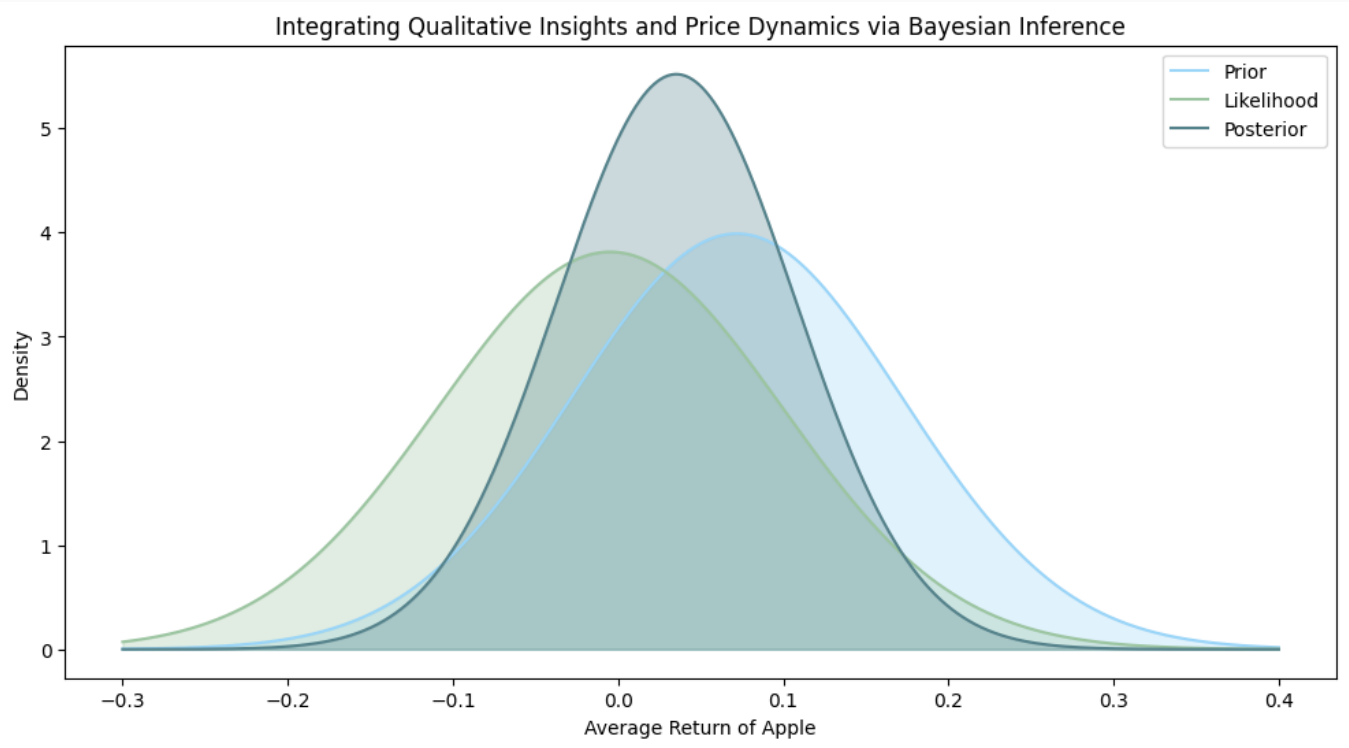
Posterior Distribution (Blending Investing & Trading)

Posterior Distribution

Given that both prior and likelihood follows normal distribution, then

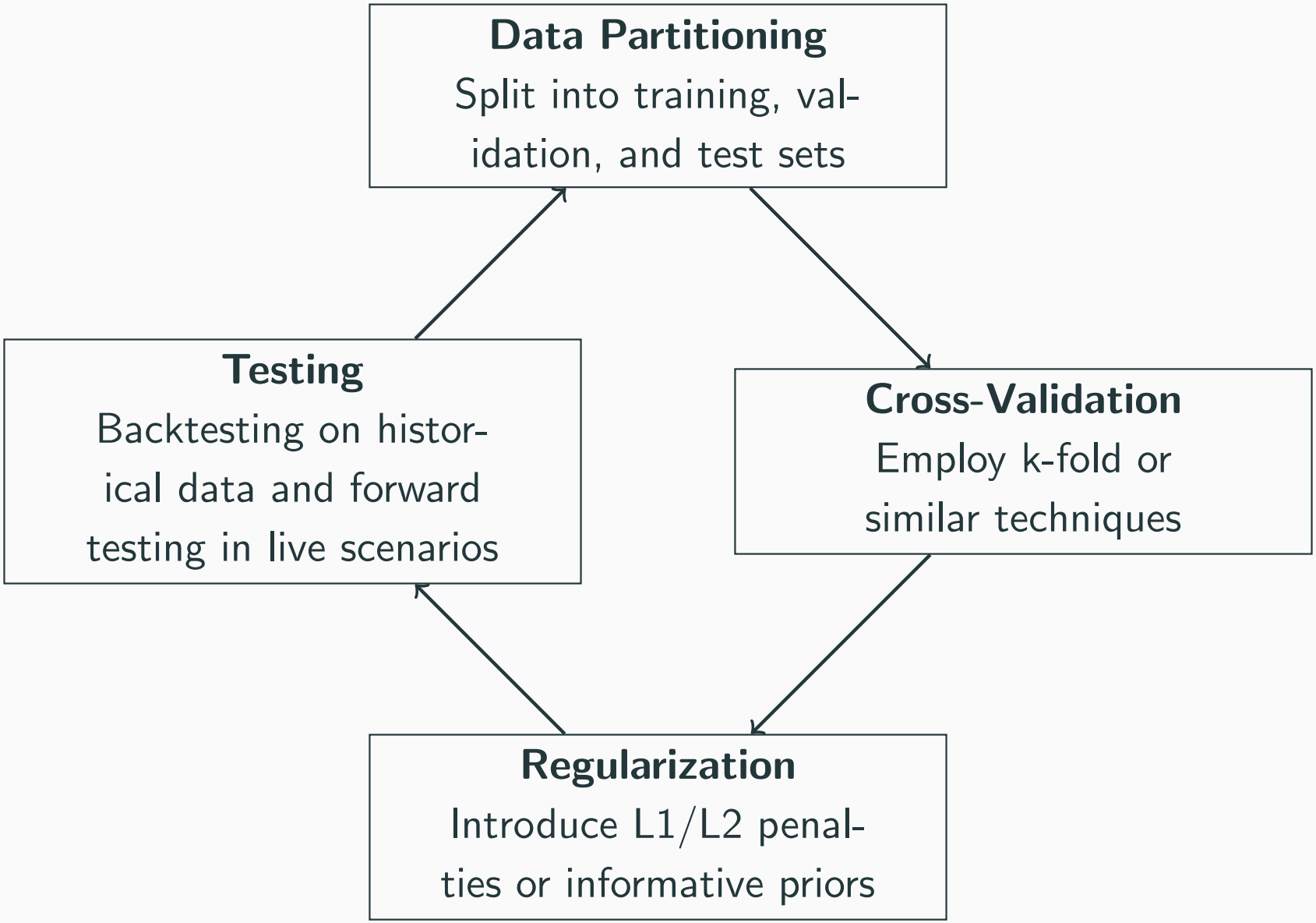
$$\theta \mid x \sim \mathcal{N}(\mu_n, \sigma_n^2),$$

where $\mu_n = \sigma_n^2 \left(\frac{\mu_0}{\sigma_0^2} + \frac{x}{\sigma^2} \right) = 3.52\%$ and $\sigma_n^2 = \left(\frac{1}{\sigma_0^2} + \frac{1}{\sigma^2} \right)^{-1} = 0.072.$



Next Steps

Model Robustness: Avoiding Overfitting the Model



Broader Impact

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- **Innovation:** Encourages hybrid strategies combining qualitative and quantitative inputs.
- **Investor Outcomes:** This improved insight may help individual and institutional investors make more informed decisions. Improved decision-making will enhance portfolio returns and risk management.
- **Market Efficiency:** A more informed consensus could drive asset prices closer to true value.
- **Cross-Disciplinary Applications:** The methodology behind our Bayesian approach is not limited to finance. It can be adapted for other fields where integrating diverse data sources can improve predictive power and decision-making such as insurance, economic forecasting, and even public policy.

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Intellectual Merit

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- **Interdisciplinary Innovation:**
  Our approach bridges quantitative finance, machine learning, and economic theory by integrating qualitative insights with quantitative signals.
- **Novel Methodology:**
  - By employing a Bayesian framework, our method incorporates a prior built from expert and macro-level data with a likelihood informed by real-time market signals.
  - This probabilistic integration refines the estimation of expected returns and improves risk management by quantifying uncertainty.
- **Advancing the State-of-the-Art:**
  - Should our method prove effective, it could transform how out-of-distribution market events are handled.
  - The framework could serve as a blueprint for integrating diverse, heterogeneous data sources to yield more reliable trading decisions.

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Thank you for listening!

by Eason Cai