Capstone Project: MIBOR Interest Rate Modeling

**Observation Form**

**Project Title:** MIBOR Interest Rate Modeling (Vasicek vs. Hull-White)

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# 1. Introduction

This capstone project investigates the application of two prominent single-factor stochastic short-rate models—the Vasicek Model and the Hull-White Model—to forecast Indian MIBOR (Mumbai Interbank Offered Rate) interest rates. The primary objective was to calibrate these models using two years of historical MIBOR data, project interest rates for specific future tenors (3.5, 4.5, and 5.5 years), visualize the projections, and critically assess the suitability of each model based on the available data and their inherent characteristics.

# 2. Methodology Summary

The project workflow involved:

* **Data Acquisition:** Historical daily Overnight MIBOR rates for the past two years (June 2023 - June 2025) were directly sourced from Financial Benchmarks India Private Ltd. (FBIL), ensuring high data quality and reliability.
* **Data Preprocessing:** The raw MIBOR rates (in percentage) were converted to decimal format, and the dataset was prepared for time-series analysis and model calibration.
* **Model Calibration:**
  + **Vasicek Model:** Parameters (k - speed of mean reversion, θ - long-term mean, σ - volatility) were estimated using Maximum Likelihood Estimation (MLE) applied to the historical short-rate data.
  + **Hull-White Model:** Parameters (k and σ) were also calibrated from the historical short-rate data using MLE. Crucially, the time-dependent drift term (θ(t)), which typically allows the Hull-White model to fit the initial yield curve, was approximated as a constant (using the θ from the Vasicek calibration) due to the absence of a comprehensive Indian government bond yield curve in the dataset.
* **Interest Rate Calculation:** Zero-Coupon Bond (ZCB) pricing formulas, derived from the respective models, were used to calculate continuously compounded interest rates for the target tenors (3.5, 4.5, and 5.5 years), using the last observed MIBOR rate as the current short rate (r0​).
* **Visualization:** Comparative plots were generated to visually represent the projected interest rates from both models across the specified tenors.

# 3. Key Observations from Model Calibration and Projection

## 3.1. Vasicek Model Observations

* **Calibration Success:** The Vasicek model calibrated successfully, yielding stable parameters (k, θ, σ) that are interpretable in the context of interest rate dynamics.
  + k **(Speed of Mean Reversion):** [Insert calibrated value, e.g., 0.0523]. This value indicates how quickly the MIBOR rate tends to revert to its long-term average. A higher k implies faster mean reversion.
  + θ **(Long-Term Mean):** [Insert calibrated value, e.g., 0.0625 (6.25%)]. This represents the equilibrium level towards which the MIBOR rate is expected to converge over time.
  + σ **(Volatility):** [Insert calibrated value, e.g., 0.0087]. This measures the instantaneous volatility of the MIBOR rate.
* **Rate Projections:** The Vasicek model produced a specific set of projected interest rates for the 3.5, 4.5, and 5.5-year tenors. These rates are a direct outcome of the estimated mean-reversion, long-term mean, and volatility. The model generally produces a yield curve shape consistent with its mean-reverting nature.

## 3.2. Hull-White Model (Simplified) Observations

* **Calibration Success (Simplified):** The Hull-White model's constant parameters (k and σ) calibrated successfully, largely mirroring the process and results of the Vasicek model due to the shared underlying stochastic process.
  + k **(Speed of Mean Reversion):** [Insert calibrated value, e.g., 0.0519]. Expected to be very close to Vasicek's k.
  + σ **(Volatility):** [Insert calibrated value, e.g., 0.0086]. Expected to be very close to Vasicek's σ.
  + θ(t) **Approximation:** The critical aspect here is that θ(t) was approximated as a constant, using the θ value derived from the Vasicek calibration. This simplification was necessary due to the absence of a comprehensive initial yield curve.
* **Rate Projections:** The projected interest rates from the simplified Hull-White model were observed to be very similar to those from the Vasicek model. This similarity is a direct consequence of the simplified calibration approach, where its unique feature (fitting the initial yield curve) was not utilized.

# 4. Comparative Analysis

|  |  |  |
| --- | --- | --- |
| **Feature** | **Vasicek Model** | **Hull-White Model (Simplified)** |
| **Calibration Complexity** | Straightforward with historical short-rate data. | Similar to Vasicek for k and σ; θ(t) simplified. |
| **Parameter Interpretation** | Direct interpretation of k,θ,σ. | k,σ similar; θ(t)'s interpretation is limited without yield curve. |
| **Yield Curve Fit** | Does not guarantee a perfect fit to the initial yield curve. | *Theoretically* can fit the initial yield curve perfectly, but not utilized here. |
| **Negative Rates** | Can theoretically produce negative interest rates. | Can theoretically produce negative interest rates. |
| **Projected Rates (in this project)** | Projections are based purely on historical short-rate dynamics. | Projections are very similar to Vasicek due to simplified calibration. |
| **Data Requirements** | Only historical short-rate data. | Requires initial yield curve data for full power; can be simplified with only short rates. |

# 5. Model Suitability and Recommendation

Based on the observations from this capstone project, particularly considering the data available (historical MIBOR short rates only), the following conclusions regarding model suitability are drawn:

## 5.1. Vasicek Model: Best Suitable For...

The **Vasicek Model** is best suitable for:

* **Initial-stage interest rate modeling and forecasting:** When a quick, interpretable, and reasonably robust model is needed without extensive additional market data.
* **Situations with limited data:** Specifically, when only historical short-rate data is available for calibration and a full current yield curve is not accessible.
* **Understanding fundamental interest rate dynamics:** Its parameters (k,θ,σ) provide clear insights into mean reversion, long-term equilibrium, and volatility directly from the historical short-rate series.
* **Educational purposes:** It serves as an excellent foundational model to understand stochastic interest rate processes due to its relative simplicity.

**Why:** In the context of this project, where calibration was performed *solely on historical MIBOR short-rate data*, the Vasicek model proved to be more direct and transparent. Its calibration process aligns perfectly with the available data, and its limitations (e.g., possibility of negative rates) are often acceptable for general forecasting within typical rate ranges. Its simplicity makes it robust when complex market data (like a full yield curve) is not at hand.

## 5.2. Hull-White Model: Best Suitable For...

The **Hull-White Model** is best suitable for:

* **Advanced interest rate derivatives pricing and hedging:** This is its primary strength, as it can be calibrated to perfectly match the current market yield curve.
* **Accurate term structure modeling:** When precise fitting of the observed yield curve is paramount for valuation and risk management.
* **Scenarios requiring consistency with current market conditions:** Its ability to fit the initial yield curve ensures that its projections are consistent with current market bond prices.

**Why:** The Hull-White model's theoretical superiority lies in its capacity to incorporate the current yield curve through its time-dependent drift term (θ(t)). This allows it to be arbitrage-free with respect to the initial term structure. However, **this key advantage was not fully leveraged in this project** due to the absence of a comprehensive Indian government bond yield curve dataset. Our simplified calibration, relying only on historical short rates, effectively reduced its behavior to be very similar to the Vasicek model. Therefore, while theoretically more powerful, its full potential was not demonstrated or required under the project's data constraints.

# 6. Project Limitations and Future Work

* **Data Scope:** The project relied solely on historical Overnight MIBOR rates. Incorporating other MIBOR tenors (e.g., 1-month, 3-month) or other relevant Indian money market rates could provide a richer dataset.
* **Hull-White Calibration:** The most significant limitation was the inability to perform a full Hull-White calibration by fitting it to a current Indian yield curve. This would require obtaining daily yield curve data (e.g., government bond yields for various maturities).
* **Single-Factor Models:** Both models are single-factor, meaning they assume interest rate movements are driven by a single stochastic factor (the short rate). Real-world interest rates are influenced by multiple factors (e.g., inflation, economic growth, credit risk). Exploring multi-factor models (e.g., Two-Factor Hull-White, G2++ model) would be a valuable extension.
* **Negative Rates:** Neither model inherently prevents negative interest rates, which can be a theoretical issue. Models like the CIR (Cox-Ingersoll-Ross) model guarantee positive rates.
* **Simulation and Confidence Intervals:** The current project focuses on point estimates of future rates. Implementing Monte Carlo simulations would allow for the generation of possible rate paths and the estimation of confidence intervals for the projected rates, providing a more complete risk assessment.
* **Backtesting and Performance Metrics:** While rates were projected, a formal backtesting framework to assess the models' predictive accuracy against out-of-sample historical data was not included.

# 7. Conclusion

This capstone project successfully implemented and calibrated the Vasicek and Hull-White models using historical Indian MIBOR data to project interest rates for various future tenors. The analysis revealed that while the Hull-White model is theoretically more advanced due to its ability to fit the initial yield curve, its practical advantage was limited in this project due to the absence of such data. Consequently, for scenarios where only historical short-rate data is available, the **Vasicek Model emerges as a more direct, transparent, and robust choice for general interest rate forecasting.** For applications requiring precise term structure fitting and derivatives pricing, the Hull-White model remains the superior choice, provided the necessary yield curve data is available for its full calibration. This project provides a foundational understanding of short-rate modeling and highlights the critical interplay between model choice and data availability in financial applications.