Hedge Strategy for Bond ETFs with Treasury Futures

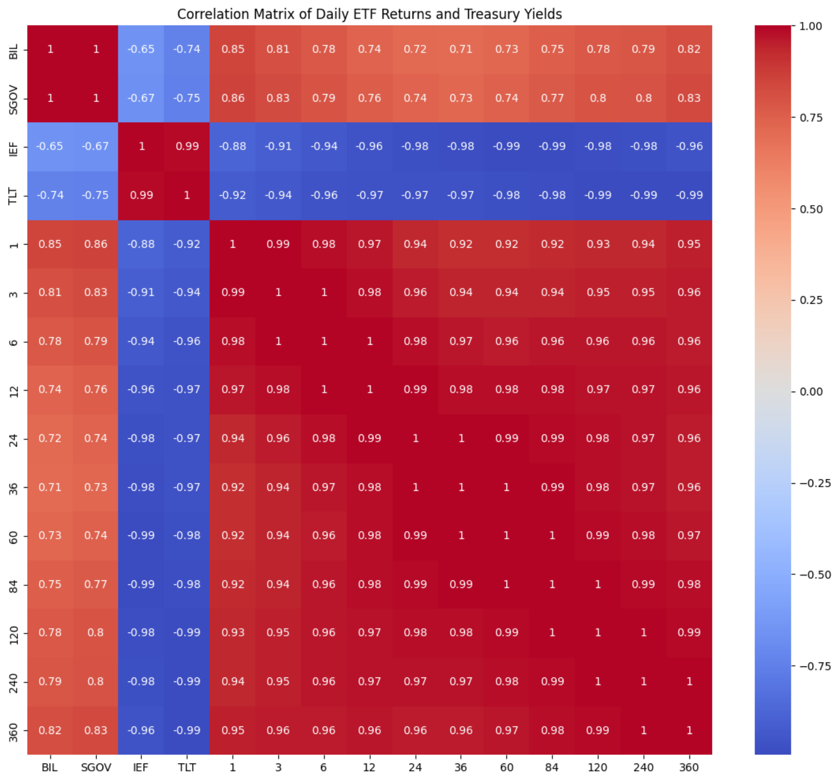
I. Summary

This project developed a hedging strategy for bond ETFs using Treasury futures and yield spread trading to enhance profitability. By predicting the direction of key yield rates and spreads using a Random Forest model with Bayesian optimization, the strategy dynamically adjusted hedge ratios and trading weights. The optimized portfolio maximizes Sharpe Ratio and shows strong performance in backtesting, demonstrating the effectiveness of combining hedging with spread trading to balance risk and return.

II. Relationship Analysis

- BIL consists of 1–3-month Treasury bills with an approximate 2-month duration, while SGOV holds 0–3-month Treasury bills. Both ETFs are most closely correlated with short-term Treasury yields, specifically the 1-month and 3-month rates. Thus, I selected the 3-month Treasury yield rate to predict the NAV movements of these ETFs and used SFR futures for hedging.
- For IEF, which comprises 7–10-year Treasury notes with a 7-year duration, and TLT, which holds over 20-year Treasury bonds with a 17-year duration, I chose the 7-year (84month) Treasury yield rate for IEF and the 20-year (240-month) Treasury yield rate for TLT. To enhance duration adjustment performance while minimizing costs, I opted for Treasury futures with slightly longer durations: TY futures for IEF and US futures for TLT.

	SGOV	*BIL*	*IEF*	*TLT*
Selected Yield Rate	3 Month	3 Month	7 Year	20 Year
Selected Future for Hedge	SFR	SFR	TY	US



III. Strategy Design

- Components:
  - Duration Adjustment Component (AR):

The duration adjustment strategy fine-tunes hedging by aligning ETF duration with selected Treasury futures to minimize interest rate risk. An adjustment ratio (AR) scales the hedge based on predicted yield changes:

$$Adjust\ Ret = Ret_{ETF} + Signal_D \times Hedge\ Ratio \times AR \times Ret_{Future} - Cost_{Future\ Contract}$$

Hedge ratio is calculated by DV01, and AR dynamically adjusts in each rolling window, balancing hedge effectiveness with market conditions to optimize returns.

- Yield Spread Trading Component:

To enhance returns alongside the hedge strategy, I incorporated a spread trading component that capitalizes on the price differences between selected Treasury yield spreads. I identified three key yield spreads that showed strong potential for profitable trading: the 3m-2y spread (3-month vs. 2-year Treasury yields), the 5s10s spread (5-year vs. 10-year Treasury yields), and the 10s30s spread (10-year vs. 30-year Treasury yields):

$$Spread\ Ret = \sum_{i=1}^{3} Weight_i \times Signal_i \times \left(Ret_{short-term,i} - Ret_{long-term,i}\right) - Cost_{Future}$$

- Optimization:

$$Portfolio\ Ret_{AR,Weight_i} = Adjust\ Return + \frac{1}{1 - \sum_{i=1}^{3} Weight_i} \times Spread\ Ret$$

$$0 \leq \sum_{i=1}^{3} Weight_i \leq 0.8, \qquad 0 \leq Weight_i, AR \leq 1$$

The optimization process was conducted using a 20-day rolling window to fine-tune the strategy's parameters, specifically targeting the adjustment ratio (AR) for duration hedging and the weights for spread trading. The primary objective was to maximize Sharpe Ratio, thereby enhancing the risk-adjusted performance of the portfolio.

Each 20-day window utilized historical data to evaluate and adjust the parameters, running simulations to identify the optimal set that achieved the lowest drawdown while maintaining a balanced risk-return profile.

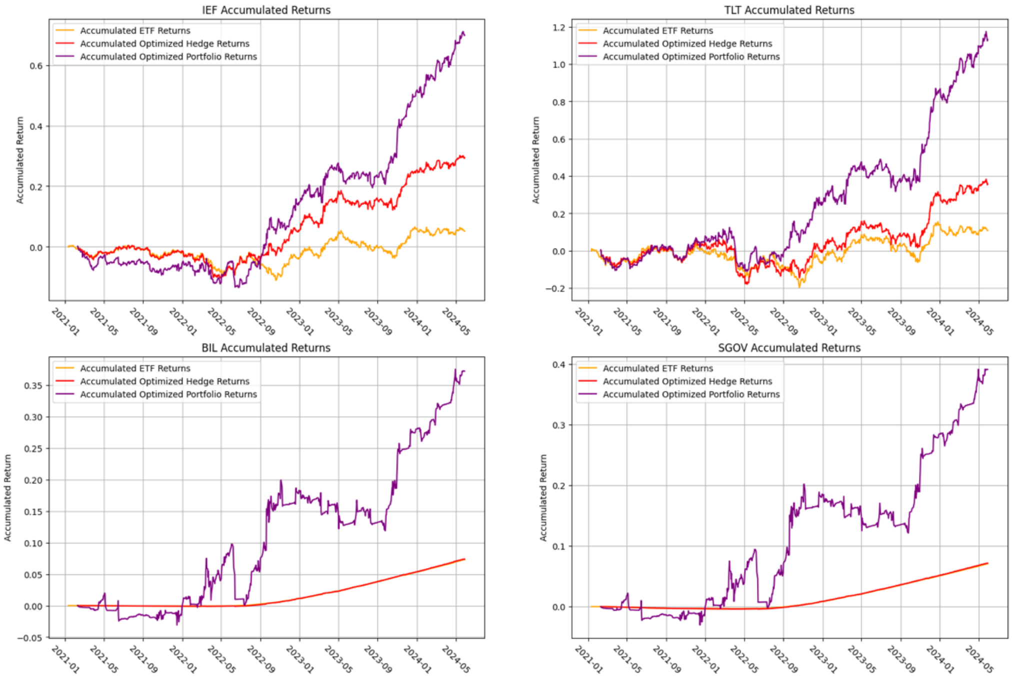
IV. Generate Signals

Signals were generated using a Random Forest model optimized with Bayesian techniques in a 3-year rolling window. The model used technical indicators such as MA (10), MA(20), EMA(10), RSI, and Bollinger Bands as inputs to predict the next-day direction of selected Treasury yield rates for hedging and yield spreads for trading. The prediction model achieved an average accuracy of around 80%, with individual rates and spreads showing accuracies ranging from 80.7% to 85.7%. These signals ('3', '84', '240' for hedging and '24-3', '120-60', '360-120' for spread trading) allowed for dynamic, data-driven strategy adjustments, enhancing overall performance.

	3	*84*	*240*	*24-3*	*120-60*	*360-120*
Accuracy	85.73%	83.42%	81.78%	82.00%	80.68%	82.55%

V. Backtesting Results

- Accumulated return



The accumulated return graphs indicate that the optimized portfolio consistently outperformed the ETF holdings across all four ETFs (BIL, SGOV, IEF, and TLT). The optimized portfolio returns (purple line) show a steeper upward trajectory compared to the accumulated ETF returns (orange line) and the optimized hedge returns (red line), demonstrating the effectiveness of the combined hedging and spread trading strategy in generating superior returns.

- Sharpe Ratio

The shape ratio is calculated based on the excess of return over Bloomberg US Treasury Total Return Unhedged USD Index (LUATTRUU).

	BIL	*SGOV*	*IEF*	*TLT*
Optimized Portfolio	0.5271	0.5640	0.9335	1.0505
Holding ETF	-0.3230	-0.3334	-0.2453	0.0058
Change	+0.8501	+0.8973	+1.1789	+1.0447

The notable increase in the Sharpe Ratios indicates that the strategy not only enhances returns but also reduces risk effectively, leading to a more favorable risk-return balance.

- Maximum Drawdown

	BIL	*SGOV*	*IEF*	*TLT*
Optimized Portfolio	-0.0880	-0.0879	-0.1351	-0.2088
Holding ETF	-0.0010	-0.0037	-0.1147	-0.2244
Change	+0.0870	+0.0842	+0.0204	-0.0155

The strategy improved returns but increased maximum drawdown for short-duration ETFs, while effectively reducing risk for longer-duration ones like TLT, highlighting the varying impact of hedging across different bond durations.