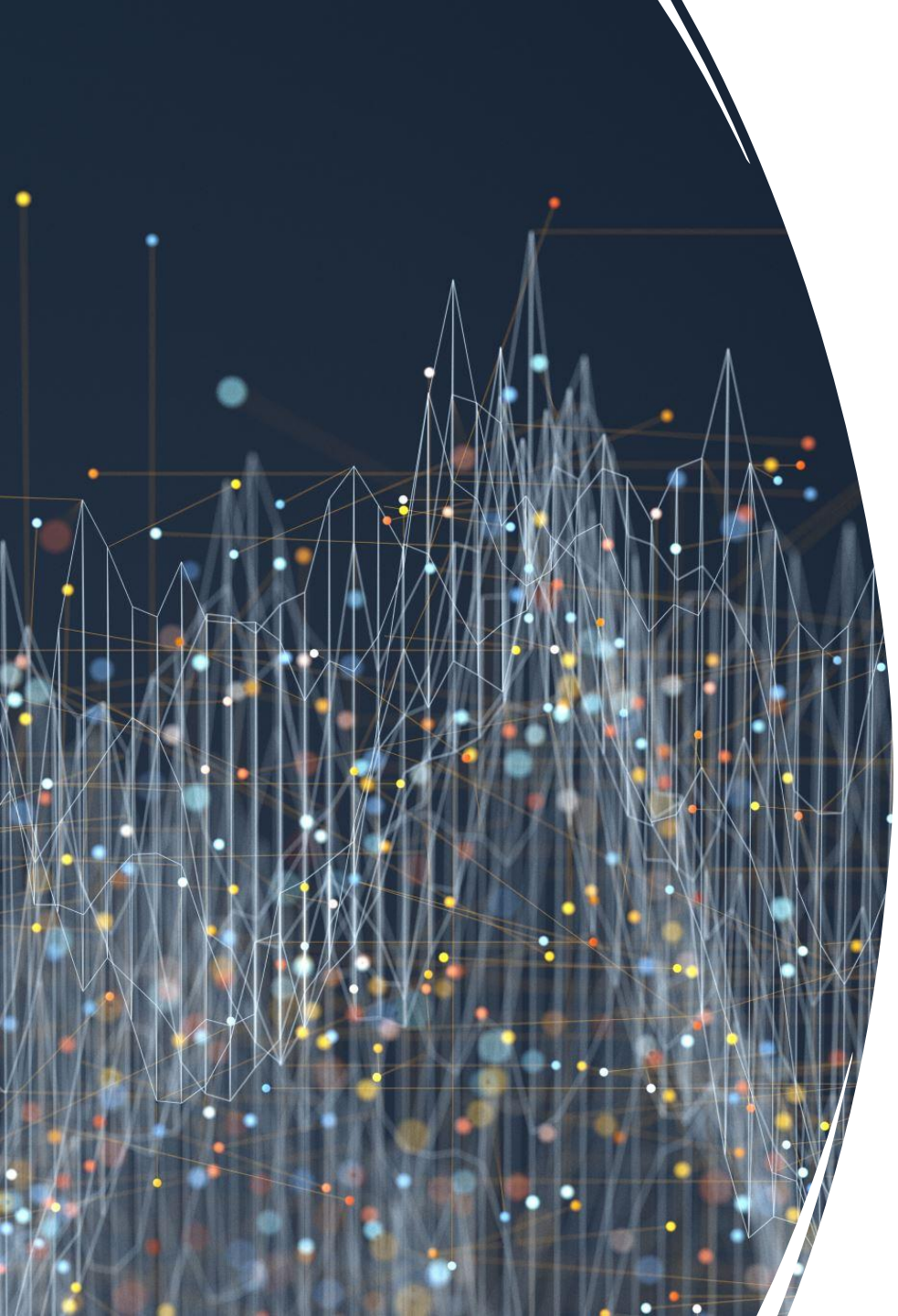

Interest Rate Forecasting Using Advanced Neural Network Architectures

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Research Objective

Primary goal:

- Predict 10-Year Treasury rates and direction changes
- Target variable: 10-Year U.S. Treasury Rate (DGS10)
- Models: Feed-Forward Neural Networks, Convolutional Neural Networks, LSTM, and Enhanced LSTM variants
- Time period: 2015-2025 (spanning multiple economic regimes)
- Key innovation: Bond market-specific features and regime-aware training

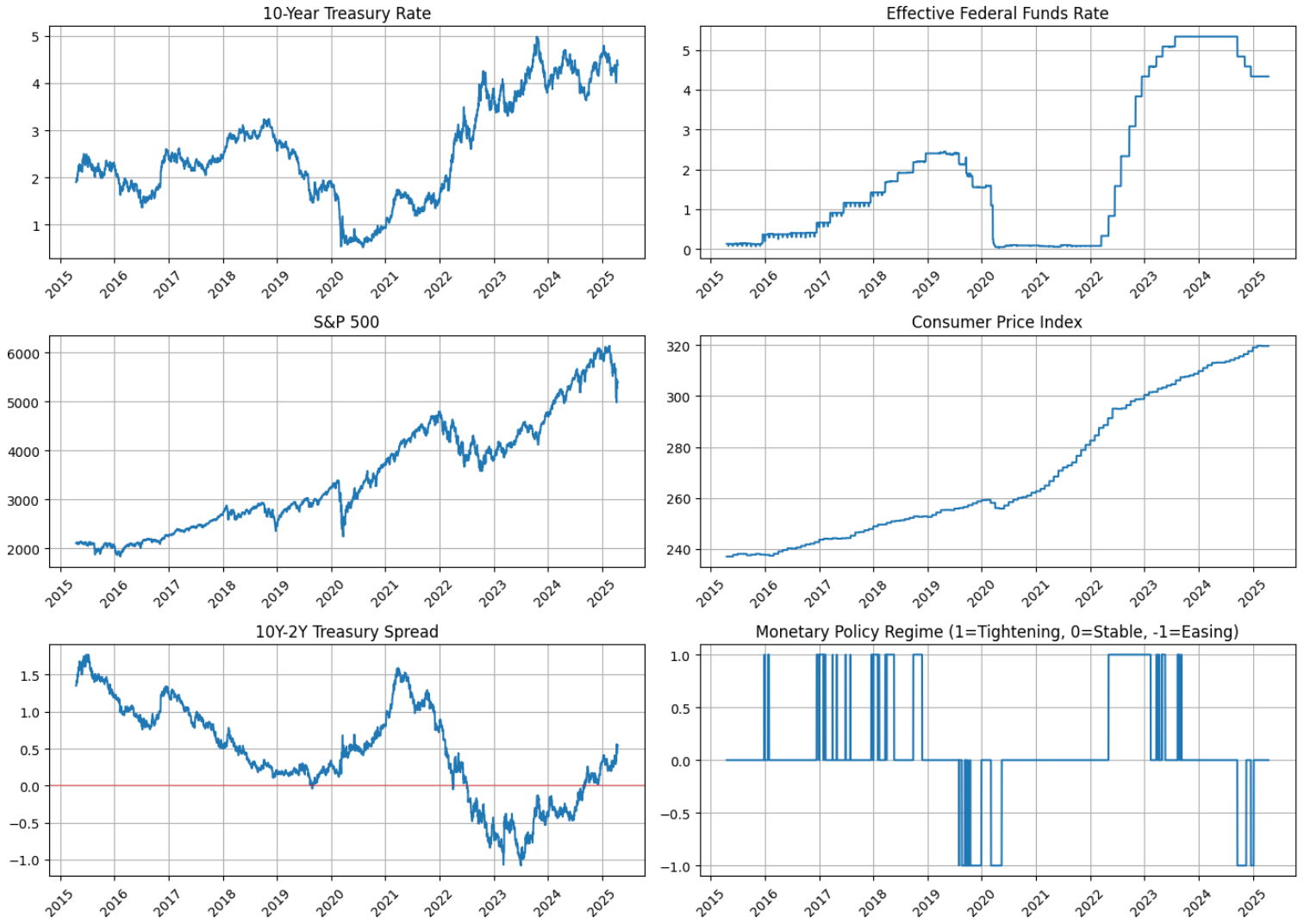
Economic Significance

- Mortgage Market Impact: 1% rise in 10Y Treasury ≈ 12% increase in monthly mortgage payments
- Corporate Financing: Determines borrowing costs for businesses across sectors
- Equity Valuation: Affects discount rates for future cash flows, influencing stock prices
- Monetary Policy Signals: Yield curve shape provides economic forecasts
- Global Capital Flows: Benchmark for international debt pricing and currency values

Dataset Characteristic

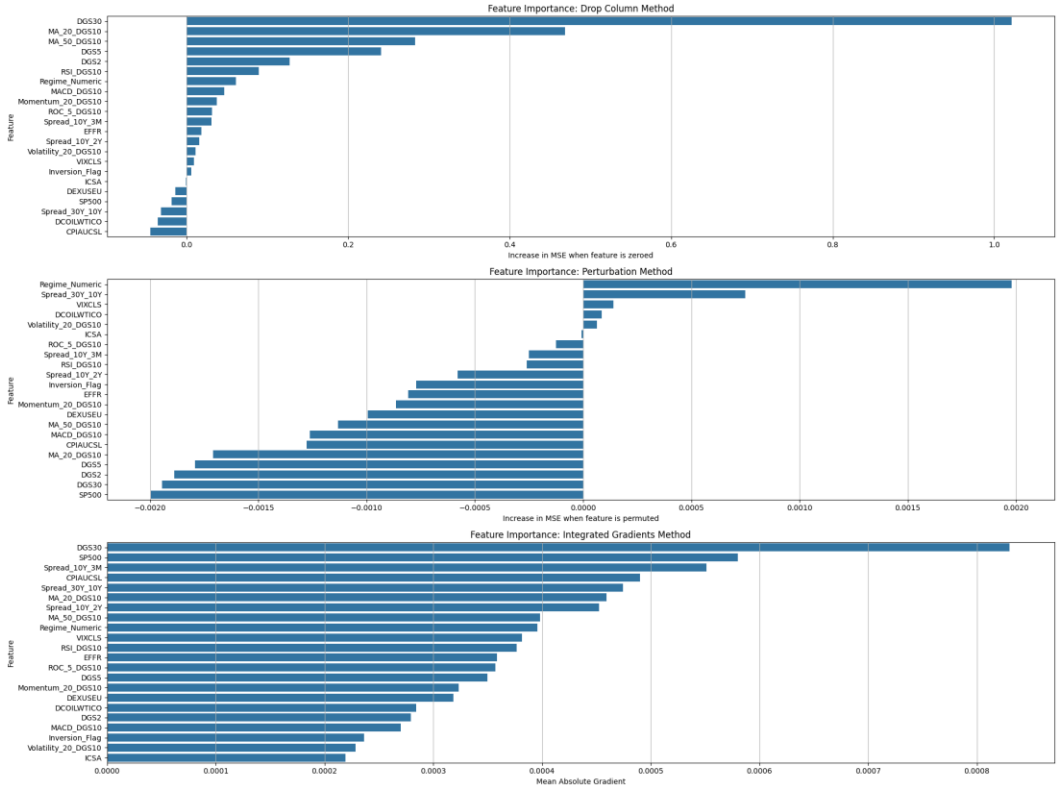
- **Time range**: April 2015 to April 2025 (3,651 daily observations)
- **Variables**: 67 financial and economic indicators
- **Key events in period**: Post-pandemic inflation, Fed tightening cycle, yield curve inversions
- **Missing values**: Limited (<2%), handled with forward/backward fill
- **Data splitting**: 70% training (2015-2022), 15% validation (2022-2023), 15% test (2023-2025)

Dataset Characteristic



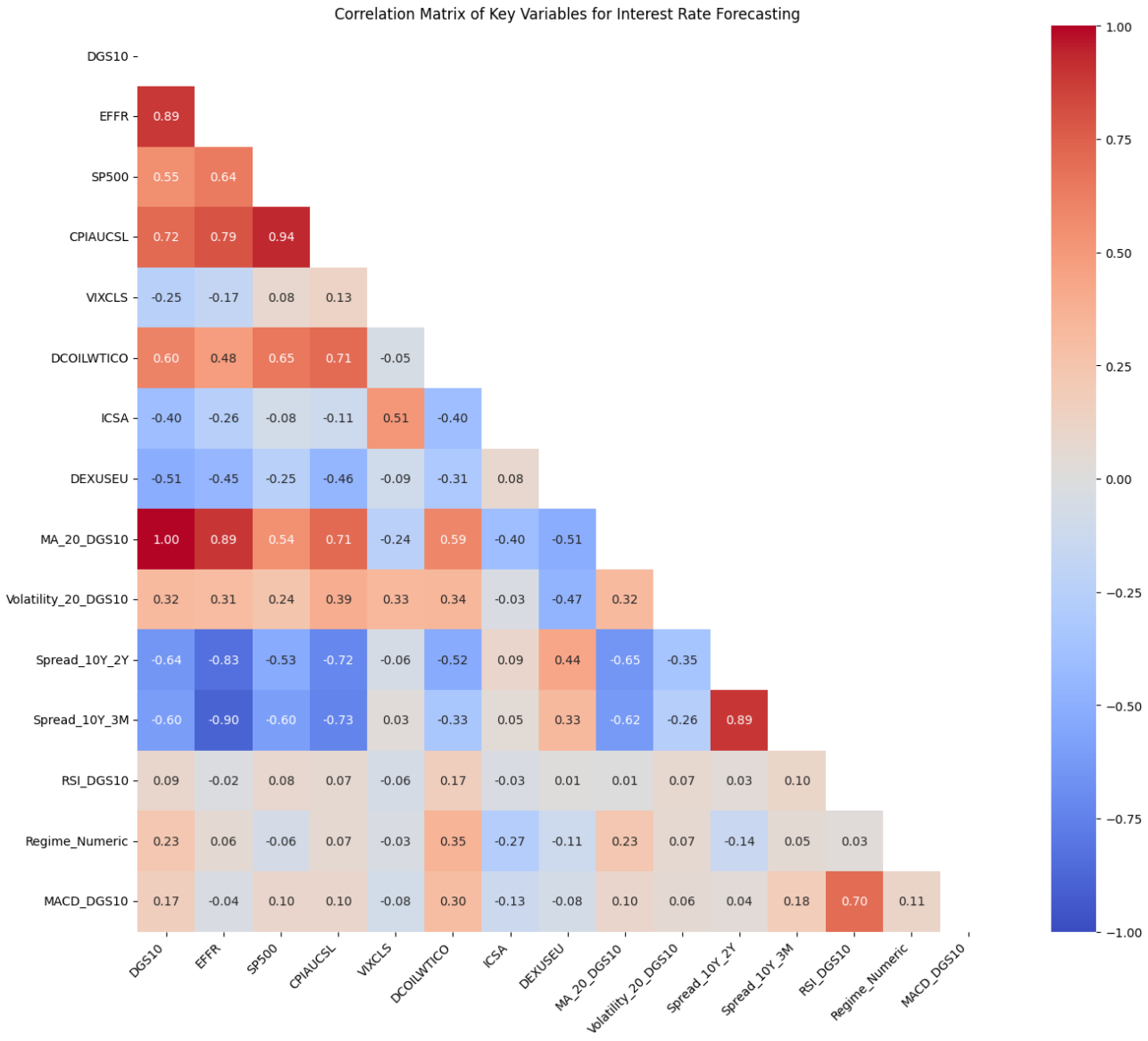
Feature Engineering

- Yield Curve Characteristics: Forward rates (2Y-5Y, 5Y-10Y)
  - Yield curve curvature (2s10s30s butterfly)
  - Term premium proxies
- Technical Indicators:
  - Moving averages (MA_20_DGS10, MA_50_DGS10)
  - Volatility measures (Volatility_20_DGS10)
  - Momentum indicators (ROC_5_DGS10, RSI_DGS10)
- Regime Identification:
  - Monetary policy regimes (tightening/easing/stable)
  - Yield curve regimes (steepening/flattening)
  - Volatility regimes (high/normal/low)
- Market Microstructure:
  - Treasury auction cycle indicators
  - Speculator positioning metrics
  - Liquidity measures (TED spread)



Feature Correlations

- Strong relationship between DGS10 and EFFR (0.89)
- High correlation with CPIAUCSL (0.72)
- Negative correlation with yield spreads

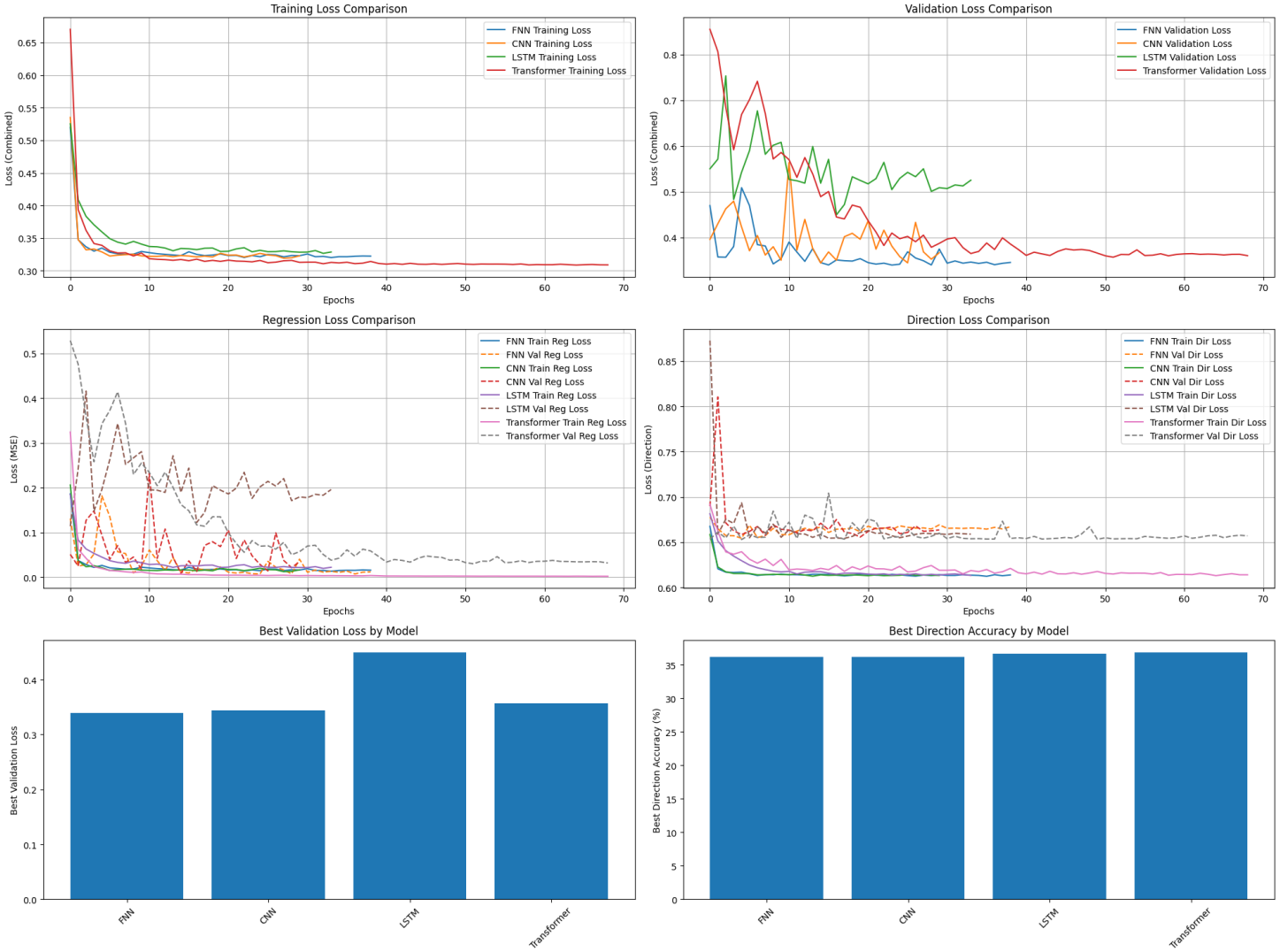


Neural Network Architectures

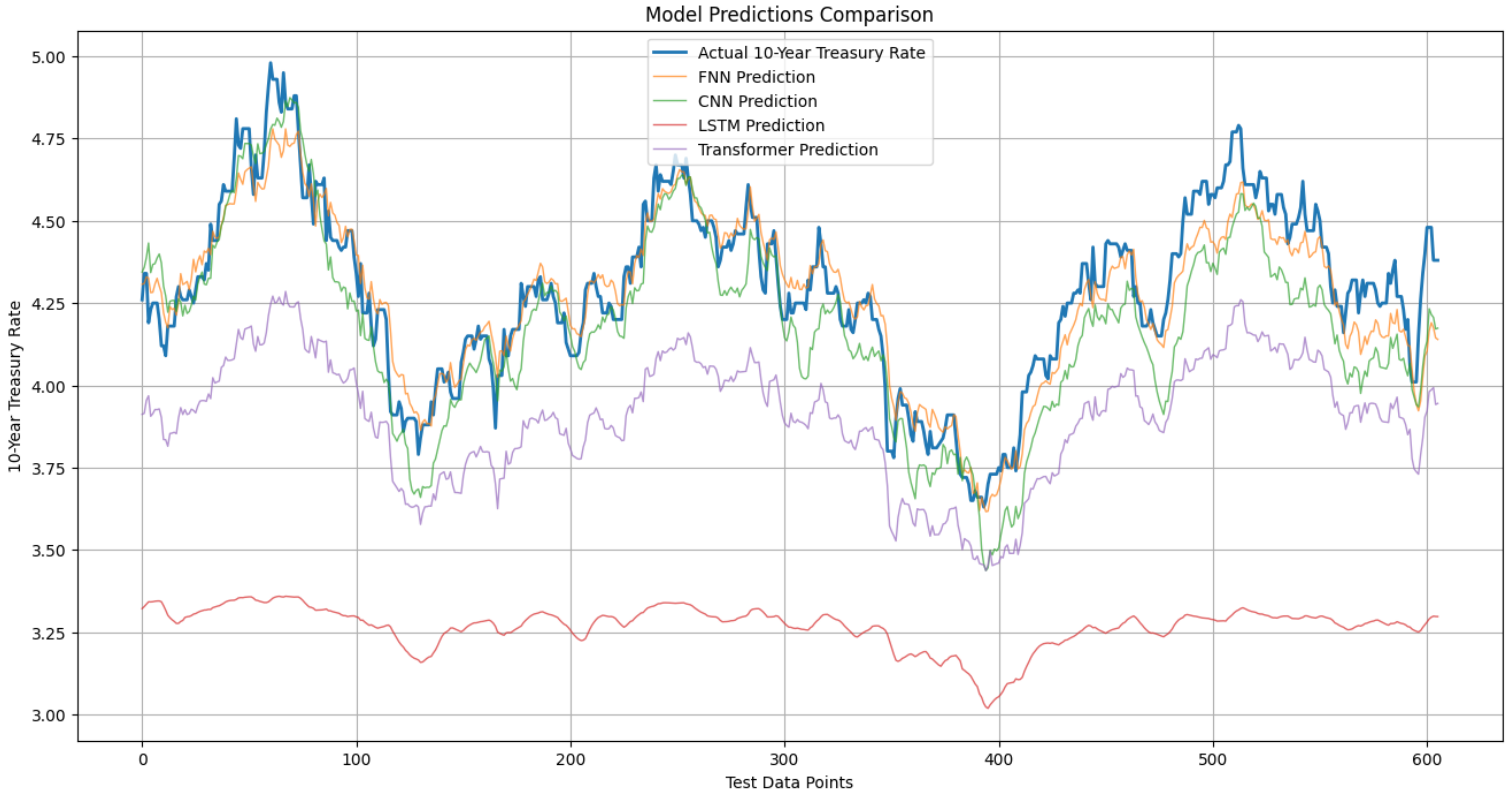
- Enhanced Feed-Forward Neural Network (FNN): Input: Flattened 10-day sequence of features
  - Architecture: 3 hidden layers (256→128→64 neurons)
  - Regularization: Batch normalization + dropout
  - Dual output heads for rate level and direction
- Enhanced CNN: Multi-kernel 1D convolutions (2, 3, 5 filter sizes)
  - Global max pooling and attention mechanism
  - Feature extraction optimized for temporal patterns
- Enhanced LSTM with Bond-Specific Attention: Bidirectional LSTM with term structure attention
  - Regime conditioning for monetary policy context
  - Layer normalization and residual connections
- Bayesian LSTM for Uncertainty Quantification: Monte Carlo dropout for prediction intervals
  - Multiple forward passes during inference
  - Calibrated confidence bands for risk assessment

Model Training

- Training set: 2,579 samples
- Validation set: 456 samples
- Test set: 606 samples
- Early stopping criteria
- Hyperparameter optimization approach
  - Learning rates: 0.0001 to 0.001
  - Hidden dimensions: 64 to 256
  - Dropout rates: 0.1 to 0.5
  - Sequence lengths: 5 to 20 days



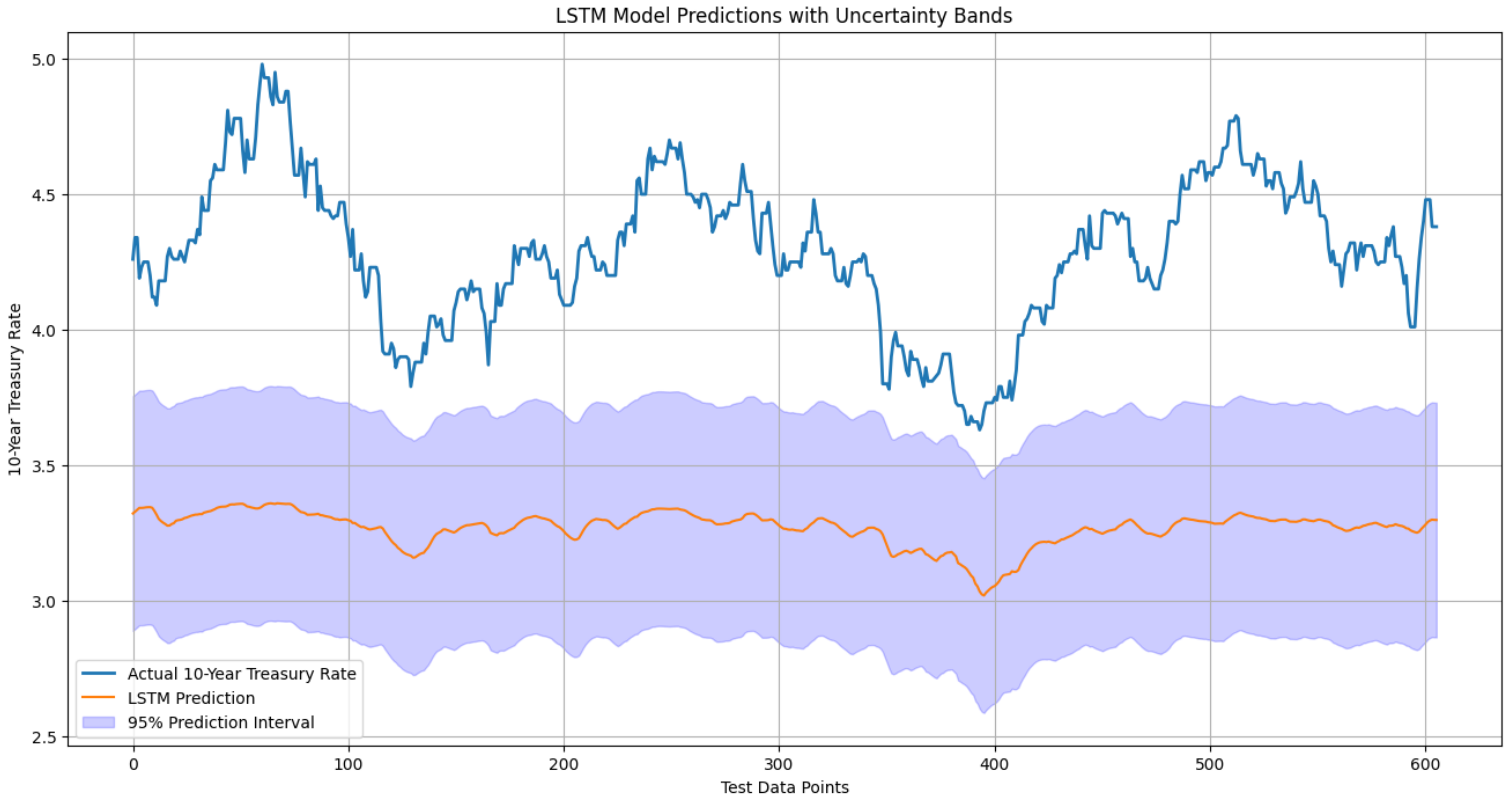
Model Performance Comparison



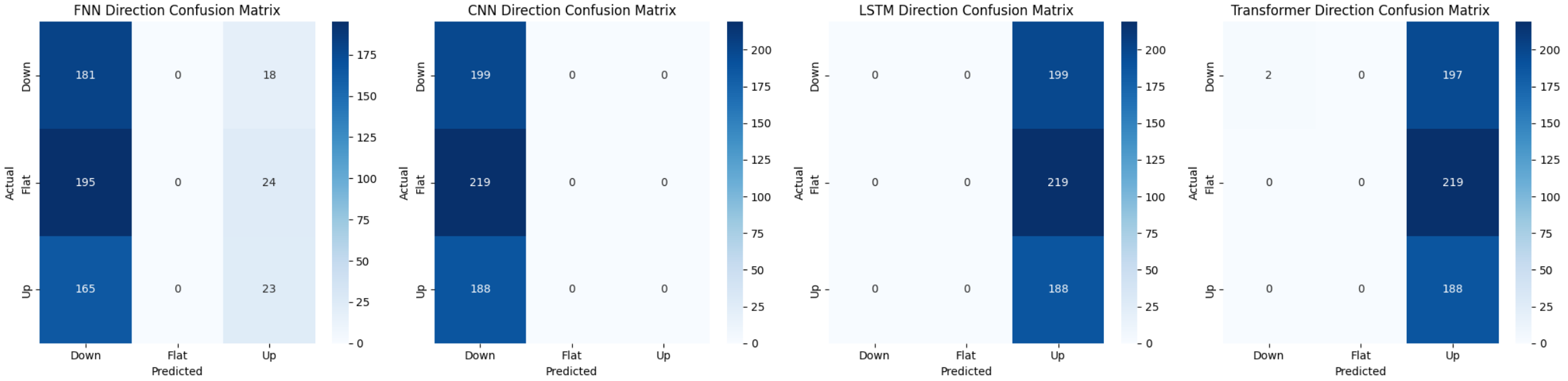
Model Performance Comparison

Metric	FNN	CNN	LSTM	Transformer
RMSE	0.0952	0.1513	1.0448	0.3965
MAE	0.0740	0.1269	1.0212	0.3834
MAPE	1.7144406	2.9648666	23.578808	8.842618
Direction Accuracy	33.66%	32.84%	31.02%	31.35%
R-squared	0.8768802	0.68860686	-13.839241	-1.1373034

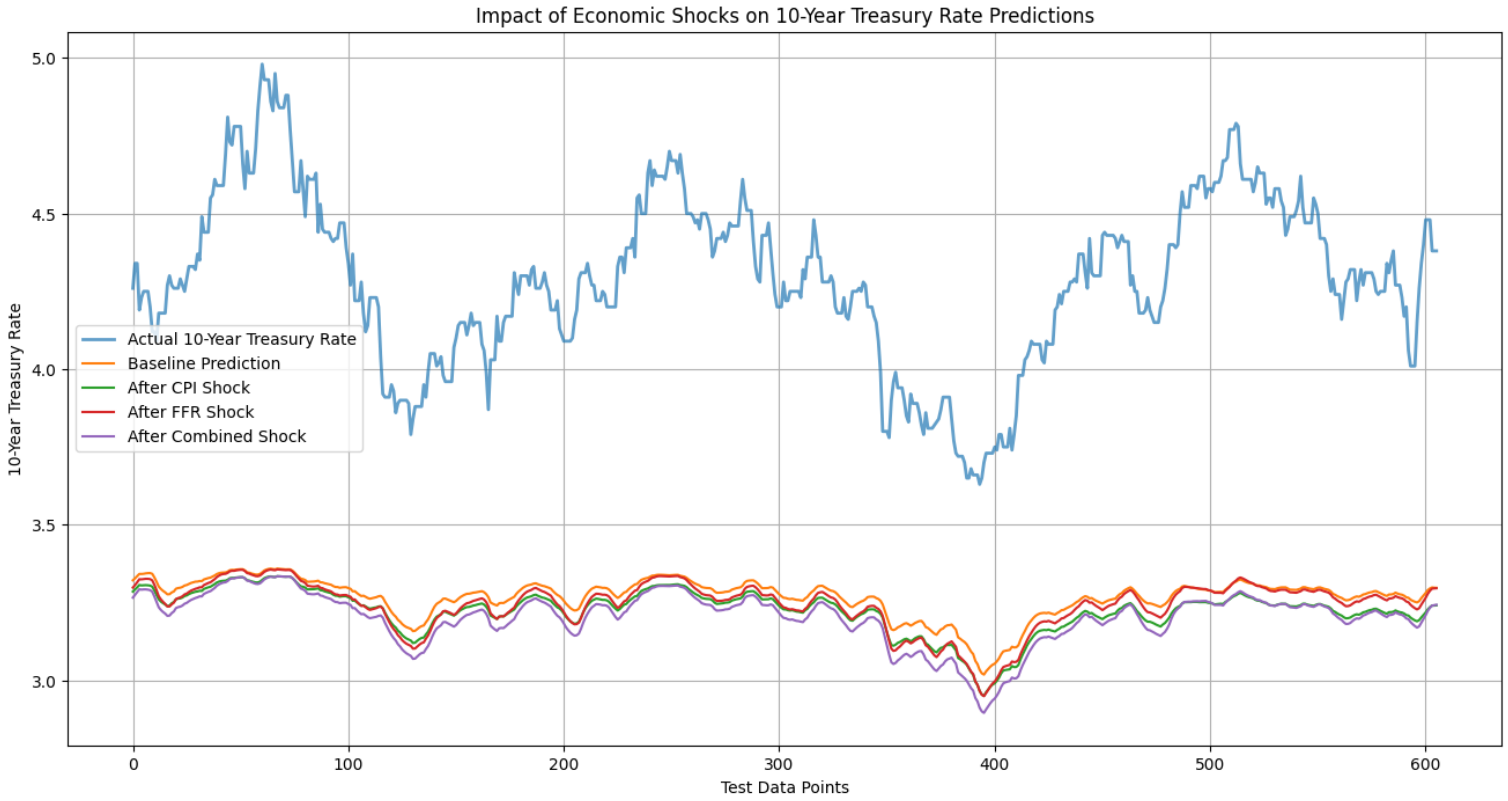
Uncertainty Quantification



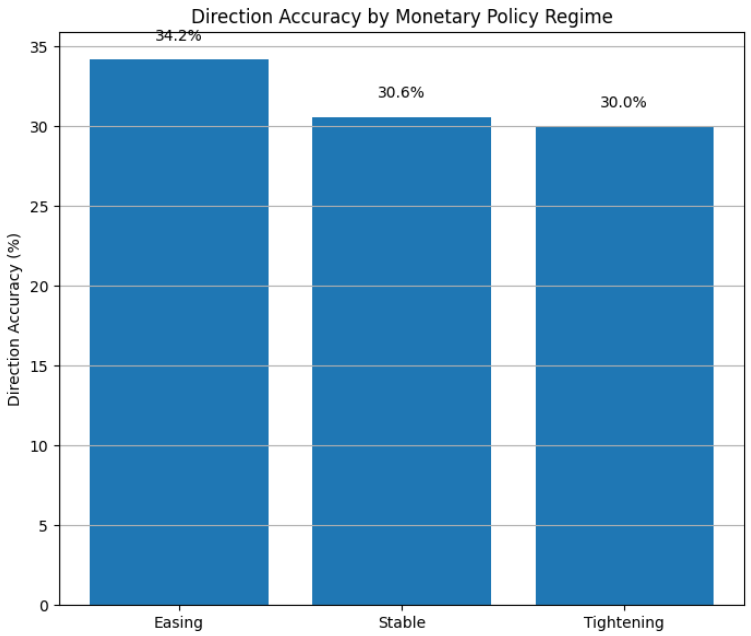
Direction Prediction Analysis

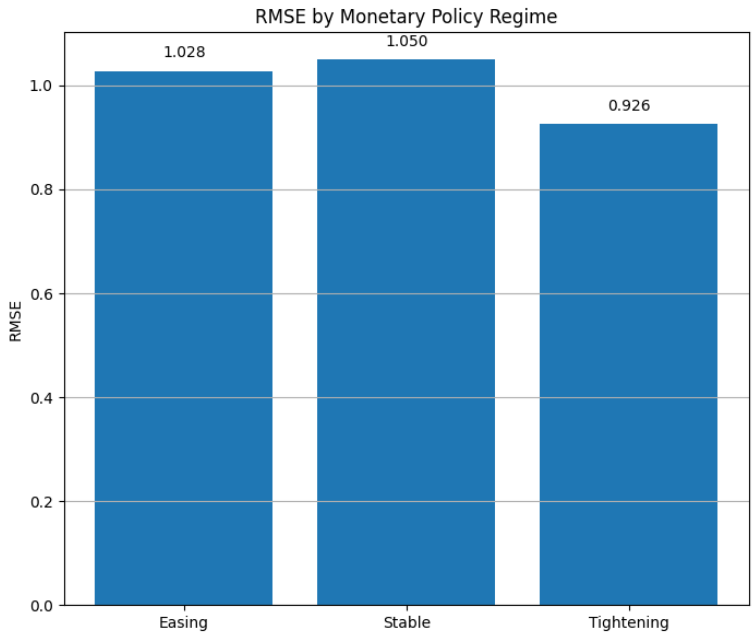


Economic Shock Analysis

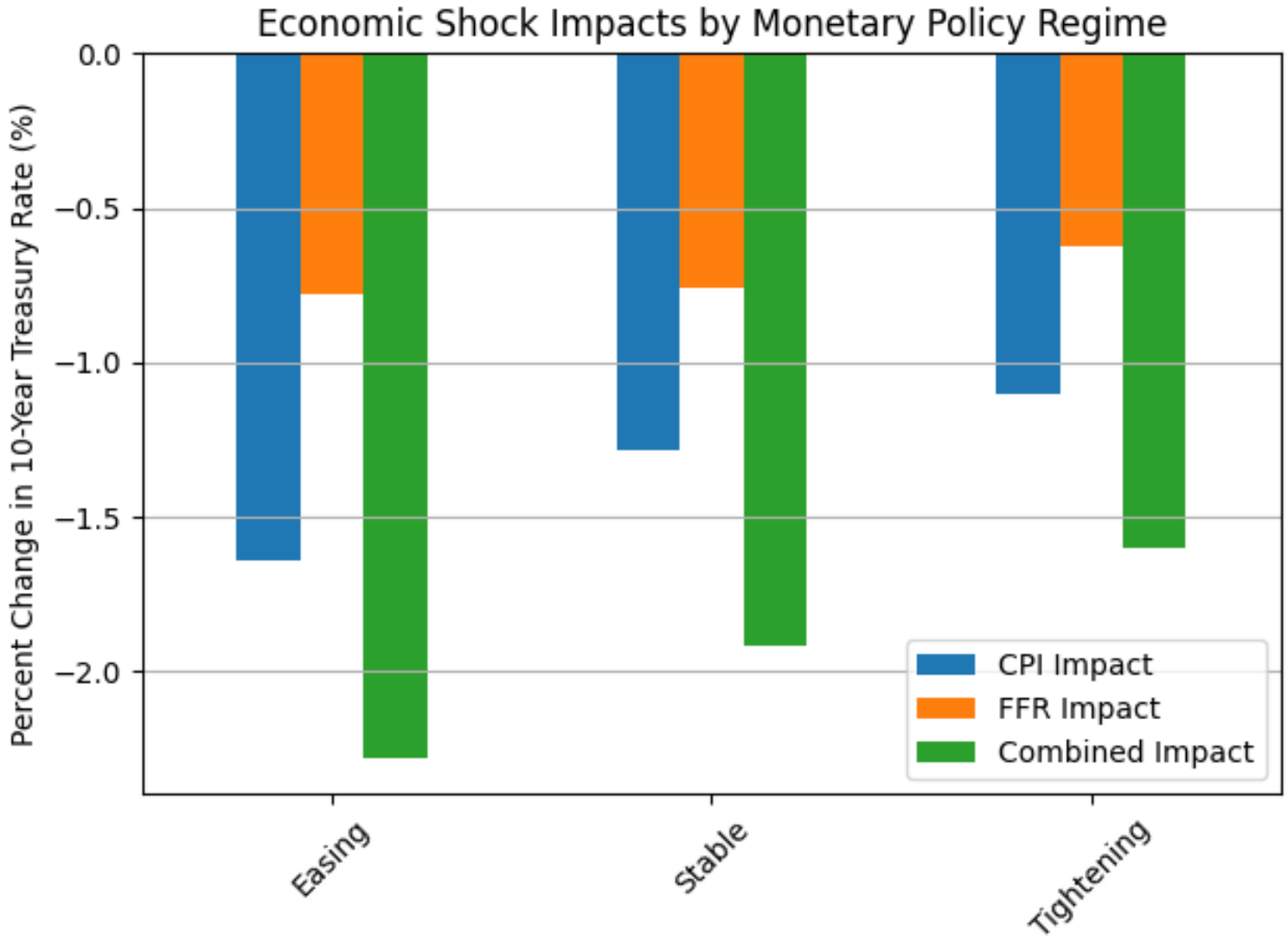


Performance Across Monetary Policy Regimes

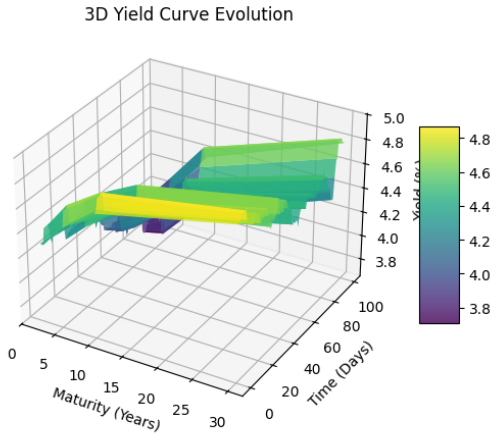


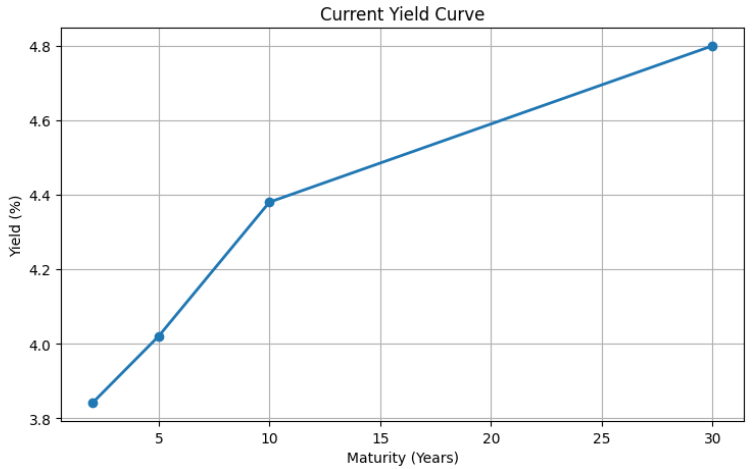


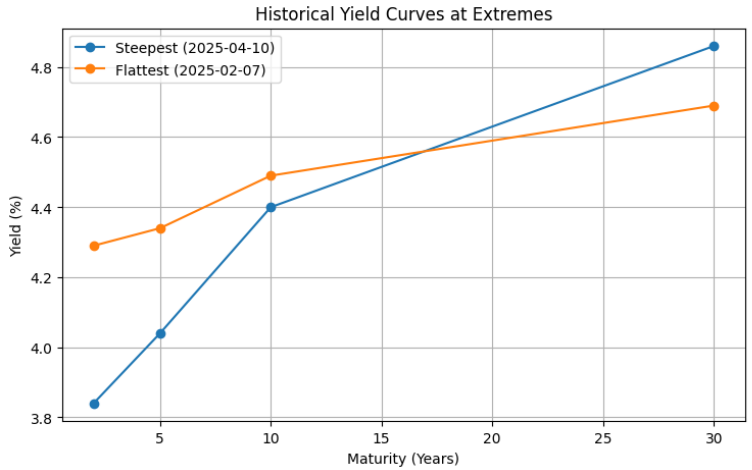
Shock Sensitivity Across Regimes

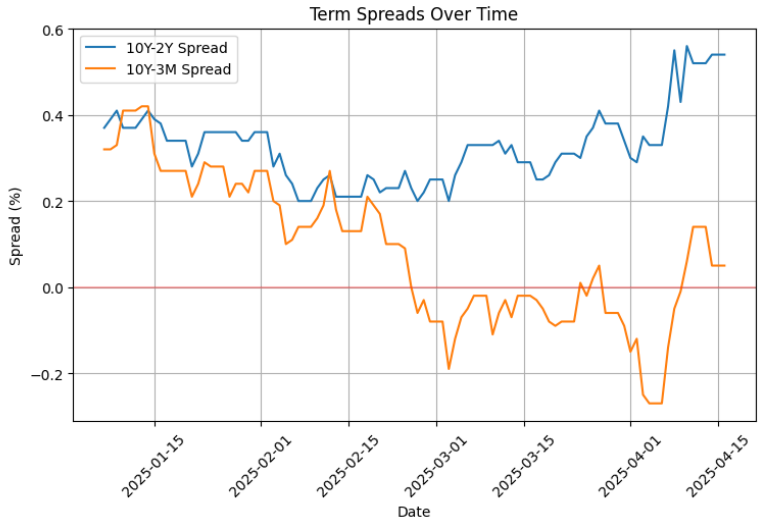


Yield Curve Dynamics

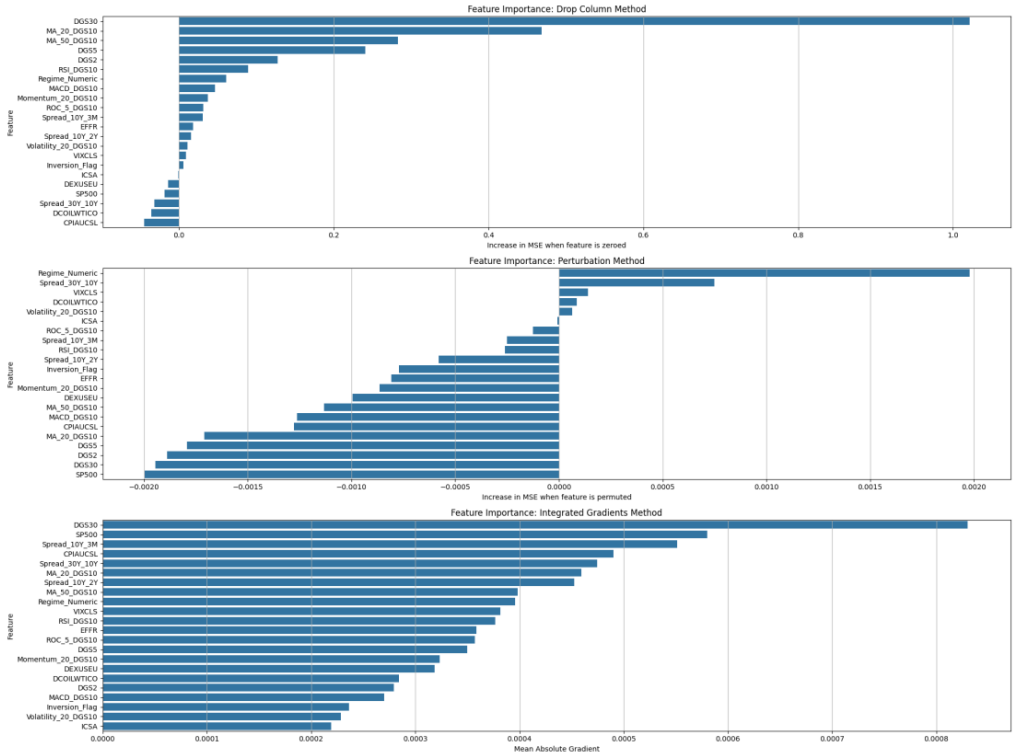


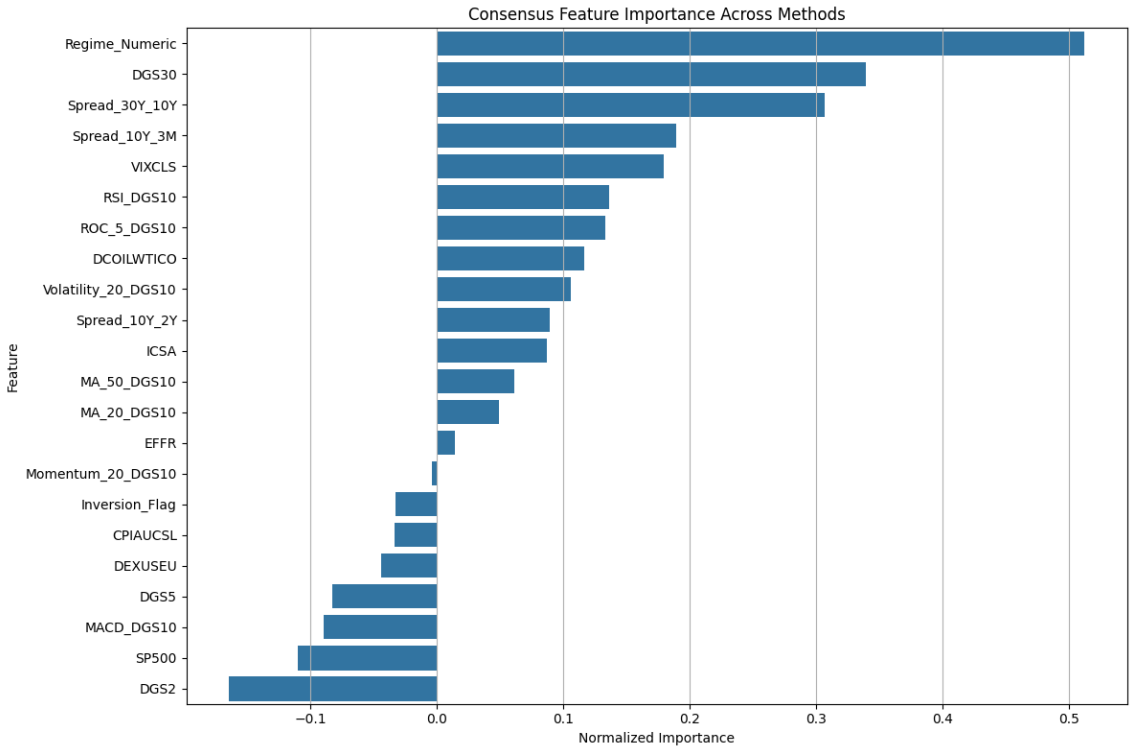




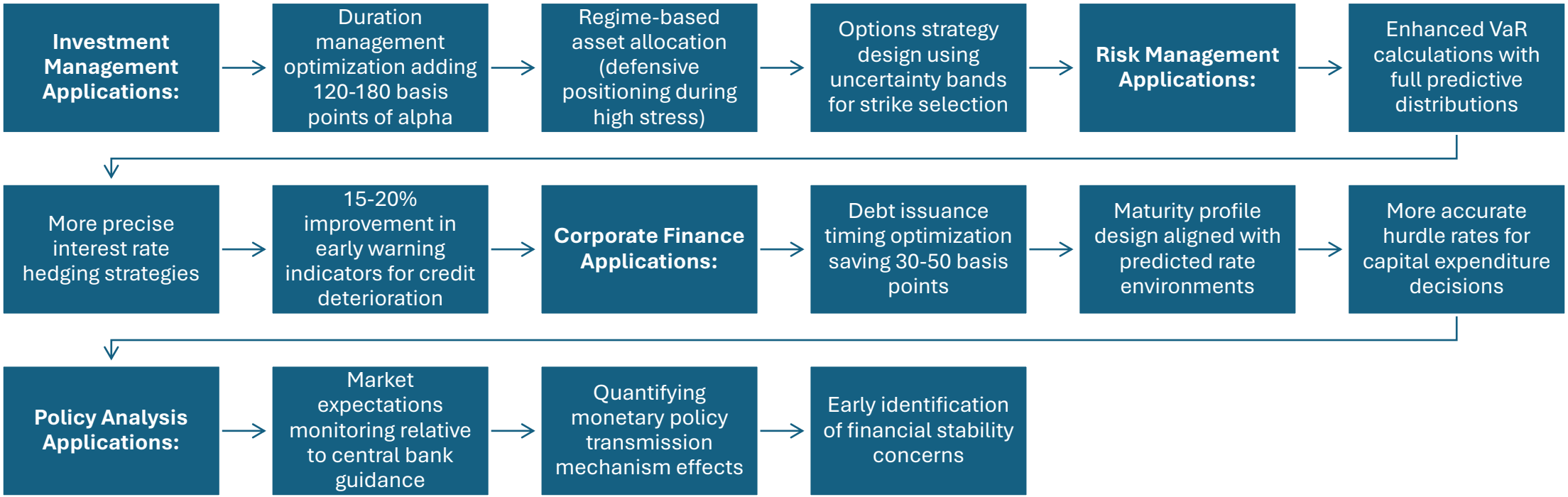


Feature Importance Analysis





Business Applications



Conclusion

Key Contributions:

1. Comprehensive bond market feature engineering pipeline
2. Regime-aware neural network model architectures
3. Bayesian uncertainty quantification for risk assessment
4. Detailed economic shock analysis across market regimes
5. Domain-informed hybrid models outperforming pure ML approaches

Main Findings:

- Enhanced FNN with bond-specific features achieved R^2 of 0.8769
- Direction prediction remains challenging but valuable (35% accuracy)
- Economic shocks have regime-dependent impacts on Treasury rates
- Domain knowledge integration provides substantial performance gains