ABSTRAK

Peramalan harga minyak mentah *West Texas Intermediate* (WTI) memainkan peran krusial dalam perencanaan ekonomi dan investasi di sektor energi global. Tingginya volatilitas harga akibat gejolak geopolitik, pandemi, dan ketidakseimbangan pasokan menuntut model prediktif yang mampu menangkap hubungan nonlinier dan pola temporal yang kompleks. Penelitian ini mengevaluasi dan membandingkan kinerja empat model *forecasting*: ARIMA, *Random Forest*, XGBoost, dan GRU untuk menentukan model terbaik dalam meramalkan harga minyak WTI.

Penelitian ini menggunakan pendekatan kuantitatif komparatif dengan data harga historis minyak WTI periode 1 Agustus 2010 hingga 30 Agustus 2025 dengan total 3.913 observasi. *Dataset* dibagi secara *chronological* dengan rasio 80:20 untuk *training* dan *testing*. ARIMA dioptimasi melalui *grid search* dengan uji stasioneritas *Augmented Dickey-Fuller* dan analisis ACF/PACF. *Random Forest* dan XGBoost dioptimasi menggunakan *Bayesian Optimization* dengan *framework* Optuna, sementara GRU menerapkan *regularization* agresif untuk mencegah *overfitting*. Validasi model dilakukan menggunakan *time-series cross validation* dengan gap 5 hari. Evaluasi menggunakan metrik MAE, RMSE, MAPE, dan *Accuracy* dengan *horizon forecasting very short-term* (t+1, t+3, t+5 hari).

Hasil penelitian menunjukkan XGBoost mengungguli model lainnya dengan akurasi pengujian tertinggi 99,35%, MAE $0,49, RMSE $0,65, dan MAPE 0,65%, serta stabilitas *multi-horizon* dengan degradasi hanya 0,07% dari t+1 ke t+5. ARIMA(4,1,4) menempati posisi kedua dengan akurasi 98,41% dan gap generalisasi terendah 8,40%, menjadikannya pilihan optimal untuk *deployment* produksi yang membutuhkan stabilitas dan interpretabilitas. *Random Forest* memberikan performa solid dengan akurasi 96,79%, gap 10,01%, dan waktu pelatihan sangat cepat (1,92 detik), ideal sebagai *baseline* cepat. GRU menunjukkan akurasi 97,29% dengan gap 8,94%, namun waktu pelatihan sangat tinggi (75+ menit) membuat model ini kurang efisien. Analisis *robustness* lintas fase pasar menegaskan XGBoost konsisten mempertahankan akurasi di atas 97% bahkan pada periode volatil dan krisis.

Kata Kunci: peramalan, minyak mentah WTI, ARIMA, *Random Forest*, XGBoost, GRU, pembelajaran mesin, pembelajaran mendalam, deret waktu

ABSTRACT

Forecasting West Texas Intermediate (WTI) crude oil prices plays a crucial role in economic planning and investment in the global energy sector. High price volatility due to geopolitical turmoil, pandemics, and supply imbalances requires predictive models capable of capturing nonlinear relationships and complex temporal patterns. This study evaluates and compares the performance of four forecasting models: ARIMA, Random Forest, XGBoost, and GRU to determine the best model for predicting WTI oil prices.

This study employs a comparative quantitative approach with historical WTI oil price data from August 1, 2010, to August 30, 2025, totaling 3,913 observations. The dataset was split chronologically with an 80:20 ratio for training and testing. ARIMA was optimized through grid search with Augmented Dickey-Fuller stationarity tests and ACF/PACF analysis. Random Forest and XGBoost were optimized using Bayesian Optimization with the Optuna framework, while GRU applied aggressive regularization to prevent overfitting. Model validation was conducted using time-series cross-validation with a 5-day gap. Evaluation employed MAE, RMSE, MAPE, and Accuracy metrics with very short-term forecasting horizons (t+1, t+3, t+5 days).

Results show XGBoost outperformed other models with the highest testing accuracy of 99.35%, MAE $0.49, RMSE $0.65, and MAPE 0.65%, along with exceptional multi-horizon stability showing only 0.07% degradation from t+1 to t+5. ARIMA(4,1,4) ranked second with 98.41% accuracy and the lowest generalization gap of 8.40%, making it the optimal choice for production deployment requiring stability and interpretability. Random Forest delivered solid performance with 96.79% accuracy, 10.01% gap, and extremely fast training time (1.92 seconds), ideal as a quick baseline. GRU achieved 97.29% accuracy with an 8.94% gap, but it is very high training time (75+ minutes) makes it less efficient. Robustness analysis across market phases confirmed XGBoost consistently maintained accuracy above 97% even during volatile periods and crises.

Keywords: *forecasting, WTI crude oil, ARIMA, Random Forest, XGBoost, GRU, machine learning, deep learning, time series prediction*