
Research article

Harnessing big data analytics across financial markets, banking, economic forecasting, and islamic finance: A unified machine learning framework

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Appendix A: Data Extraction and Verification Methodology

The cross-country panel data used in this study is extracted entirely from the World Bank Global Financial Development Database (GFDD). The dataset covers 267 countries and territories over a 24-year horizon (2000–2023), totalling 6,384 country-year observations. Target and predictor metrics—including non-performing loan (NPL) ratios, bank concentration percentages, and lending-to-deposit interest rate spreads—were cross-verified against the International Monetary Fund (IMF) International Financial Statistics to ensure consistency across reporting jurisdictions. Missing values were treated using longitudinal interpolation where country series were continuous.

Appendix B: Baseline Econometric Specifications and Diagnostics

To validate the performance improvements of the ensemble tree models, two classical baseline specifications were estimated:

1. VIX Forecasting Ordinary Least Squares (OLS): The baseline VIX model evaluates a linear combination of the 20-day lagged macro-financial feature vector. Standard errors are adjusted using White's heteroskedasticity-consistent covariance estimator. The resulting out-of-sample performance yields an RMSE of 28.26.

2. Panel Fixed-Effects Regression for NPLs: The cross-country baseline utilizes a static panel data model with country fixed effects (α_i) and year dummies γ_t to control for unobserved time-invariant country heterogeneity and global macroeconomic shocks:

$$NPL_{i,t} = \alpha_i + \gamma_t + \beta X_{i,t} + \varepsilon_{i,t}$$

This baseline yields an out-of-sample R^2 of 0.091 and an RMSE of 7.43 percentage points, which is significantly outperformed by the Random Forest architecture (R^2 of 0.224, RMSE of 4.92).



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