Forecasting Key Macroeconomic Indicators in Ghana Using a Time-Varying VECM with Conformal Prediction Intervals

Abstract—**This paper presents a six-month ahead forecast of three key Ghanaian macroeconomic indicators: the USD/GHS exchange rate, the Consumer Price Index (CPI) and the Monetary Policy Rate (MPR). A Time-Varying Vector Error Correction Model (TV-VECM) is utilized to capture dynamic interrelationships among the variables. Conformal prediction intervals are incorporated to quantify uncertainty under minimal distributional assumptions. The results suggest moderate currency depreciation, persistent inflationary trends and stability in nominal interest rates over the forecast horizon.**

Index Terms—**Time-Varying VECM, Conformal Prediction, Exchange Rate Forecasting, Inflation, Ghana, Monetary Policy**

I. INTRODUCTION

Forecasting macroeconomic indicators is essential for effective policy design and economic planning. This study employs a Time-Varying Vector Error Correction Model (TV-VECM) to analyze short-term movements in three critical Ghanaian macroeconomic variables: the USD/GHS exchange rate, the Consumer Price Index (CPI) and the Monetary Policy Rate (MPR). The TV-VECM framework captures both long-run equilibrium and evolving short-term dynamics. To account for forecast uncertainty, conformal prediction intervals are utilized which offer valid coverage without assuming specific error distributions.

II. METHODOLOGY

A. Data Description

Monthly data from January 2014 to June 2025 were compiled. CPI data were obtained from the Ghana Statistical Service, while exchange rate and MPR data were sourced from the Bank of Ghana. All series were tested for unit roots using the Augmented Dickey-Fuller (ADF) test and found to be integrated of order one, I(1). Cointegration was verified using Johansen's method, confirming at least one cointegrating relationship among the variables.

The ADF test is based on the following regression:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \epsilon_t \tag{1}$$

The Johansen cointegration test is derived from the Vector Autoregression (VAR) representation:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \epsilon_t \tag{2}$$

where the rank of the matrix Π determines the number of cointegrating relationships.

B. Model Specification

A Time-Varying VECM was implemented using a rolling window approach. This technique allows model parameters to evolve, accommodating structural breaks and time-varying relationships. The model captures both equilibrium correction mechanisms and short-term adjustments.

C. Forecasting and Conformal Prediction

A six-month forecast horizon was selected. To quantify forecast uncertainty, conformal prediction intervals were constructed using residual-based nonconformity scores. These intervals maintain valid coverage under mild assumptions and are robust to model misspecification.

Gradient Boosting Regression was employed to generate point forecasts. This method builds an ensemble of decision trees in a forward stage-wise fashion, minimizing a loss function by iteratively fitting residuals:

$$F_0(x) = \arg \min_{\gamma} \sum_{i=1}^{n} L(y_i, \gamma) \tag{3}$$

$$F_m(x) = F_{m-1}(x) + \nu \cdot h_m(x) \tag{4}$$

$$h_m(x) = - \left[\frac{\partial L(y, F(x))}{\partial F(x)} \right]_{F(x) = F_{m-1}(x)} \tag{5}$$

III. RESULTS AND DIAGNOSTICS

A. Residual Plot Observations

- **ln_CPI:** Residuals are centered around zero with low variance but show a slight increase in variance from 2022 onward.
- **MPR:** High residual variance with frequent spikes, suggesting potential outliers or structural breaks.
- **ln_USDGHS:** Residuals are mostly stable over time, with a few sharp spikes between 2022 and 2023 likely reflecting volatility during that period.

B. Autocorrelation Function (ACF) Observations

- **ln_CPI Residuals:** All spikes are within the 95% confidence bands across lags 0 to 10, confirming the absence of significant autocorrelation.
- **MPR Residuals:** A visible spike at lag 2 exceeds the confidence bounds, indicating residual autocorrelation.
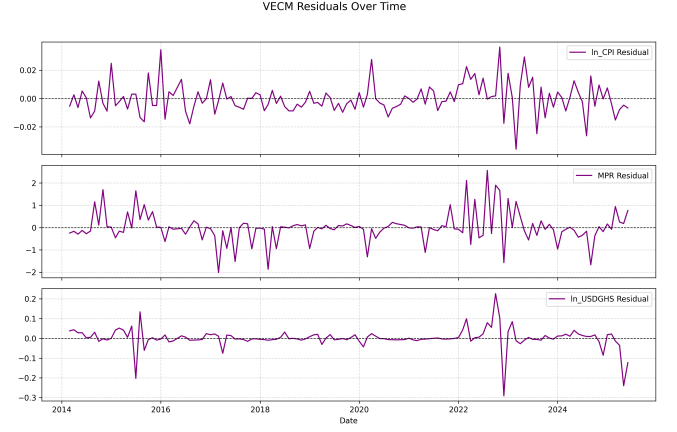- **ln_USDGHS Residuals:** All spikes remain within the confidence bounds, confirming white noise residuals.

Fig. 1: Residual plot for ln_CPI, MPR, and ln_USDGHS

TABLE I: Forecast and 90% Conformal Prediction Intervals (July–December 2025)

| Date	USD/GHS	[PI]	CPI	[PI]	MPR	[PI]
2025-07-31	10.4600	[10.12, 10.90]	258.87	[254.09, 261.07]	28.00	[28.00, 28.05]
2025-08-31	10.5900	[10.19, 10.93]	261.36	[260.11, 262.67]	28.00	[28.00, 28.01]
2025-09-30	10.7100	[10.42, 11.07]	264.56	[262.61, 265.19]	28.00	[28.00, 28.01]
2025-10-31	10.8400	[10.55, 11.21]	268.25	[265.82, 268.43]	28.00	[28.00, 28.01]
2025-11-30	10.9700	[10.67, 11.35]	272.09	[269.53, 272.18]	28.00	[28.00, 28.01]
2025-12-31	11.1000	[10.80, 11.48]	275.99	[273.39, 276.08]	28.00	[28.00, 28.01]
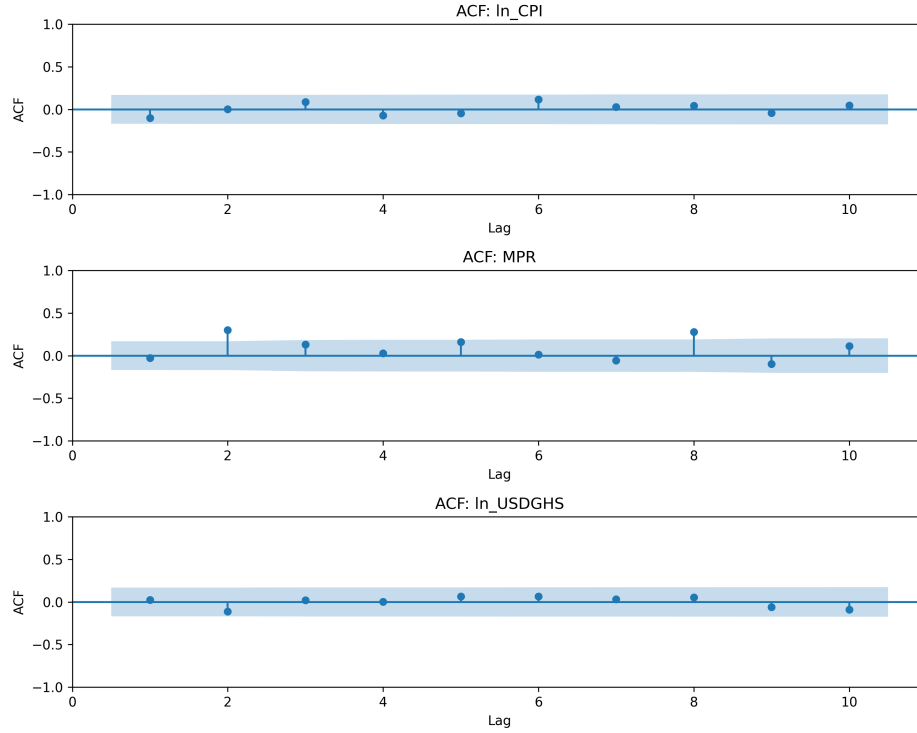
Fig. 2: Autocorrelation Function (ACF) plot for residuals

IV. DISCUSSION

A. USD/GHS Exchange Rate

The forecasted exchange rate path indicates a gradual depreciation of the Ghanaian Cedi, rising from 10.46 to 11.10 over the six-month period. The widening prediction intervals over time reflect increasing uncertainty as the forecast horizon extends.

B. Consumer Price Index

CPI is projected to increase gradually from 258.87 to 275.99, suggesting continued inflationary pressure. The forecast intervals remain tight, indicating strong model confidence in the inflation trajectory over the horizon.

C. Monetary Policy Rate

The MPR remains effectively stable at around 28.00% across the entire forecast window. The extremely narrow interval bounds suggest little model uncertainty and high temporal persistence in this rate.

V. MODEL PITFALLS AND DEPLOYMENT

From the estimated parameters value and diagnostic plots, we observed that Monetary Policy Rate residuals show strong autocorrelation and large spikes especially after 2022, confirming that the model does not capture MPR dynamics well. **This suggests the presence of possible outliers, structural breaks after 2022, and insufficient lags. Therefore, the model can be deployed to forecast only the Consumer Price Index (CPI) and USD/GHS. The long-run links look usable, but MPR short-term forecasts may not be reliable unless the MPR pitfalls are fixed and improved.**

VI. CONCLUSION

This study utilizes a Time-Varying VECM with conformal prediction to forecast Ghana's key macroeconomic indicators over a six-month horizon. Results suggest moderate exchange rate depreciation, persistent inflation, and stability in nominal interest rates. These forecasts are grounded in historical data patterns and subject to limitations arising from policy shocks or structural changes outside the model's framework.

DISCLAIMER