Stochastic Modeling of Exchange Rate Volatility with R: MCMC Simulation and Divergence Analysis

Gabriel Alberto Agudelo Torres* Biviana Marcela Suárez Sierra†
Jhonathan Estiven Díaz Vargas‡

August 22, 2025

Abstract

The aim of this study is to characterize asymmetries and heterogeneities in the stochastic dynamics of exchange rate volatility, using `R` tools to build a solid probabilistic framework for comparing risk structures across currencies. Stochastic volatility is modeled as a latent process that captures phenomena such as volatility clustering, persistence, and episodes of high uncertainty in currency markets.

Estimation is carried out through a Bayesian approach fully implemented in `R`, with a Gibbs sampler complemented by Metropolis–Hastings steps for conditional distributions without closed form. Custom routines were programmed to generate MCMC chains, perform convergence diagnostics (Geweke, Gelman–Rubin, Heidelberger–Welch, and Raftery–Lewis via `coda`), and produce dynamic visualizations of parameters and latent volatility paths.

The analysis was applied to daily returns in U.S. dollars for 14 currencies, processing the data with `readxl` and exporting results with `writexl`. From the simulated volatility trajectories, daily normal distributions were generated and Kullback–Leibler divergences were computed using the `LaplacesDemon` package. These calculations yielded a matrix of statistical distances that served as input for clustering and visualization techniques in `R`, providing a structured perspective on interdependence and segmentation in international currency markets.

In conclusion, this work shows how `R` can be used not only to implement Bayesian simulation algorithms for stochastic volatility models from scratch, but also to integrate diagnostics, visualization, forecasting, and comparative analysis into a reproducible workflow for financial research.

*Universidad EAFIT, Master's Program in Applied Mathematics, Medellín, Colombia. Email: gagudel4@eafit.edu.co

†Universidad EAFIT, Master's Program in Applied Mathematics, Medellín, Colombia. Email: bmsuarezs@eafit.edu.co

‡Universidad EAFIT, Master's Program in Applied Mathematics, Medellín, Colombia. Email: jediazv1@eafit.edu.co