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Comparative and Generative Analysis of Monte Carlo, EWMA, and LSTM Models for Financial Value-at-Risk Forecasting

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***Abstract*—Forecasting risk accurately is an important contributor to financial stability and strategic investment. Existing volatility models, such as the Exponentially Weighed Moving Average (EWMA), which assumes that returns are normally distributed, have difficulty capturing large or extreme losses during volatile periods, or they underestimate them. Deep learning, such as Long Short-Term Memory (LSTM) networks, can model nonlinear dependencies but struggle with short-term forecasting and interpretability. This research presents the Hybrid Monte Carlo–EWMA stimulator (HME-Stimulator) and integrates the sequential stochastic precision of Monte Carlo simulation with the rollover adaptive volatility method using EWMA and validates the methodology through the performance metric Mean Squared Area Error Function (MSAEF). Using Tesla (TSLA) daily stock data from 2010 to 2017, the study compares each of the Monte Carlo, EWMA, and LSTM models for forecasting 1-day 99 %, value-at-risk (VaR). The results show that the HME-Stimulator provides the best short-term accuracy and interpretability compared to the standalone statistical (MWMA or MCS) and deep learning methodology (LSTM).**

***Index Terms*—Monte Carlo Simulation, EWMA, MSAEF, Value-at-Risk, Financial Risk Forecasting, Hybrid Model**

I. Introduction

A. Problem Statement

To maintain capital adequacy and meet applicable regulatory requirements under the Basel III framework, financial institutions are required to produce reliable estimates of potential losses at a specific confidence level [8]. Traditional parametric models typically rely on fixed distributional assumptions and may yield distorted results during periods of market volatility [12]. This paper addresses the issue of enhancing the robustness of 1-day 99% VaR estimates by developing a generative Risk Stimulator, which we assess against traditional and deep-learning models in our analysis.

B. Motivation and Objectives

Though the EWMA model is conceptually simple to model, it has a limited capacity to model heavy-tailed distributions because of the stringent format it requires [1], [9]. While deep learning models (e.g., LSTMs) are highly expressive, their typical implementations require either substantial data or long sequence lengths, which can lead to instability in forecasting financial transactions over shorter periods. Furthermore, standard backtracking methods for VaR are limited in their consideration of breaches as they do not consider the extent of losses that occurred on failed attempts to realize a return. Adding to this complexity is the proposed Hybrid Monte Carlo - EWMA Stimulator (HME-Stimulator) as a solution, which will be examined via the Mean Squared Adaptive Error Function (MSAEF) and utilizes a continuous penalty for proximity to actual losses. Finally, a Monte Carlo, EWMA and LSTM comparison will be conducted, utilizing Tesla's stock returns from 2010 - 2017 as a basis for the analysis.

C. Overview of Models

Monte Carlo modeling employs stochastic simulation to generate synthetic return paths for probabilistic risk estimation [10]. EWMA applies exponentially decaying weights to past returns to estimate conditional volatility, enabling rapid responsiveness to changing market conditions. Although Long Short-Term Memory (LSTM) networks capture non-linear temporal dependencies, they require large historical