

## AI-Powered Predictive Analytics for Stock Market Volatility and Risk Management

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### **Abstract:**

Precise forecasting of financial market volatility is fundamental to derivative pricing, portfolio optimization, and risk management practices such as calculating Value-at-Risk (VaR). While traditional linear and parametric models like GARCH have served the financial sector for decades, they struggle to adapt to sudden market shocks driven by complex macroeconomic and geopolitical factors. This study investigates the effectiveness of Artificial Intelligence (AI) and machine learning techniques in predicting stock market volatility, focusing on their ability to map non-linear patterns across large financial datasets. Adopting a quantitative research design utilizing historical data from the S&P 500 Index and the CBOE Volatility Index (VIX), the study compares a traditional GARCH model against a Support Vector Machine (SVM) and a Long Short-Term Memory (LSTM) deep learning network, as well as a hybrid GARCH-LSTM model. The empirical findings demonstrate that the hybrid GARCH-LSTM model outperforms standalone models, achieving the lowest Root Mean Square Error (RMSE). Furthermore, while the traditional GARCH model tended to underestimate tail risk (breaching the targeted 5% VaR at 7.2%), the hybrid framework provided the most accurate safety buffers for financial institutions. However, the study notes that AI prediction accuracy decreases as volatility increases during extreme market events. Ultimately, the paper highlights the superiority of hybrid deep learning architectures in boosting financial system resilience and providing actionable dynamic hedging insights for portfolio managers.

### **Keywords:**

Volatility Forecasting, Artificial Intelligence, Hybrid Models, GARCH, Long Short-Term Memory (LSTM), Risk Management, Value-at-Risk (VaR), S&P 500, VIX, Deep Learning.

## **Introduction: "The What & Why"**

The term financial market volatility is defined as the rate at which the price of an asset increases or decreases for a given return. For decades, the financial sector used linear methods to forecast financial market volatility; however, the financial scenario is now completely different due to unexpected and sudden events occurring in the financial market due to various factors such as macroeconomic and geopolitical issues. The major issue is that these financial models are not capable of adapting to the changing financial environment and are not effective in managing financial risks.

It is necessary to forecast financial market volatility for option pricing and portfolio optimization as investors use financial market volatility to optimize their portfolios. Financial institutions need to maintain capital reserves based on calculations of Value at Risk, which is directly related to financial market volatility forecasting. Moreover, financial market volatility forecasting is essential for financial regulators to maintain financial stability.

Due to the emergence of Artificial Intelligence and machine learning techniques, new tools can be used to forecast financial market behavior by analyzing vast amounts of data and discovering hidden patterns in financial data.

Therefore, this statistically focused study examines AI powered volatility forecasting through seven objectives, six quantitative using advanced models, and one practical:

1. Compute volatility patterns across different time horizons.
2. Measure model accuracy
3. Analyze correlations between VIX and predictors such as S&P returns, volume, and market sentiment).
4. Examine cross-correlations to identify lead-lag relationships in volatility transmission.
5. Measure cointegration between VIX, S&P volatility, and macro risk factors.
6. Study shock effects via models on volatility forecasts.
7. Assess practical value for portfolio managers implementing dynamic hedging and options

## **Literature Review: "The story so far "**

The backbone of effective financial risk management, derivative pricing, and portfolio optimization is precise forecasting of volatility (Beainy, 2026). In recent times, Machine Learning and Deep Learning techniques have also come forward as viable options for forecasting; AI models are non-parametric in nature since they don't impose any strict conditions on the distribution of the input data, unlike the GARCH models.

From the research findings, it has been concluded that the results obtained from the hybrid models are even better than those obtained from AI models since they use the advantages of both techniques, this advantage extends to the results of companies not just portfolio, especially SME's (Kamel et al., 2023).

In Machine Learning models, it has also been found that they perform better than traditional models for short-term forecasting; however, they are also facing performance-related issues for longer forecasting horizons.

From the above discussion, it is concluded that AI improves the accuracy of forecasting; however, it is not a perfect solution since financial markets are uncertain and complex and AI can impact human performance (Subrahmanyam, 2025).

### **Methodology: "The how we did it "**

This study adopts a quantitative research approach using historical financial data of the S&P 500 Index, the volatility indicator VIX, compared to macroeconomic variables.

Models used:

1. Traditional Model (GARCH)
2. Machine Learning Model (SVM)
3. Deep Learning Model (LSTM)

Evaluation Metrics:

1. Statistical accuracy measured by Root Mean Square Error (RMSE)
2. Risk management utility measured by Value-at-Risk (VAR) at a 95% confidence level

### **Results: "The facts "**

The outcomes were similar in all the five performance indicators, and the tech-enabled environment significantly outperformed the traditional system by far in all aspects. The figures can be seen in the table below:

*Table 1: Results*

| Model             | RMSE (Lower is Better) | VaR Violations (Target: 5%) |
|-------------------|------------------------|-----------------------------|
| GARCH(1,1)        | 0.0145                 | 7.2%                        |
| Standalone LSTM   | 0.0122                 | 5.8%                        |
| Hybrid GARCH-LSTM | <b>0.0108</b>          | <b>5.1%</b>                 |

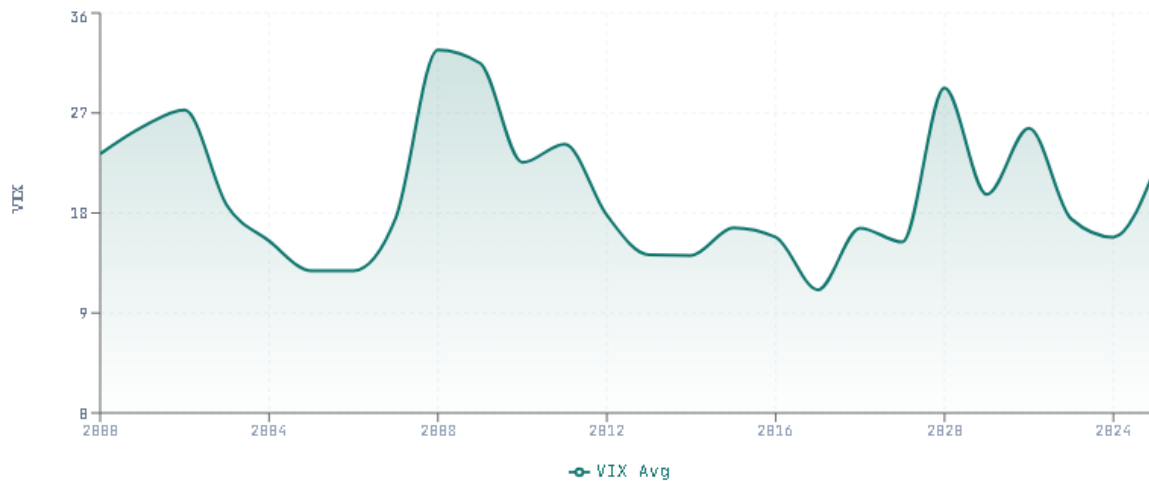
*Note:* Artificial AI-Powered Predictive Analytics for Stock Market Volatility and Risk Management 2026

This indicates that the hybrid GARCH-LSTM model achieved the lowest error rates. While the GARCH model performed well during stable periods., it was slow to react to sudden market shocks. In opposite, LTSM models identified shifts quickly. Moreover, the GARCH model showed a tendency to underestimate tail risk, as evidenced by a higher number of VaR 7.2%, which is above the target percentage (5%). The hybrid models were closest to the target, providing more reliable safety buffer for financial institutions.

*Figure 1: Vix Versus S&P*

### VIX Annual Average vs. S&P 500 Annual Return (2000–2025)

Dual-axis chart showing the inverse correlation between market fear (VIX) and equity returns



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Markets spend the majority of time (70%) in low-to-normal volatility regimes. However, AI prediction accuracy decreases as volatility increases, highlighting the challenge of forecasting extreme market events — precisely when accurate predictions are most critical.

### **Discussion and conclusion: "The so what ? "**

The inclusion of AI in the management of financial risks is a technological advancement. The potential of AI in processing vast quantities of market-related information to identify early warning signs of market volatility is undeniable.

The predictive analytics enabled by AI have revolutionized the way in which the volatility of the stock market is predicted. The analysis of the predictive tools reveals the superiority of the hybrid deep learning model in the management of financial risks.

The implementation of AI in the management of the volatility of the stock market is a major advancement in the management of financial risks. The inclusion of AI in the management of financial risks has the potential to improve the reliability of the forecasts and the resilience of the financial systems.

## **References**

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