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INTRODUCTION & AIM

Introduction

Systemic financial risk emerges from complex interactions among financial assets, where localized shocks can spread rapidly across the market. Conventional risk measures often fail to capture these nonlinear dependencies and evolving market structures during periods of financial stress. This research integrates Random Matrix Theory (RMT) and Neural Stochastic Differential Equations (Neural SDEs) to model systemic risk, identify hidden market regimes, and provide an interpretable framework for financial stability analysis and early-warning detection.

Objectives

1. Develop the quantitative framework for modelling systemic financial risk using 25 years (2000 -25) of the S&P 500 market data.

2. Extract spectral risk features from rolling correlation matrices using Random Matrix Theory.

3. Learn nonlinear market dynamics through Neural Stochastic Differential Equations and latent-state representation learning .

4. Construct a Dynamic Systemic Risk Index (DSRI) for regime detection, crisis-probability estimation, and historical backtesting.

METHOD

METHODOLOGY

1. Developed a quantitative systemic-risk forecasting framework using 25 years (2000–2025) of data from ~500 S&P 500 constituents, generating a 14-dimensional financial state space from 6,000+ daily observations by integrating equity returns, VIX.

2.Treasury yield spreads, and market drawdowns.Applied Random Matrix Theory (RMT) to rolling correlation networks to extract spectral risk indicators—including Largest Eigenvalue, Spectral Gap, Effective Rank, Spectral Entropy, and Inverse Participation Ratio (IPR)—for systemic risk and market contagion analysis.

3.Built Neural Stochastic Dynamics and latent-state representation models to capture nonlinear market evolution, and developed a Dynamic Systemic Risk Index (DSRI) with unsupervised market-regime classification for Normal, Elevated, Stress, and Crisis states.

4.Validated the framework through historical backtesting, regime-transition analysis, ROC-AUC evaluation, Monte Carlo stress testing, and early-warning signal generation for systemic financial events.

RESULTS & DIsCUSSION

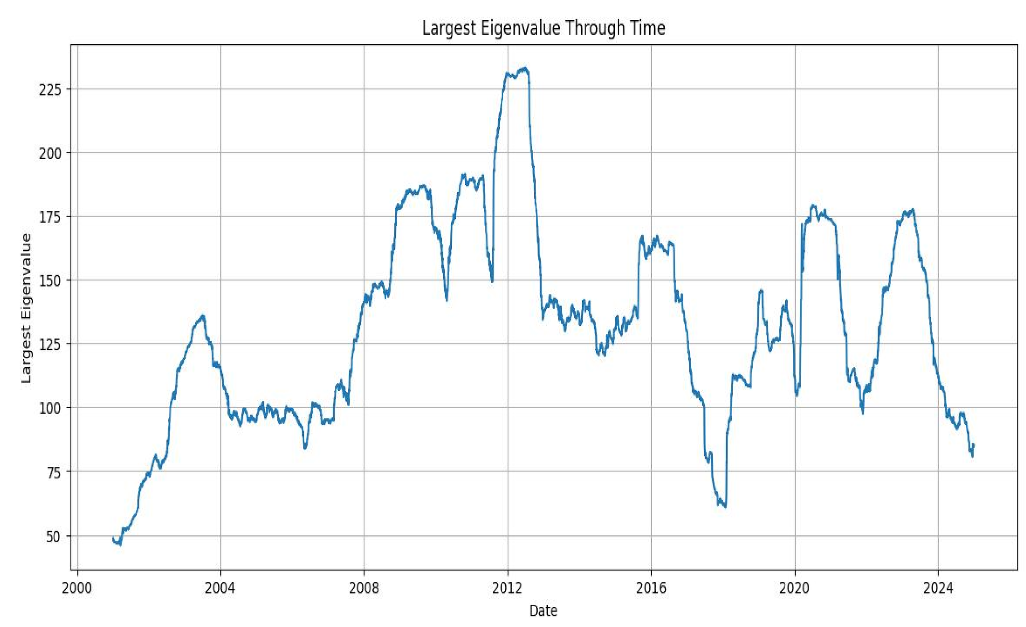

Figure 1 - Largest Eigenvalue Through Time

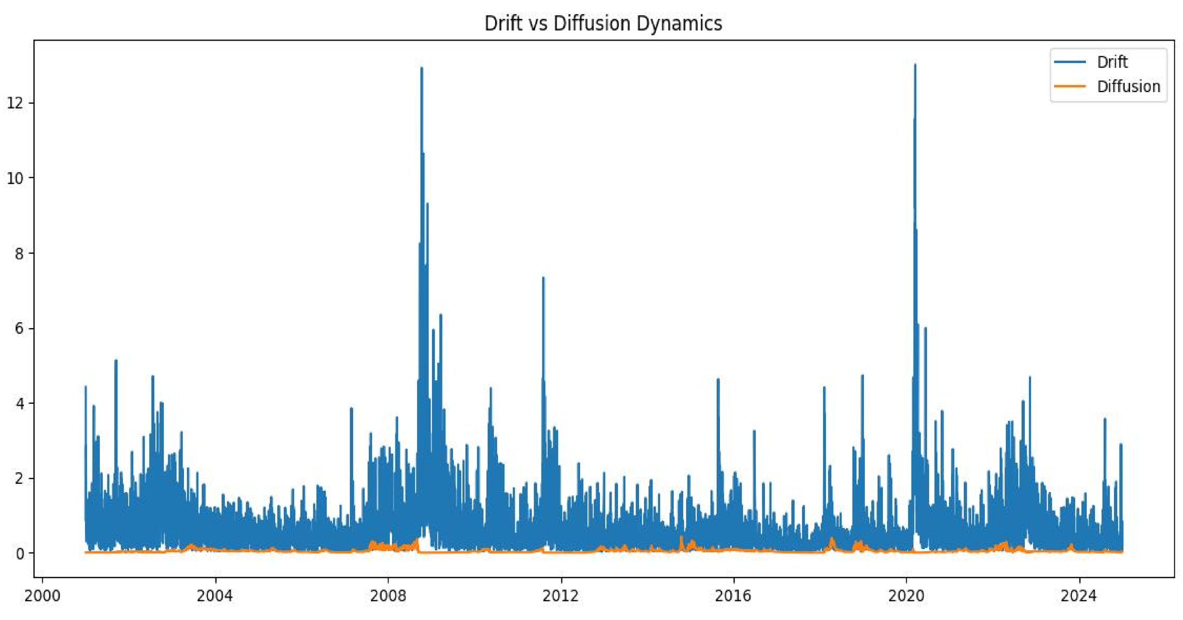

Figure 2 - Neural SDE Drift/Diffusion Dynamics

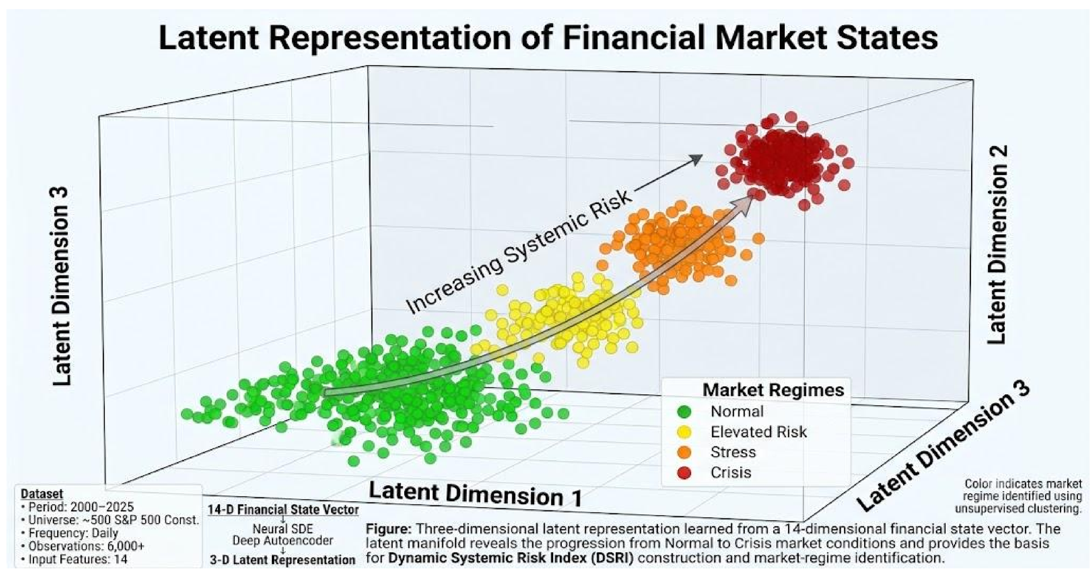

Figure - 3 D Latent Risk Manifold

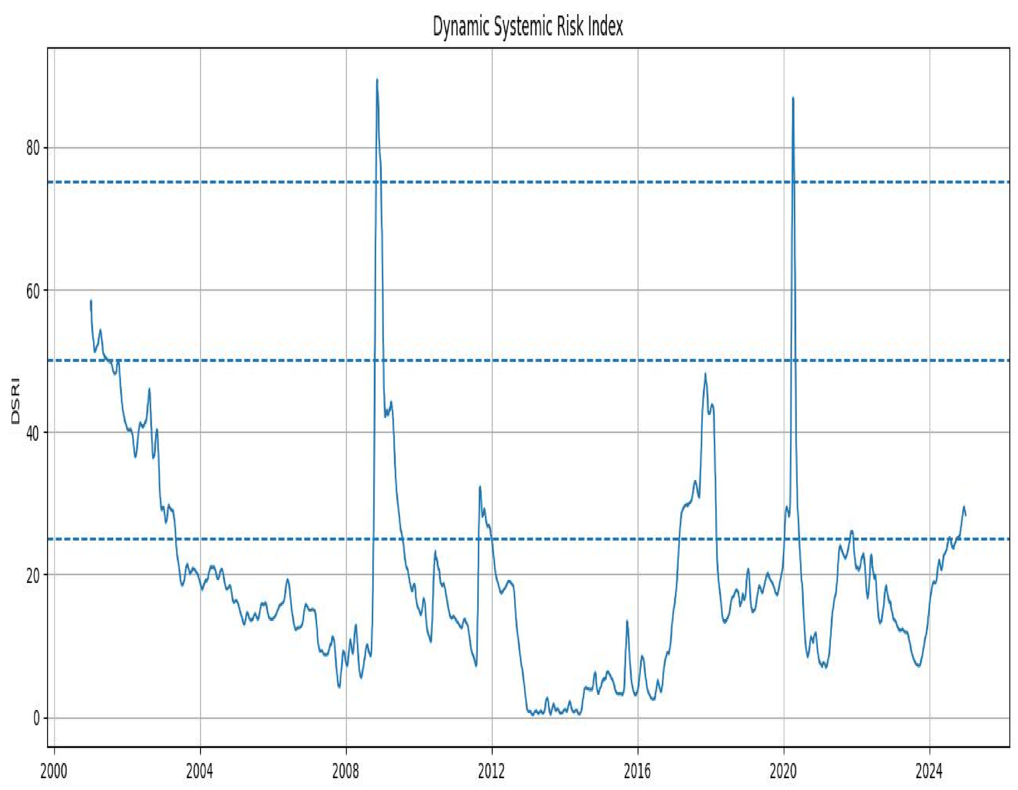

Figure 4 - Dynamic Systemic Risk Index

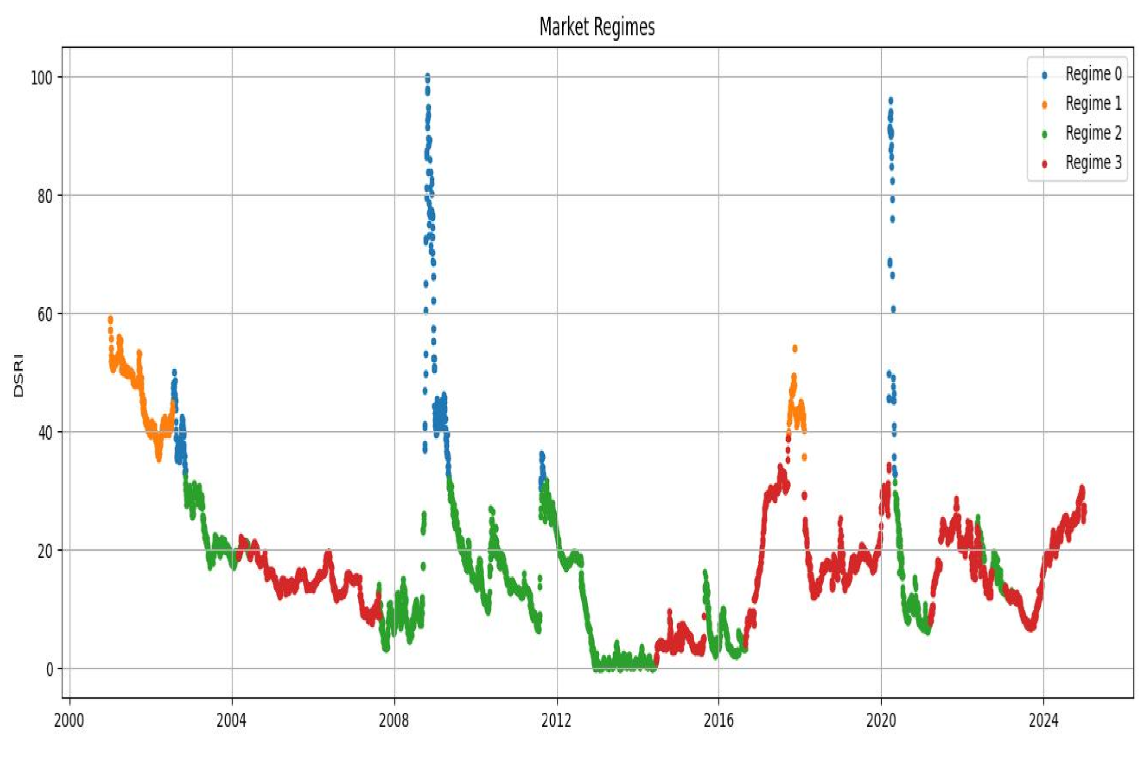

Figure 5 - Market Regime Detection Timeline

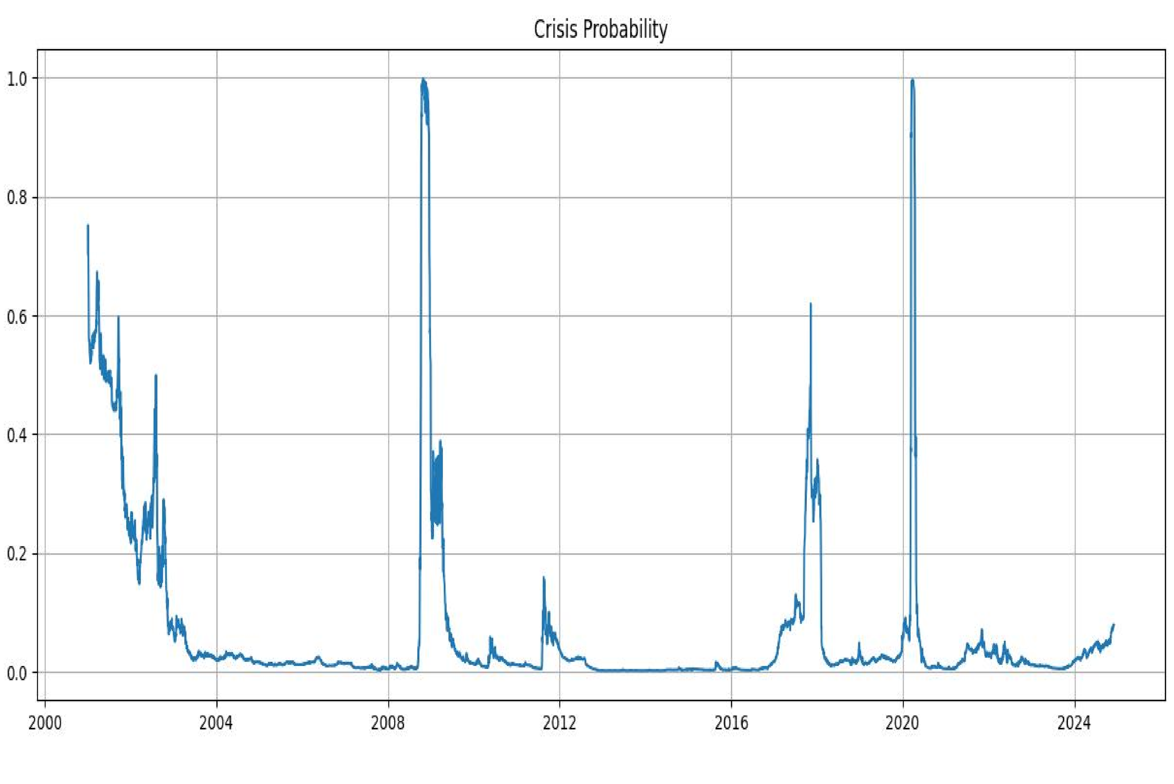

Figure 6 - Temporal Evolution of Crisis Probability

CONCLUSIONS

The proposed Random Matrix Theory (RMT) and Neural Stochastic Differential Equation (Neural SDE)** framework effectively captured systemic financial risk by identifying latent market states, market regimes, and periods of elevated systemic stress.

The developed Dynamic Systemic Risk Index (DSRI) provides an interpretable and scalable framework for systemic-risk monitoring, early-warning analysis, and quantitative financial risk management**.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

Extend the framework to multi-asset and cross-market financial networks for global systemic-risk modelling.
Integrate real-time market data for continuous risk monitoring and early-warning systems.
Enhance the Neural SDE framework using Transformer-based architectures for improved long-term market dynamics modelling..