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Analysis of terminal risks and interbank correlations in Iranian listed banks: A hybrid model approach of deep learning and Gaussian processes)

Sepideh Azimi [1], Saeed Kianpoor[2*], Alireza Homayounfar

[1.]Instructor,Department of Basic Science,Faculty of Basic and General Studies,Technical and Vocational University(TVU),Tehran,Iran.

[2.] Assistant Professor, Department of Management, Payame Noor University, Tehran, Iran

[3.] Instructor, Department of Social Sciences, Payame Noor University, Tehran, Iran.

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Abstract

Background and Objective: This research was conducted to measure tail risks and interbank correlations within the Iranian banking system and to identify the root causes of systemic fragility. The focus is on the extended period following the global financial crisis (from 2008 to 2024), during which the banking system has been under severe pressure from structural factors such as fixed provisional profit payments to depositors, widespread overdrafts from the central bank, severe balance sheet imbalances, and macroeconomic shocks. The primary objective is to assess the current state of systemic vulnerability and forecast probable future paths using advanced hybrid modeling approaches.

Methodology: This study employs a novel hybrid model integrating deep learning, Gaussian processes, Time-Varying Parameter Vector Autoregression (TVP-VAR) models, interbank network analysis, and extensive Monte Carlo simulations. Quarterly data on twelve key banking variables (including overdrafts, non-performing loans, capital adequacy ratio, liquidity, etc.) alongside macroeconomic variables (inflation, exchange rate, economic growth, etc.) from 2008 to 2024 were analyzed. A systemic vulnerability index and the magnitude of risk transmission through various channels (particularly the trust channel) were calculated and compared with conventional methods.

Results and Findings: The results indicate that the Iranian banking system entered a stable critical and chaotic regime at the beginning of 2008 and has remained in this state until the end of 2024. The systemic vulnerability index surpassed 0.96 in 2024, signifying a highly fragile condition nearing a critical point. Shocks to the system operate in a highly asymmetric manner, with negative shocks being approximately ten times stronger than positive ones and tending to be nearly permanent. Risk transmission among banks occurs almost entirely (close to 100%) through the trust channel and hidden correlations. The root cause of this fragility is the continued policy of paying fixed provisional profits to depositors (despite real resource-use imbalances) and the widespread overdrafting of banks from the central bank, which has created a vicious cycle of liquidity expansion and steadily increasing systemic risk. Simulations estimate the probability of a systemic collapse by the end of 2026, assuming the current trend continues, at over 87%. Conversely, immediate and decisive structural reforms, including the complete elimination of fixed provisional profit payments, the dissolution or merger of insolvent banks, and a serious overhaul of corporate governance, could steer the banking system toward a stable and self-reinforcing regime. The forecasting accuracy of the proposed model is significantly higher than that of traditional methods.

Keywords: "Tail Risk", "Interbank Correlation", "Systemic Risk", "Hybrid Deep Learning Model", "Iranian Banking System".

[*] **Correspong Author Email**: s_kianpoor@pnu.ac.ir

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EXTENDED ABSTRACT

Introduction

The banking system constitutes the backbone of any economy, playing a pivotal role in financing businesses, allocating resources, and maintaining macroeconomic stability. In Iran, however, the banking sector has been under severe and prolonged pressure since the late 2000s due to chronic high inflation, repeated currency jumps, extensive international sanctions, and deep structural distortions — most notably the persistent payment of fixed provisional (ali-alhesab) profit rates to depositors despite severe asset-liability mismatches and massive recurring overdrafts from the Central Bank. This study investigates tail risks (extreme but rare events with catastrophic consequences) and interbank contagion channels among banks listed on the Tehran Stock Exchange (TSE) over the long period from 2008 to the end of 2025 (1387–1403 in the Persian calendar). The research particularly focuses on the dominant role of the confidence channel in risk transmission, the strong asymmetry of shocks, the persistent chaotic regime of the banking system since 2008, and the probability of systemic collapse in the coming years under the baseline scenario versus decisive structural reform scenarios. The main objective is to quantify the current degree of systemic fragility, identify the root structural causes, and provide evidence-based policy pathways to prevent an imminent systemic crisis.

Methodology

This research develops and applies a novel hybrid non-parametric Bayesian framework called Deep GP-VAR, which integrates:

- deep learning (LSTM layers) for capturing highly non-linear patterns and long memory dependencies,
- deep Gaussian Processes for flexible, uncertainty-aware modeling of time-varying coefficients,
- low-rank approximation + Gaussian copula for modeling tail dependencies and heavy-tailed distributions,
- time-varying parameter VAR structure,
- complex network analysis of interbank linkages,
- large-scale Monte Carlo simulations for stress testing and policy scenario evaluation.

Quarterly panel data from 9–10 TSE-listed banks covering 78 quarters (2008Q1–2025Q3) were utilized. Core banking variables included ROA, ROE, net interest margin, non-performing loans ratio (NPL), capital adequacy ratio, leverage ratio, operational cash flow, and overdraft from the Central Bank. Macroeconomic variables comprised free-market exchange rate, CPI inflation rate, and a constructed index of oil sanction intensity.

The model was estimated using variational inference accelerated by stochastic gradient descent, with results cross-validated via No-U-Turn Sampler MCMC chains. Predictive performance was evaluated against five conventional benchmarks (linear VAR, TVP-VAR, DCC-GARCH, plain LSTM, simple GP-VAR) using RMSE, MAE, CRPS, Kupiec and Christoffersen backtests for tail risk measures, and the Diebold–Mariano test for superior predictive accuracy.

Results and Findings

The findings demonstrate that the Iranian banking system has been trapped in a persistent chaotic and crisis regime since 2008 and has shown no sign of exiting this state by the end of 2025. The composite Systemic Vulnerability Index reached above 0.96 in 2025 — an unprecedented critical level. Shocks exhibit extreme negative asymmetry: negative shocks are

up to approximately 10 times more powerful and almost permanent in their effects, while positive shocks produce limited and transitory impacts. Nearly 100% of interbank risk transmission occurs through the confidence channel and hidden correlation structures rather than direct balance-sheet exposures. The root structural cause is identified as the continued policy of paying fixed provisional profit rates to depositors despite severe mismatches, combined with chronic and massive overdrafts from the Central Bank — generating a self-reinforcing vicious liquidity illusion cycle that continuously escalates systemic risk. Monte Carlo simulations (100,000 paths) under the baseline (no-reform) scenario estimate the probability of full systemic collapse by the end of 2026 (1405) at over 87%, with more than 94% probability of massive deposit withdrawal following even a small confidence shock, and potential output loss equivalent to 42–68% of GDP. In sharp contrast, immediate and decisive structural reforms — including complete elimination of fixed provisional profit rates, mandatory liquidation or merger of deeply insolvent banks, full balance-sheet transparency, and fundamental corporate governance overhaul — are capable of shifting the system into a stable, self-reinforcing equilibrium with a drastic reduction in systemic vulnerability (from 0.96 to below 0.50) and collapse probability to under 10%. The hybrid Deep GP-VAR model substantially outperforms all traditional benchmarks in tail risk forecasting, directional shock asymmetry detection, and long-horizon crisis prediction — confirming both main research hypotheses.

Conclusion

This study provides compelling evidence that the Iranian banking system is currently in an advanced and critical stage of systemic fragility, locked in a permanent chaotic regime since 2008. Without radical and comprehensive structural reforms implemented before the end of 2025, a systemic banking collapse in the 2026–2027 horizon appears highly probable. The overwhelming dominance of the confidence channel, extreme negative asymmetry of shocks, and self-reinforcing liquidity illusion cycle constitute the core mechanisms driving this trajectory. The superior performance of the proposed Deep GP-VAR hybrid framework highlights the necessity of moving beyond conventional linear and semi-parametric models toward flexible, non-parametric, and network-aware approaches for systemic risk analysis in highly stressed, sanction-affected, and chronically inflationary emerging banking systems.
The findings offer concrete, simulation-backed policy recommendations for the Central Bank of Iran and financial authorities: immediate removal of fixed provisional profit rates, prohibition of overdrafts with severe penalties, forced resolution of insolvent institutions, mandatory international-standard transparency, and establishment of a real-time systemic risk dashboard based on the hybrid model presented in this research. Future studies could extend the framework to the entire banking system (including non-listed banks), incorporate high-frequency data, and conduct comparative analyses with other heavily sanctioned economies.

Declarations

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Authors' Contribution

Authors contributed equally to the conceptualization and writing of the article. All of the authors approved the content of the manuscript and agreed on all aspects of the work declaration of competing interest none.

Conflict of Interest

The authors declare no conflict of interest.

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