Independent Model Validation Review

Entropy-Based Risk Framework - Credit Stress Application

Objective and Scope

This independent validation assesses a relative-entropy (exponential tilting) risk framework applied to credit spread proxy losses (HYG–LQD differential) using 2020–2025 market data. The purpose of this review was to evaluate.

- Theoretical soundness
- Parameter sensitivity and fragility
- Empirical performance during stress events
- Stability across macro regimes
- Suitability for Model Risk Management (MRM) governance

The analysis benchmarks entropy-adjusted expected losses against traditional risk measures (Mean, VaR, CVaR) and evaluates forward-looking conservatism via rolling backtesting. The validation scope is aligned with stress testing, liquidity risk, and asset-liability management applications relevant to institutional balance sheet risk oversight.

Theoretical Framework and Parameter Sensitivity

The entropy framework reweights the empirical loss distribution using exponential tilting controlled by robustness parameter θ. As θ increases, tail losses receive progressively greater weight, allowing interpolation between baseline expectation and extreme stress outcomes.

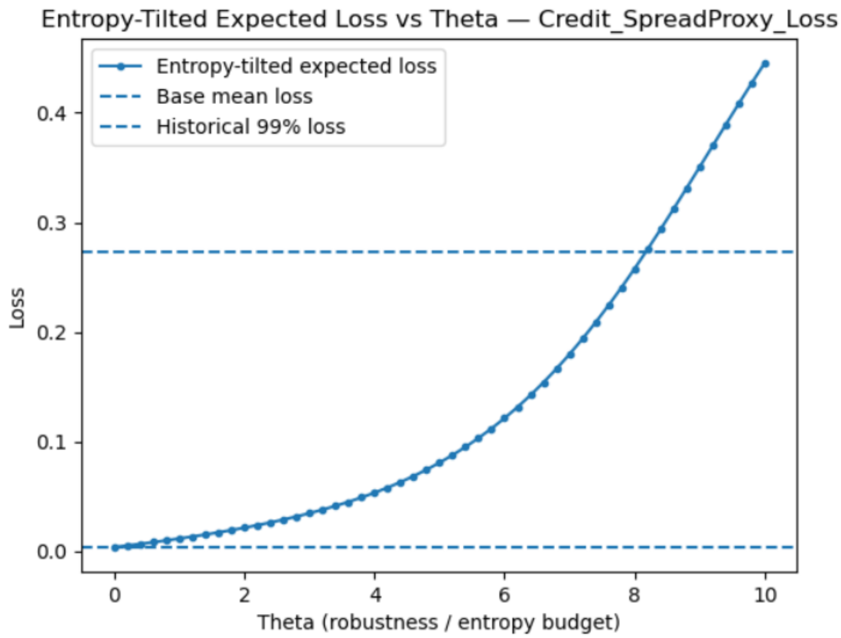
Empirical findings:

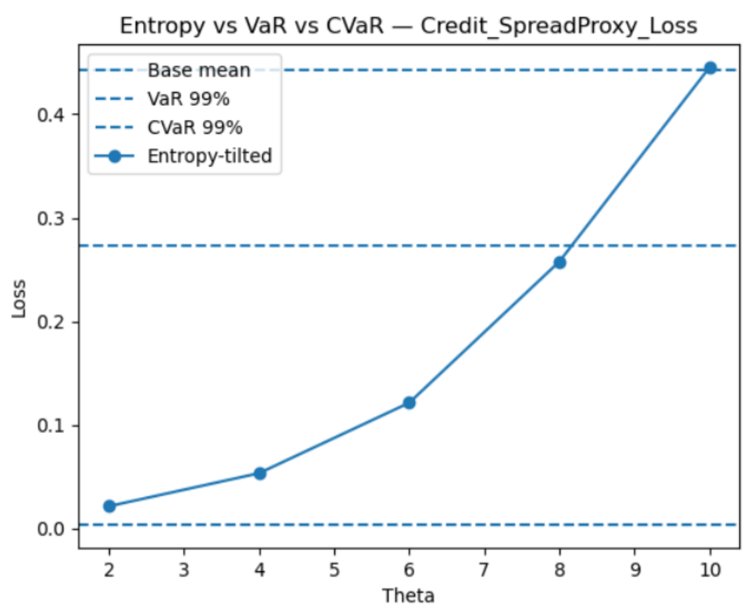
- Base mean loss: 0.0037
- 99% VaR: 0.2729
- 99% CVaR: 0.4429
- Entropy-adjusted loss at $\theta = 6$: 0.121
- Entropy-adjusted loss at $\theta = 10$: 0.445

Losses increase nonlinearly in θ, approximating CVaR levels around $\theta \approx 10$. Marginal sensitivity ($dLoss/d\theta$) peaks near $\theta \approx 9$–10, indicating a fragility inflection zone where small parameter changes materially amplify stress estimates. The convex response is mathematically coherent and consistent with the theoretical structure of relative entropy. However, nonlinear amplification beyond moderate θ values introduces governance risk if calibration boundaries are not formally defined.

Independent Model Validation Review

Entropy-Based Risk Framework - Credit Stress Application





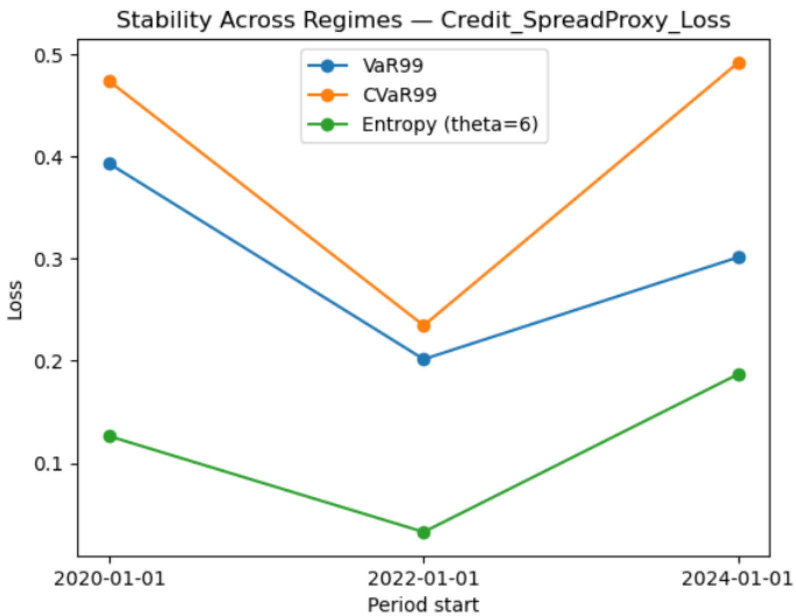
Stability Across Macro Regimes

Subsample analysis across three macro periods (2020–2021, 2022–2023, 2024–2025) indicates that entropy-adjusted loss (θ=6) tracks directional regime shifts while exhibiting lower volatility than VaR and CVaR. During stress-intensive periods (2020 and 2024–2025), tail metrics expanded materially, whereas entropy-adjusted loss responded more smoothly. This suggests that entropy acts as a controlled robustness overlay rather than a pure tail estimator. From an MRM perspective, smoother regime transitions enhance monitoring stability but may reduce sensitivity to sudden tail expansions if calibration remains static.

Niraj Neupane
Quantitative Researcher
K&T QUANT LABS
Quantitative Research & Market Analytics

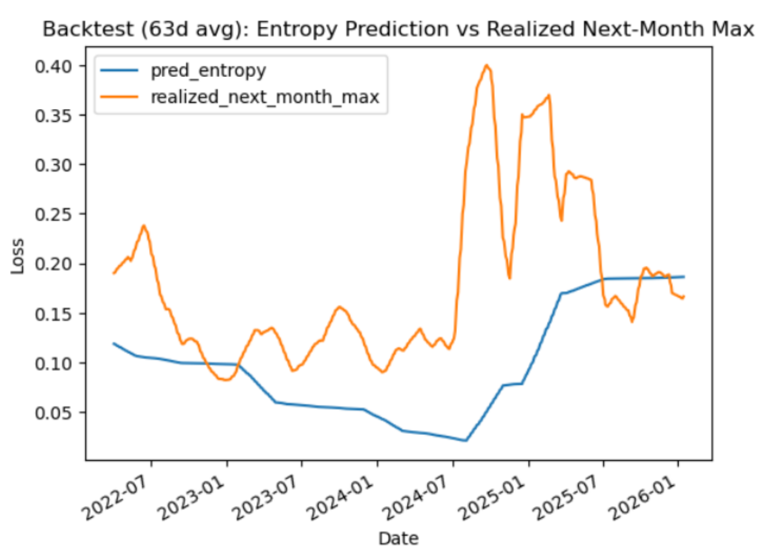
Independent Model Validation Review

Entropy-Based Risk Framework - Credit Stress Application



Empirical Backtesting and Forward Conservatism

A rolling backtest using a 2-year estimation window and 1-month forward maximum loss horizon evaluated predictive conservatism. At θ=6, the entropy framework achieved a conservatism hit-rate of 23.7%, indicating that extreme stress exceeded model predictions in most forward periods. This finding suggests that fixed-θ implementation underestimates stress during rapid regime transitions. While entropy mitigates distributional misspecification risk, static calibration limits responsiveness to abrupt tail expansion. From a model validation standpoint, dynamic θ calibration linked to volatility or spread indicators or implementation of conservative governance floors is recommended.



Niraj Neupane

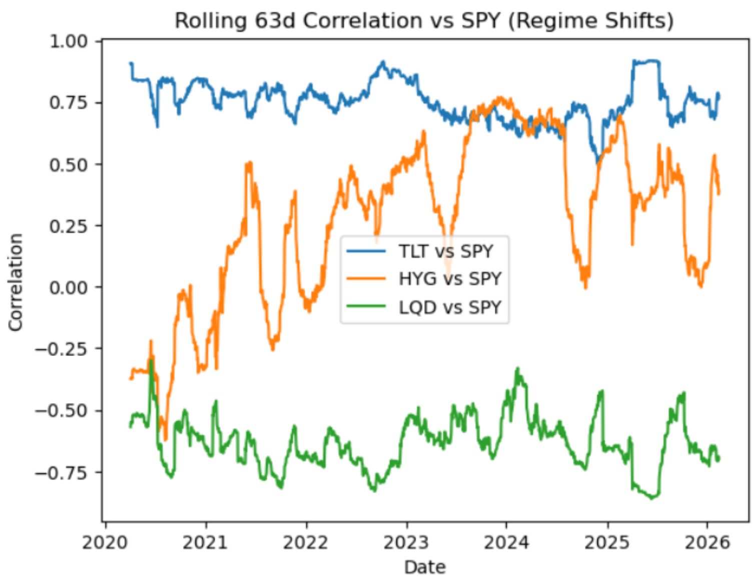
Quantitative Researcher

K&T QUANT LABS

Quantitative Research & Market Analytics

Correlation Structure and Stress Co-Movement

Rolling 63-day correlation analysis reveals regime-dependent instability in cross-asset relationships among equities, credit, and rates. Correlation breakdowns during stress reinforce the importance of robustness adjustments, as covariance structures may deteriorate under extreme conditions. While entropy amplifies tail outcomes, it does not explicitly model structural correlation shifts. Integration with stress correlation overlays would further enhance liquidity and ALM risk applications.



. Governance Assessment and MRM Implications

From a Model Risk Management perspective, the entropy framework is:

- Theoretically coherent and convex in parameterization
- Empirically meaningful across macro regimes
- Moderately sensitive to robustness calibration
- Governance-dependent in implementation

However:

- Nonlinear amplification beyond $\theta \approx 8$ introduces fragility risk
- Fixed calibration underestimates forward extreme stress
- Backtest performance indicates insufficient conservatism

Recommended Governance Enhancements:

- Cap θ below fragility inflection zone ($\theta < 8$)
- Introduce state-dependent θ calibration tied to volatility/spread metrics
- Position entropy as complementary overlay to VaR/CVaR
- Implement rolling backtest monitoring thresholds
- Formalize calibration review documentation and governance cadence

Overall Validation Conclusion

The entropy-based model risk framework provides a mathematically sound and operationally flexible robustness overlay suitable for stress-testing and credit risk contexts. It effectively interpolates between expectation-based and tail-based risk measures while delivering smoother regime transitions than traditional VaR/CVaR.

However, static calibration underestimates extreme forward stress. Production implementation would require dynamic calibration controls and explicit governance boundaries.

Indicative Model Risk Rating:
Moderate, subject to calibration enhancement and formal governance controls.

Niraj Neupane
Quantitative Researcher
K&T QUANT LABS
Quantitative Research & Market Analytics