Discussion of “Bridging Structured Knowledge and Data: A Unified Framework with Finance Applications”

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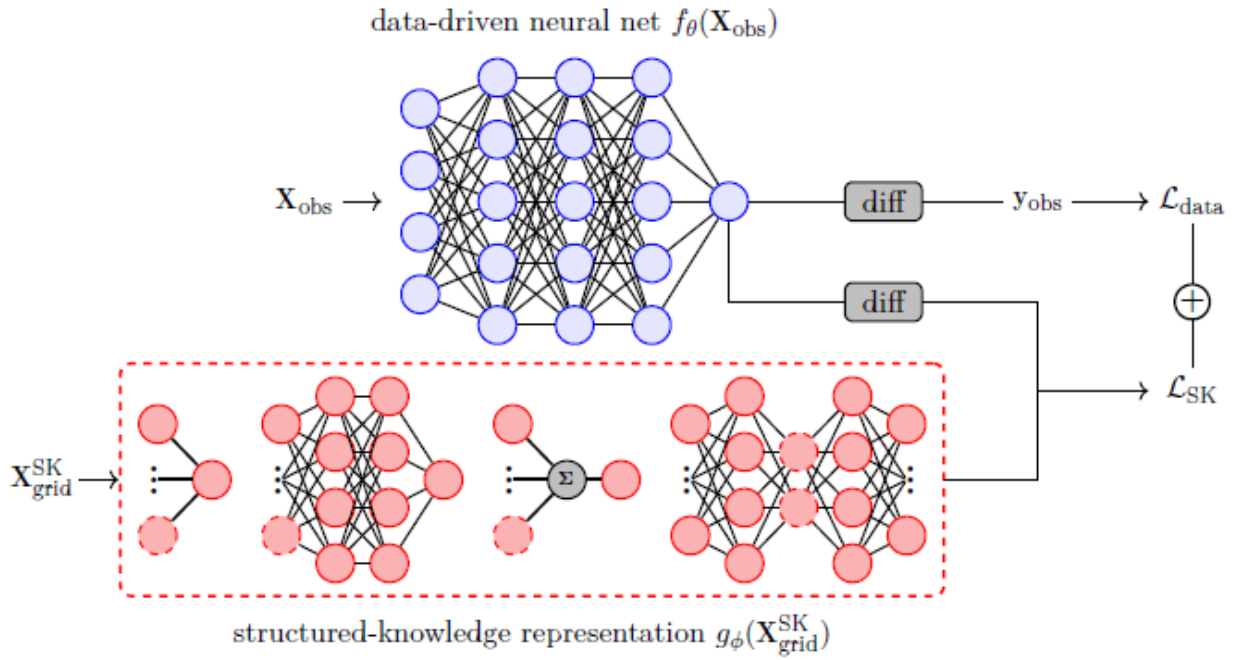
What the Paper Does

- Proposes SKINNs: Structured-Knowledge-Informed Neural Networks
- Joint estimation of neural network (flexible) and structural model (economic)
- Goal: combine flexibility with discipline



Core Mechanism

$$L(\theta, \phi) = L_{data} + \lambda L_{SK}$$

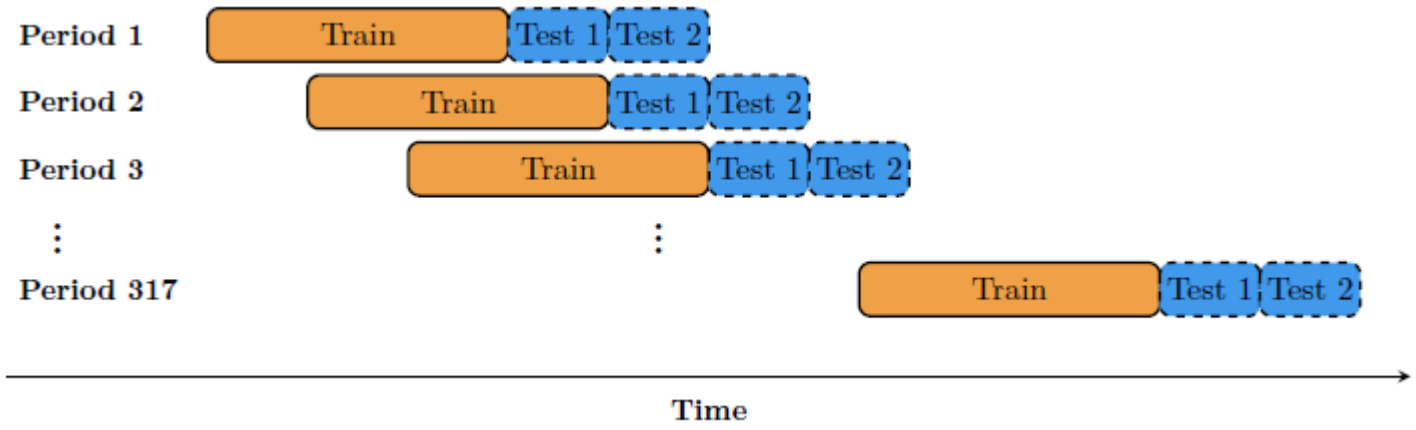
- Composite loss combines data fit and structural consistency
- Structural knowledge enters as a soft constraint
- Collocation enforces consistency beyond observed data

Why This Matters

- Financial data are noisy and non-stationary
- Structural models are often misspecified
- Pure ML models may overfit
- SKINNs aim to improve generalization and stability
- In comparison, Physics Informed NN (PINNs) suffer from gradient instability issues and unobserved state variables;

Application in Option Pricing

- S&P 500 options from 1996 to 2022 (exclude weekly and 0DTEs)
- Benchmarks: neural networks and structural models
- Evaluation: pricing RMSE and hedging performance



Main Results

- SKINNs outperform both NN and structural benchmarks
- OOS RMSE improves by ~10–15%
- Hedging performance also improves
- Gains stronger at longer horizons and high volatility

Authors' Interpretation

- Structural component acts as regularization
- Improves stability and generalization
- Gains increase in high-VIX environments
- Latent variables evolve smoothly
- SKINNs is not only a predictive device but also an economic estimator

Overall Assessment

- Elegant integration of theory and machine learning
- Strong empirical performance
- Broad applicability (conceptually)
- Natural next step: understand what the model is learning

Comment 1. The Role of λ

- λ controls weight on structure vs data
- λ is fixed in current framework
- Structural models may fail in stressed markets
- λ may act as a regime-weighting parameter
- Suggestions: allow λ to vary with market conditions (e.g., VIX, volatility, liquidity)

Comment 2. Identification of Structural Parameters

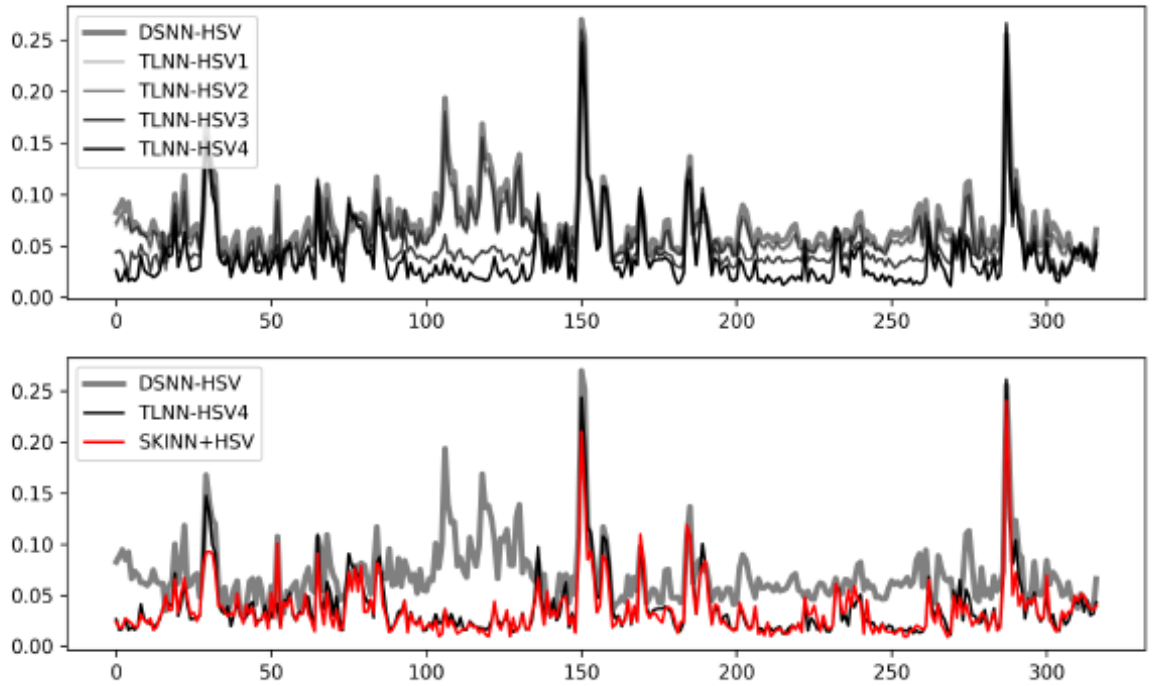
- Neural network is highly flexible
- Structural parameters may become weakly identified
- Risk that structural component becomes cosmetic
- ϕ has economic meaning: volatility dynamics; risk premia
- Suggestions: test under misspecification; show stability; provide economic interpretation

Comment 3. Interpretability and Decomposition

- Hybrid structure improves interpretability vs NN
- Still unclear what drives predictions
- Difficult to attribute performance: structural vs data-driven
- Suggestions: decompose predictions; provide case studies (e.g., stressed periods)

Comment 4. Benchmarking and Performance Comparison

- Pairwise DM tests show SKINNs outperform
- Visual evidence (e.g., Figure 9) shows less clear dominance
- Recent literature suggests transfer learning as strong benchmark
- Suggestions: include stronger benchmarks; clarify economic magnitude; reconcile tests vs visuals



Comment 5. Performance Metric: RMSE

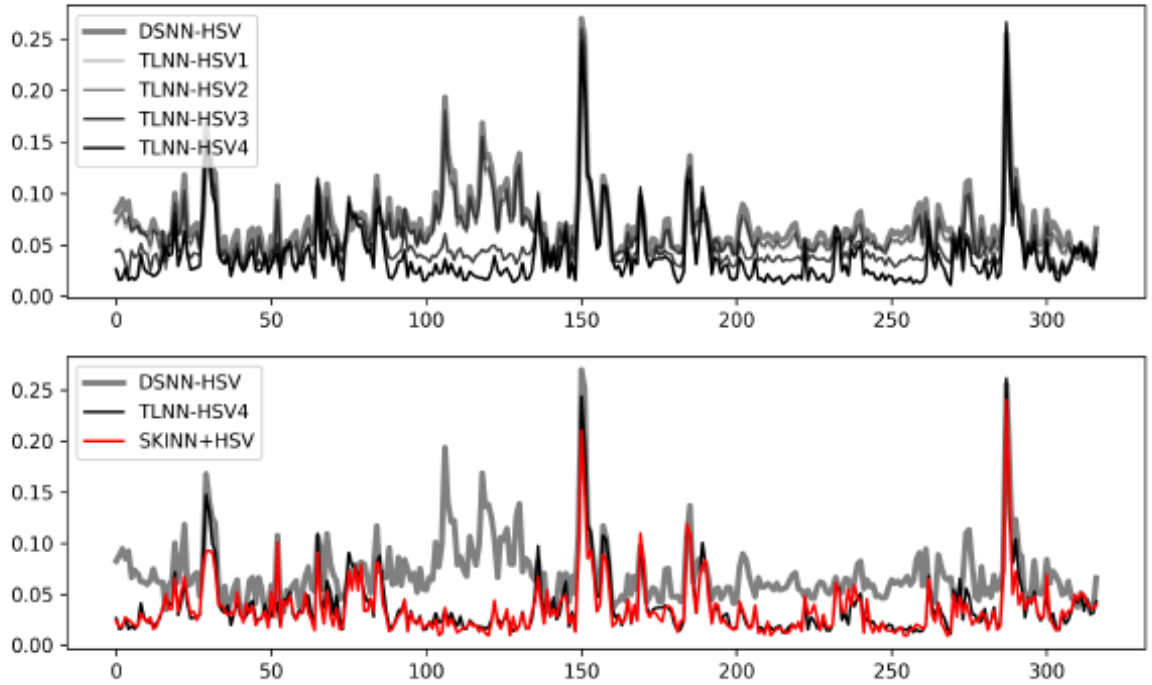
- RMSE evaluates pricing accuracy
- Appropriate for customer-facing pricing
- For market makers: pricing errors can create opportunities
- Mean-reverting errors can be profitable
- Large RMSE is not necessarily undesirable
- Suggestions: analyze error autocorrelation; evaluate trading strategy performance

Comment 6. Sensitivity to Structured Knowledge

- Performance depends on structural component
- Structural models differ in quality
- Unclear sensitivity to choice of structure as current draft does not compare SKINN models among themselves
- Suggestions: compare specifications; test robustness to weaker/stronger priors

Comment 7. Regime Differences and High VIX Periods

- Stronger (relative) performance in high volatility
- Stronger performance at longer horizons (why?)
- Suggestions: analyze crisis periods; clarify role of structure; characterize volatility exposure



Minor Comments

- Collocation may increase training cost and the magnitude is not clearly documented
- Suggestions: report training time; test sensitivity to grid; assess simpler setups
- Table legends often repetitive; figures not fully self-contained
- Suggestions: improve captions; make tables and figures self-contained