

Connecting the Dots: Navigating Credit Risk with Causal Discovery at Allegro Pay

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Risk Machine Learning,
Allegro Pay



Introduction

allegro pay.

**KUP TERAZ,
ZAPŁAĆ PÓŹNIEJ**

Płać za zakupy za 30 dni lub dziel na mniejsze części.
Sprawdź ile środków przyznamy Ci do wykorzystania!

[SPRAWDŹ SWOJE ŚRODKI](#)



Credit Risk

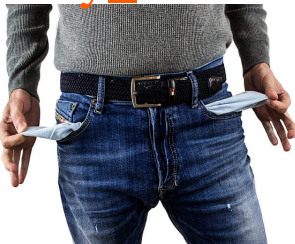
Credit Risk ~ borrower's inability/unwillingness to clear his debt on time

payments



FINANCIAL LOSS

money_off



CASH FLOW DISRUPTION

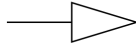
gavel



LEGAL & RECOVERY

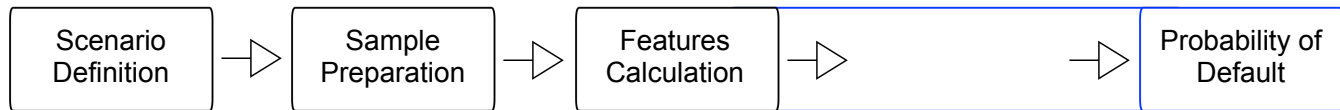
Measured as Probability of Default

Credit Risk ML Model



Probability of Default

WHAT IF?



Time-Consuming

Tiring

Might Become Costly

Scenario
Definition



Sample
Preparation



Features
Calculation



Credit Risk
ML Model



Time-Consuming

Tiring

Might Become Costly

Scenario
Definition



Sample
Preparation



Features
Calculation

Credit Risk
ML Model



Probability of
Default

What's the Risk
Trajectory?

How does it Relate to
Different Risk Sources?

What can we do about it?

Let's Build a Stress Testing Framework using Causal Inference Principles!

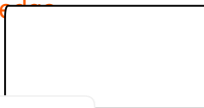
Is it a bird? Is it a DAG? No, it's our Custom Knowledge Graph!



Standard (FIBO)



Add E-Commerce and BNPL-Specific Knowledge



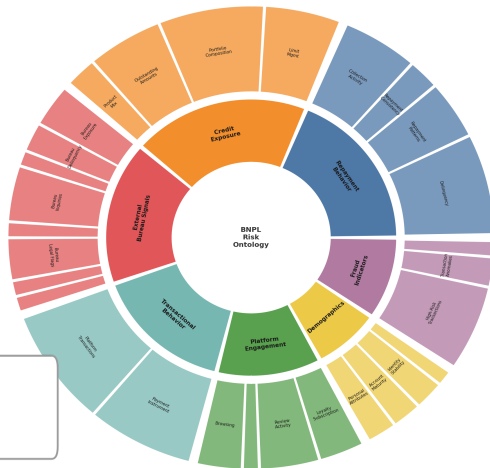
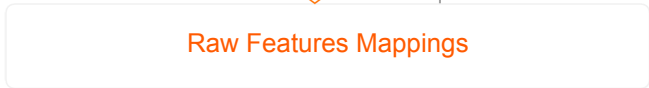
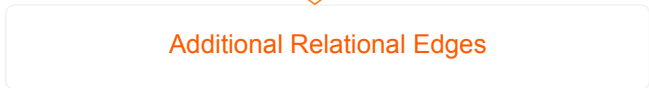
Concepts Hierarchy



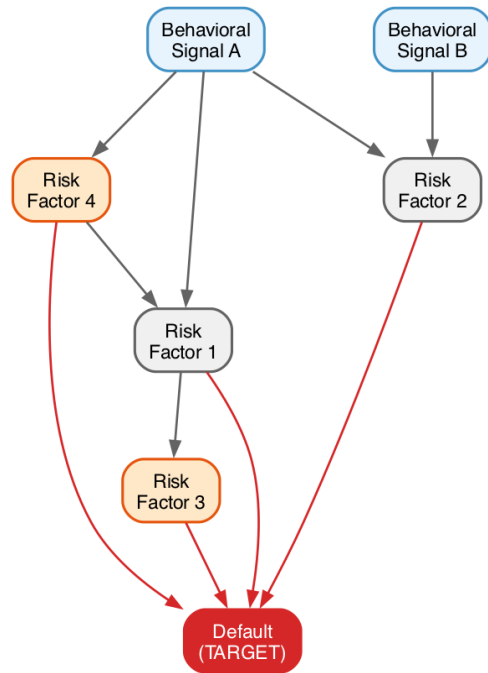
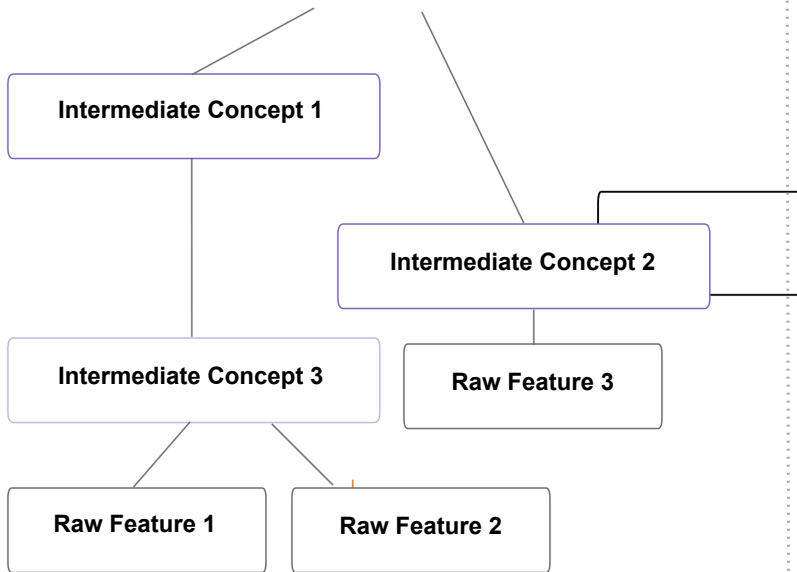
Additional Relational Edges

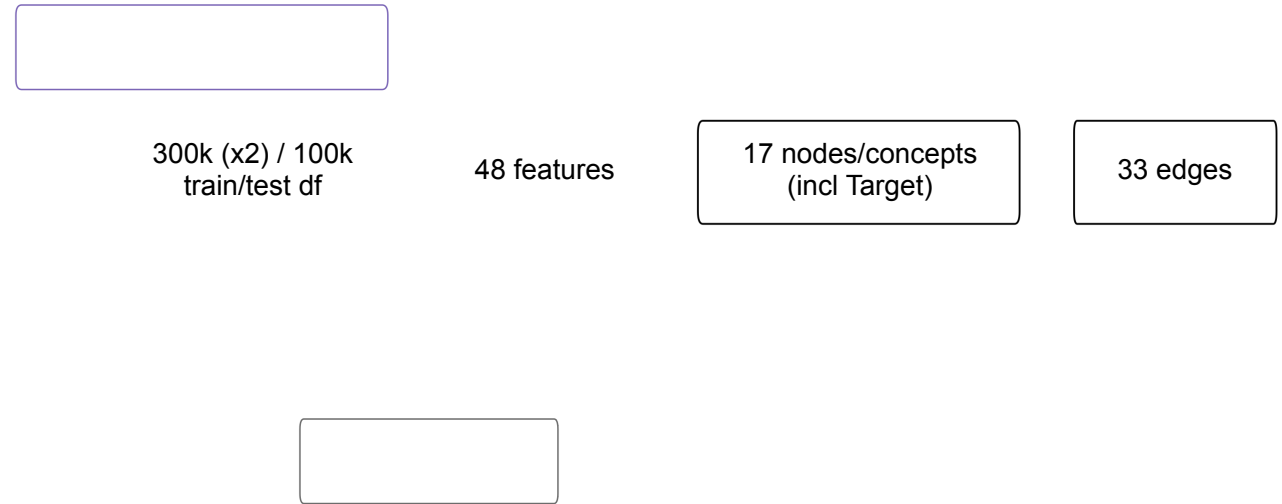


Raw Features Mappings



Root Concept





300k (x2) / 100k
train/test df

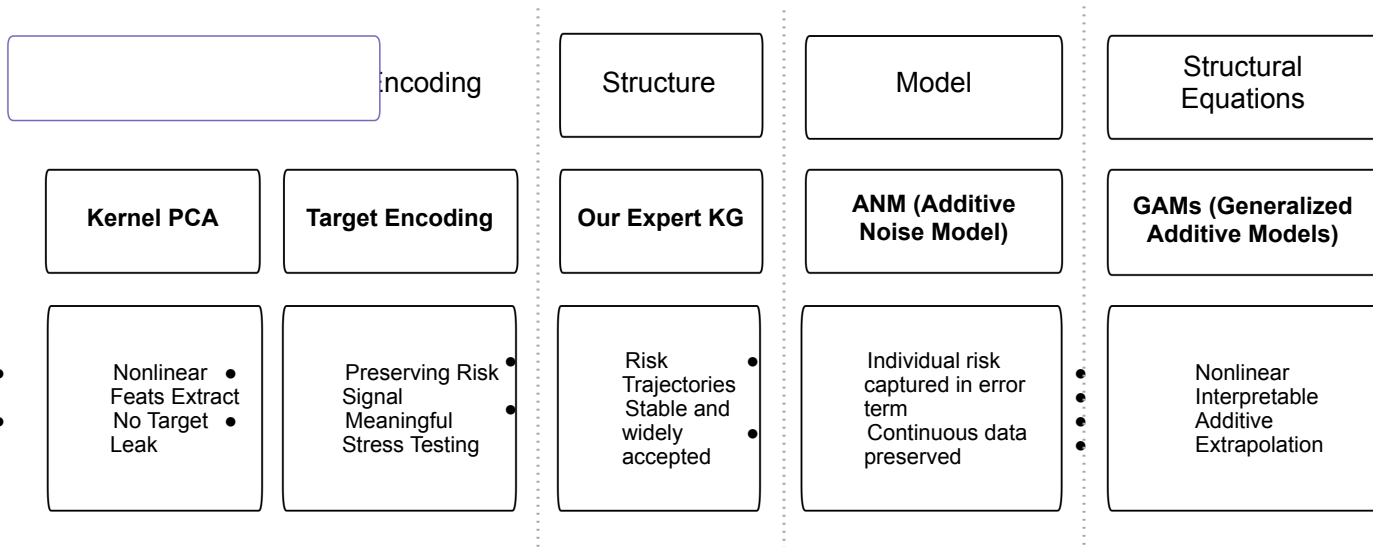
48 features

17 nodes/concepts
(incl Target)

33 edges

Structural Causal Model

SCM - “Proper” Causal Framework



How (is it Supposed to) Work?

Concepts

GAM Structural Equations:
 $X_{\text{child}} = \sum s_k(X_{\text{parent}_k}) + \varepsilon$

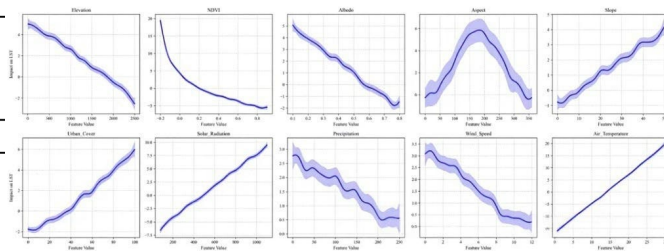
ANM assumption: $\varepsilon \perp X_{\text{parents}}$

Stress = intervene on X_{concept} , propagate forward through equations

-
-
-
-

Each Customer = Residual
Under Stress → Shift the Structural Equation
Keep the Residual
“Better than Expected Customer” Stays Better than Expected even under Stress

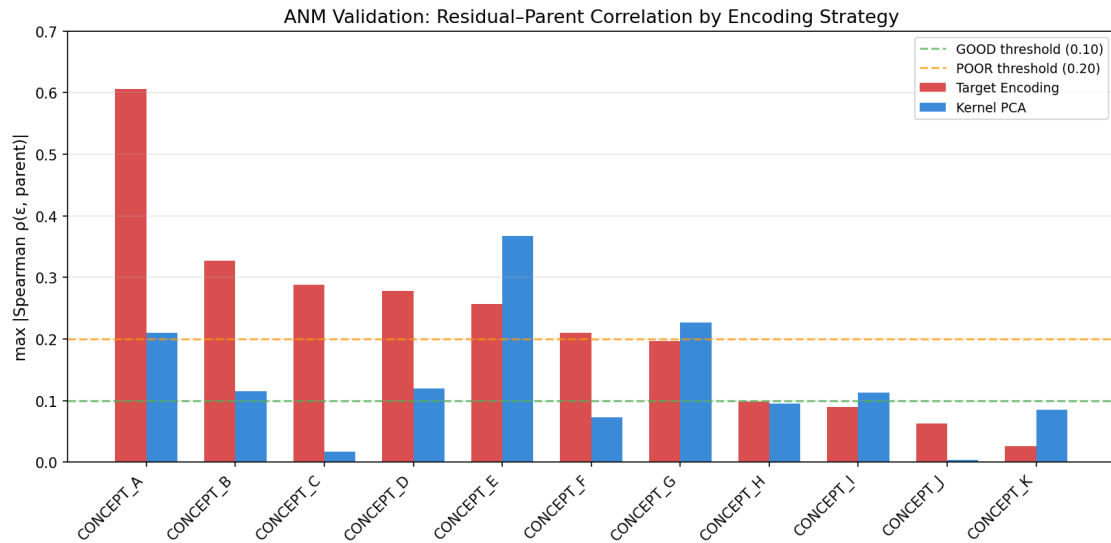
GAM Partial Dependence Plots



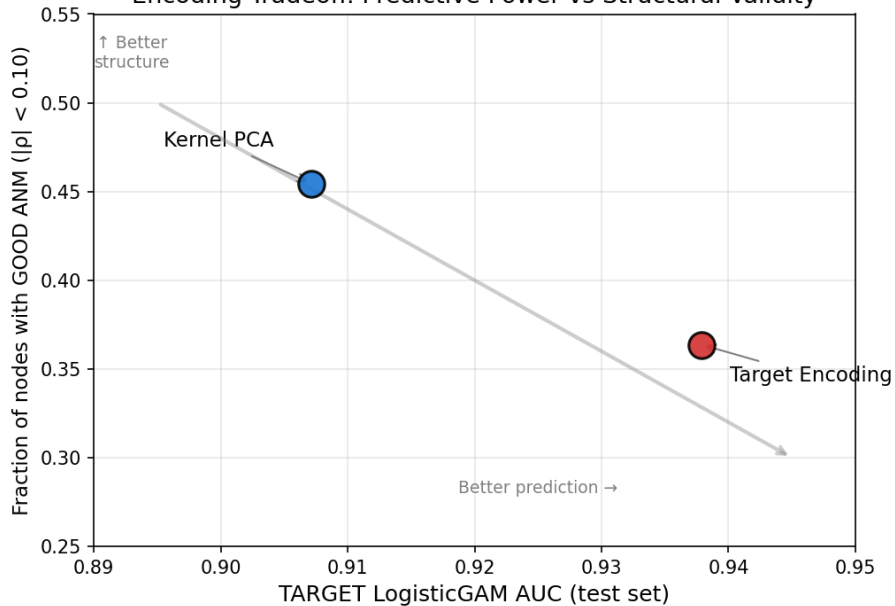
Hilbert-Schmidt Independence Criterion (HSIC)
Permutation Test for Error Term Independence ($\varepsilon \perp \text{Parents}$) — ANM Assumption

Node	HSIC p-value	Result
CONCEPT_A	0.0000	X VIOLATED
CONCEPT_B	0.0000	X VIOLATED
CONCEPT_C	0.0000	X VIOLATED
CONCEPT_D	0.0000	X VIOLATED
CONCEPT_E	0.0000	X VIOLATED
CONCEPT_F	0.0000	X VIOLATED
CONCEPT_G	0.0000	X VIOLATED
CONCEPT_H	0.0000	X VIOLATED
CONCEPT_I	0.0000	X VIOLATED
CONCEPT_J	0.0000	X VIOLATED
CONCEPT_K	0.0000	X VIOLATED

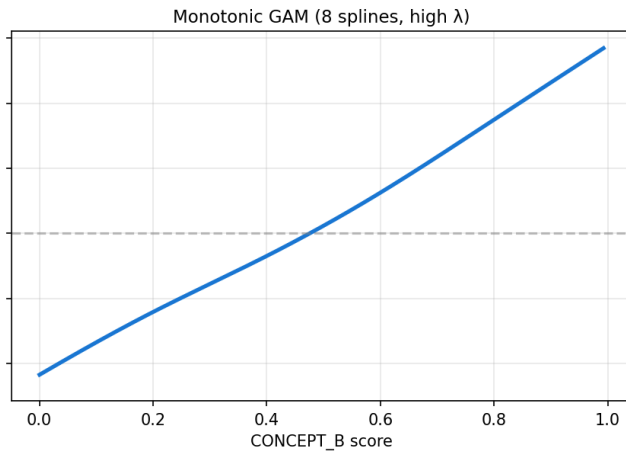
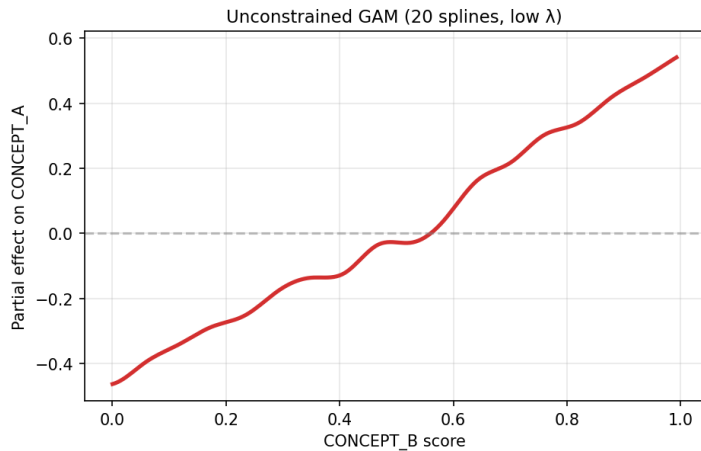
$n = 2,000$ (subsampled) · 1,000 permutations · $\alpha = 0.05$ · Result: 0/11 nodes pass



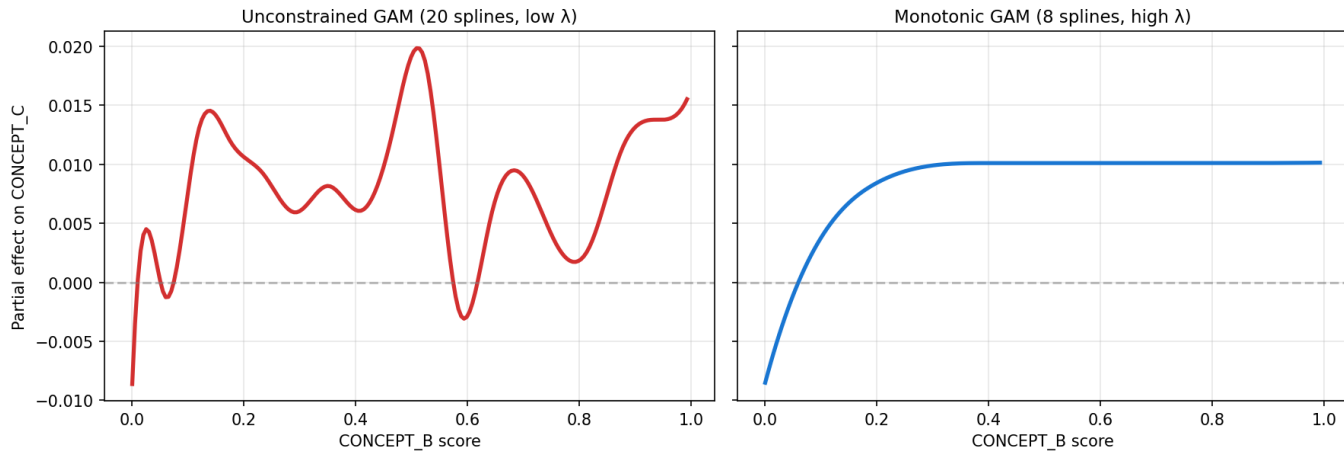
Encoding Tradeoff: Predictive Power vs Structural Validity



Partial Dependence: CONCEPT_B $\rightarrow$ CONCEPT_A



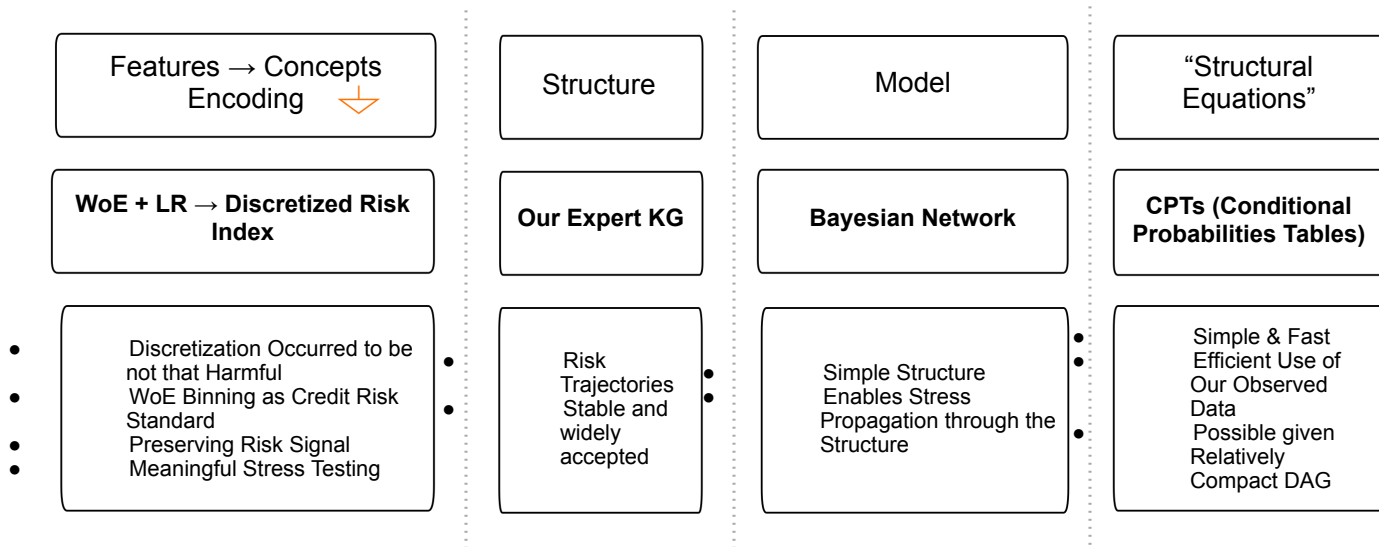
Partial Dependence: CONCEPT_B $\rightarrow$ CONCEPT_C



Directed by
ROBERT B. WEIDE

Bayesian Network

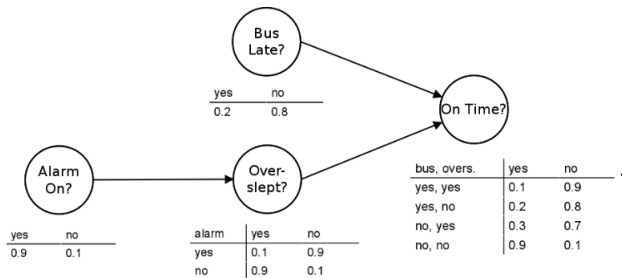
BN - Usable and Meaningful Structural Framework



How does it Work?

Features → Concepts

DAG Structure: Assumed using our Expert KG



Parameter Estimation
Baseline State Distributions - Empirical from
Training Data
CPTs: $P(\text{child}=k \mid \text{parent}_1=i, \text{parent}_2=j, \dots)$

Stress Application

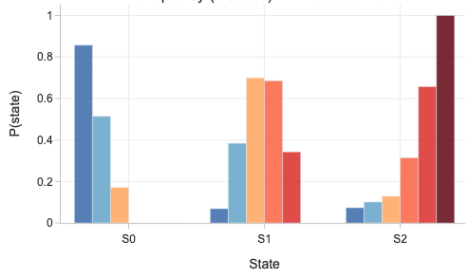
Choose: Concept(s), Fraction (% Affected), Severity (Shift Magnitude)
Shift State Distribution of Stressed Concept(s) Towards Worse States
Propagate through DAG via CPTs
(Parents → Children → ... → Target)
Infer Stressed PD through Exact Inference

Stress Testing Demo

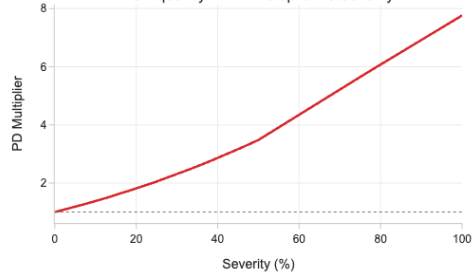
Stress Mechanics: How Severity Shifts State Distributions

sev=0% sev=20% sev=40% sev=60% sev=80% sev=100%

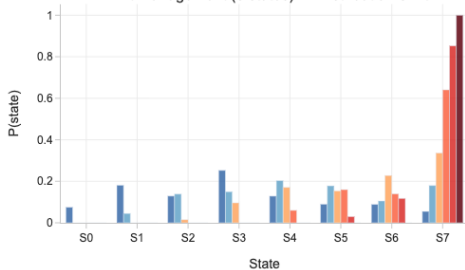
Delinquency (3 states) — Distribution Shift



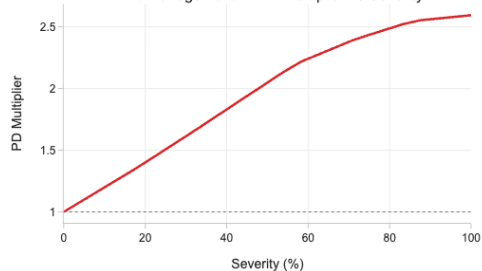
Delinquency — PD Multiplier vs Severity



Limit Management (8 states) — Distribution Shift



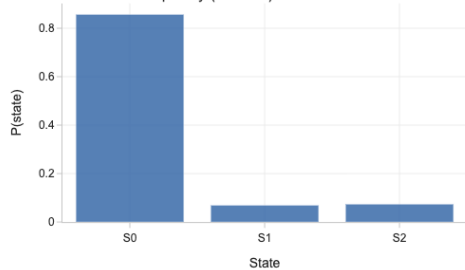
Limit Management — PD Multiplier vs Severity



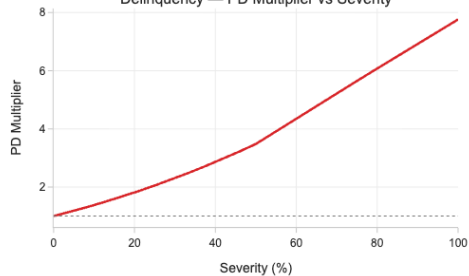
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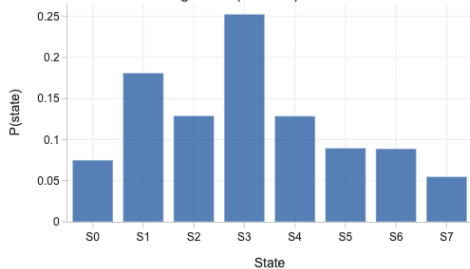
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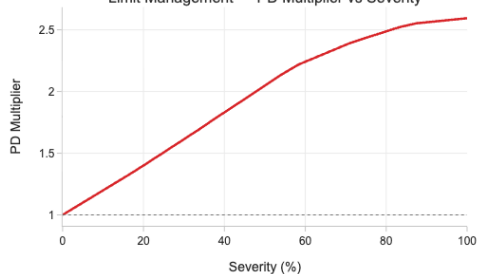
Delinquency — PD Multiplier vs Severity



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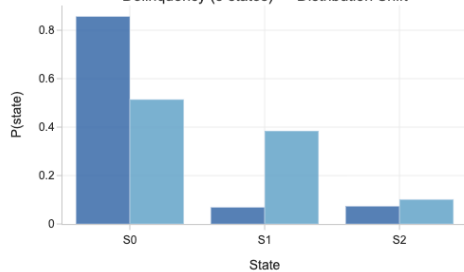
Limit Management — PD Multiplier vs Severity



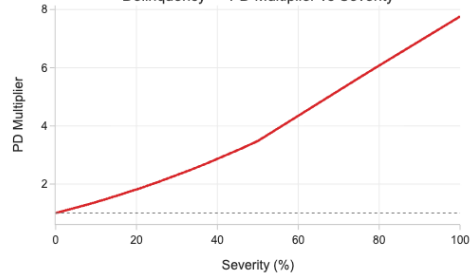
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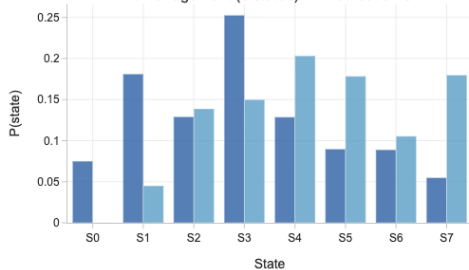
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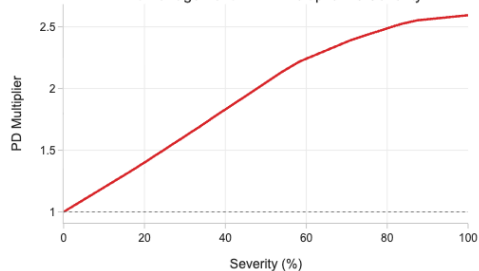
Delinquency — PD Multiplier vs Severity



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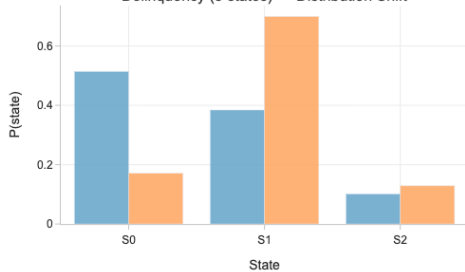
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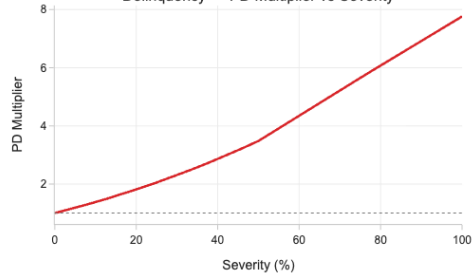
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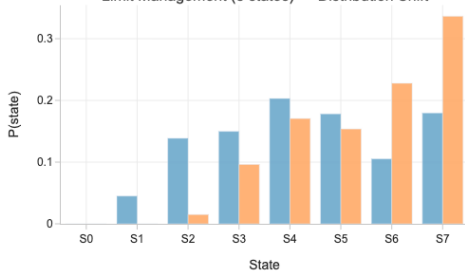
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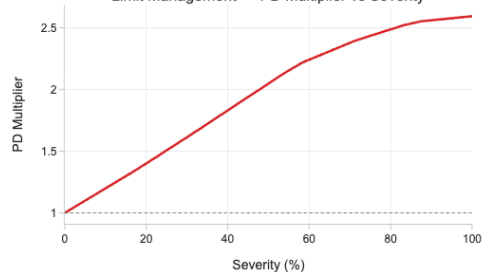
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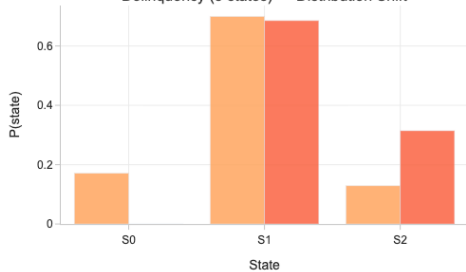
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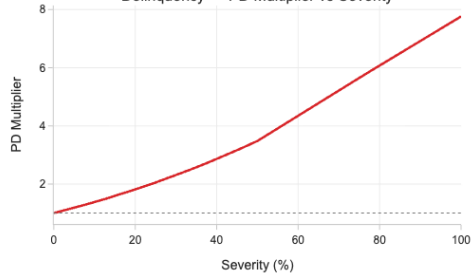
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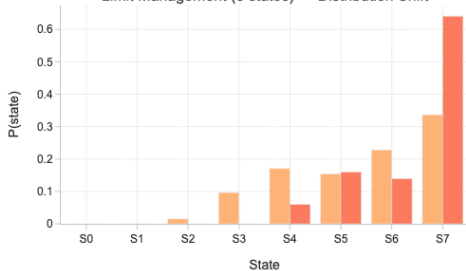
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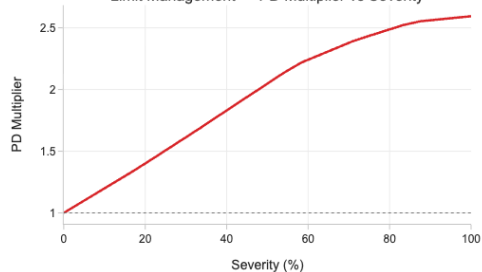
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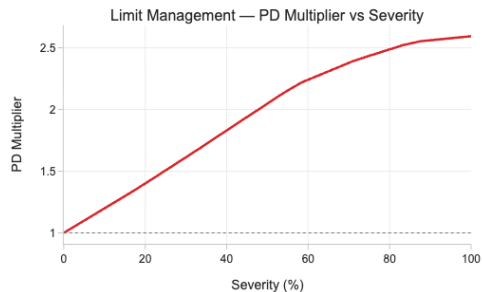
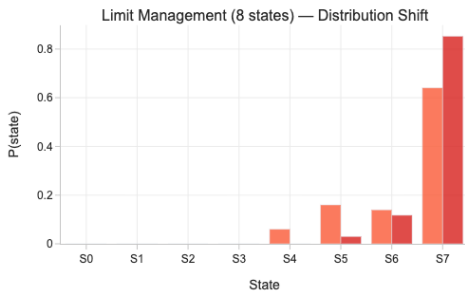
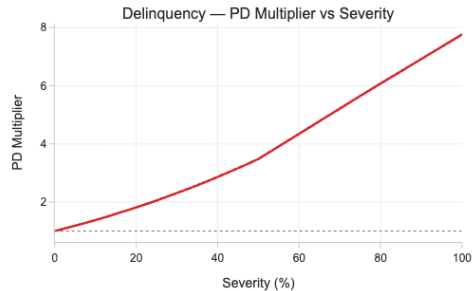
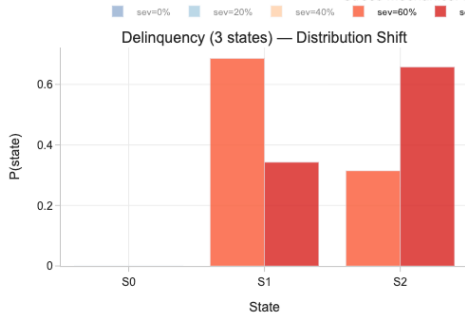
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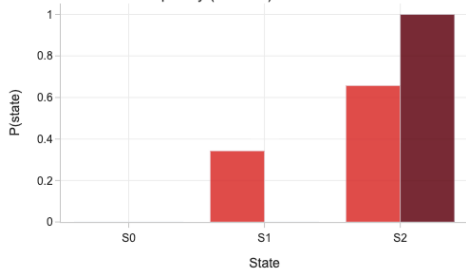
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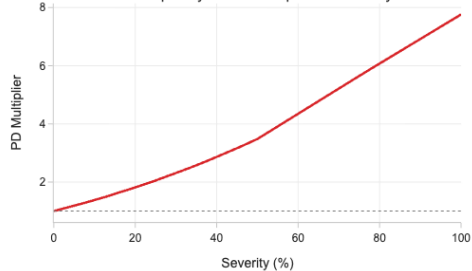
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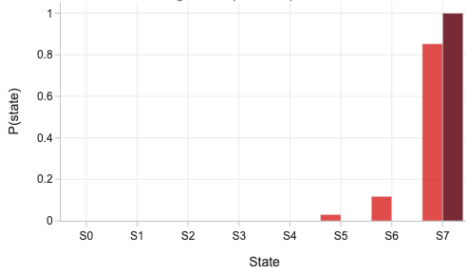
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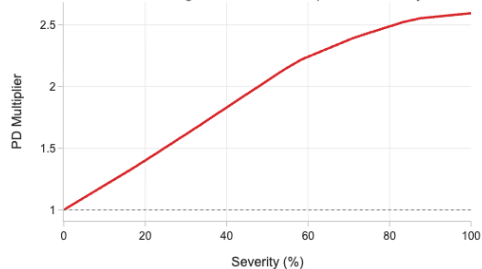
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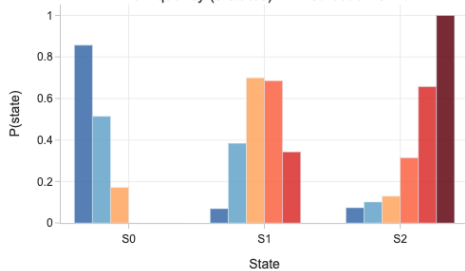
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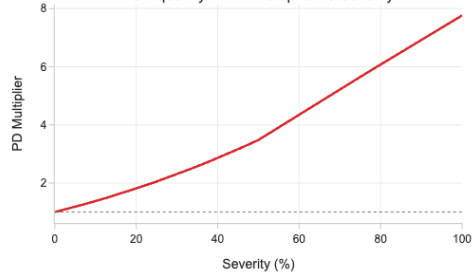
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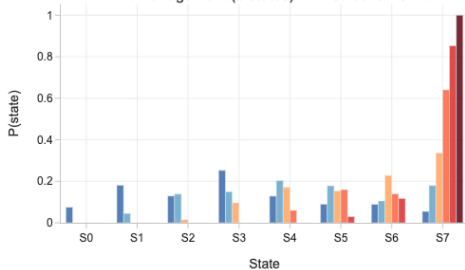
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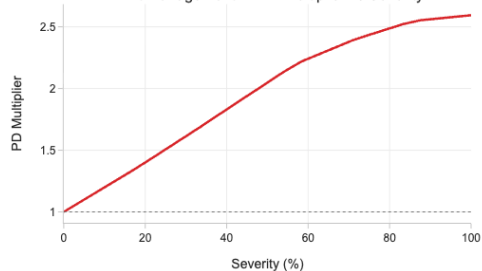
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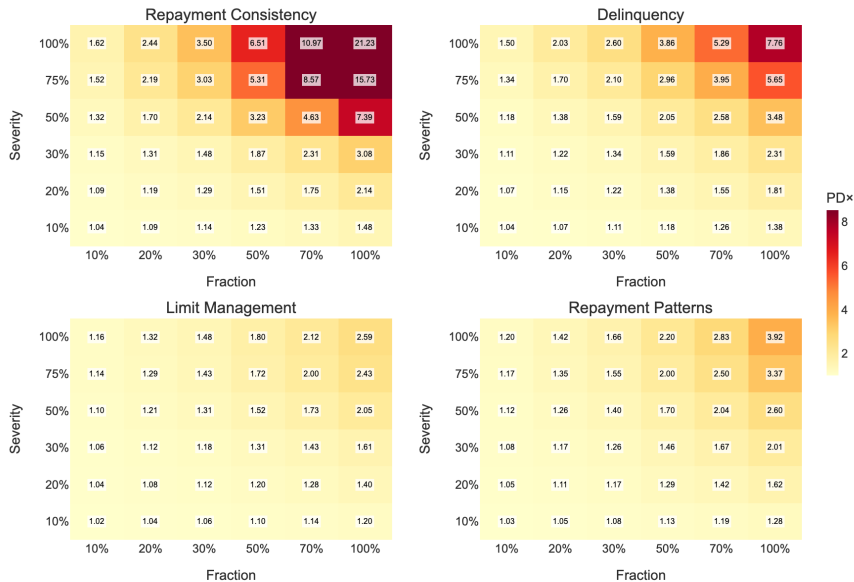
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Limit Management — PD Multiplier vs Severity

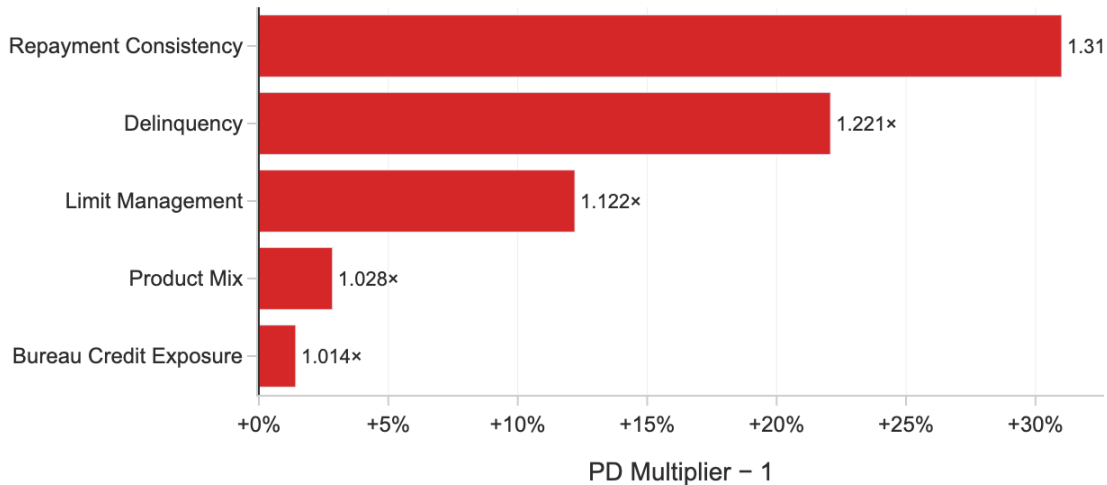


Severity Surface — PD Multiplier by Fraction × Severity



Single-Factor Sensitivity

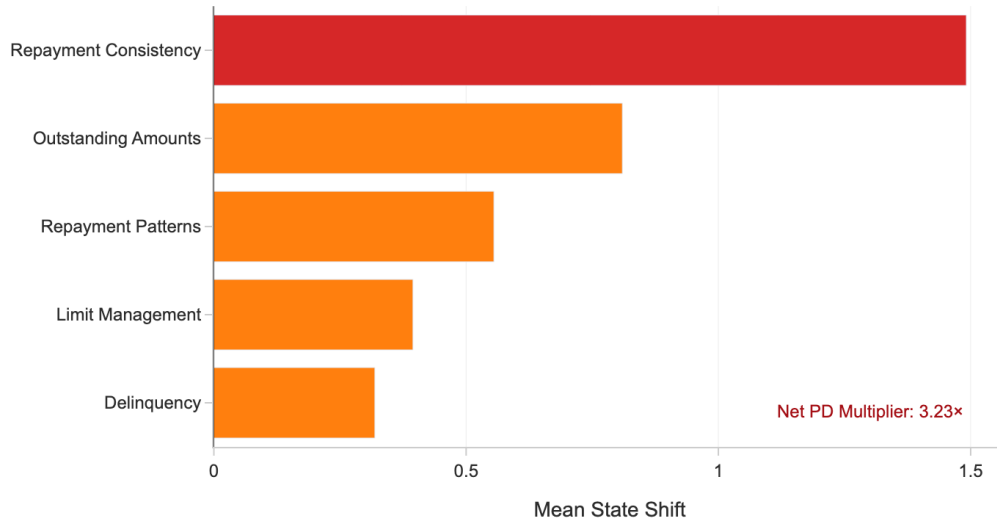
20% of portfolio affected, 30% severity



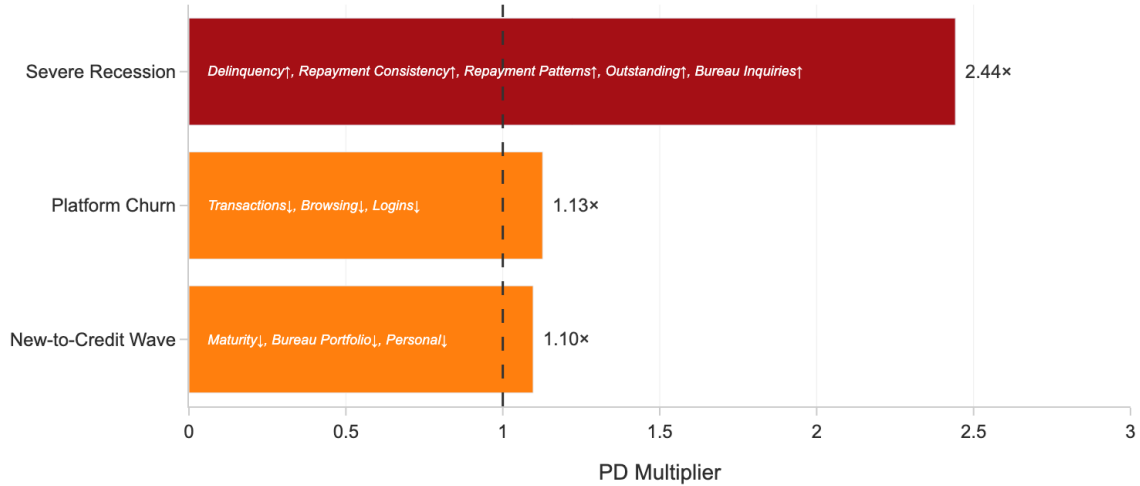
Causal Propagation: Repayment Consistency → Downstream Effects

Root node stressed (50% fraction, 50% severity)

■ Directly Stressed ■ Propagated via DAG



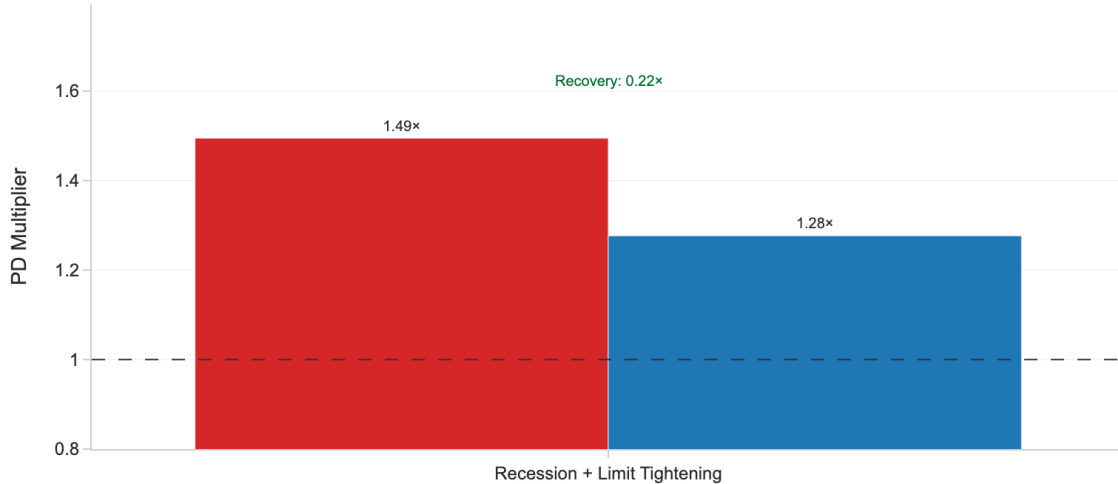
Stress Scenarios — PD Multiplier



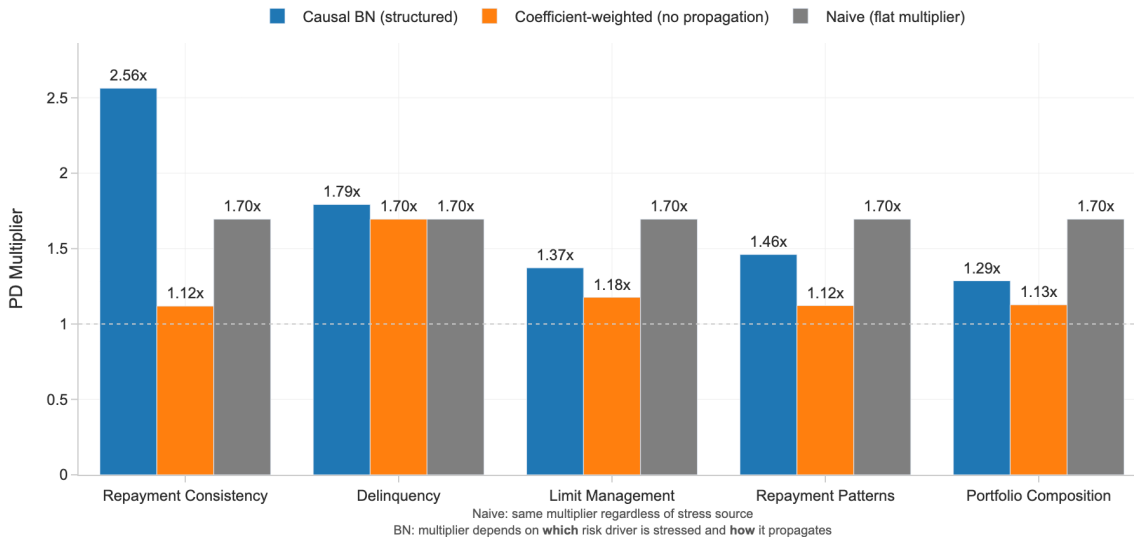
Counterfactual Interventions: Shock vs Net Effect After Response

Red = uncontrollable shock | Blue = net after our intervention

■ Shock Only (uncontrollable) ■ After Intervention (net)



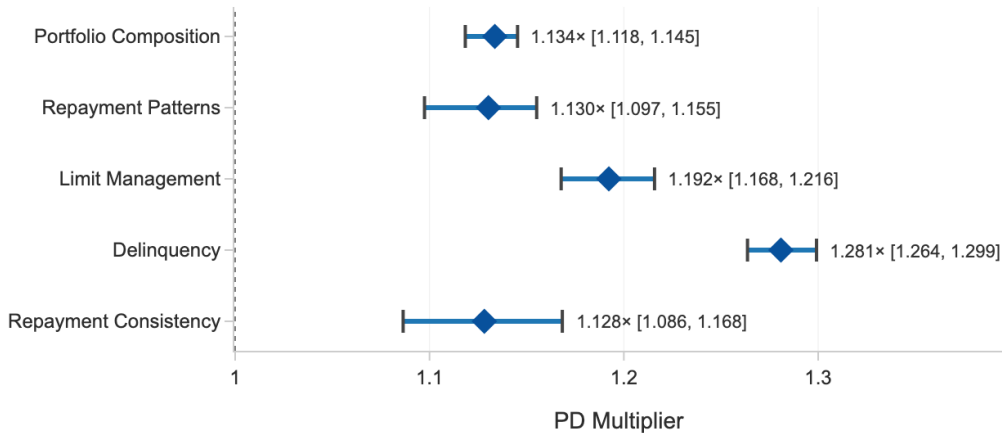
Why Structure Matters: Causal BN vs Naive Stress Testing



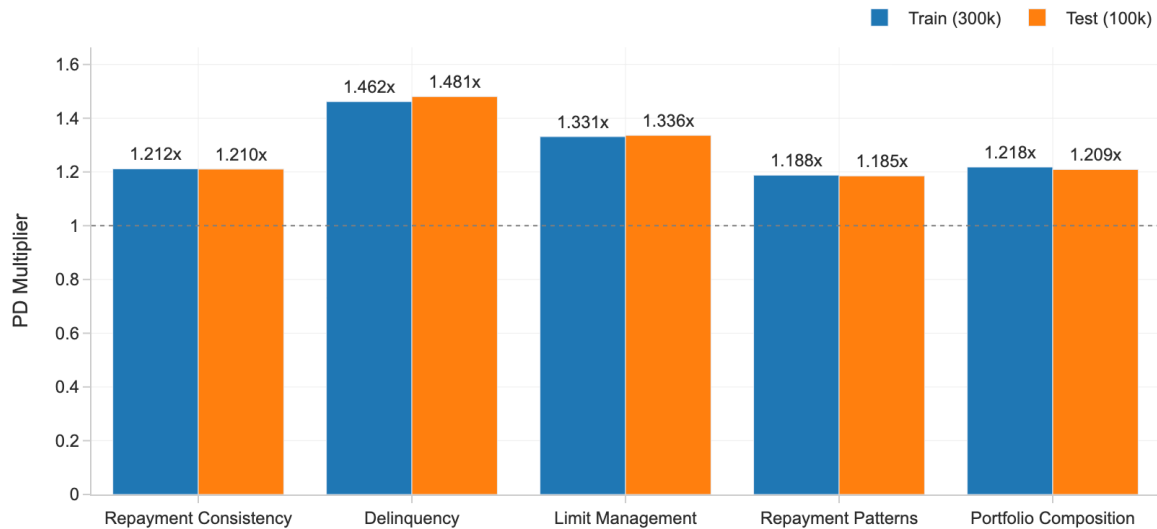
Do we Trust it?

Bootstrap 95% CI for PD Multipliers

50 resamples (300k each), 30% fraction, 30% severity

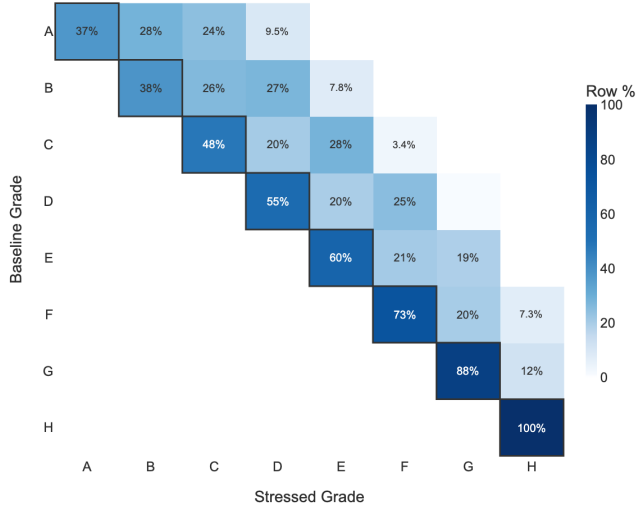


Train vs Test: PD Multiplier Stability (30% fraction, 50% severity)



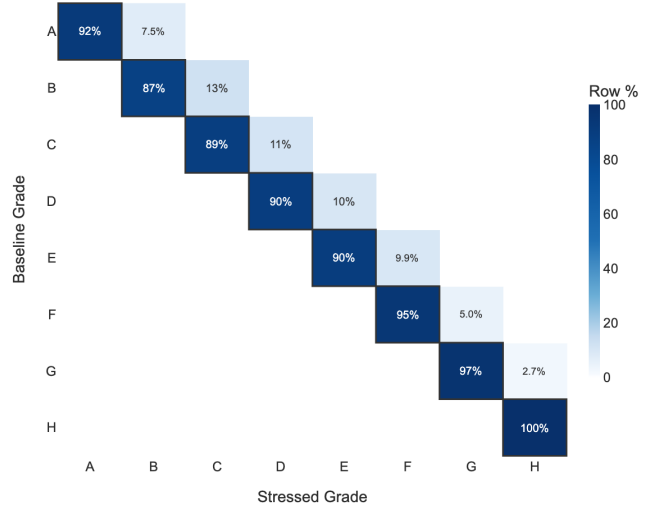
Rating Migration — Severe Recession

Avg stay-in-grade: 62.4% | Avg downgrade flow per grade: 37.6%



Rating Migration — Mild Downturn

Avg stay-in-grade: 92.7% | Avg downgrade flow per grade: 7.3%



Conclusions

You CAN Build Causal Stress Testing / Scenario Analysis Framework on Top of Existing Credit Risk / ML Infra

WoE + BN = Pragmatic Middle Ground Between “Just Multiply PD” and Full SCM

Sometimes Expert DAG > Discovered DAG - Your Domain Knowledge is the Asset

Real-World Data is Messy, but Useful

It's Fun (at least for me) :)



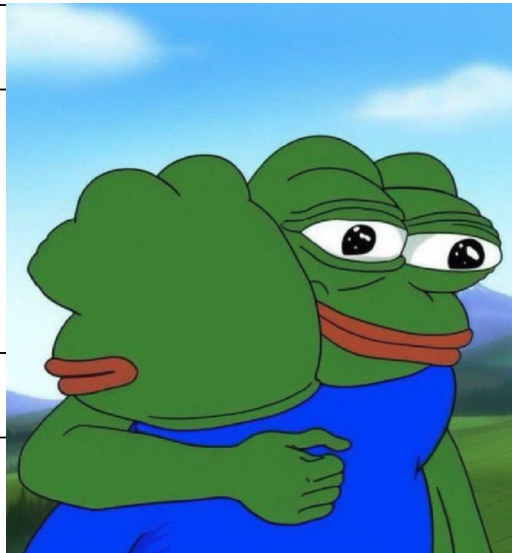
Limitations

No Extrapolation Beyond Observed states - we can only Redistribute Mass Across States we've Seen

Target is Used in Encoding - CPTs Inherit Associations from Encoding Step

Causal Direction is Assumed, not Tested - DAG Edges Reflect Expert Belief (it's Fine, but a Limitation)

Single Time Slice - no Temporal Dynamics



Future Work

Macro-Conditioned Stress (Unemployment, Inflation, Consumer Confidence)

Product-Level Actionable Scenarios - Abstract "Stress Concept X" → Business Decisions

Hierarchical Stress Decomposition - Stress at Ontology Root / Super-Concept Level

Revisit Continuous Structural Equations!

Hybrid BN + LGBM Scoring - BN for Direction and Magnitude, ML for Individual-Level Base PD



Thank You!
...Questions? :)