Choosing Regulatory Stress Scenarios to Control Systemic Risk

Matt Pritsker

Federal Reserve Bank of Boston and Office of Financial Research

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Based on "Choosing Stress-Scenarios for Systemic Risk Through Dimension Reduction" and "Network Uncertainty and Interbank Markets." The views in this presentation are those of the author and not necessarily those of the Federal Reserve Board, Federal Reserve Bank of Boston, others in the Federal Reserve System, and of the Office of Financial Research.

Outline

Motivation-I

- "Macroprudential" Stress-Testing of banks has become important.
- Basic U.S. methodology in banking book:
  1. Create 3 common regulatory scenarios. For each scenario:
     - Generate a path $\tilde{Z}$ for $\approx$ 30 macro/financial variables.
     - Other variables X set to $E(X|\tilde{Z})$.
  2. Each BHC creates BHC-scenarios **tailored** to its portfolio.
  3. Test BHC's capital adequacy in the scenarios.
  4. BHC's have to take "capital actions" if capital is inadequate.
- U.S. trading book methodology is similar but with 20,000 variables.
- **Goal** of stress-testing is to ensure systemic risk is low.
- **Question**: How should we choose regulatory scenarios to achieve the goal?
  1. Which variables should we stress?
  2. In what directions?
  3. By how much should variables be stressed?

Motivation-II

- TV Screen analogy for stress-testing.
  1. Each point on screen represents a different economic scenario.
  2. Stress tests illuminate banks losses *accurately* at a few points and ensure banks hold enough capital to be resilient near points stress-tested.
  3. Uncertainty about how far resilience extends.
- Approaches to improve stress-testing.
  1. Use multiple scenarios but give up some accuracy.
  2. Choose a few *robust* scenarios such that if banks are well capitalized against them, then systemic risk is low.
  3. Notions of systemic risk.
     - 3.1 The risk too many banks become undercapitalized together.
     - 3.2 Market breakdowns due to opacity of positions or network connections.

     Note: Undercapitalization exacerbates opacity problems.

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This Paper

- **Main features of approach**
  1. There is a systemic risk objective function.
  2. Banks exposures to many variables X used in scenario design.
  3. **Variable selection**: statistics identify which variables $x \in X$ are important.
  4. **Dimension reduction**: identify systemic risk factors F_A that depend on x
  5. A stress scenarios is $\tilde{F_A}$ and $X(\tilde{F_A}) = E(X|\tilde{F_A})$.
- **Main result**: [When there is no position opacity], A stress scenario can be chosen so that if banks are well capitalized for it, then *an approximation of systemic risk* is low.
- Variables to stress and directions and amounts to stress them are solved for automatically.
- **Extension**: Accounting for position and network opacity and uncertainty.

Main Ideas

1. X depends on a smaller set of factors $F = \{F_A, F_B\}$.
2. Banks hedge some factors (F_B) while remaining exposed to others (F_A).
3. Systemic risk is generated if banks become jointly undercapitalized due to their F_A exposures.
4. This suggests stress scenarios should be based on movement in F_A.
5. **Solution Approach**: Solve for scenario $\tilde{F}_A$ and $X(\tilde{F}_A)$ such that if banks hold enough capital to cover losses, then for other plausible scenarios banks joint distress is low, i.e. systemic risk is low with high probability.

- Roadmap.
    - Systemic Risk Measure: Prob banks experience low regulatory capital ratios together.
    - Methodology to identify F_A and choose stress scenarios.
    - Accounting for position and network uncertainty.

Systemic Risk Measure using System Assets in Distress (SAD)

- **Notation**: A_i = Assets, CI_i = Cap. Inj., $\tilde{X}$ = Variables , ω_i = Exposure.
- Bank i's maximal intermediation capacity $= \gamma A_i$.
- Bank i's distress $= D_i\left(\frac{\text{Cap}_{i(T)}}{\sigma_i(\text{Cap}_i)}\right) = D_i[\omega_i(\tilde{X}) + r_f CI_i] \in [0,1]$.
- Loss of i's capacity $= \gamma A_i \times D_i[\omega_i(\tilde{X}) + r_f CI_i]$
- Percentage of economy's intermediation capacity lost:

$$SAD_T(CI,\Omega,\tilde{X}) = \frac{\sum_i \gamma A_i \times D_i[\omega_i(\tilde{X}) + r_f CI_i]}{\sum_i \gamma A_i} = \sum_i w_i D_i[\omega_i(\tilde{X}) + r_f CI_i]$$

- **Systemic Risk**

$$\text{Systemic Impairment Threshold} = \zeta.$$

$$\psi = \text{Prob}(SAD_T(CI,\Omega,\tilde{X}) > \zeta) \text{ is a measure of systemic risk}$$

How Regulators Solve for F_A

- Assumptions:
  1. Regulators can randomly draw X from its distribution.
  2. Regulators know banks exposures to X, denoted $\omega_i(X)$
  3. Factors are a linear combination of X: $F_{A,k} = \sum \beta_{i,k} X_i$
  4. Factors can be identified by subset of variables $x \in X$.
- Methodology to identify F_A [Sliced Inverse Regression, Li (1991)].
  1. Make N draws of X (a function of F_A and F_B).
  2. Compute banks losses $\omega_i(X)$ (a function of F_A).
  3. Compute $SAD(\Omega(X))$ (a function of F_A).
  4. Compute $E(X|SAD)$ and $\Sigma_{E(X|SAD)}$ (functions of F_A).
- Under approp regularity condns the principal components of $\Sigma_X^{-1}\Sigma_{E[X|SAD]}$
  1. Span the same space as F_A
  2. Are ordered by their ability to explain systemic risk SAD.
  3. F_A can be identified even if SAD is nonlinear in F_A.
- If X is high dimensional need to use variable selection.

Choosing a Stress Scenario

- Estimate linear statistical relation between all variables X and the factors (F_A).

$$X = \alpha + F_A\theta + \epsilon_{B,X}$$

  where $\epsilon_{B,X}$ contains F_B factors against which banks hedge.

- Stress-scenario formation steps.
  1. Choose F_A realization.
  2. Set $X = E(X|F_A) = \alpha + F_A\theta$

- **Goal**: Choose the most plausible F_A for a scenario such that if banks are well capitalized for the scenario, then systemic risk is low.

  Note: Choosing F_A is reverse engineering.

SAD Approximation (ASAD) and Main Result

- Linearize banks portfolio value in X: $\omega_j(X) = X\omega_j$.
- Linearize SAD in banks portfolio value: $X\omega_j + CI_j r_f$:

$$\begin{aligned} ASAD &= \text{Const} + \sum_j D_{j,1}[X\omega_j + CI_j r_f] & (4) \\ &= \text{Const} + \sum_j D_{j,1}[(\alpha + F_A\theta + \epsilon_{B,X})\omega_j + CI_j r_f] & (5) \\ &= \text{Const} + \alpha + F_A\Theta + E + \text{Cap Inj. Equivalent (CIE)} & (6) \end{aligned}$$

- Estimate $H(.)$, the CDF of random variable $F_A\Theta + E$.
- Find CIE^* such that $\text{Prob}(ASAD \geq \zeta) \leq \psi$.
- Choose F_A^* such that banks losses require them to inject CIE^* of capital.
- **Main Result**: If stress scenario is $X = \alpha + F_A^*\theta$, equivalent capital injected will be approx CIE^*, and $\text{Prob}(ASAD \geq \zeta) \leq \psi$.

Results Recap

- Start with a systemic risk objective function.
- Find economic factors that explain systemic risk.
- Solve for stress-tests to ensure banking system is well enough capitalized against movements in the systemic risk factors.
- Beyond stress-testing the factors are potentially useful for identifying sources of financial fragility.
  - What directions do variables move as F_A changes.

    Example: If many banks were betting on yield curve steepening, the yield curve slope changes with F_A. We can detect that.
- Accounting for position uncertainty.
  1. Want low systemic risk as banks' exposures change.
  2. Want low systemic risk given banks' opacity.
  3. Want low systemic risk given uncertainty over counterparty exposures.

Accounting for Position Uncertainty

- Can account for position uncertainty in
  - Regulatory stress-testing.
  - Regulatory monitoring of the financial system.
- Accounting for position uncertainty / opacity in stress-testing.
  1. Simulate X variables and exposures ω.
  2. Solve for factors F_A such that if banks are well capitalized against its movements, then systemic risk is low given most realizations of ω and X.
     - Ideally should account for hedging or failures in hedging when modeling ω.
     - Ideally account for risk based capital regulations when modeling ω.
     - Ideally ω should be simulated to account for opacity ?
     - In these ideals, additional capital required for uncertainty/opacity covers failures in hedging or improves upon capital based on risk-based capital alone.

Accounting for Network Uncertainty

- I model banks connected through interbank market.
  1. Banks' annualized PD is proportional their distress: $PD = kD(.)$
  2. The return on interbank assets depends on ΔPD.

  1 and 2 $\Rightarrow$ banks distress functions are jointly determined.
- D(connected) solved around D(not connected) when interbank exposures are known:

$$\begin{aligned} D(T)(\text{connected}) &\approx (I-\psi)^{-1}D(T)(\text{not connected}) + \text{other terms} \\ &= [I+\psi+\psi^2+\ldots]D(T)(\text{not connected}) + \ldots \end{aligned}$$

$$\begin{aligned} \psi &= \Gamma \times \Omega_{IB} \times LGD \\ &= \text{Financial Fragility} \times \text{Interbk Port Wts} \times LGD \end{aligned}$$

- Implications:
  1. Interbk exposure uncertainty can be treated like position uncertainty.
  2. Network effects are small if fragility is kept small.

Figure: Network Uncertainty Effects Illustrated: Baseline

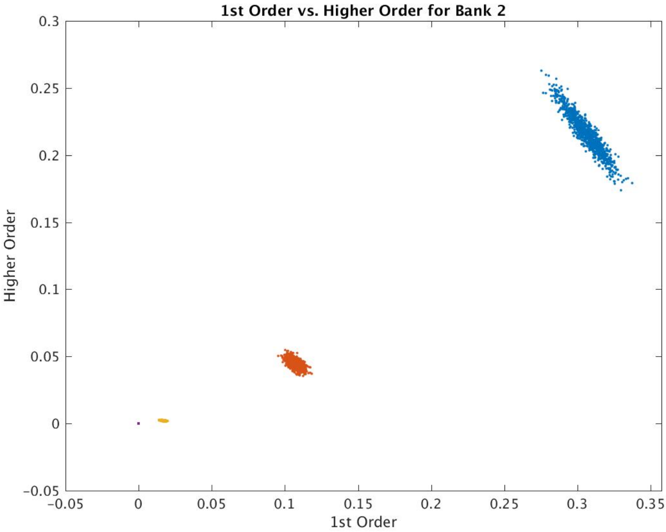
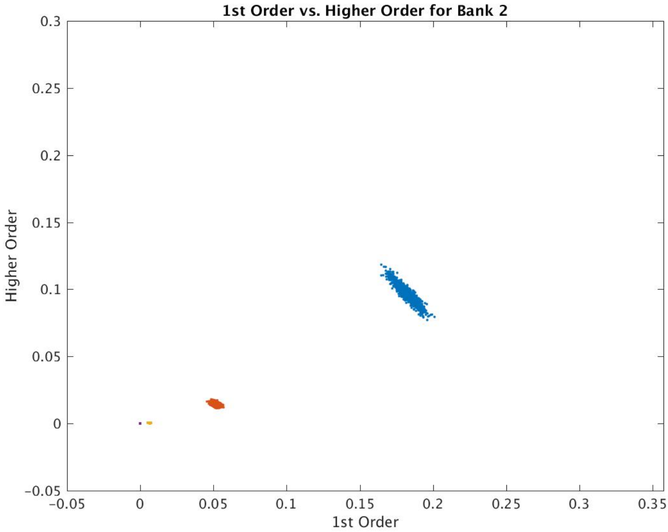


Figure: Network Uncertainty Effects Illustrated: Cap Injections



Summary

1. There is value in using an explicit systemic risk objective function in regulatory stress-testsing.
    - This provides an explicit goal for stress-testing.
    - It helps guide choice of variables, directions, and magnitudes of stresses.
    - A means of assessing what goals are achievable with stress-testing. Sometimes multiple scenarios are needed to achieve stress-testings goals. A reverse stress-test will not always achieve goals of stress-testing.
2. 2 forms of systemic risk discussed.
    - Banks becoming undercapitalized together.
    - Uncertainty / opaqueness over exposures including interbank exposures.
    - Keeping banks from becoming undercapaitalized helps avoid problems of opacity.
3. Much scope for further study on when and how to use stress testing.