Measuring Systemic Risk

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Joint work with

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Systemic Risk: Motivation

- Systemic risk can be defined as:
  - Joint distress of several financial institutions with externalities that disrupt the real economy

- Systemic risk is very costly
  - Bailout costs
    - Bank credit risk leads to sovereign credit risk
  - Impact on the real economy
    - GDP
    - Unemployment
    - World trade
  - Financial institutions fail to internalize externalities
Systemic Risk: Way Forward

- Systemic risk must be measured to be managed
  - Overall systemic risk:
  - Each institution’s contribution to systemic risk

- Once measured, financial institutions must be incentivized to
  - Internalize expected costs
  - Reduce risk taking and increase capital / reduce leverage
  - Consider interconnections

- The challenges are:
  - to use economic theory to find a measure of systemic risk
  - that is useful in managing it
  - and assess its empirical success
What are *Systemic Risk* and *Systemic Risk Contributions*?

- **Conventional wisdom:**

  Systemic risk (contribution) =
  
  - what would happen if bank X failed?
  
  - or, what crucial infrastructure is operated by bank X? (triparty repo, payment system, etc.)

- **Our view:**

  Systemic risk =
  
  - Too little aggregate capital in the financial system
    
    • Too little capital inhibits intermediation and credit provision
    
    • A failed bank with crucial infrastructure can be taken over if there is enough capital in the system
    
    • Example: Lehman vs. Barings

  Systemic risk contribution =
  
  - A financial institution’s capital shortfall when the aggregate capital in the system is too
Our Results: Insights from Economic Theory

- Each financial institution’s *contribution* to systemic crisis can be measured as its systemic expected shortfall (SES):
  - SES = expected capital shortfall, conditional on a future crisis

- A financial institution’s SES increases in:
  - its own leverage and risk
  - the system’s leverage and risk
  - the tail dependence between the institution and the system
  - the severity of the externality from a systemic crisis

- **Managing** systemic risk:
  - Incentives can be aligned by imposing
    - Systemic capital requirements
    - Systemic risk fee, and/or
    - Mandatory insurance scheme against systemic losses
How to regulate based on the systemic risk measure?
- We show that taxing based on SES implies that banks internalize externalities
- Taxing based on “crucial infrastructure” does not work since infrastructure crucial no matter how well capitalized

In case of tax, how to translate into right units?
- We show that SES is scaled in meaningful units

How to scale wrt. size of institution? Example, consider these three firms:
- Firm A = Citibank
- Firm B = 1 share of Citibank
- Firm C = 1 share of Citibank + $1 Trillion worth of Treasuries
- We show that SES taxes each correctly
- Other measure of systemic risk (e.g. based on “connections”) get this wrong
  - Same tax in dollars for A and B, or
  - Way higher tax for C than B

How to handle if institutions merge or split up?
- We show that SES handles this immediately
Our Results: Empirical Implementation

- Empirical methodology:
  - we provide a very simple way of estimating SES

- SES in the cross-section:
  - higher for securities dealers and brokers – every year 1963-2008
  - higher for larger institutions that tend to be more levered

- Institutions’ ex-ante SESs
  - predict their losses during the subprime crisis
  - with more explanatory power than measures of idiosyncratic risk
  - works with equity and CDS
  - predict the outcome of the stress tests

- SES in the time series:
  - higher during periods of macroeconomic stress, especially for securities dealers and brokers
Managing risk within and across banks

- Standard measures of risk within banks:
  - Value at risk: \( Pr( R \leq -VaR ) = \alpha \)
  - Expected shortfall: \( ES = -E(R \mid R \leq -VaR) \)

- Banks consists of several units \( i=1,\ldots, I \) of size \( y_i \):
  - Return of bank is: \( R = \sum_i y_i r_i \)
  - Expected shortfall: \( ES = -\sum_i y_i E(r_i \mid R \leq -VaR) \)

- Risk contribution of unit \( i \): Marginal expected shortfall (MES)
  \[
  MES^i := \frac{\partial ES}{\partial y_i} = -E[r_i \mid R \leq -VaR]
  \]

- We can re-interpret this as each bank’s contributions to the risk of overall banking system:
  The loss of bank \( i \) when overall banking is in trouble

- We develop an economic theory that extends these ideas
Economic model

- Many banks $i=1,..N$ and two dates

- Time 0: Choice of investments & leverage
  - Each bank has given initial level of capital $w_{i,0}$
  - Issue debt $b_i$ at face value $f_i$: a fraction $\alpha_i$ can be insured by govt
  - Assets: $a_i = w_{i,0} + b_i$
  - Allocate investments among $j=1…J$ risky assets and cash

- Time 1: Returns are realized
  - Limited liability if insolvent, but government bails out insured depositors

\[
\begin{align*}
\hat{y}_i^i &= \sum_{j=1}^{J} r_j^i x_j^i, \\
\phi^i &= \Phi (\hat{y}_i^i, f_i^i), \\
w_1^i &= \hat{y}_i^i - \phi^i - f_i^i
\end{align*}
\]
- $W_1$ be aggregate net worth of financial system at time 1
- Systemic distress happens if $W_1$ falls below a cutoff $W^* = zA$
- Imposes negative externality $e(W^* - W_1)$ on economy
  - Extension:
    - Institutions run crucial infrastructure
    - Endogenous merger market
    - Low aggregate capital ~ failures and inability of other institutions to take over

\[ W_1 = \sum_{i=1}^{N} \omega_i \]

\[ W^* = zA \]
Objective functions

- Each bank:
  \[
  \max_{w_0^i, \beta, \{\alpha_j^i\}} \ c \cdot (\bar{w}_0^i - w_0^i - \tau^i) + \mathbb{E} \left( u \left( 1_{[\omega_1^i > 0]} \cdot w_1^i \right) \right)
  \]

- Tax \( \tau^i \) is set by the planner whose objective is to maximize \( P_1 + P_2 + P_3 \):
  \[
  P_1 = \sum_{i=1}^{N} c \cdot (\bar{w}_0^i - w_0^i - \tau^i) + \mathbb{E} \left[ \sum_{i=1}^{N} \omega_1^i \left( 1_{[\omega_1^i > 0]} \cdot w_1^i \right) \right]
  \]
  \[
  P_2 = \mathbb{E} \left[ g \sum_{i=1}^{N} 1_{[\omega_1^i < 0]} \alpha^i \cdot w_1^i \right]
  \]
  \[
  P_3 = \mathbb{E} \left[ c \cdot 1_{[W_1 < zA]} \cdot (zA - \bar{W}_1) \right]
  \]
Economic model - results

- Without government intervention,
  - Banks choose leverage level and exposures \( x = (x_1, ..., x_S) \) with a risk level higher than socially optimal.

- To correct this, government could charge a tax based on two components:

\[
ES^i = -E \left[ w_1^i \mid w_1^i < 0 \right] \quad \text{and} \quad SES^a = E \left[ z a^i - w_1^i \mid W_1 < zA \right]
\]

\[
r^i = \frac{\alpha_i \theta \cdot P_r(w_1^i < 0) \cdot ES^i + \epsilon \cdot P_r(W_1 < zA) \cdot SES^a}{c}.
\]

- In our model, these are sufficient metrics of systemic risk contributions available to design optimal taxation (a normative benchmark)
Efficient regulation

- Tax system with two components

- **Default Expected Shortfall (DES):**
  - *The bank’s expected losses upon default*
  - Analogous to the FDIC insurance premium.
  - Justified by government guarantees on deposits and related cost (g).

- **Systemic Expected Shortfall (SES):**
  - *The bank’s expected losses in a crisis*
  - Expected contribution of bank to the aggregate shortfall of capital during a crisis.
  - Justified by the externality (e).
A bank’s SES is larger if
- the externality is more severe \((e)\),
- systemic under-capitalization is more likely \((Pr[W_l < W^*])\)
- the bank takes a larger exposure \((x_s)\) in an asset \(s\) that experiences loses when other banks are in trouble
- the bank is more leveraged \((w_0)\)

In our empirical work, we focus on the cross-sectional part of SES, taking as given (i) the size of externality or the level of tax; (ii) the likelihood of systemic crisis, the time-series part
Empirical Methodology

- **MES:**
  - Very simple non-parametric estimation:
    - find the 5% worst days for the market
    - compute each institution’s return on these days
  - Parametric

- **SES:**
  - Consider both MES and Leverage

- **Data:** CRSP and COMPUSTAT

- **Tests**
  - Stock returns during July 2007- Dec 2008
  - CDS changes during July 2007- Dec 2008
  - First set of stress tests
2007-08: Predictive power of MES (Equity)

Return during crisis: July07 to Dec08

MES5 measured June06 to June07
## 2007-08: Predictive power of MES (Equity)

Panel A. OLS regression analysis: The dependent variable is Realized SES, the company stock returns during the crisis

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Lasse H. Pedersen
2007-08: Predictive Power of MES (CDS)
 Directed by Rob Engle

We have introduced a page providing estimates of risk for the largest US and global financial firms

**NYU Stern Systemic Risk Ranking:** Risk is estimated both for the firm itself and for its contribution to risk in the system.

This is updated weekly/daily to allow regulators, practitioners and academics to see early warnings of system risks.

Extended to global firms: Collaboration with Universite de Lausanne and Australian Graduate School in Sydney
NYU-Stern VLAB’S Risk Page

Systemic Risk Rankings for 2012-11-02 (MES is equity loss for a 2% daily market decline)

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<th>Institution</th>
<th>SIRSk (RNK)</th>
<th>SIRSk (s)</th>
<th>MES</th>
<th>Beta</th>
<th>Cor</th>
<th>Vol</th>
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Plot Options
- SIRsk
- MES
- Betas
- Correlation
- Volatility
- Leverage

Display Options
Firms to display: 160
Implementation: Our proposal

- SES signals institutions likely to contribute to aggregate crises

Three ways to implement our proposal

1. **Systemic Capital Requirement**
   - Capital requirement proportional to estimated systemic risk

2. **Systemic Fees (FDIC-style)**
   - Fees proportional to estimated systemic risk
   - Create systemic fund

3. **Private/public systemic insurance**
   - Compulsory insurance against own losses during crisis
   - Payment goes to systemic fund, not the bank itself
   - Insurance from government, prices from the market
     - Say 5 cents from private; 95 cents from the government
     - Analogy to terrorism reinsurance by the government (TRIA, 2002)
     - A market-based estimate of the contribution to crises and externalities
       » Private sector has incentives to be forward looking

Gives bank an incentive to be less systemic and more transparent:

- To lower capital requirements/ fees/ insurance payments
Conclusion: Systemic Risk

- Economic model of systemic risk gives rise to SES
  - *How under-capitalized is a particular institution expected to be if the overall system becomes under-capitalized?*

- Systemic expected shortfall (SES)
  - Measures each financial institution’s *contribution* to systemic crisis
  - Increases in: leverage, risk, comovement, tail dependence
  - An SES tax/insurance incentivizes banks to contribute less to crisis

- Empirically
  - Ex ante SES predicts ex post crisis loses
  - We analyze its cross-sectional and time series properties
Two Approaches to Regulation

- Traditional approach: Firm-level risk management
  - Goal: Limit risk of collapse of each bank seen in isolation
  - Requirement: Detailed knowledge of activities inside the firm

- We advocate in addition: Systemic approach
  - Goal: Limit risk of collapse of the system
  - Requirement: Understand risks and externalities across firms