

# Measuring Systemic Risk

Viral V Acharya, Lasse Heje Pedersen,  
Thomas Philippon, and Matthew Richardson

*New York University Stern School of Business*

*NBER, CEPR*

# Systemic Risk

- What is systemic risk?
  - Widespread failure of financial institutions or freezing of capital markets that impair financial intermediation – payments system and lending to corporations/households.
- When does it emerge?
  - Financial sector has too little capital to cover its liabilities.
- In this crisis,
  - In early Fall of 08, the GSEs, Lehman, Merrill Lynch, Wamu, Wachovia, Citigroup, ... effectively failed. Markets were already or began to freeze.
  - Outcome of systemic risk in the Fall of '08 and Winter '09:
    - Stock Markets: US -42%, UK -46%, Europe -49%, Japan -35%, Latin America -50%
    - GDP: Advanced economies -3.2%, Global -0.8%
    - International Trade -12%

# Challenges for Systemic Regulation

- Identify ex-ante the firms that pose greater systemic risk
- Make firms internalize external costs of systemic risk
- Outline of our work
  - Start from simple economic theory
  - Identify sensible measure of systemic risk
  - Provide empirical evidence of its usefulness, e.g., (i) stress tests of Spring 2009, and (ii) Equity decline in 2007-08
  - Propose a regulatory system to achieve regulatory goals (“A Tax on Systemic Risk”, forthcoming, NBER proceedings on *Quantifying Systemic Risk*, Joe Haubrich and Andy Lo, eds. 2010)

But first, from 100 largest financial firms, here are percentage contributions to systemic risk on march 2007 and august 2008, and per share risk estimates (given a loss of at least 2% on the market)

FIRM	% cont 3/07	Per share risk	FIRM	% cont 8/08	Per share risk
Morgan S	19	4.33	Citi	14	4.13
Merrill L	14	4.05	Merrill L	8	5.87
Goldman S	12	3.94	Morgan S	8	5.00
Lehman	10	4.70	BofA	8	2.94
Freddie	10	2.33	Goldman S	7	4.6
Fannie	9	2.52	Freddie	7	3.74
Bear S	7	4.40	JPM	7	2.62
Citi	6	2.48	Fannie	6	3.97
Metlife	3	2.21	Lehman	5	7.74
JPM	2	2.16	Wachovia	5	3.52
Hartford	2	1.96	AIG	5	2.98
Prudential	2	1.60	WaMu	2	5.70
Lincoln	1	2.31	Pru	2	2.59
WaMu	1	2.13	Hartford	2	2.54

# Related literature

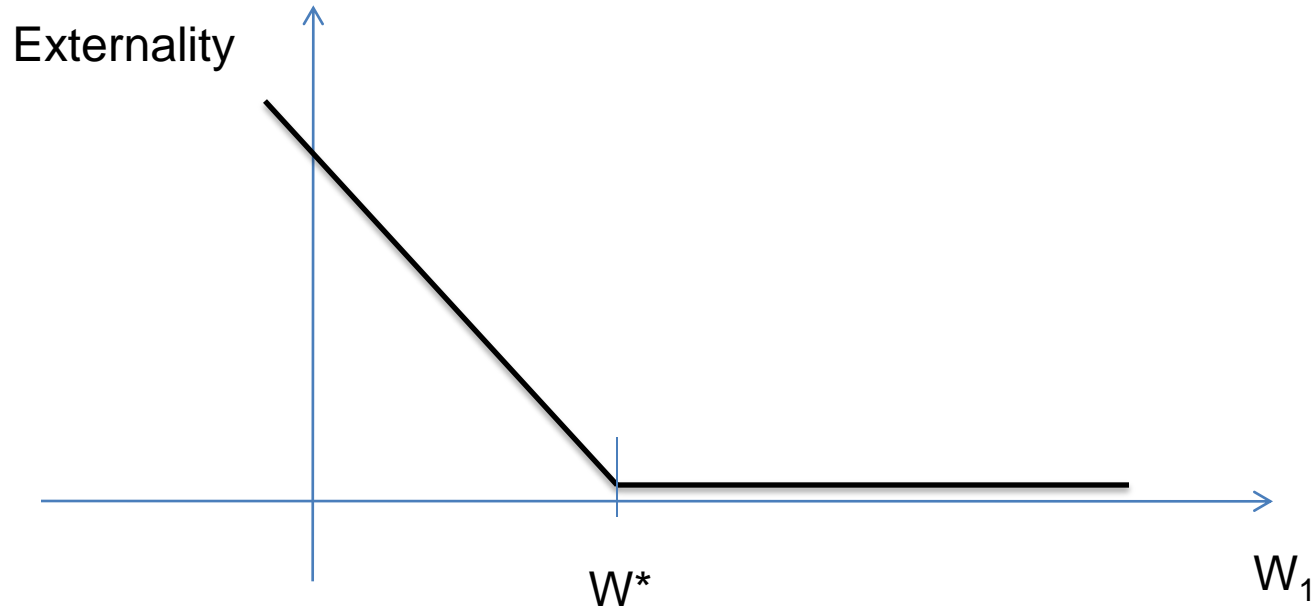
- Contingent claims analysis
  - Lehar (2005), Gray, Merton, and Bodie (2008), Gray and Jobst (2009)
- Statistical measures:
  - De Bandt and Hartmann (2000), Hartmann, Straetmans and de Vries (2006), Huang, Zhou, and Zhu (2009), Adrian and Brunnermeier (2009), Tarahev, Borio and Tsatsaroinis (2009), De Jonghe (2009)
- Other proposals
  - Kashyap, Rajan, and Stein (2008), Wall (1989), Doherty and Harrington (1997), Flannery (2005), Hart and Zingales (2009), Squam lake group's report, NYU book (chapter 13), ...

# I. THEORY - Our 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/deposits implicitly or explicitly insured by government
  - Allocate investments among  $s=1..S$  risky assets and cash
- Time 1: Returns are realized
  - Returns realized. Pay creditors, keep profits.
  - Limited liability: if insolvent, government bails out depositors & potentially some debt holders

# Our model: Externality

- Let  $W_1$  be aggregate net worth of financial system at time 1
- Systemic distress happens if  $W_1$  falls below some cutoff  $W^*$
- Imposes negative externality  $e(W^* - W_1)$  on economy



# Economic model - results

- Without government intervention,
  - Banks choose leverage level and exposures  $x=(x_I, \dots, x_S)$  with a risk level higher than socially optimal.
- To correct this, government could regulate
  - Leverage level (capital requirements)
  - Exposures  $x=(x_I, \dots, x_S)$  (Glass-Steagall)
  - Or, optimally, charge a “tax”/”insurance premium”
- What is the “best” regulation?
  - We assume sufficient metrics of systemic risk contributions available to design optimal taxation (a normative benchmark)



# Efficient regulation

- Tax system with two components

$$\tau_i = DES_i + e \cdot SES_i$$

- Default Expected Shortfall (DES):

- *The bank's expected losses upon default*
- Analogous to the FDIC insurance premium. Justified by government guarantees on deposits.

- 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  $e$ .

## II. MEASURING SYSTEMIC RISK

$$e \cdot SES_i = \left\{ e \cdot \left[ \left( z \sum_{i=1}^N a^i - \sum_{i=1}^N w_1^i \right) \cdot I \right] \cdot \Pr(I) \right\} \cdot \left\{ E \left[ \left( z a^i - w_1^i \right) \cdot \frac{1}{z \sum_{i=1}^N a^i - \sum_{i=1}^N w_1^i} \mid I \right] \right\}$$

where  $I \equiv 1_{\left[ \sum_{i=1}^N w_1^i \leq z \sum_{i=1}^N a^i \right]}$

Two components:

- Expected systemic costs (e.g., Caprio & Klingebiel (1996), Honohan & Klingebiel (2000), Hoggarth, Reis & Sapporta (2002), Reinhart & Rogoff (2008), Borio & Drehmann (2009)).
- % contribution to losses of the financial sector.

We focus on the second component (cross-sectional) as opposed to the first component (time-series).

# Measuring Systemic Risk continued...

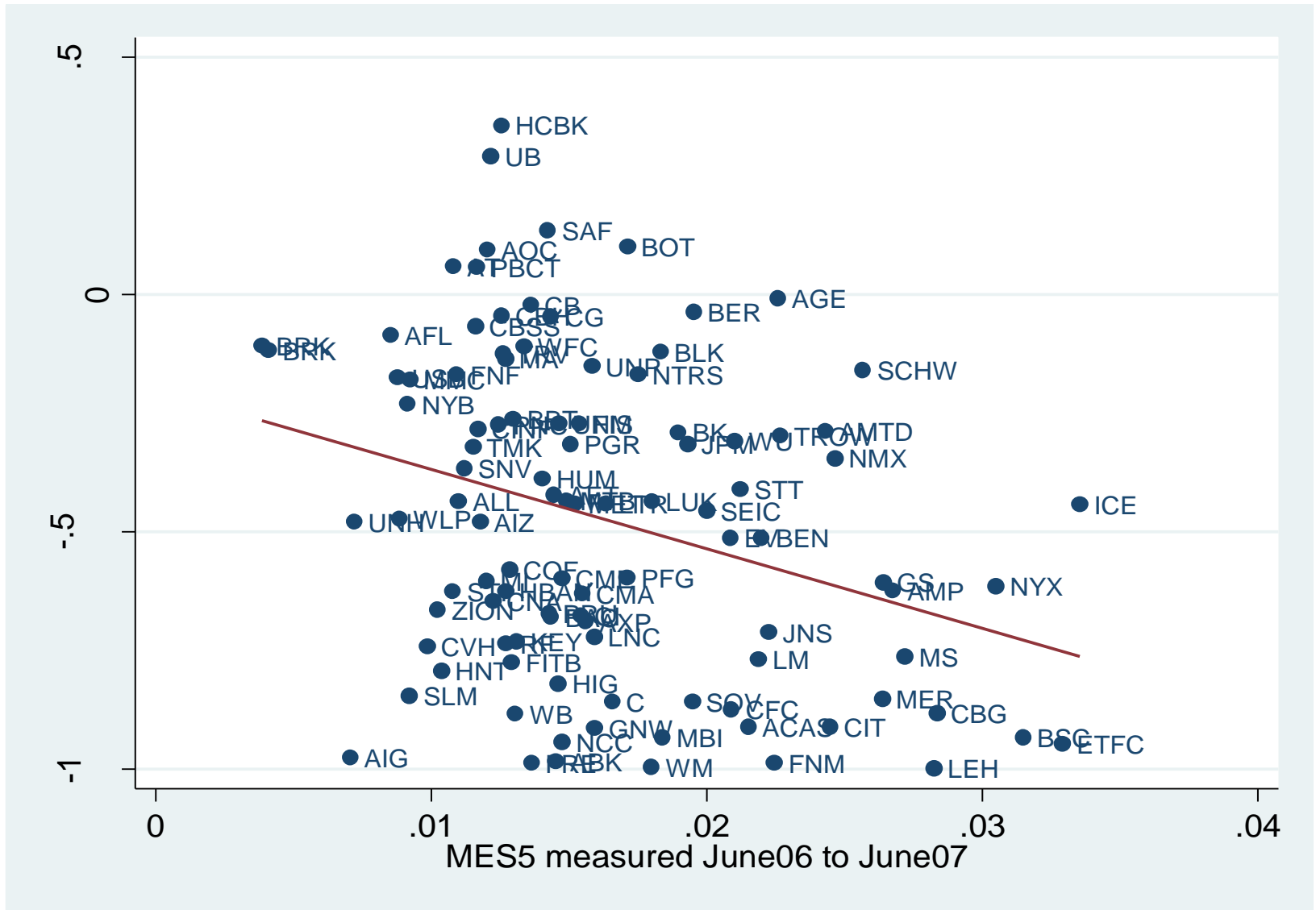
- Scaled by initial equity, we get two components for the firm's contribution to losses:
  - The extent to which the firm is already undercapitalized, i.e.,  $z \times \text{leverage} > 1$ .
  - Expected return on the firm's equity conditional on the crisis.
    - Estimate marginal expected shortfall (MES) (compute expected firm returns when market falls by at least 2%, incorporating the volatility of the firm and its correlation with the market, as well as its performance in extremes (Brownlees and Engle (2010))
    - If we assume returns follow a multivariate process with "normal distributions" and power law ones, power laws dominate in the tail (Gabaix (2009)). IMPORTANT :
      - cross-section is maintained as MES is just scaled up,
      - but financial distress costs do not, implying role for leverage.

### III. Two EMPIRICAL EXAMPLES of the CRISIS

- We use realized returns on equities during crisis and look at how well MES and leverage measures (pre-crisis) capture crisis behavior.
- We use ex ante estimate of capital shortfall during the crisis and look at how well MES and leverage measure this:
  - Feb 25: Fed, FDIC, OCC to examine 19 largest Bk. Hold. Cos. Capital Assistance Program (CAP) as backstop.
  - May 7: Results: Overall losses of 19 banks for 2009-2010 estimated as \$600B under adverse scenario. 9 of 19 have enough capital and future earnings to withstand losses. Other 10 need to raise a total of \$75B.

# Example #1

## 2007-08: Predictive power of MES (equity)



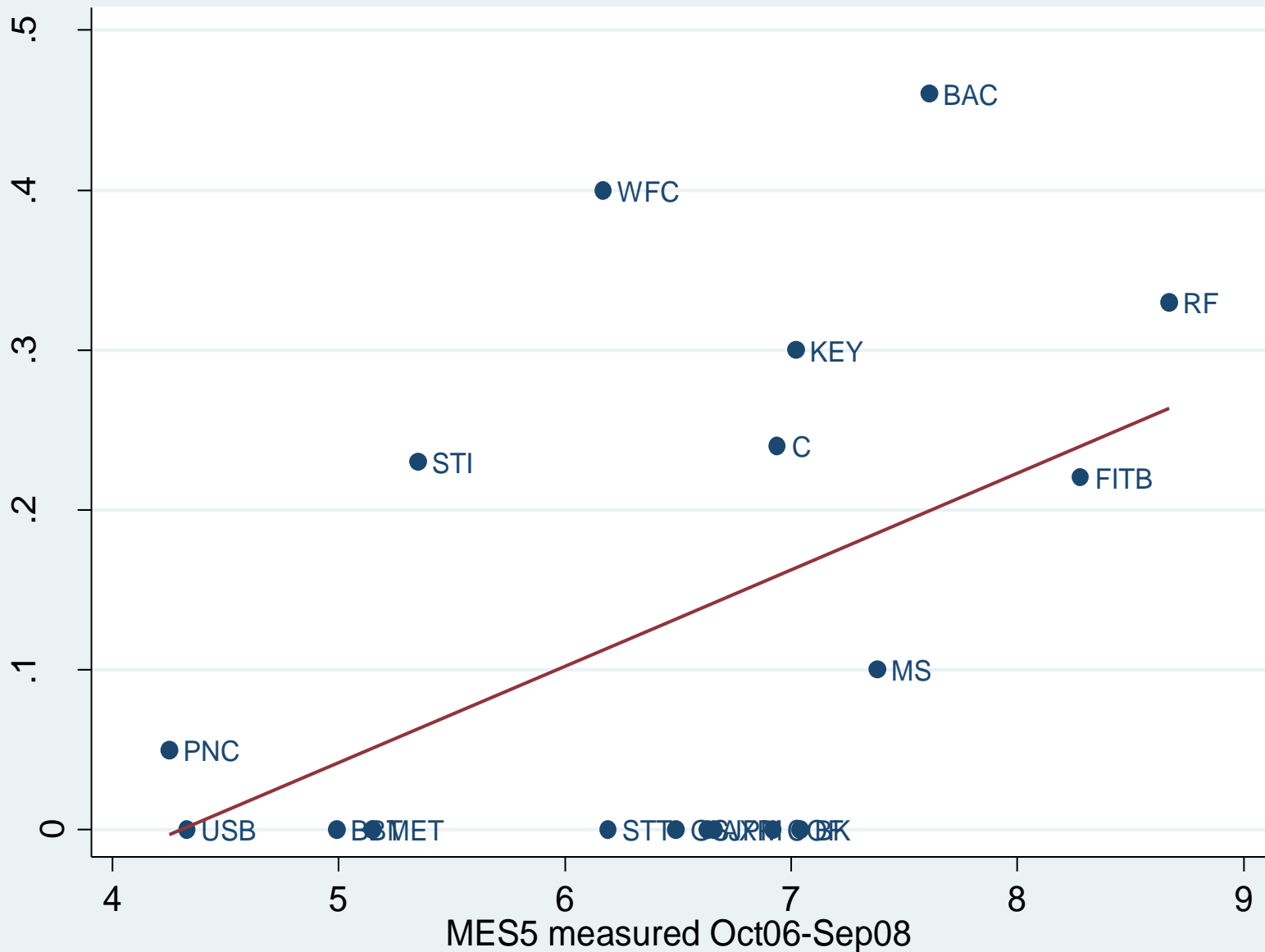


# Example #3:

## Stress test of Spring 2009: Summary results

Panel A							
Bank Name	SCAP	Tier1	Tier1Comm	SCAP/Tier1	SCAP/Tier1Comm	MES	LVG
REGIONS FINANCIAL CORP							
NEW	2.5	12.1	7.6	20.66%	32.89%	14.8	44.42
BANK OF AMERICA CORP	33.9	173.2	75	19.57%	45.50%	15.05	50.38
WELLS FARGO & CO NEW	13.7	86.4	34	15.86%	40.41%	10.57	20.58
KEYCORP NEW	1.8	11.6	6	15.52%	30.00%	15.44	24.36
SUNTRUST BANKS INC	2.2	17.6	9.4	12.50%	23.40%	12.91	39.85
FIFTH THIRD BANCORP	1.1	11.9	4.9	9.24%	22.45%	14.39	67.16
CITIGROUP INC	5.5	118.8	23	4.63%	24.02%	14.98	126.7
MORGAN STANLEY DEAN							
WITTER & CO	1.8	47.2	18	3.81%	10.11%	15.17	25.39
P N C FINANCIAL SERVICES							
GRP INC	0.6	24.1	12	2.49%	5.13%	10.55	21.58
AMERICAN EXPRESS CO	0	10.1	10	0.00%	0.00%	9.75	7.8
B B & T CORP	0	13.4	7.8	0.00%	0.00%	9.57	14.78
BANK NEW YORK INC	0	15.4	11	0.00%	0.00%	11.09	6.46
CAPITAL ONE FINANCIAL CORP	0	16.8	12	0.00%	0.00%	10.52	33.06
GOLDMAN SACHS GROUP INC	0	55.9	34	0.00%	0.00%	9.97	18.94
JPMORGAN CHASE & CO	0	136.2	87	0.00%	0.00%	10.45	20.43
METLIFE INC	0	30.1	28	0.00%	0.00%	10.28	26.14
STATE STREET CORP	0	14.1	11	0.00%	0.00%	14.79	10.79
U S BANCORP DEL	0	24.4	12	0.00%	0.00%	8.54	10.53

# Stress tests: Predictive power of MES (equity)





# Stress test: Predictive power of MES and LVG

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## Panel A: Dependent Variable is SCAP Shortfall/Tier1

April08-March09

	OLS			Probit		
	(I)	(II)	(III)	(IV)	(V)	(VI)
<b>Intercept</b>	-17.29 (-2.2)	3.14 (1.16)	-17.33 (-2.00)	-5.44 (-2.72)	-2.43 (-2.26)	-6.04 (-2.24)
<b>MES</b>	1.91 (3.00)		1.91 (2.46)	0.45 (2.72)		0.34 (1.65)
<b>LVG</b>		0.09 (1.35)	-0.001 (-0.01)		0.10 (2.16)	0.09 (1.61)
<b>Adj. R<sup>2</sup></b>	32.03%	4.65%	27.5%	40.68%	45.09%	53.22%
<b>No. Obs</b>	18	18	18	18	18	18

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Oct07-Sep08

	OLS	
	(VII)	(VIII)
	-13.46 (-1.50)	3.94 (1.12)
	3 (2.19)	3.29 (2.04)
		0.15 (0.66)
		-0.09 (-0.37)
<b>Adj. R<sup>2</sup></b>	18.27%	-3.46%
<b>No. Obs</b>	18	18

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# Conclusion

- Economic model of systemic risk gives rise to SES
- Systemic expected shortfall (SES)
  - Measures each financial institution's *contribution* to systemic crisis
  - Increases in: tail-dependence with the economy/market/financial sector as a whole, and in leverage
  - An SES tax/insurance incentivizes banks to contribute less to crisis
- Empirically
  - Ex ante SES predicts ex post crisis losses
  - We analyze its cross-sectional properties
  - In different periods, different markets, predicts “worst” systemic firms