Measuring Systemic Risk

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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 asses 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 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

Measuring Systemic Risk: The Right Units for a Systemic Tax

- 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,…, 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 <u>contribution</u> of unit i: Marginal expected shortfall (MES)

$$MES^i := \frac{\partial ES}{\partial y_i} = -E\left[r_i \mid R \leq -VaR\right]$$

- 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 α_i can be insured by govt
  - Assets: $a_i = w_{i,0} + b_i$
  - Allocate investments among j=1…J risky assets and cash

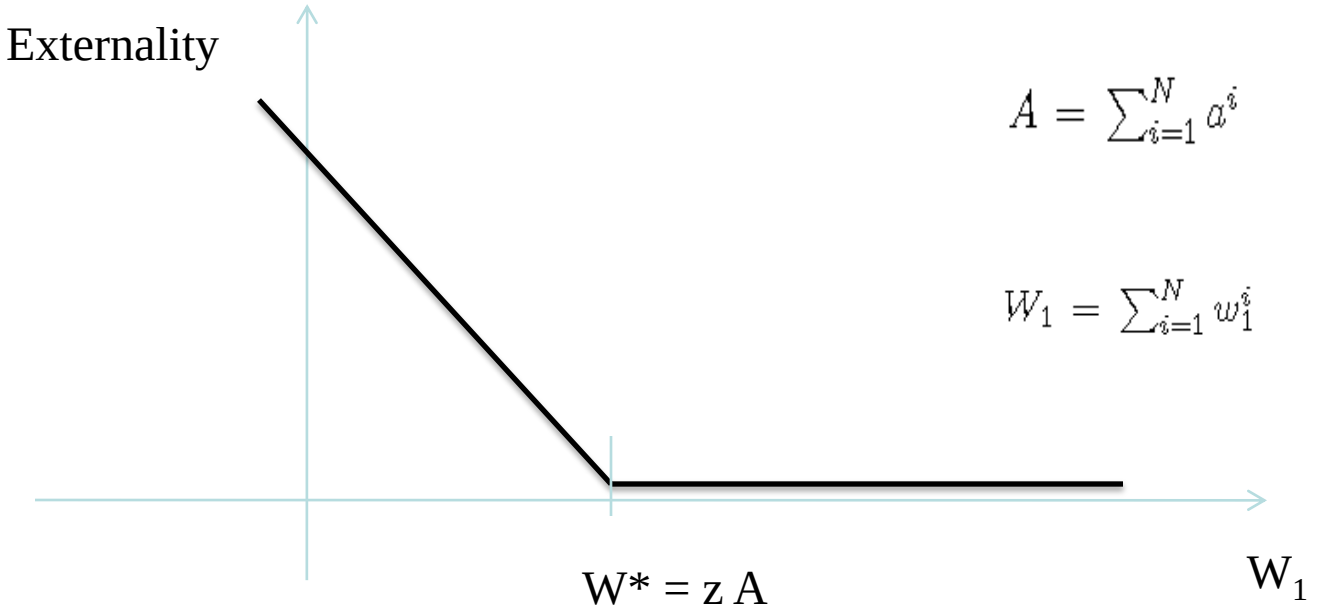
- Time 1: Returns are realized
  - Limited liability if insolvent, but government bails out insured depositors

Pre-distress income cost of financial distress net worth

$$\hat{y}^i = \sum_{j=1}^{J} r_j^i x_j^i \qquad \phi^i = \Phi\left(\hat{y}^i, f^i\right) \qquad w_1^i = \hat{y}^i - \phi^i - f^i$$

Externality

- 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



Objective functions

- Each bank:

$$\max_{w_0^i, b^i, \{x_j^i\}_j} \; c \cdot \left(\bar{w}_0^i - w_0^i - \tau^i \right) + E\left(u\left(1_{[w_1^i > 0]} \cdot w_1^i \right) \right)$$

- Tax τ_i is set by the planner whose objective is to maximize P1 + P2 + P3 :

$$P^1 = \sum_{i=1}^{N} c \cdot \left(\bar{w}_0^i - w_0^i - \tau^i \right) + E\left[\sum_{i=1}^{N} u^i \left(1_{[w_1^i > 0]} \cdot w_1^i \right) \right]$$

$$P^2 = E\left[g \sum_{i=1}^{N} 1_{[w_1^i < 0]} \alpha^i w_1^i \right]$$

$$P^3 = E\left[e \cdot 1_{[W_1 < zA]} \cdot \left(zA - W_1 \right) \right]$$

Economic model - results

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

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

$$ES^i \equiv -E\left[w_1^i \,|\, w_1^i < 0\right] \qquad SES^i \equiv E\left[za^i - w_1^i \,|\, W_1 < zA\right]$$

$$\tau^i = \frac{\alpha^i g}{c} \cdot Pr\left(w_1^i < 0\right) \cdot ES^i + \frac{e}{c} \cdot Pr\left(W_1 < zA\right) \cdot SES^i .$$

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

Efficient regulation

- Tax system with <u>two components</u>

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

- <u>Systemic Expected Shortfall</u> (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*).

Systemic Expected Shortfall

- A bank's SES is larger if
  - the externality is more severe (e),
  - systemic under-capitalization is more likely *($Pr[W_1 < W^*]$)*
  - 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

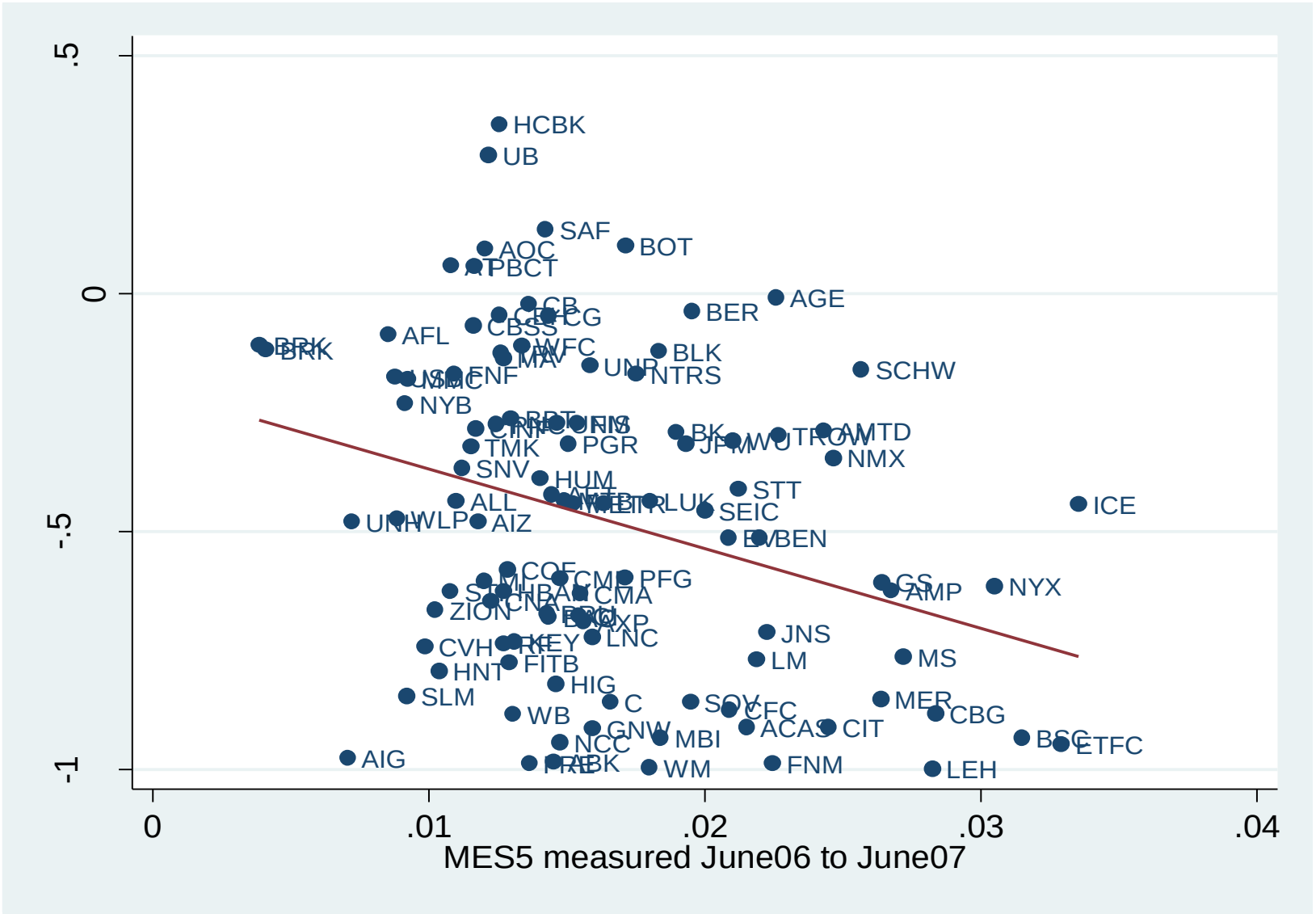
Empirical Methodology

- 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

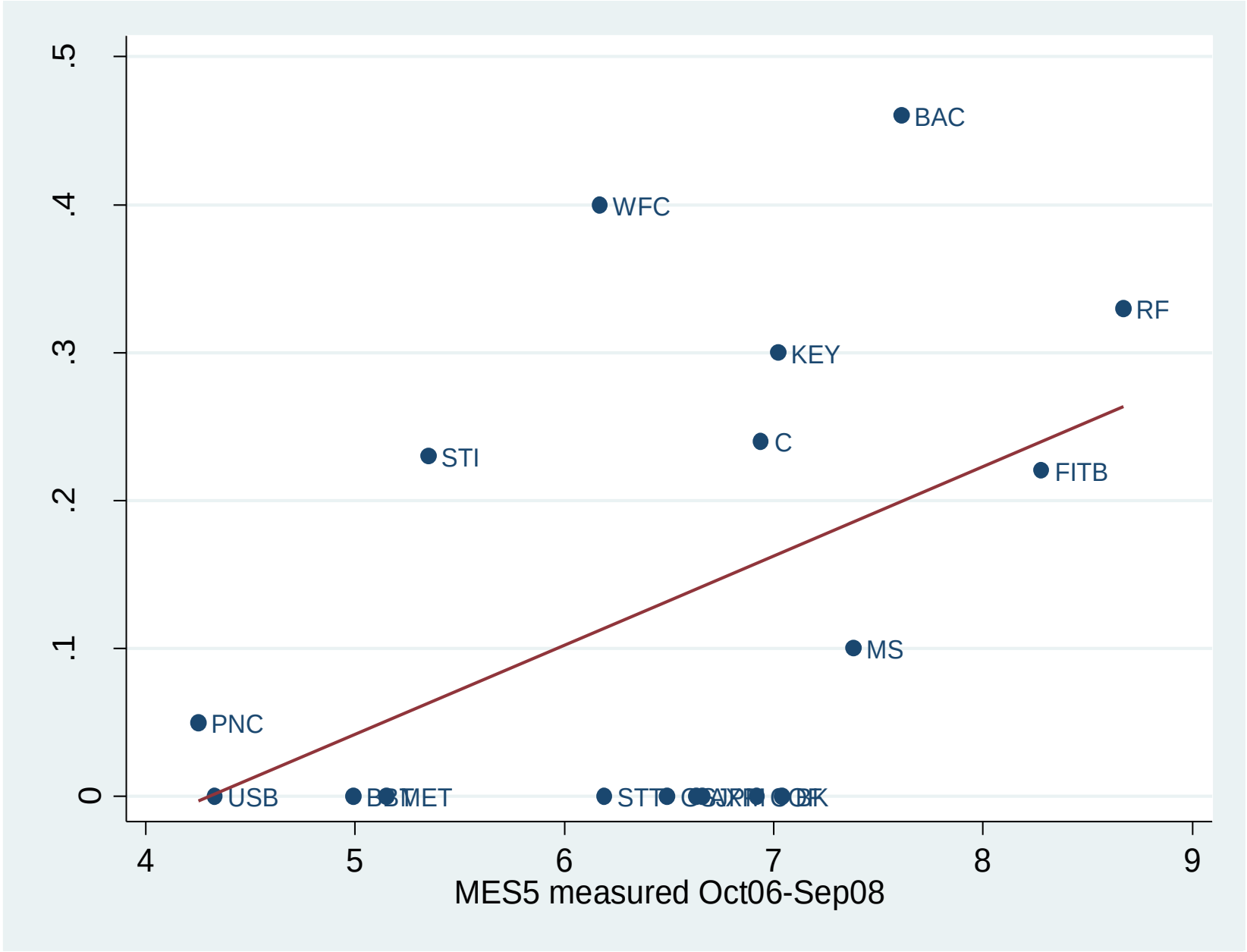
2007-08: Predictive power of MES (Equity)



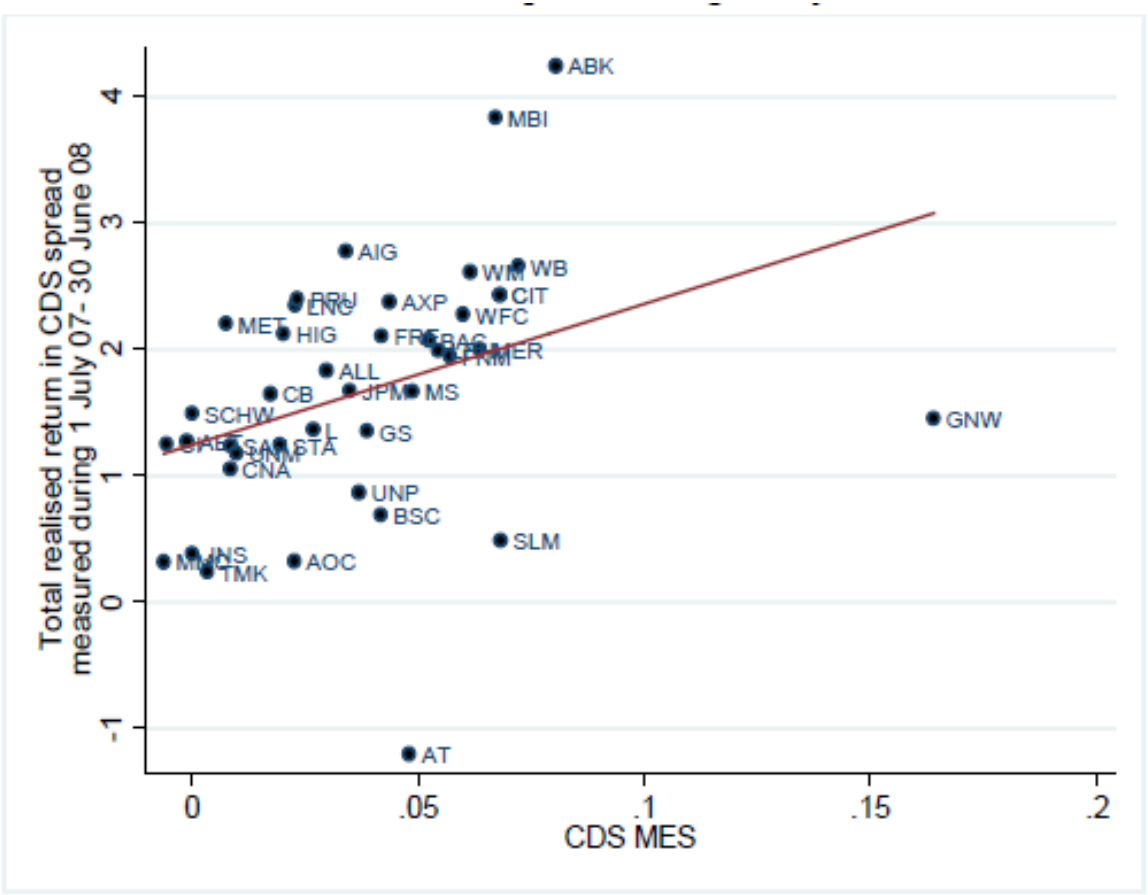
2007-08: Predictive power of MES (Equity)

Panel A, OLS regression analysis: The dependent variable is Realized SES, the company stock returns during the crisis								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ES	-0.05							
	(-1.14)							
Vol		0.04						-0.07
		(0.07)						(-0.12)
MES			-0.21***			-0.15**		-0.17**
			(-2.90)			(-2.25)		(-2.08)
Beta				-0.29**				
				(-2.24)				
LVG					-0.04***	-0.04***		-0.03**
					(-5.73)	(-5.43)		(-2.29)
Log Assets							-0.09***	-0.05*
							(-4.86)	(-1.69)
Industry dummies								
Constant	-0.32***	-0.44***	-0.13	-0.18	-0.18**	0.02	0.61***	0.50
	(-2.71)	(-3.81)	(-1.09)	(-1.42)	(-2.50)	(0.20)	(2.75)	(1.61)
Other	-0.04	-0.09	0.01	0.012	-0.20**	-0.12	-0.25***	-0.15
	(-0.33)	(-0.91)	(0.14)	(0.12)	(-2.44)	(-1.35)	(-2.87)	(-1.61)
Insurance(x100)	0.43	-0.68	-3.63	-2.95	-8.86	-10.17	-0.09	-0.11
	(0.05)	(-0.08)	(-0.45)	(-0.36)	(-1.19)	(-1.39)	(-1.13)	(-1.55)
Broker-dealers	-0.09	-0.16	0.11	0.06	-0.02	0.16	-0.17	0.14
	(-0.65)	(-1.20)	(0.71)	(0.36)	(-0.18)	(1.19)	(-1.56)	(1.02)
Adj. R^2	0%	-1.36%	6.72%	3.62%	24.27%	27.34%	18.46%	28.02%
No. Obs	102	102	102	102	101	101	101	101

Stress tests: Predictive Power of MES (Equity)



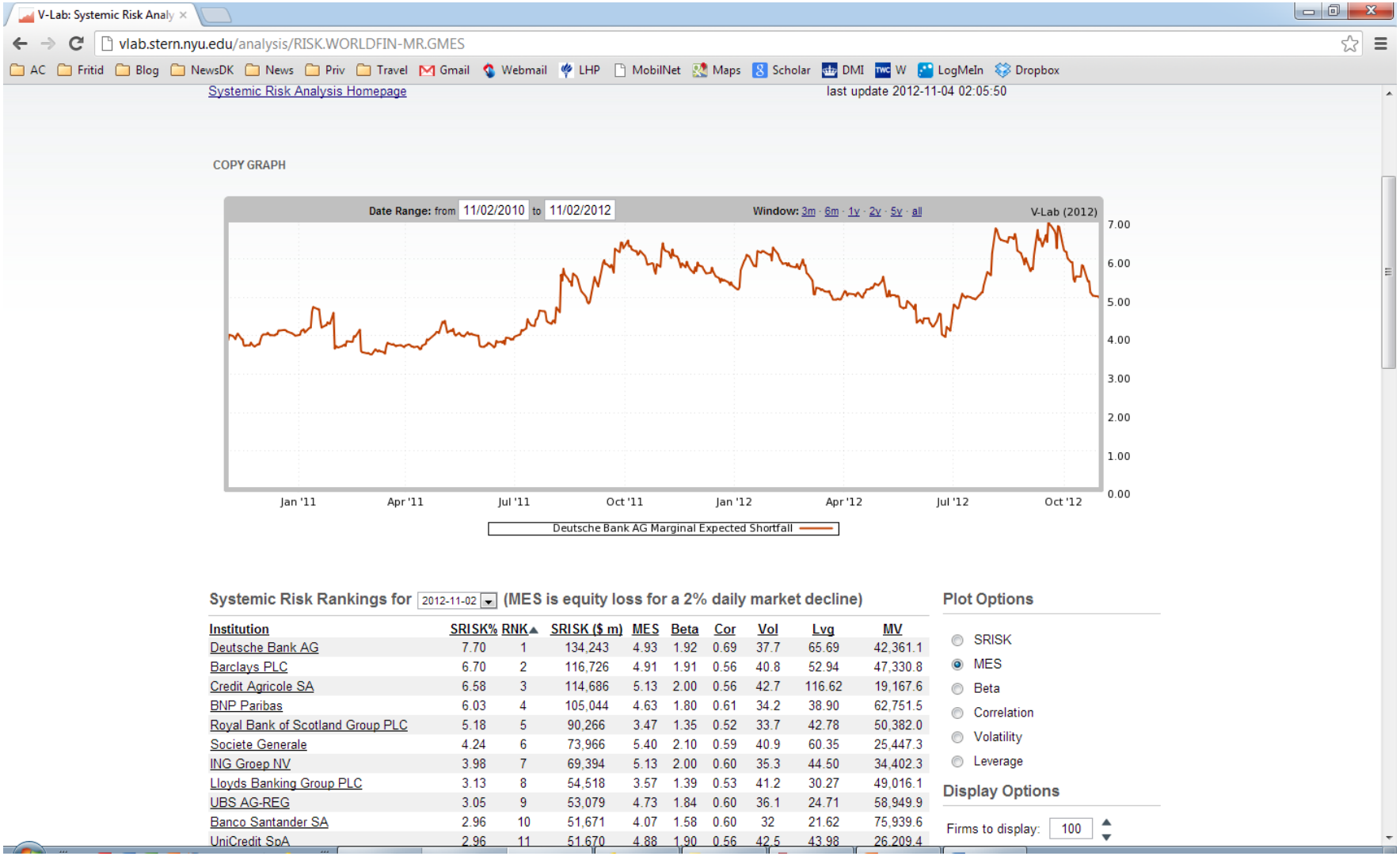
2007-08: Predictive Power of MES (CDS)



NYU-Stern VLAB'S Risk Page

- 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



Institution	SRISK%	RNK▲	SRISK ($ m)	MES	Beta	Cor	Vol	Lvg	MV
Deutsche Bank AG	7.70	1	134,243	4.93	1.92	0.69	37.7	65.69	42,361.1
Barclays PLC	6.70	2	116,726	4.91	1.91	0.56	40.8	52.94	47,330.8
Credit Agricole SA	6.58	3	114,686	5.13	2.00	0.56	42.7	116.62	19,167.6
BNP Paribas	6.03	4	105,044	4.63	1.80	0.61	34.2	38.90	62,751.5
Royal Bank of Scotland Group PLC	5.18	5	90,266	3.47	1.35	0.52	33.7	42.78	50,382.0
Societe Generale	4.24	6	73,966	5.40	2.10	0.59	40.9	60.35	25,447.3
ING Groep NV	3.98	7	69,394	5.13	2.00	0.60	35.3	44.50	34,402.3
Lloyds Banking Group PLC	3.13	8	54,518	3.57	1.39	0.53	41.2	30.27	49,016.1
UBS AG-REG	3.05	9	53,079	4.73	1.84	0.60	36.1	24.71	58,949.9
Banco Santander SA	2.96	10	51,671	4.07	1.58	0.60	32	21.62	75,939.6
UniCredit SpA	2.96	11	51,670	4.88	1.90	0.56	42.5	43.98	26,209.4

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