Risk-neutral systemic risk indicators

NYU Stern–Federal Reserve Conference on Extracting and Understanding the Risk Neutral Probability Density from Options Prices

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Overview

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Assessment

Issues

Working paper available at

`http://www.newyorkfed.org/research/staff_reports/sr607.pdf`

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Overview

- Represent systemic risk as market risk of a portfolio of large-bank stocks
  - Version of *CoVaR*, *SES*, *MES* and *DIP* based on derivatives prices
  - But uses firms' market values, not liabilities or asset values, as exposure/loss metric
- Requires only contemporaneously observed market data, no historical data
  - Can be computed daily using only that day's data
- Risk-neutral, so contains risk premiums
- Option-Based Systemic Expected Shortfall Statistics (OBSESS)

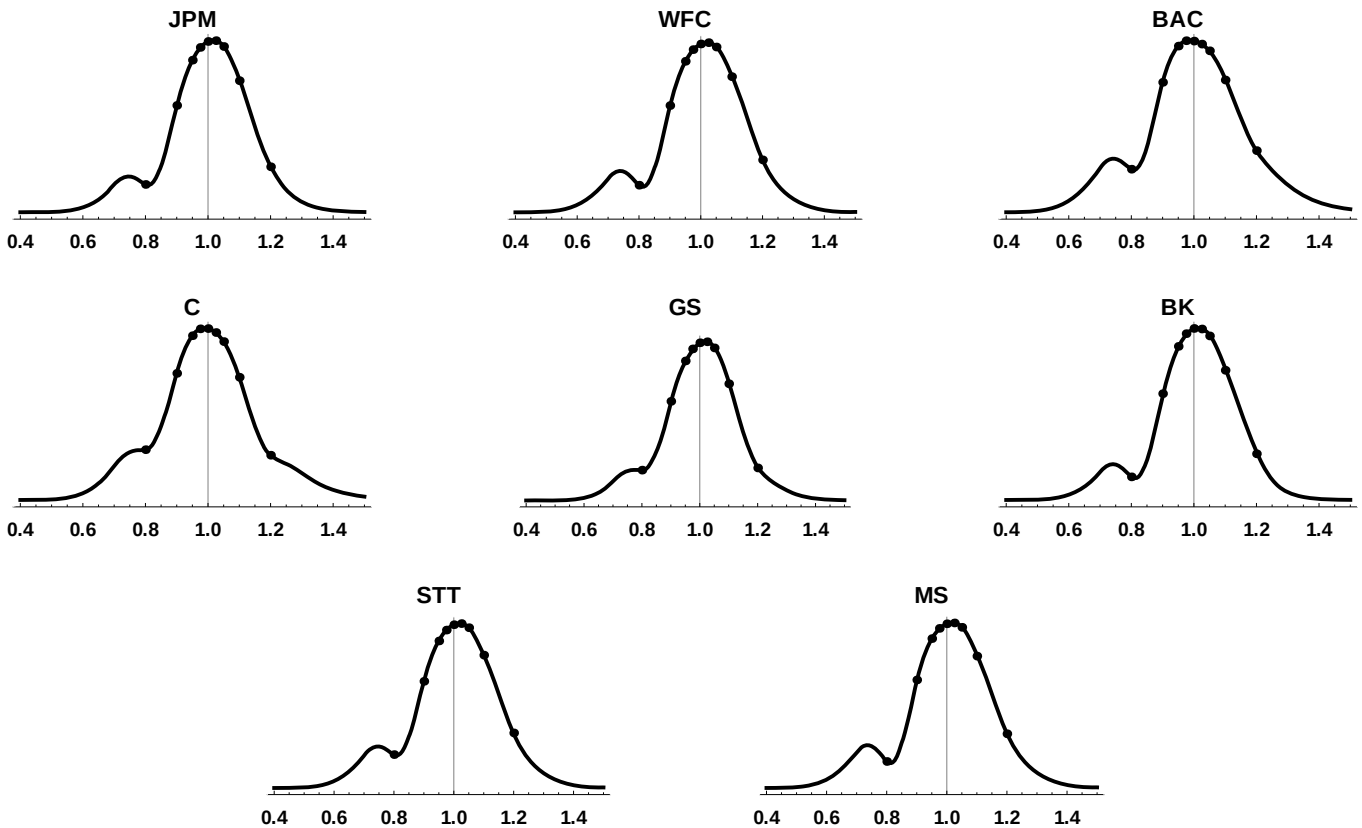
Overview of construction of indicators

- 3 building blocks
  - Option-based risk-neutral probability distributions
  - Option-based equity implied return correlation
  - Copula model to tie risk-neutral distributions together and generate simulations
- 8 U.S. banks listed as global systemically important financial institutions (G-SIFIs) by Financial Stability Board (FSB)

Risk-neutral distributions

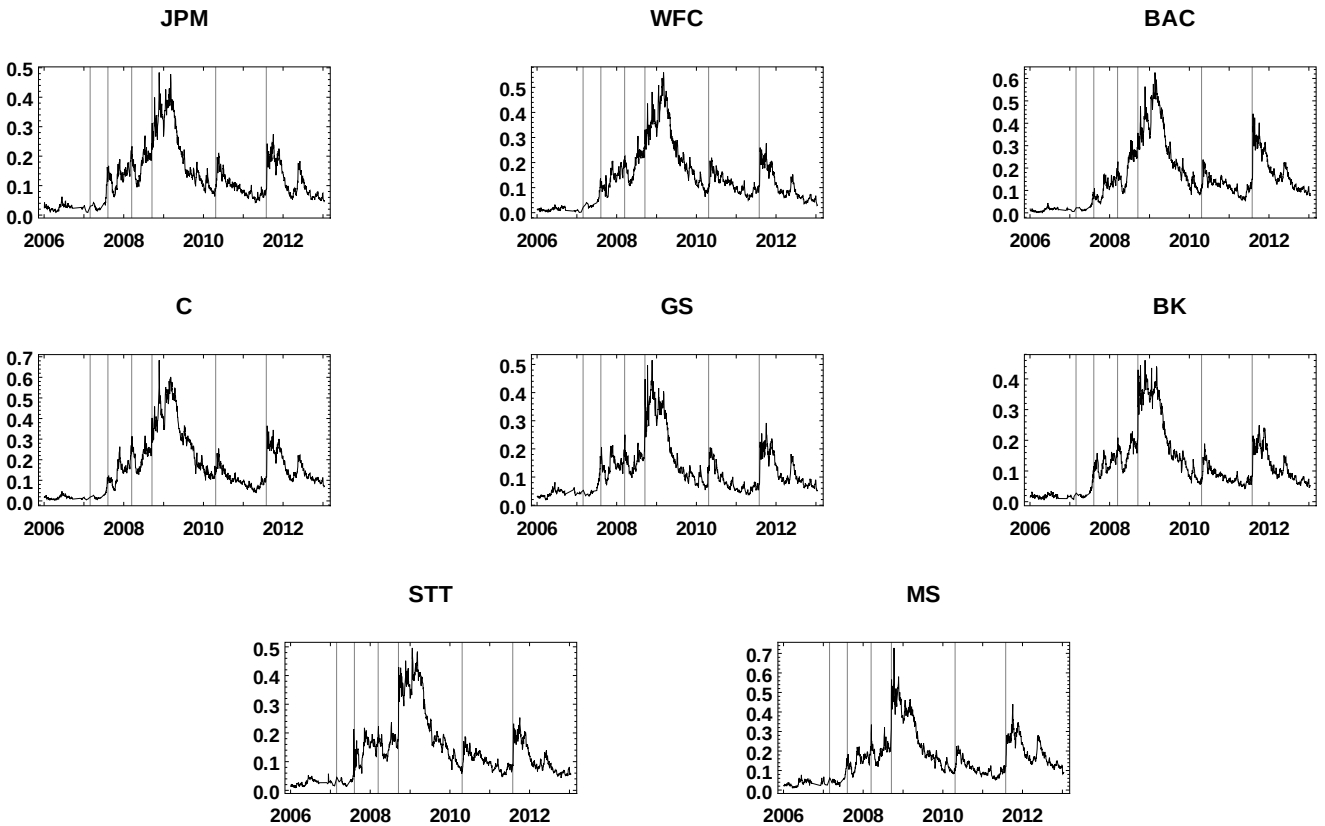
- Data: Bloomberg implied volatility datasets
  - Three-month single-stock and index options
- Volatility smile interpolation
  - Cubic spline with clamped endpoints
  - In moneyness-volatility space
  - Differencing→risk-neutral CDF and PDF
- OBSESS not dependent on this particular data or RNPDF estimation technique

Risk-neutral densities of major U.S. financial firms



Density of the ratio of the stock price three months hence to the current outright forward price, Feb. 11, 2011. The forward price is computed using the 3-month T-bill yield and a trailing dividend yield. Points represent the observed implied volatilities.

Risk-neutral probability of large loss 2006–2013

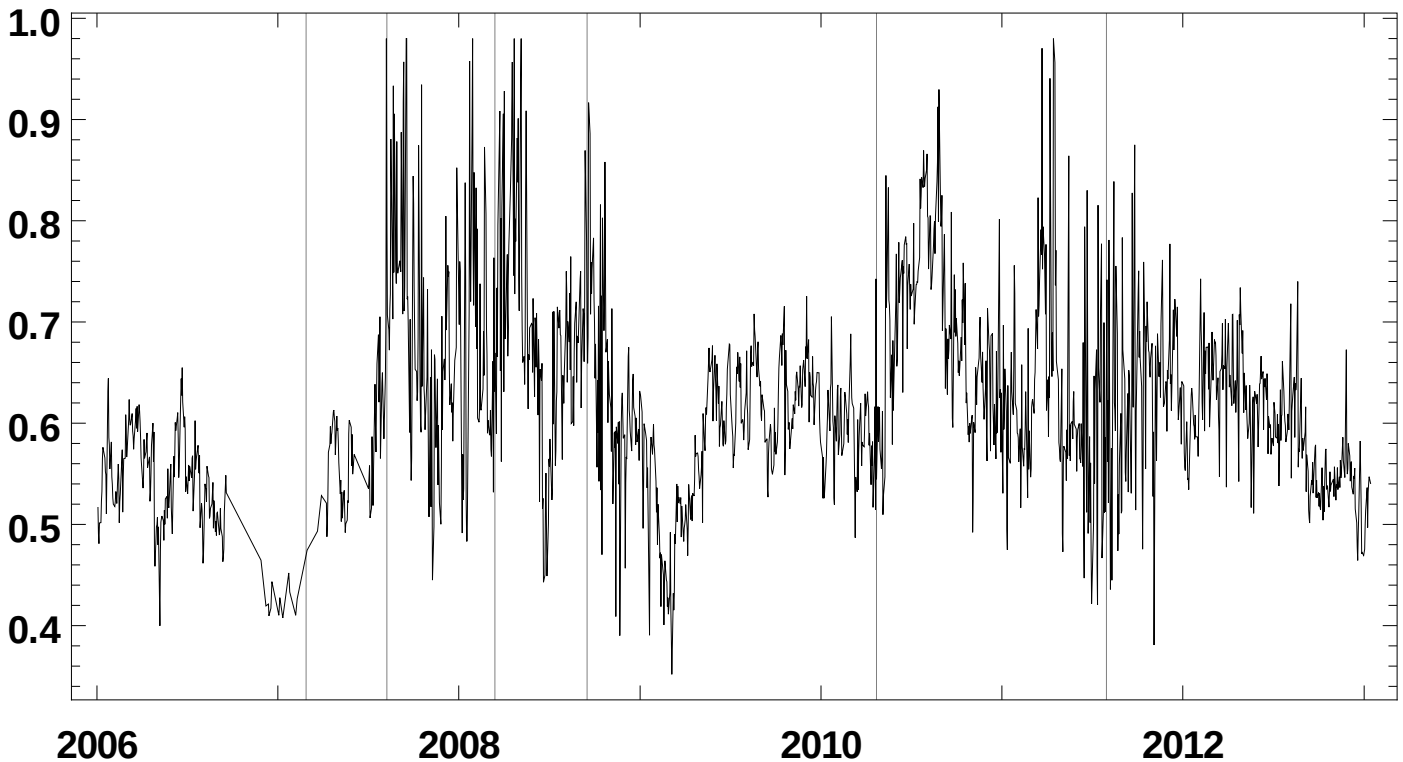


Risk-neutral cumulative probability of a decline in equity value in excess of 25 percent over the subsequent three months, daily, Jan. 4, 2006 to Jan. 14, 2013. Vertical grid lines: first volatility event of the crisis (27 Feb. 2007), BNP Paribas redemption halt (09Aug07), Bear Stearns run (14Mar08), Lehman bankruptcy (16Sep08), first Greek bailout request (23Apr10), U.S. debt ceiling deal (31Jul2011).

Equity implied correlation

- Risk-neutral implied correlation of banks' stock returns
- Estimates from index and constituent vols
  - All ATM and of same 3-month tenor
- KBW Bank Sector Index (ticker BKX)
  - Overlap with but not identical to the list of G-SIFIs (GS, MS not in BKX)
  - Few other sources of market data on correlation
- Constant pairwise correlation☹, but new estimate each day☺
- Contrast to S&P corr: decline post-Lehman

Risk-neutral BKX implied correlation 2006–2013



Three-month, daily, Jan. 4, 2006 to May 21, 2012. Vertical grid lines: first volatility event of the crisis (27 Feb. 2007), BNP Paribas redemption halt (09Aug07), Bear Stearns run (14Mar08), Lehman bankruptcy (16Sep08), first Greek bailout request (23Apr10), U.S. debt ceiling deal (31Jul2011).

Computing the indicators via a copula model

- Why a copula model?
  - Joint (and portfolio) return distribution unknown
  - But marginal distributions known: RNPDFs, updated daily
  - As well as correlation matrix, updated daily
  - But all off-diagonal elements equal
- Normal copula; but can use other copula models, e.g. t-copula
  - Doesn't assume *returns* multivariate normal
  - Rather, "normal z's" corresponding to probabilities corresponding to returns are multivariate normal
  - Fat-tailed marginals (RNPDFs) generate tail dependence

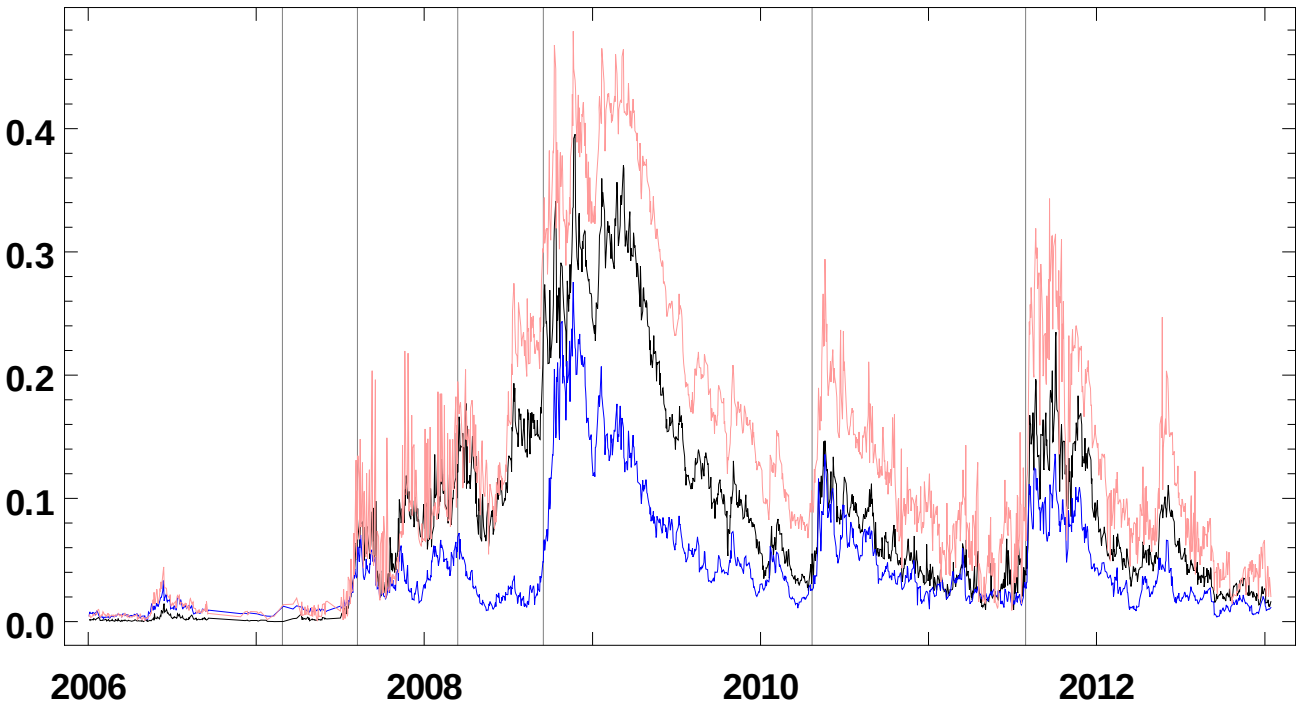
From simulation results to indicators

- Daily simulation procedure
  - Draw from multivariate normal
  - Map to firms' equity returns via RNPDFs
  - Raw results: 10 000 simulations of each firm's equity return
- Sort and otherwise manipulate to get
  - Portfolio returns by cap-weighting within each simulation
  - Simulated returns sorted by order statistics of any firm's or portfolio's simulated returns
  - Unconditional or conditional risk metrics
  - Probability of loss of given size, quantiles, VaR, expected shortfall at given confidence level

Unconditional systemic risk measures

- Definition of systemic risk event: portfolio loss of given severity or low probability
- E.g. firm or portfolio loss $\geq$ 25 percent over subsequent 3 months

Probability of a systemic risk event 2006–2013

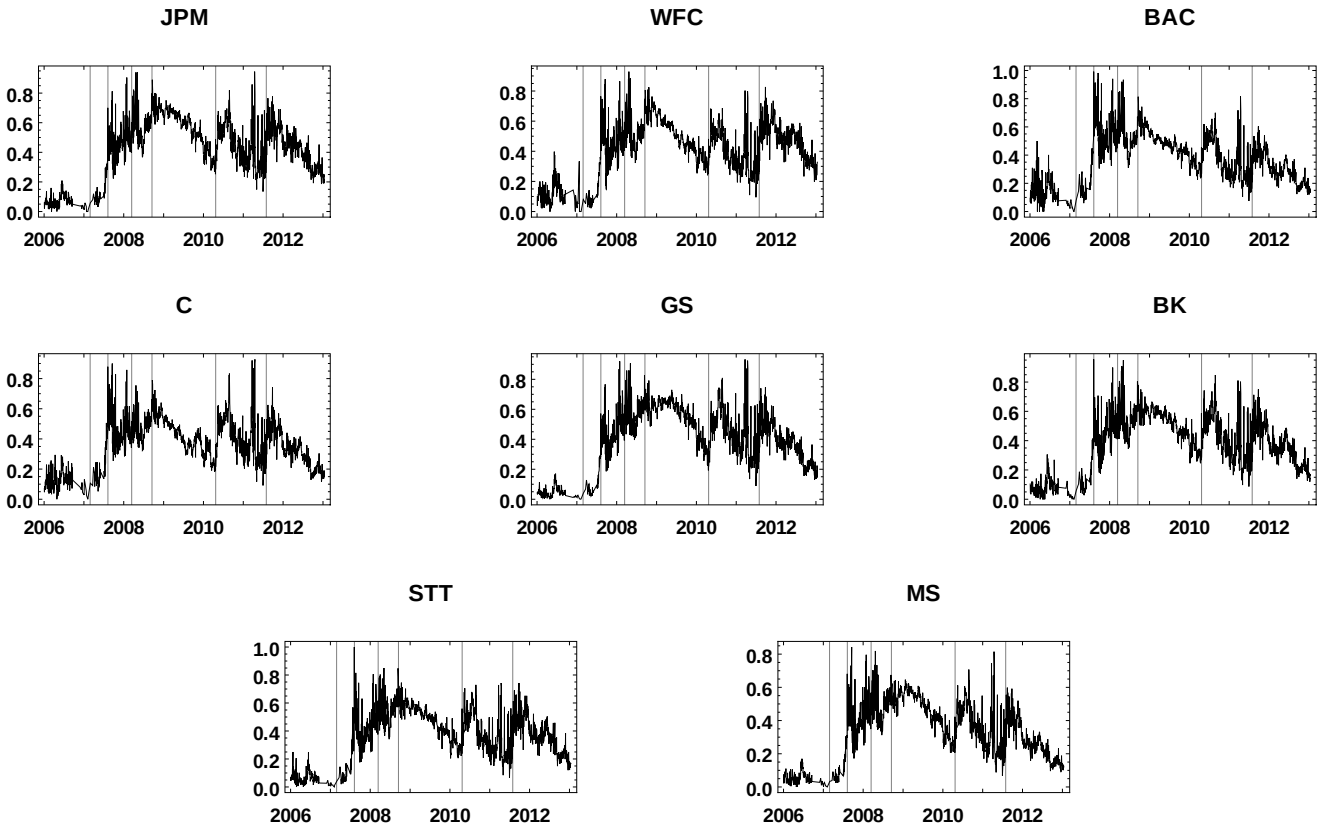


Systemic risk event: 3-month decline in 8-bank equity portfolio value in excess of 25 percent. Black plot: OBSESS portfolio-based systemic risk probability, blue plot: SPX index-based probability, red plot: BKX index-based probability. Daily, Jan. 4, 2006 to Jan. 14, 2013. Vertical grid lines: first volatility event of the crisis (27 Feb. 2007), BNP Paribas redemption halt (09Aug07), Bear Stearns run (14Mar08), Lehman bankruptcy (16Sep08), first Greek bailout request (23Apr10), U.S. debt ceiling deal (31Jul2011).

Conditioning from individual bank to portfolio

- "Conditional systemic event probability," probability of systemic risk event conditional on individual FI experiencing extreme loss
- Varies more over time than across firms:
  - Should be high for large firm, since much dependence of other banks on its financial health ("contagion")
  - Should be high for small, relatively non-fragile firm, since only very severe shock associated with conditioning event
- Can also compute system expected shortfall conditional on individual FI experiencing loss $\geq$ given quantile
  - Analogue to *CoVaR*

Conditional systemic event probability 2006–2013

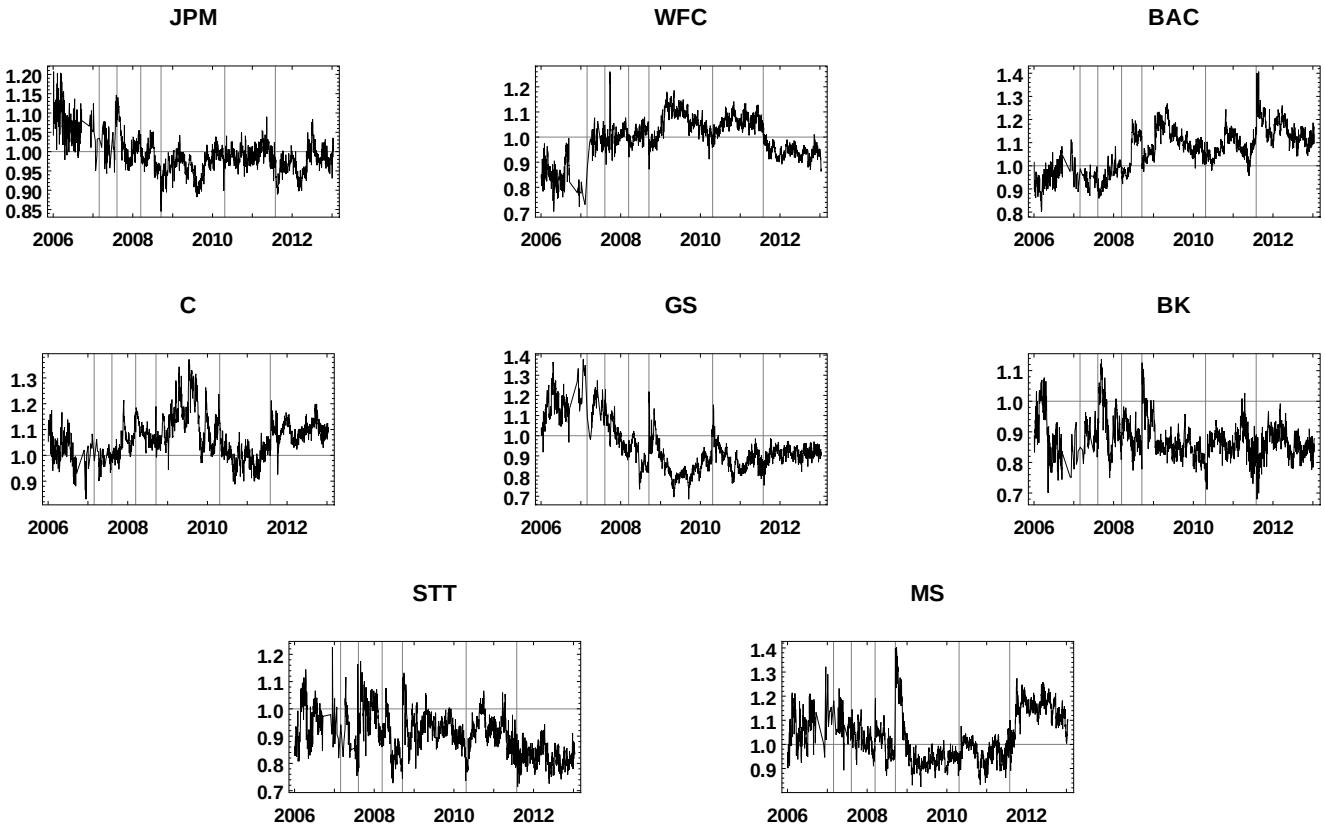


Conditioning event is a 25 percent market capitalization loss of the firm over the subsequent three months. Systemic risk event is a 25 percent market capitalization loss of the portfolio over the subsequent three months. Daily, Jan. 4, 2006 to Jan. 14, 2013. Vertical grid lines: first volatility event of the crisis (27 Feb. 2007), BNP Paribas redemption halt (09Aug07), Bear Stearns run (14Mar08), Lehman bankruptcy (16Sep08), first Greek bailout request (23Apr10), U.S. debt ceiling deal (31Jul2011).

Conditioning from portfolio to individual bank

- "Conditional expected shortfall": firm's expected shortfall, conditional on systemic event
- "Conditional expected shortfall ratio": divide by portfolio expected shortfall
  - Is conditional expected shortfall over- or underproportional to firm's market cap?
  - Too-big-to-fail indicator?
- Probability, VaR or expected shortfall of bank experiencing extreme firm loss conditional on systemic risk event
- Analogues to:
  - *DIP* (but equity rather than liabilities)
  - *SES* (but conditioning on FI portfolio loss, not overall stock market)

Conditional expected shortfall ratios 2006–2013

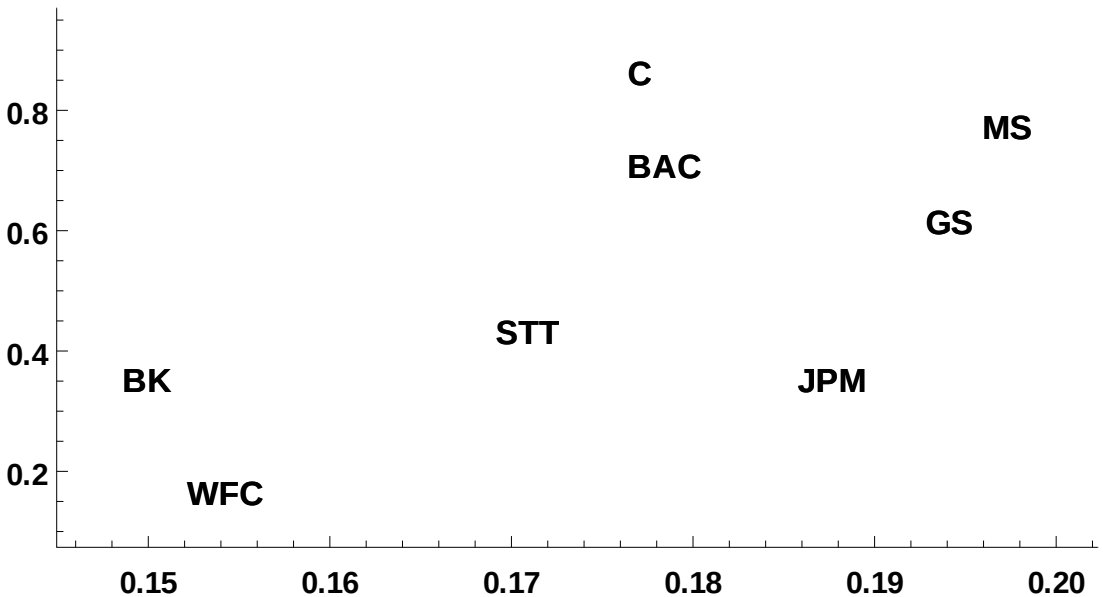


Ratio of conditional expected shortfall of the firm to the system expected shortfall, both at a 5 percent confidence level. Conditioning event is a 25 percent market capitalization loss of the 8-firm portfolio over the next three months. Daily, Jan. 4, 2006 to Jan. 14, 2013. Vertical grid lines: first volatility event of the crisis (27 Feb. 2007), BNP Paribas redemption halt (09Aug07), Bear Stearns run (14Mar08), Lehman bankruptcy (16Sep08), first Greek bailout request (23Apr10), U.S. debt ceiling deal (31Jul2011).

How do we validate OBSESS?

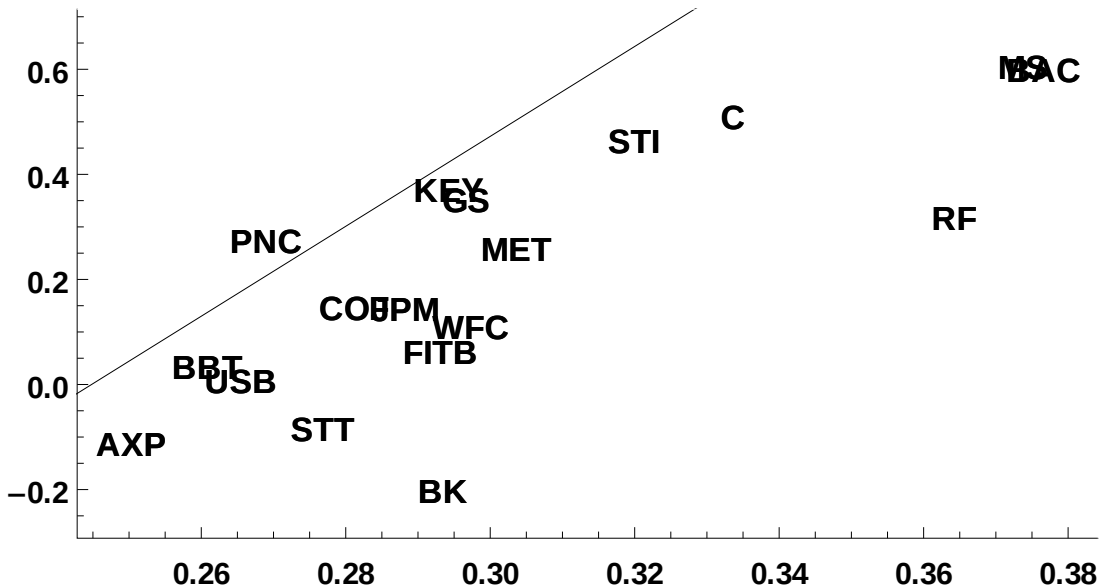
- Predictive power: second half of 2008
- Comparison with other approaches (using larger portfolio)
  - CCAR results as "fundamentals-based" or "real-world" estimate of losses
  - Compare with another, similar systemic risk measure, marginal expected shortfall (MES), defined as the loss a firm would suffer in the event of a 2 percent decline in the broader equity market.

Conditional expected shortfall and crisis losses



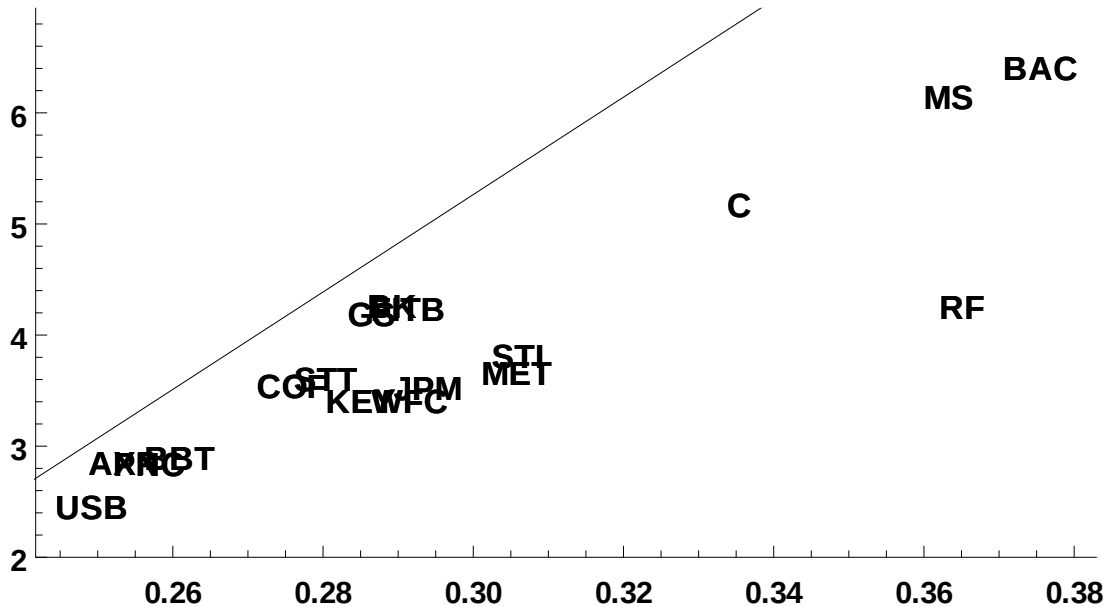
Values on x-axis: firms' conditional expected shortfall at the 95 percent level (ratio to market capitalization) on July 3, 2008. Values on the y-axis are realized equity market losses between July 3 and Dec. 31, 2008.

Conditional expected shortfall and stress test results



Values on x-axis: firm's average conditional expected shortfall at the 95 percent level (ratio to market capitalization) between Feb. 10 and Mar. 8, 2012. Values on y-axis: $(-1\times)$ the ratio of each firm's Net Income before Taxes, Table 4 of CCAR 2012 documentation, to average market capitalization between Feb. 10 and Mar. 8, 2012.

Conditional expected shortfall and V-Lab marginal expected shortfall



Values on x-axis: firm's average conditional expected shortfall at the 95 percent level (ratio to market capitalization), Apr. 2-30, 2012. Values on y-axis: *MES* for Apr. 30, 2012 from `http://vlab.stern.nyu.edu/analysis/RISK.USFIN-MR.MES`.

Issues

- Great hopes placed in systemic risk indicators
  - But was problem really lack of data?
- Do OBSESS have predictive value?
  - Challenge of measuring predictive power of tail probability measures
- Can we identify the real-world distribution component of OBSESS?
  - And if not, how are they useful?
- Use as benchmark
  - Nice to have something sensitive other than CDS
  - Point of comparison to analogues based on historical data and fundamentals
- Market-based cross-sectional systemic risk measures consistent with macro prudential approach to regulation
- But based on a particular view of causes of financial crises?
  - Contagion, externalities, common shocks/canary in the coal mine?

Appendix: banks included in OBSESS

Ticker	Name	Market cap (Dec. 2011)	Share of total
	G-SIFIs		
WFC	Wells Fargo & Co	137.0	18.6
JPM	JPMorgan Chase & Co	121.2	16.4
C	Citigroup Inc	76.1	10.3
BAC	Bank of America Corp	52.7	7.1
GS	Goldman Sachs Group Inc	46.0	6.2
MS	Morgan Stanley	28.9	3.9
BK	Bank of New York Mellon Corp	23.2	3.1
STT	State Street Corp	19.7	2.7
	other SCAP/CCAR banks		
AXP	American Express Co	54.5	7.4
USB	US Bancorp	49.6	6.7
MET	MetLife Inc	32.0	4.3
PNC	PNC Financial Services Group	29.0	3.9
COF	Capital One Financial Corp	19.9	2.7
BBT	BB&T Corp	16.8	2.3
FITB	Fifth Third Bancorp	11.1	1.5
STI	SunTrust Banks Inc	8.8	1.2
KEY	KeyCorp	6.8	0.9
RF	Regions Financial Corp	5.0	0.7