CoVaR

A Systemic Contribution Risk Measure

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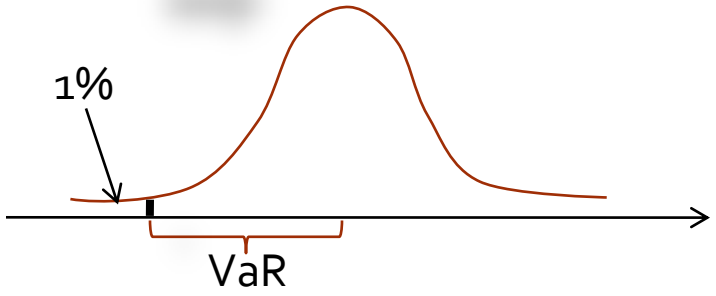
Current financial regulation

1. Risk of each bank in isolation ⇨ Value at Risk
   - Capital requirements
   - Haircuts/margins
   - Ratings



2. Procyclical of capital requirements, haircuts, ratings
3. Focus on asset side of the balance sheet
   Liability side – maturity mismatch gets little attention
   - Maturity rat race
   - Implicit subsidies for short-term funding
4. Focus on banks –
   shadow banking system gets little attention

Three challenges ….

1. Focus on externalities – systemic risk contribution
   - What are the externalities?
     - Regulate based on externalities (functional citerion)
   - How to measure externalities (contribution to systemic risk)?
     - CoVaR
2. Countercyclical regulation
   - Avoid procyclicality
     - leverage, maturity mismatch,… predict future CoVaR
3. Incorporate funding structure
   asset-liability interaction, debt maturity, liquidity risk

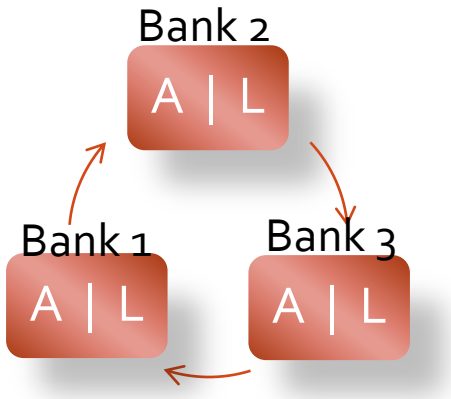
1. Externalities

"stability is a public good"

1. Fire-sale externality
   - Maturity mismatch + Leverage — *liquidity*
     - Raise new funds — **FUNDING LIQUIDITY** *(rollover risk)*
     - Sell off assets — **MARKET LIQUIDITY**
       (at fire sale prices due to crowded trades)

   ⇒ *Fire-sales depress price also for others*

2. Hoarding externality
   - micro-prudent response:
     Hoard funds/reduce lending
   - … but not necessarily macro-prudent
   - Systemic risk is endogenous (multiple equl)

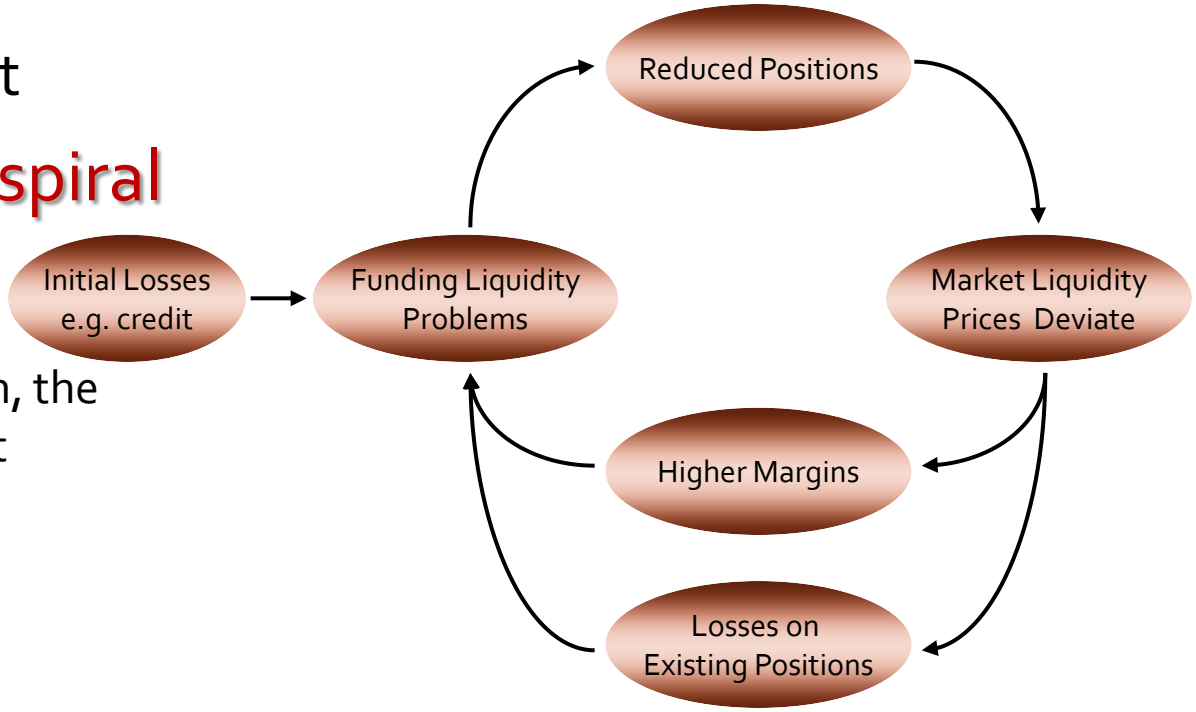


3. Runs – dynamic co-opetition
4. Network Externality
   - Hiding own's commitment ⇒ uncertainty for counterparties

See Brunnermeier (2009) Journal of Economic Perspectives

2. Procyclicality due to Liquidity spirals

- **Loss spiral**
  - same leverage
  - mark-to-market
- **Margin/haircut spiral**
  - Margin/haircut
    max leverage
  - The more short-term, the
    lower margin/haircut
  - ***delever!***
  - mark-to-model
    - Mark-to-funding



Brunnermeier-Pedersen (2009)

Margin/haircut spiral - Procyclicality

- Margins/haircut increase in times of crisis ⇒ delever
  margin = f(risk measure)
- Three reasons:
  1. Backward-looking estimation of risk measure
     - Use forward looking measures
     - Use long enough data series

     Great moderation $\stackrel{?}{=}$ great complacency
  2. Fundamental volatility increases
  3. Adverse selection
     - Debt becomes more information sensitive (not so much out of the money anymore)

- Credit bubbles
  - whose bursting undermines financial system

⇒ Countercyclical regulation

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Credit/Leverage Bubble

- Why did nobody delever/act against it earlier?
  - "dance as long as the music plays"
  - Lack of coordination when to go against the bubble
    - Not riding a bubble for too long is … can cost you your shirt
    - Even if one identify bubbles, predicting the time of its bursting is infinitely more difficult
    - Investors/institutions ride the bubble which allows it to persist
    - Little heterogeneity

- Credit bubble led to housing bubble
  - Note similarity to Nordic countries, Japan,…
    (foreign capital, agency problems were less of an issue there)

Macro-prudential regulation

1. Externality:
   - Measure contribution of institution to systemic risk: CoVaR
   - Response to current regulation
     "hang on to others and take positions that drag others down when you are in trouble"
     (maximize bailout probability ⇨ **Moral Hazard**)
     - become big
     - hold similar position (be in trouble when others are)
     - become interconnected
2. Procyclicality:
   - Lean against "credit bubbles" – laddered response
     - Bubble + maturity mismatch impair financial system (vs. NASDAQ bubble)
   - Impose Capital requirements/Pigouvian tax/Private insurance scheme
     - *not directly* on ΔCoVaR, but on
     - frequently observed factors, like maturity mismatch, leverage, B/M, *crowdedness* of trades/credit, …
3. Funding: Asset-Liability Maturity Match

Who should be regulated?

group	examples	macro-prudential	micro-prudential
"individually systemic"	International banks (national champions)	Yes	Yes
"systemic as part of a herd"	Leveraged hedge funds	Yes	No
non-systemic large	Pension funds	No	Yes
"tinies"	unlevered	No	No

- Micro: based on risk in isolation
- Macro: Classification on systemic risk contribution measure, e.g. CoVaR
- Annual list (not publicized)

CoVaR

- $CoVaR_q^i$ is implicitly defined as quantile

$$\Pr(X^i \leq VaR_q^i) = q$$

- $CoVaR_q^{j|i}$ is the VaR conditional on institute *i* (index) is in distress (at it's VaR level)

$$\Pr(X^j \leq CoVaR_q^{j|i} \mid X^i = VaR_q^i) = q$$

- $\Delta CoVaR_q^{j|I} = CoVaR_q^{j|i} - VaR_q^j$

- Various conditioning possibilities? (direction matters!)

Contribution Δ CoVaR

- Q1: Which institutions contribute (in a non-causal sense)
- $VaR^{system}|$ institution *i* in distress

Exposure Δ CoVaR

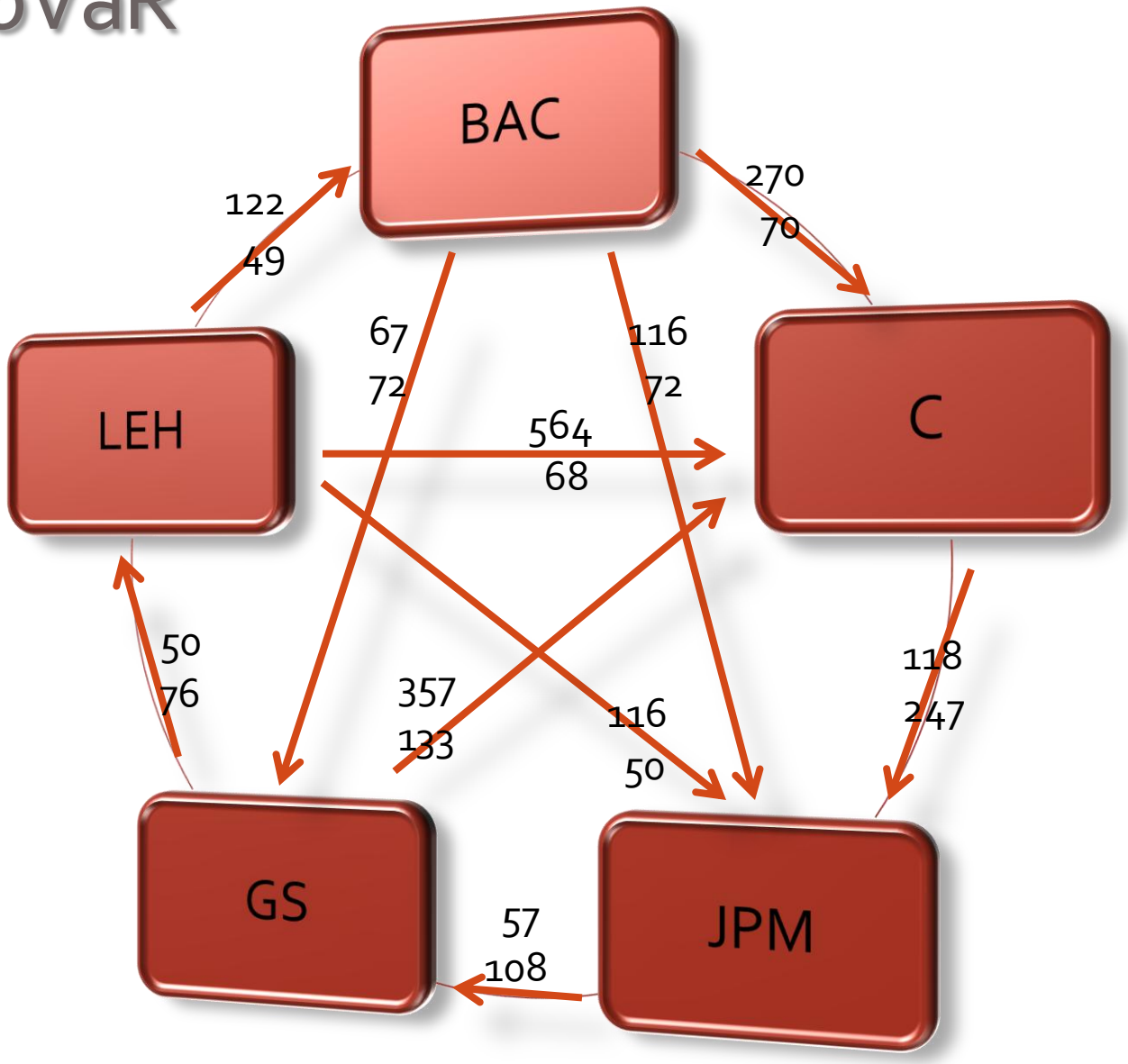
- Q2: Which institutions are most exposed if there is a systemic crisis?
- $VaR^i|$ system in distress

Network Δ CoVaR

- VaR of institution *j* conditional on *i*

Can be extended to Co-Expected Shortfall!

Network CoVaR



- conditional on origin of arrow

Overview

- Challanges
- Measuring Systemic Risk Spillover/Externalities
- One Method: Quantile Regressions
- CoVaR vs. VaR
- Addressing Procyclicality
  - Predict using institutions' characteristics
    - Balance sheet variables
    - Market variables (CDS, implied vol.,…)

Quantile Regressions: A Refresher

- OLS Regression: min sum of squared residuals

$$\beta^{OLS} = \arg\min_{\beta} \Sigma_t \quad y_t - \alpha - \beta x_t \quad ^2$$

  - *Predicted value:* $E[y \mid x] = \alpha + \beta x$

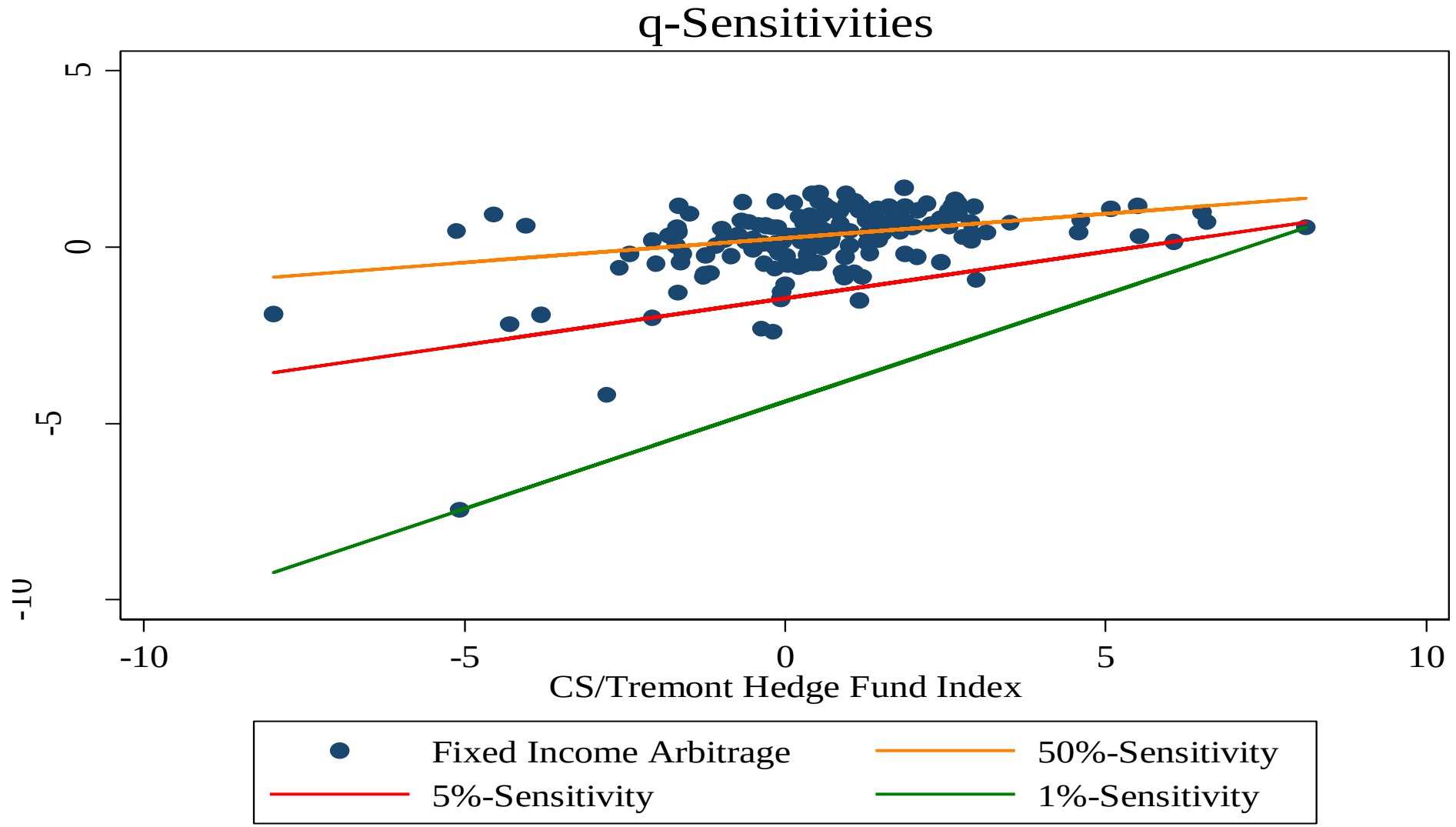
- Quantile Regression: min weighted absolute values

$$\beta^q = \arg\min_{\beta} \Sigma_t \begin{cases} q\left|y_t - \alpha - \beta x_t\right| & \text{if} \quad y_t - \alpha - \beta x_t \geq 0 \\ 1-q \ \left|y_t - \alpha - \beta x_t\right| & \text{if} \quad y_t - \alpha - \beta x_t < 0 \end{cases}$$

  - *Predicted value:* $VaR_q \mid x = F_y^{-1}(q \mid x) = \alpha_q + \beta_q x$

Note out (non-traditional) sign convention!

Quantile Regression: A Refresher



Financial Intermediary Data

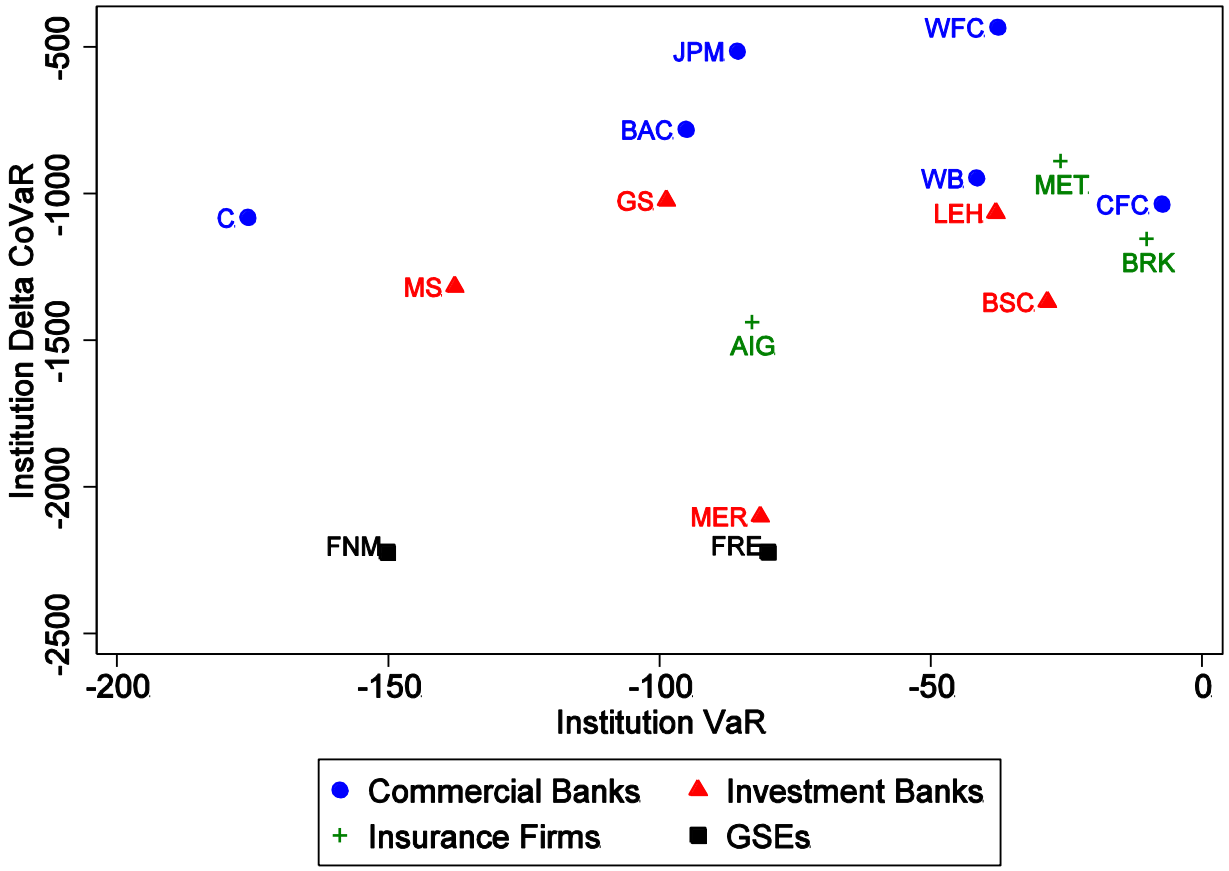
- Publicly traded financial intermediaries 1986-2008
  - Commercial bank, security broker-dealers, insurance companies, real estate companies, etc.
  - Weekly market equity data from CRSP
  - Quarterly balance sheet data from COMPUSTAT

- CDS and option data of top 10 US banks, daily 2004-2008

Overview

- Measuring Systemic Risk Contribution
- One Method: Quantile Regressions
- CoVaR vs. VaR
- Addressing Procyclicality
  - Time-varying CoVaR/VaR
  - Predict using institutions' characteristics
    - Balance sheet variables
    - Market variables (CDS, implied vol.,…)

ΔCoVaR vs. VaR



- VaR and Δ CoVaR relationship is very weak
- Data up to 12/06

Overview

- Challanges
- Measuring Systemic Risk Contribution
- One Method: Quantile Regressions
- CoVaR vs. VaR
- Addressing Procyclicality
  - Step 1: Time-varying CoVaRs
  - Step 2: Predict CoVaR using institution characteristics
    - Balance sheet variables
      (leverage, maturity mismatch, + interdependence, …)
    - Market variables (CDS, implied vol.,…)

Step 1: Time-varying CoVaR

- Relate to macro factors, M_t

	interpretation
VIX Level	"Volatility"
3 month yield	
Repo – 3 month Treasury	"Flight to Liquidity"
Moody's BAA – 10 year Treasury	"Credit indicator"
10Year – 3 month Treasury	"Business Cycle"
Real estate index	"Housing"
Equity market risk	

⇨ Obtain Panel data of CoVaR

- Next step: Relate to institution specific (panel) data

Step 1: Time-varying ΔCoVaR

- Derive time-varying VaR_t
  - For institution *i*:

$$X_t^i = \alpha_q^i + \beta_q^i M_t + \varepsilon_t^i$$

  - For financial system:

$$X_t^{system} = \alpha_q^{system} + \beta_q^{system} M_t + \varepsilon_t^{system}$$

- Derive time-varying $CoVaR_t$

$$X_t^{system} = \alpha_q^{system|i} + \beta_q^{system|i} M_t + \gamma X_t^i + \varepsilon_t^{system|i}$$

- $\Delta CoVaR_t = CoVaR_t - VaR_t$

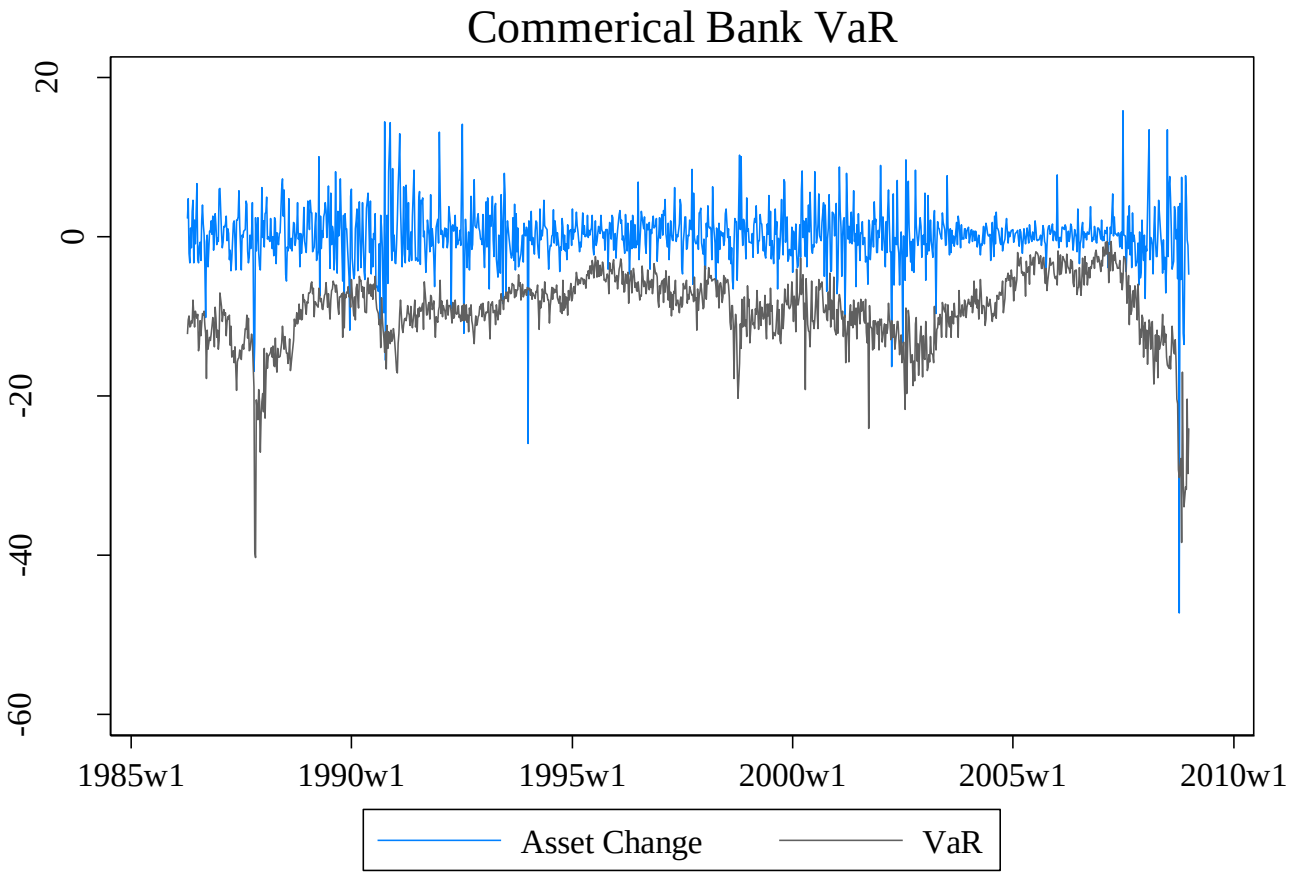
Table 2: Average Exposures to Risk Factors

INSTITUTIONS

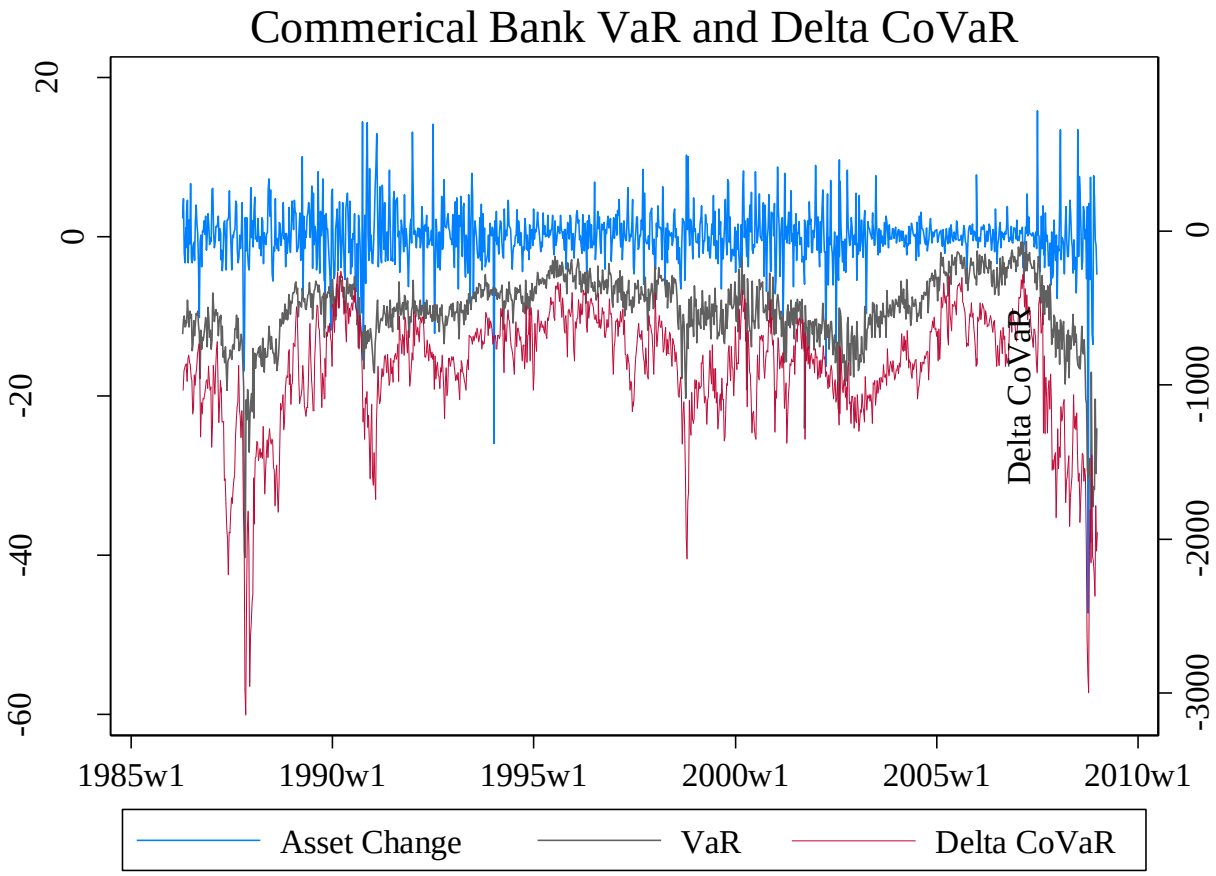
COEFFICIENT	VaR^{system}	VaR^{i}	$CoVaR^{system|i}$
Repo spread (lag)	-1163***	-0.60	-877.94***
Credit spread (lag)	-107.75	-0.47	-226.75**
Term spread (lag)	128.71	0.64	18.80
VIX (lag)	-68.97***	-0.16***	-43.35***
3 Month Yield (lag)	118.73	0.42	15.95*
Market Return (lag)	242.74***	0.50***	196.00***
Housing (lag)	5.63	0.03	5.17

*** p< 0.01
** p< 0.05
* p< 0.1

Time-varying VaR



Time-varying VaR and ΔCoVaR



Step 2a: Portfolios Sorted on Characteristics

- Institutional characteristics matter
- … but individual financial institutions have changed the nature of their business over time
- Form decile portfolios, each quarter, according to previous quarter's data:
  1. Leverage
  2. Maturity mismatch
  3. Size
  4. Book-to-Market
- Add 4 industry portfolios
  1. Banks
  2. Security broker-dealers
  3. Insurance companies
  4. Real estate companies

Table 3A: ΔCoVaR Forecasts by Characteristics Cross-section, Portfolios, 1%

COEFFICIENT	2 Years	1 Year	1 Quarter
ΔCoVaR (lagged)	0.71***	0.80***	0.94***
VaR (lagged)	-1.99***	-2.27***	-0.47***
Leverage (lagged)	-9.43***	-10.73***	-2.53**
Maturity mismatch (lagged)	-0.89***	-0.30	-0.14
Relative Size (lagged)	170.84***	-161.99***	-38.58***
Book-to-Market (lagged)	85.24***	87.65***	31.03**
Constant	-40.92**	-50.04**	-19.93*
Observations	3627	3805	3939
R^2	0.62	0.69	0.89

Table 3B: ΔCoVaR Forecasts by Characteristics Cross-section, 2 years

COEFFICIENT	1%	5%	10%
ΔCoVaR (lagged)	0.71***	0.63***	0.70***
VaR (lagged)	-1.99***	-1.86***	-1.38***
Leverage (lagged)	-9.43***	-5.08***	-4.23**
Maturity mismatch (lagged)	-0.89***	-0.51***	0.10
Relative Size (lagged)	-170.84***	-105.62***	-86.84***
Book-to-Market (lagged)	85.24***	26.95***	-14.77**
Constant	-40.92**	-14.70*	36.88***
Observations	3627	3627	3627
R^2	0.62	0.62	0.70

Table 4: ΔCoVaR Forecasts by Characteristics Time Series/Cross Section, Portfolios, 1%

COEFFICIENT	2 Years	1 Year	1 Quarter
ΔCoVaR (lagged)	0.41***	0.58***	0.86***
VaR (lagged)	-1.30***	-1.74***	0.06
Leverage (lagged)	0.92	-8.10***	-1.64
Maturity mismatch (lagged)	-0.31	-0.53	-0.33
Relative Size (lagged)	-230***	-229***	-56***
Book-to-Market (lagged)	29.25	42.69	31.03**
Constant	-332.58***	-239.05***	-96.84***
Observations	3627	3805	3939
R^2	0.69	0.73	0.89

Timing of tail risk is harder to forecast than cross-section contribution

Step 2b: Forecasting with Market Variables

- CDS spread and equity implied volatility for 10 largest US commercial and investment banks (from Bloomberg)
- Betas:
  - Extract principal component from CDS spread changes/implied vol changes within each quarter from daily data
  - Regress each CDS spread change/ implied vol change on first principal component

Table 6: ΔCoVaR Forecasts by Market Variables Cross Section, Portfolios, 1%

COEFFICIENT	2 Years	1 Year	1 Quarter
ΔCoVaR (lagged)	0.60***	0.79***	0.94***
VaR (lagged)	-1.84	0.05	-0.08
CDS beta (lagged)	-1.727**	787.92	95.37
CDS (lagged)	1.320	-2.211	-40.26
Implied Vol beta (lagged)	-8.30	-590.28**	-85.78
Implied Vol (lagged)	-144.60	111.02	234.56***
Constant	-335.30	-147.72	-114.07*
Observations	114	154	184
R^2	0.36	0.57	0.77

short data-span (2004-2008)!

Extension to our Analysis

- Co-Expected Shortfall ("Co-ES")
  - Advantage: coherent risk measure
  - Disadvantage: any estimate "in" the tail is very noise

- Inclusion of additional information
  - derivative positions
  - off-balance sheet exposure
  - Crowdedness measure
  - Interdependence measures
  - Bank supervision information

Countercyclical Regulation

- *When market is relaxed*
  Strict Laddered Response
  - **Step 1:** supervision enhanced
  - **Step 2:** forbidden to pay out dividends
    - See connection to debt-overhang problem)
  - **Step 3:** No Bonus for CEOs
  - **Step 4:** Recapitalization within two months + debt/equity swap
- *When market is strict*
  Relax regulatory requirement

What type of charge?

- Capital charge
  - Strictly binding
  - Might stifle competition
- Pigouvian tax + government insurance
  - Generates revenue
  - In times of crisis it is cheap to issue government debt
  - very salient
- Private insurance scheme
  - (Kashap, Rajan & Stein, 2008 + NYU report)
  - Requires lots of regulation

Conclusion

- Macro-prudential regulation
  - Focus on externalities
  - Measure for systemic risk is needed, e.g. CoVaR
  - Maturity mismatch (+ Leverage) – encourage long-term funding
- Countercyclical regulation
  - Find variables that predict average future CoVaR
  - Forward-looking measures, spreads, …
- Also,
  - VaR measure is not sufficient – incorrect focus
  - Quantile regressions are simple and efficient way to calculate CoVaR