Systemic Risk and the Macroeconomy: An Empirical Evaluation

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Introduction

- **Many systemic risk measures proposed** in aftermath of 2007 financial crisis
- Individual measures explored separately, little/no empirical analysis as a group
- Preliminary step: provide a basic quantitative description of existing SR measures
  - Construct 17 previously proposed measures of systemic risk in the US and 10 measures for the UK and EU
  - Extend series as far as possible, at least past 1990s (contrast with last decade)
- Each measure shown to work to capture some particular aspects of financial distress
- **Not a clear picture of which aspects of systemic risk they are capturing or what is the criterion to judge them**

Introduction

- Three fundamental questions about systemic risk
  - **Definition** - What is SR?
  - **Measurement** - How do we measure and detect SR?
  - **Welfare** - How does SR affect us?
- We start from Welfare to evaluate Measurement, and aim to provide stylized facts that say something about Definition

Three Main Objectives

1. Propose a criterion for evaluating SR measures
   - To be relevant for **policy**, interested in SR to the extent that it has consequences for economic welfare
   - Can we detect ways that SR affects the **real economy**?
   - Quantify this by looking at **conditional quantiles** of real activity variables and their relation with SR measures

Three Main Objectives

- We apply the criterion and evaluate how many proposed measures of SR actually associate with greater risk for the real economy
  - Only a few SR measures are associated with higher risks to the real economy
- Perhaps each measure contains *some* information that is useful to capture SR
  - Do not always move together
  - May capture different aspects of distress in financial markets

Three Main Objectives

2. **Propose dimension reduction techniques** to detect relationship between the real economy and SR measures jointly
   - Suppose a latent SR factor drives the SR measures and the quantiles of future real macro variables
   - We propose two dimension reduction estimators to estimate this factor; prove they are asymptotically unbiased
   - Empirical finding: **Information gain from aggregation** $\rightarrow$ SR measures as group informative about macro variables

Three Main Objectives

3. **Produce stylized facts** on the relation between SR and the macroeconomy
   - We can study which measures work and which don't work, by our metric
   - These stylized facts can aid future work to dig deeper into the underlying mechanisms

Three Main Objectives

- Three stylized facts
  1. SR affects the **lower tail** of the future macroeconomic distribution, not the center
  2. **Financial volatility** is informative
  3. Government responds to distress but not enough

Summary: Systemic Risk and the Real Economy

- Results reach **positive** conclusion regarding the empirical systemic risk literature
- Increases in SR index associated with a large widening in the left tail of economic activity
- One s.d. increase in SR shifts the 20th percentile of the IP growth distribution down by more than 50%, from around -1.4% per quarter unconditionally, to -2.2%
- During crises 20th percentile drops below -3% per quarter, twice as large as in normal times
- SR index also predicts reactions of policymakers: the 20th percentile of changes in the federal funds rate drops by 60%, from -50bps to -80bps.

Landscape of Systemic Risk Measures

Which Measures?

1. Aggregated versions of institution-specific measures: **CoVar, ΔCoVar, MES, SES, MES-BE**.

2. Comovement and contagion: **Absorption Ratio, DCI, International Spillover Index.**

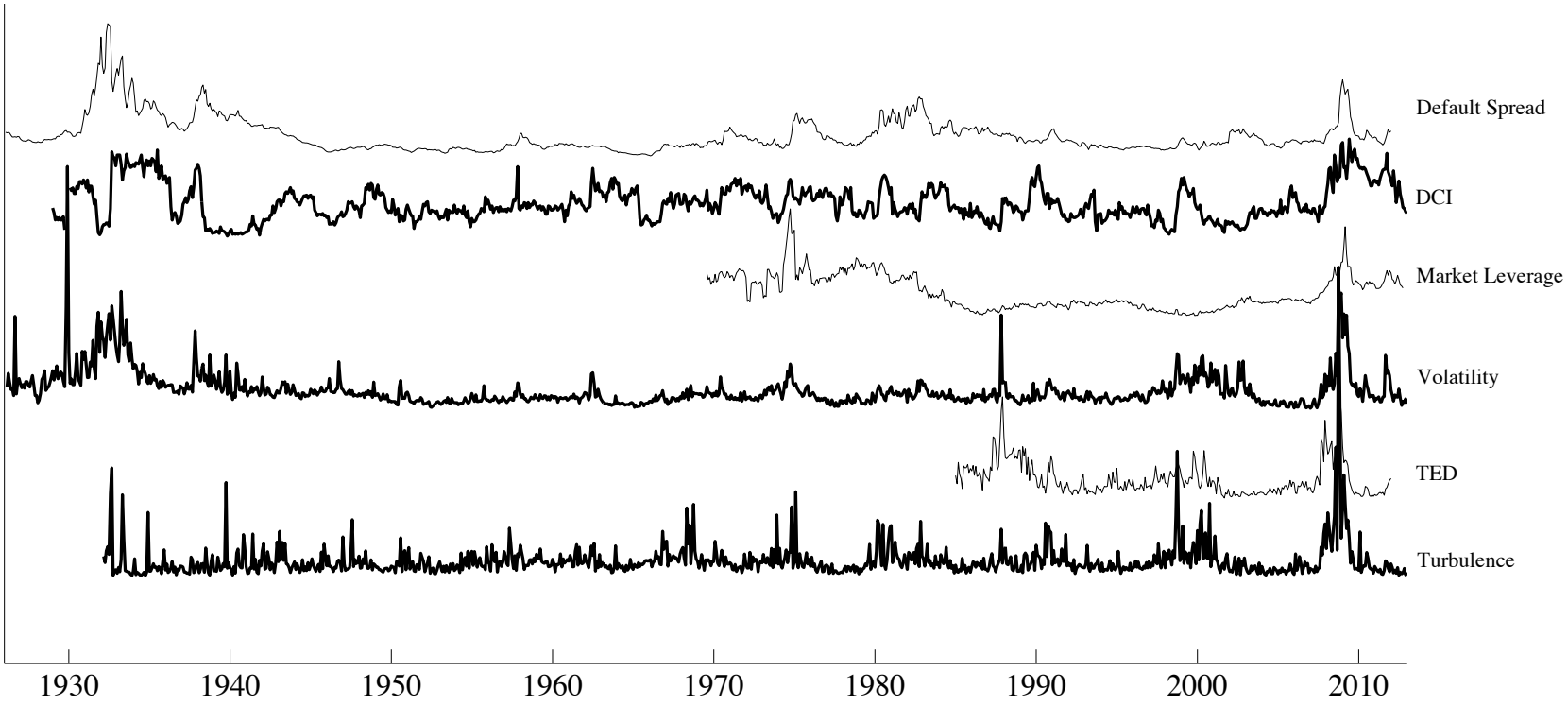
3. Liquidity and credit: **AIM, TED Spread, Default spread, Term spread**

4. Instability and volatility: **Volatility, Turbulence, Book Leverage, Market Leverage, Size Concentration**

- We do not cover direct linkages and CDS-based measures

- We construct measures for the US, plus UK and Euro Area (France, Germany, Italy, Spain)

Systemic Risk Measures



Summary of Comovement Among Measures

- All spiked during financial crisis, not surprising given *a posteriori* origins
- Correlations among measures are low on average ~ 0.2.
  - Some measures lead others (CoVaR, credit spreads, volatility), some only "coincident" indicators
- In long sample, many reached similar levels as in recent crisis. Interpretations include
  - Measures are simply noisy
  - Sometimes capture stress in financial system that does not result in economic crises either because either policy response diffused instability or system stabilized itself

Macroeconomic Criterion and Accompanying Tests

Motivation

- Financial distress impacts real outcomes through capital / credit / liquidity contraction
- Bernanke & Gertler (1989), Kiyotaki and Moore (1997), Bernanke, Gertler & Gilchrist (1999), Brunnermeier & Sannikov (2010), Gertler & Kiyotaki (2010), Mendoza (2010), He & Krishnamurthy (2012)
- Emphasis on **non-linearity**. Distribution of **real outcomes** changes when degree of SR changes. Particularly interested in effects at low quantiles of real outcomes
- *"... what measurements will be the most fruitful to support our understanding of linkages between financial markets and the macroeconomy is an open issue."* Hansen (2012)

A Criterion for Evaluating Measures

- SR indicator should demonstrably associated with future macroeconomic outcomes
  - Important from regulatory point of view
  - Summarizes vast amount of economic activity and decision-making
- This criterion addresses the field's need of an empirical description of link between proposed financial markets and the real economy

Operationalizing Criterion: Quantile Regression

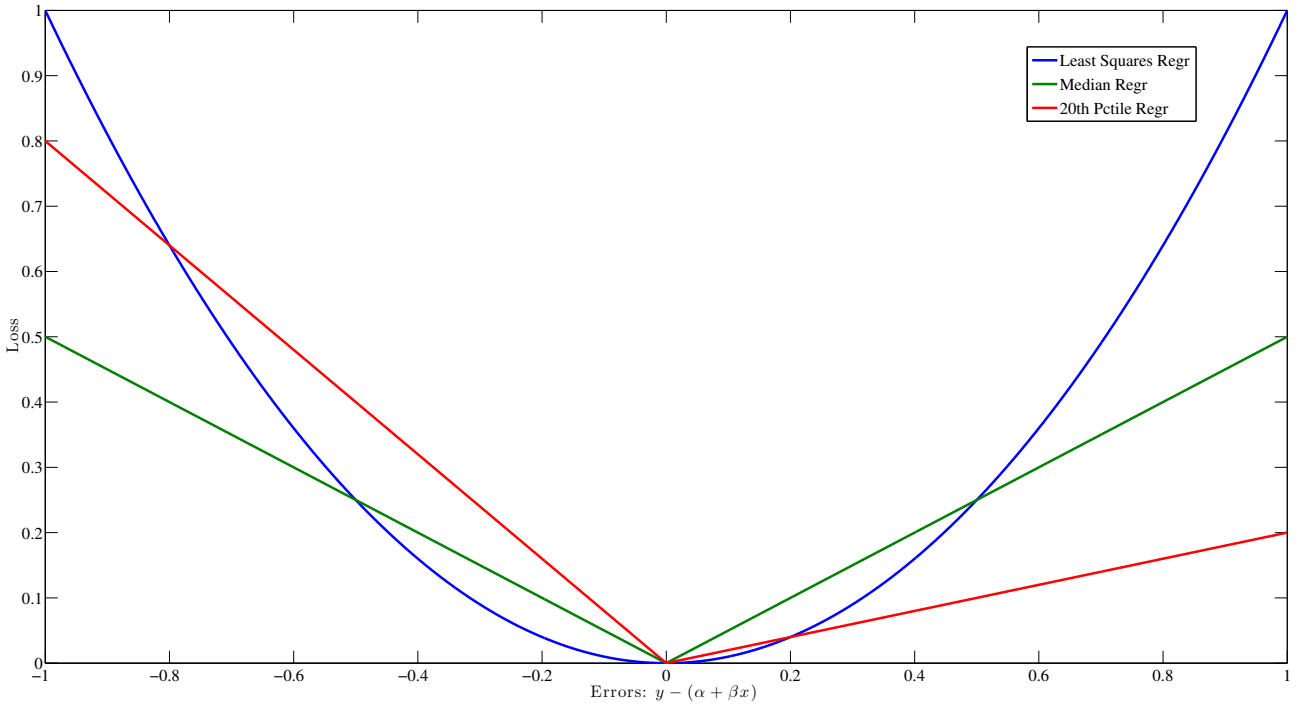
- Operationalize: Quantile regression test for the SR measure's ability to predict distribution of future macro shocks
  - OLS models the **conditional mean** relationship b/w X and y
  - QR models the **conditional quantile** relationship b/w X and y
- Main advantages
  - Reduced-form implementation of theoretical SR/macro association (e.g. He and Krishnamurthy)
  - Broader view of the conditional distribution of y given X
  - Can flexibly evaluate the relationship at different parts of y's distribution
    - eg. lower tail, central tendency, upper tail

Quantile Regression in Thirty Seconds

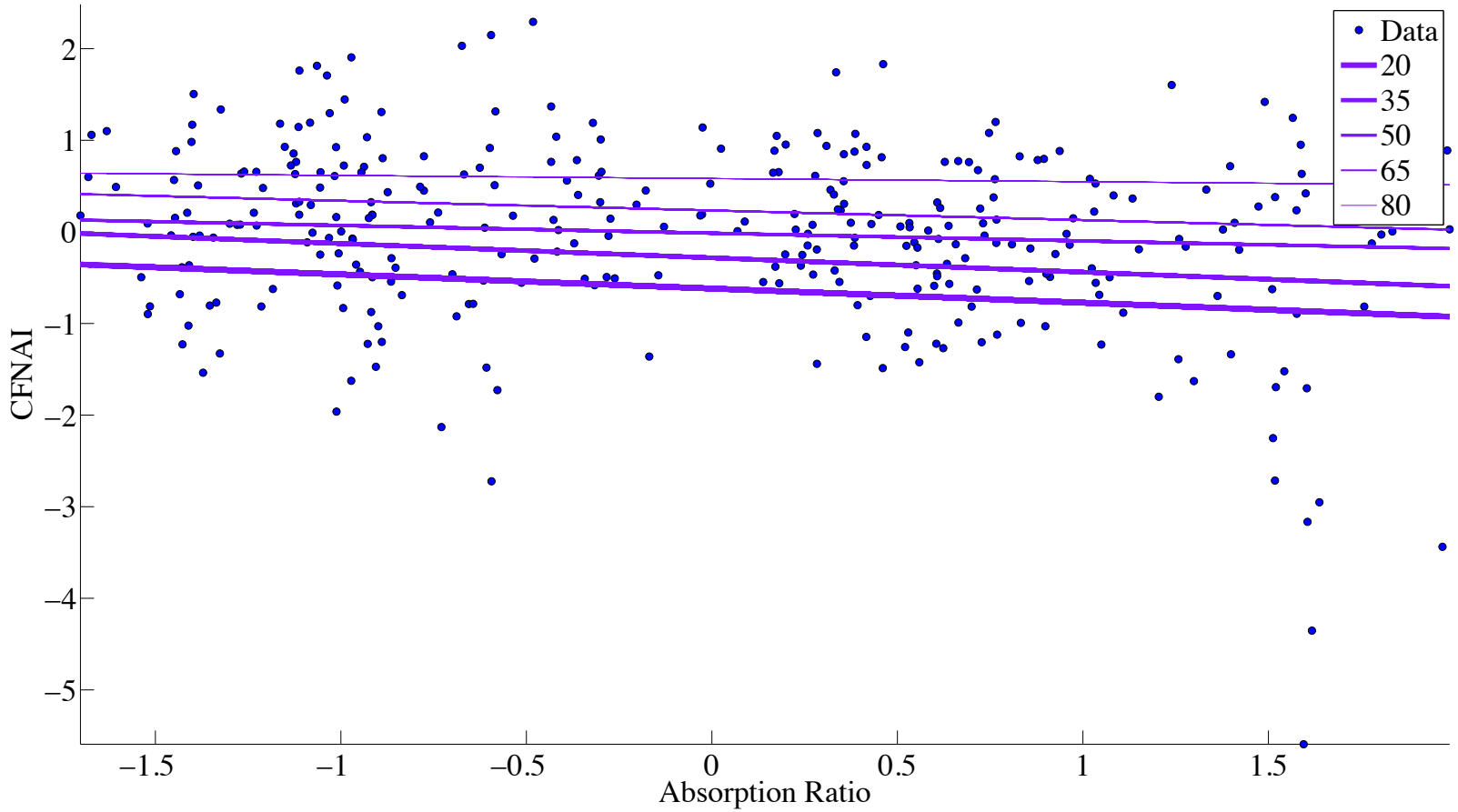
$$Q_\tau(y_{t+1}|\mathcal{I}) = \alpha(\tau) + \boldsymbol{\beta}(\tau)'\boldsymbol{x}_t$$

- Varying τ' leads to different $\alpha(\tau'), \boldsymbol{\beta}(\tau')$ in general
  - Different $\boldsymbol{x}, y$ relationships at different parts of y's distribution
- The quantile loss function estimates $\alpha, \boldsymbol{\beta}$ **and** evaluates the forecasts
  - in OLS: mean-squared-error estimates parameters and evaluates the forecasts

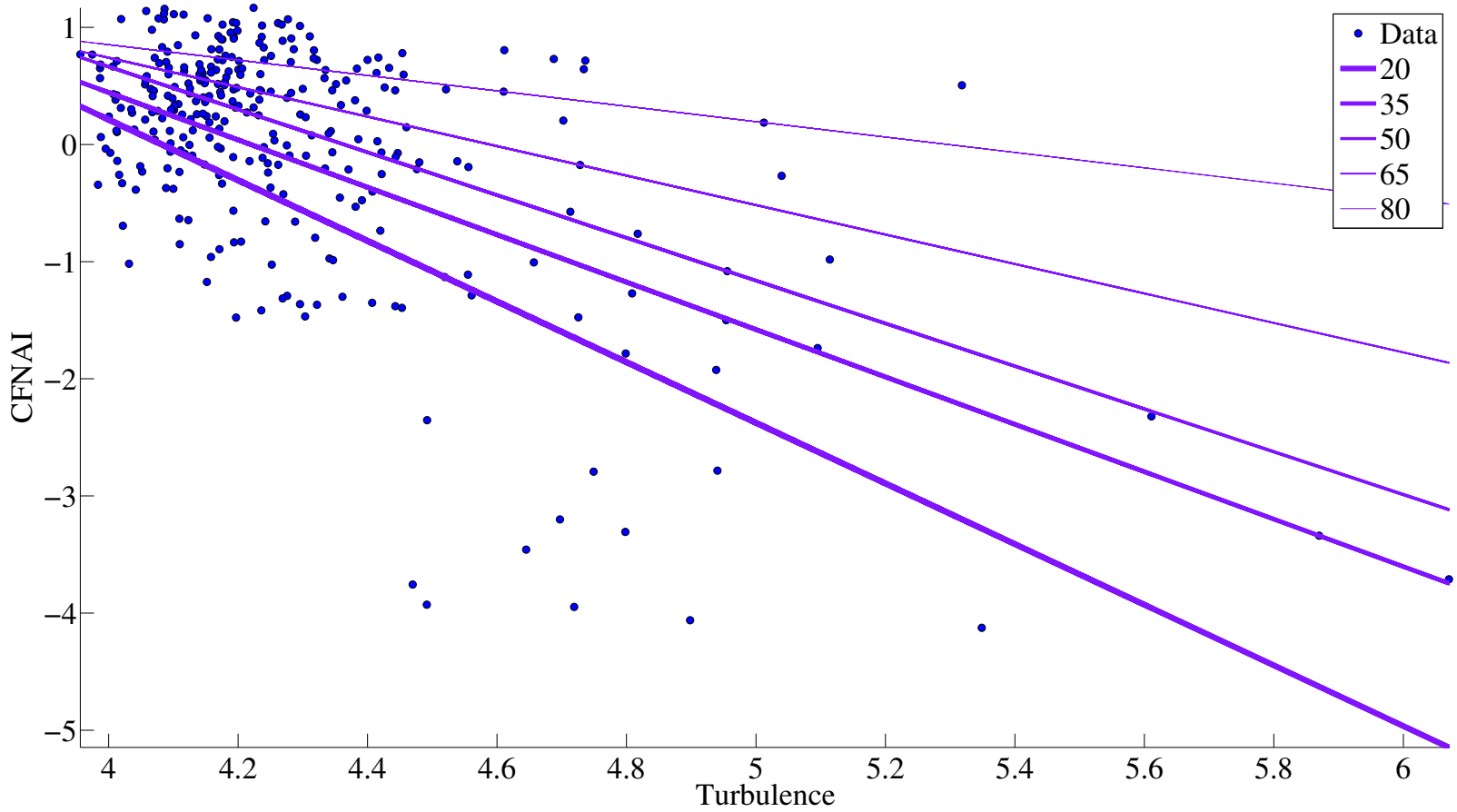
Loss Functions



Example of No Quantile Relation: Absorption Ratio



Example of Strong Quantile Relation: Turbulence



Dependent Variable: Macroeconomic Shocks

Macroeconomic target y_t is a shock derived from:

- Industrial Production
- CFNAI, or CFNAI subcomponent
  - Aggregate index (Total)
  - Production and Income (PI)
  - Employment, Unemployment and Hours (EUH)
  - Personal Consumption and Housing (PH)
  - Sales, Orders and Inventory (SOI)
- y_t is a one quarter-ahead "shock," or innovation to $AR(p)$
- US: IP 1946-2011, CFNAI 1967-2011; less for UK, EU

Robust: Recursive; AIC; ARX(p)

Benchmark Quantile Forecast Analysis

$$Q_\tau(y_{t+1}|x_t) = \alpha + \beta x_t$$

- Benchmark results use 20^{th} percentile ($\tau = 0.2$)
- Focus out-of-sample: Test significance of forecast power using Diebold-Mariano (1995) and West (1996)
  - A more stringent F-test
- Report the QR "R^2"

$$R^2 = 1 - \frac{\text{Mean Quantile Loss Using Predictors}}{\text{Mean Quantile Loss Using Unconditional Quantile}}$$

Out-of-Sample 20^{th} Percentile IP Shock Forecasts

	US			UK	EU
Out-of-Sample start	1950	1970	1985	1985	2000
Absorption	−2.80	−4.38	−3.96	0.39	5.36*
AIM	2.99**	4.01**	4.07*	−0.28	0.50
CoVaR	1.71	2.11	1.85	6.45**	4.86**
ΔCoVaR	−0.45	−0.86	−0.97	5.42**	4.86*
MES	−0.10	0.21	0.97	2.24	2.44
MES-BE	−1.24	−0.78	−6.70	−1.59	2.84
Book Lvg.	–	–	3.87***	−2.98	0.80
DCI	−1.61	−1.75	−2.92	−5.15	5.34**
Def. Spr.	−0.29	0.69	8.60***	15.87***	11.41*
ΔAbsorption	−0.83	−0.10	−0.27	0.11	0.05
Intl. Spillover	–	0.34	1.41	−0.15	−1.32
Size Conc.	−2.48	−7.37	−3.59	7.06**	10.93***
Mkt. Lvg.	–	–	12.70***	−3.63	−0.57
Volatility	3.27**	6.19**	8.03*	8.35**	6.83
TED Spr.	–	–	10.18***	−1.06	1.06
Term Spr.	0.32	2.13	1.14	−2.70	1.23
Turbulence	3.50***	6.93***	12.78***	−3.62	−0.38

Out-of-Sample 20^{th} Percentile CFNAI Shock Forecasts

	Total	PH	PI	SOI	EUH
	Panel A: Individual Systemic Risk Measures				
Absorption	−4.58	−1.85	−2.66	−3.11	−3.00
AIM	−3.42	−2.60	−2.69	−3.44	−1.67
CoVaR	−1.82	−2.98	−2.83	−3.27	−0.94
ΔCoVaR	−4.55	−2.59	−4.11	−4.49	−4.31
MES	−3.62	−2.51	−4.81	−3.64	−3.09
MES-BE	−2.25	−1.68	−0.60	−2.70	−2.50
Book Lvg.	0.49	−2.19	1.36	−0.47	1.19
DCI	−2.14	−0.67	−2.28	−3.50	−2.42
Def. Spr.	−0.38	−3.88	−0.84	−3.15	−3.19
ΔAbsorption	−0.37	−1.92	1.16	−0.53	0.59
Intl. Spillover	−2.52	−3.62	−0.94	−1.78	−2.38
Size Conc.	−1.84	−1.66	−0.60	−2.77	−0.17
Mkt. Lvg.	4.26^{*}	−0.78	4.14^{*}	5.70^{**}	4.14^{*}
Volatility	1.65	−0.07	1.00	2.97	2.14
Term Spr.	3.03	0.64	3.32	2.64	2.36
Turbulence	7.37^{**}	4.82^{**}	7.97^{***}	8.40^{***}	4.46^{*}

Results for Individual Measures

- Individual predictors: Mixed, somewhat weak out-of-sample performance
  - Notable exception: Financial volatility variables, leverage
- Can we fruitfully put them together?

Dimension Reduction Techniques

Quantile Regression with Many Predictors

- How do we forecast quantiles when number of predictor variables is large?
- Multiple QR works poorly due to standard "many-predictor" issues
- Two new methodologies:
  - Principal Component Quantile Regression
  - Partial Quantile Regression: Analogue of PLS for quantiles

Framework

- Quantiles of y_{t+1}, conditional on t info, as a linear in unobservable factor f_t,

$$Q_\tau(y_{t+1}|\mathcal{I}_t) \equiv Q_\tau(y_{t+1}|f_t) = \alpha f_t$$

- Assume large set of observable predictors $\boldsymbol{x}_t$ that are linear in f_t, as well as other factors $\boldsymbol{g}_t$

$$\boldsymbol{x}_t = \phi f_t + \boldsymbol{\Psi}\boldsymbol{g}_t + \varepsilon_t$$

Principal Component Quantile Regression (PCQR)

$$Q_\tau(y_{t+1}|\mathcal{I}_t) \equiv Q_\tau(y_{t+1}|f_t) = \alpha f_t$$

$$\boldsymbol{x}_t = \phi f_t + \boldsymbol{\Psi}\boldsymbol{g}_t + \varepsilon_t$$

Stage 1: Use PCA to extract common factors among $\boldsymbol{x}_t$, denoted $\hat{\boldsymbol{F}}_t = (\hat{f}_t, \hat{\boldsymbol{g}}_t)$

Stage 2: Use $\hat{\boldsymbol{F}}_t$ to forecast $Q_\tau(y_{t+1}|\mathcal{I}_t)$

- Construct systemic risk index that assigns more weight to x_{it}'s that better capture the comovement among $\boldsymbol{x}_t$

Partial Quantile Regression (PQR)

$$Q_\tau(y_{t+1}|\mathcal{I}_t) \equiv Q_\tau(y_{t+1}|f_t) = \alpha f_t$$

$$\boldsymbol{x}_t = \boldsymbol{\phi} f_t + \boldsymbol{\Psi} \boldsymbol{g}_t + \boldsymbol{\varepsilon}_t$$

Stage 1: Estimate $Q_\tau(y_{t+1}|x_t) = \alpha_i + \beta_i x_{it}$ for each i

Stage 2: Construct $\hat{f}_t$ as weighted average of x_{it}'s in which $\hat{\beta}_i$'s are weights

Stage 3: Use $\hat{f}_t$ to forecast $Q_\tau(y_{t+1}|\mathcal{I}_t)$

- Construct f_t by assigning more weight to x_{it}'s with strongest predictive content for $Q_\tau(y_{t+1}|\cdot)$

Comparison of PCQR and PQR

$$Q_\tau(y_{t+1}|\mathcal{I}_t) \equiv Q_\tau(y_{t+1}|f_t) = \alpha f_t$$

$$\boldsymbol{x}_t = \underbrace{\phi f_t}_{\text{relevant}} + \underbrace{\boldsymbol{\Psi}\boldsymbol{g}_t + \varepsilon_t}_{\text{irrelevant}}$$

- PCQR optimal when you're confident you can extract all factors via PCA
  - This is case when forecast-relevant factors are dominant source of variation in x_{it}'s
- PQR works generally, including cases in which PCA may extract $\boldsymbol{g}_t$ and miss f_t

Econometrics

- Latent variables system: error-in-variables (EIV) bias
- Both PCQR and PQR have a mismeasured factor in the **last step**
- Measurement error in QR is hard to deal with – no expression for the quantile solution
- Angrist, Chernozhukov, Fernandez-Val (2006) misspecified QR: We adapt to express the EIV bias and analyze in our asymptotic experiment under our assumptions
- Since we look at N, T limit, factors will become precisely estimated and the bias goes to zero
- PQR has EIV even in the first stage

Econometrics

- PCQR: asymptotically unbiased as $N, T \to \infty$, assuming all factors extracted in first stage
- PQR: asymptotically unbiased as $N, T \to \infty$, assuming a bit more structure on problem

Contribution: A methodology for constructing systemic risk indices that are asymptotically unbiased in large SR panels

Real test is how they work in finite samples

- Simulation evidence supports the asymptotics
- Empirically successful, as we now see ...

Out-of-Sample 20^{th} Percentile Shock Forecasts

Industrial Production

	US			UK	EU
Out-of-Sample start	1950	1970	1990	1990	2000
Multiple QR	−23.66	−18.52	15.21***	−14.39	−3.25
PCQR1	0.68	0.13	1.61	6.01**	12.03**
PCQR2	6.47***	10.52***	16.67***	3.38	9.33*
PQR	6.58***	10.82***	12.39***	4.49*	5.14*

CFNAI

	Total	PH	PI	SOI	EUH
Multiple QR	−36.74	−47.07	−52.06	−20.00	−54.18
PCQR1	−1.07	−0.73	−1.96	−2.06	−0.24
PCQR2	0.89	−2.44	0.20	−0.65	0.28
PQR	7.09**	2.16	5.36*	9.72***	2.15

Robustness: Other Quantiles

Out-of-Sample 10^{th} Percentile IP Shock Forecasts

	In-Sample	Out-of-Sample		
		start		
		1950	1970	1985
Panel A: Individual Systemic Risk Measures				
AIM	6.97^{**}	6.30^{***}	7.32^{**}	6.70^{*}
Book Lvg.	4.07^{***}	–	–	7.30^{***}
DCI	1.45	0.56	0.48	4.63^{*}
Def. Spr.	1.78^{*}	0.66	1.00	6.82^{***}
Mkt. Lvg.	17.87^{***}	–	–	20.93^{***}
Volatility	3.63^{**}	2.95^{*}	5.49^{**}	4.98
Turbulence	3.77^{**}	2.27	4.17^{*}	12.50^{**}
Panel B: Systemic Risk Indexes				
Multiple QR	38.86^{***}	−54.86	−33.99	17.14^{**}
PCQR1	7.77^{*}	−0.41	3.60^{*}	−0.81
PCQR2	27.28^{***}	7.19^{***}	16.20^{***}	19.38^{***}
PQR	12.96^{***}	5.19^{*}	11.36^{***}	10.28^{**}

Robustness: Other Quantiles

Out-of-Sample 10^{th} Percentile CFNAI Shock Forecasts

	Total	PH	PI	SOI	EUH
		Panel A: Individual Systemic Risk Measures			
AIM	−0.93	−7.86	−3.29	1.26	−4.48
Book Lvg.	2.74*	−4.35	0.60	2.62	4.31***
DCI	−7.13	−5.47	−3.85	−6.72	−4.31
Def. Spr.	−2.99	−4.79	−2.53	−4.51	−1.47
Mkt. Lvg.	11.48***	−1.71	7.58*	13.85***	8.83**
Volatility	6.65	0.78	3.68	6.11*	4.35
Turbulence	11.76***	4.07	12.77**	9.48***	8.77**
		Panel B: Systemic Risk Indexes			
Multiple QR	−68.49	−85.59	−95.11	−41.80	−61.78
PCQR1	−3.84	−0.70	−4.45	0.35	0.37
PCQR2	0.03	0.07	1.70	3.21	0.30
PQR	9.07**	2.20	9.50**	8.84**	6.55

What do we learn from these results?

- There is a SR factor strongly related to future downside macroeconomic risk
  - One s.d. increase in SR shifts the 20th percentile of the IP growth distribution down by more than 50%, from around -1.4% per quarter unconditionally, to -2.2%
  - During crises 20th percentile drops below -3% per quarter, twice as large as in normal times

- Financial-sector volatility may be most "fruitful" for understanding the linkages between financial markets and the macroeconomy

- Next: What can we say about the nature of SR?

Stylized Facts about Systemic Risk and the Macroeconomy

(1) Downside Macroeconomic Risk

- So far we have shown the ability of SR measures to predict the **lower tail** of the distribution of future macroeconomic outcomes
- What happens if we look at medians?

(1) Downside Macroeconomic Risk

Median Forecasts: Weaker predictability for central tendency

	US			UK	EU
Out-of-Sample start	1950	1970	1985	1985	2000
Panel A: Individual Systemic Risk Measures					
AIM	0.07	−1.68	−0.12	0.13	−0.01
CoVaR	0.33	−1.26	−8.23	−2.59	1.52
MES (APPR)	−0.23	−1.46	−6.77	−2.85	−0.05
SRISK	−1.17	−0.44	−0.95	2.24	−0.41
Volatility	1.21	2.46	−0.49	−0.16	−1.34
Term Spr.	0.08	0.21	−1.99	−0.66	−1.68
Turbulence	1.37**	2.60**	3.23*	0.38	−0.47
Panel B: Systemic Risk Indexes					
Multiple QR	−19.78	−19.17	−0.35	−11.30	−15.92
PCQR1	−0.36	−1.99	1.36	1.24	−0.66
PCQR2	1.00	−0.80	2.31	1.00	−2.54
PQR	−1.64	−4.39	3.64*	−1.76	−9.73

(1) Downside Macroeconomic Risk

Median Coefficient vs. 20^{th} Percentile Coefficient: t Tests

	Median	20^{th} Pctl.	Difference	t
Absorption	−0.0021	−0.0010	0.0012	1.88
AIM	0.0003	−0.0072	−0.0075	−11.84
CoVaR	−0.0030	−0.0048	−0.0019	−2.89
ΔCoVaR	−0.0024	−0.0031	−0.0007	−1.02
MES	−0.0024	−0.0040	−0.0016	−2.54
Book Lvg.	−0.0014	−0.0023	−0.0009	−1.36
DCI	0.0001	−0.0014	−0.0016	−2.47
Def. Spr.	−0.0036	−0.0033	0.0003	0.52
ΔAbsorption	0.0004	−0.0018	−0.0023	−3.57
Intl. Spillover	0.0000	−0.0019	−0.0019	−2.87
Mkt. Lvg.	−0.0028	−0.0071	−0.0042	−6.48
Volatility	−0.0041	−0.0054	−0.0014	−2.13
TED Spr.	−0.0026	−0.0057	−0.0031	−4.65
Term Spr.	0.0017	0.0038	0.0021	3.34
Turbulence	−0.0040	−0.0060	−0.0020	−3.16
PQR	−0.0037	−0.0052	−0.0015	−2.32

(1) Downside Macroeconomic Risk

- All of these measures, *including* volatility, are much more successful for the **lower tail** of macro outcomes
- Financial market distress creates or makes the economy susceptible to **downside macroeconomic risk**

(2) What is the Role of Policy?

- How did policy behave in these episodes?
- Does monetary policy respond to SR distress?

(2) What is the Role of Policy?

Out-of-Sample Fed Funds Forecasts

	Median	20^{th} Percentile
Volatility	0.43	4.46^{*}
Turbulence	1.33^{**}	3.08^{*}
PQR	-8.97	6.60^{*}

Out-of-sample begins in 1970.

(3) The Special Role of Financial Volatility

IP Shock Forecasts: Financial Volatility and Nonfinancial Volatility

	In-Sample	Out-of-Sample		
		start		
		1950	1970	1985
Panel A: 20^{th} Percentile				
Financial Volatility	3.43^{***}	2.64^{**}	5.77^{***}	12.18^{***}
Non-financial Volatility	1.37	-0.94	0.02	1.56
Panel B: Median				
Financial Volatility	2.43^{***}	1.73^{*}	3.78^{**}	8.00^{**}
Non-financial Volatility	1.26^{**}	0.37	1.09	2.55^{*}

Uses financial and nonfinancial portfolios

(3) The Special Role of Financial Volatility

- Is this about **Aggregate Volatility** ...
  - "Uncertainty shock" literature like Bloom (2009) traces a response of average macroeconomic outcomes to increases in Aggregate Volatility (return volatility on aggregate portfolio)
- ... or about **Financial Volatility** in particular?

(3) The Special Role of Financial Volatility

VAR Perspective

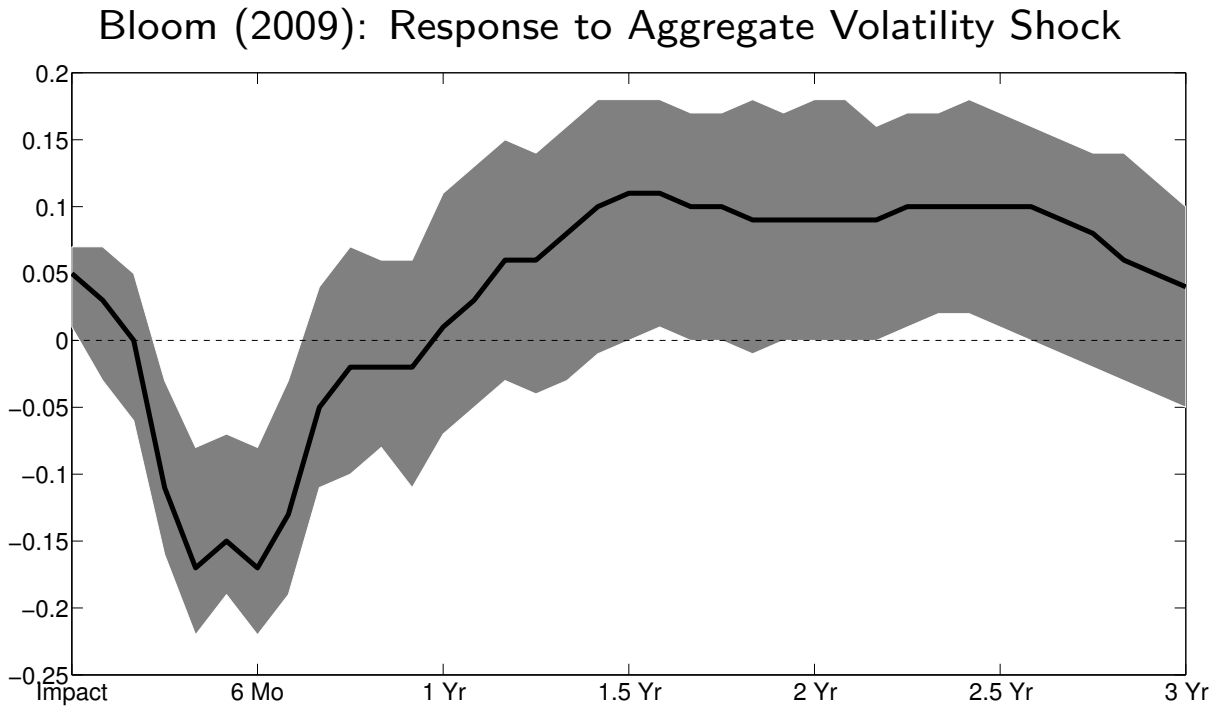
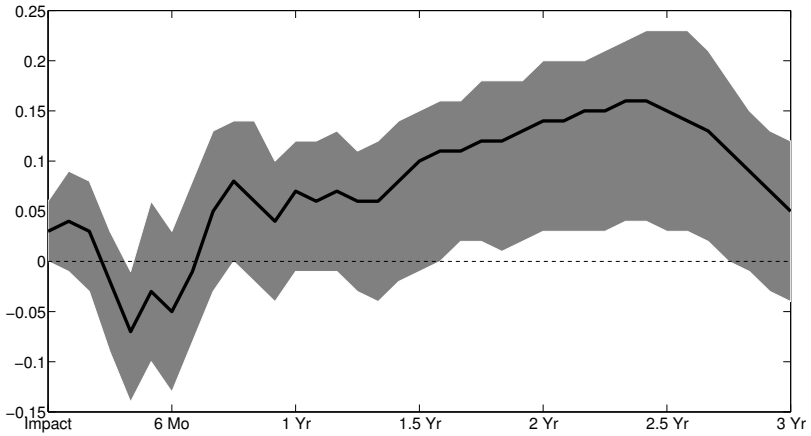


Figure: Impulse Responses: Aggregate Volatility Preceding Financial Volatility in VAR

(3) The Special Role of Financial Volatility

VAR Perspective

Panel A: Response to Aggregate Volatility Shock



Panel B: Response to Financial Volatility Shock

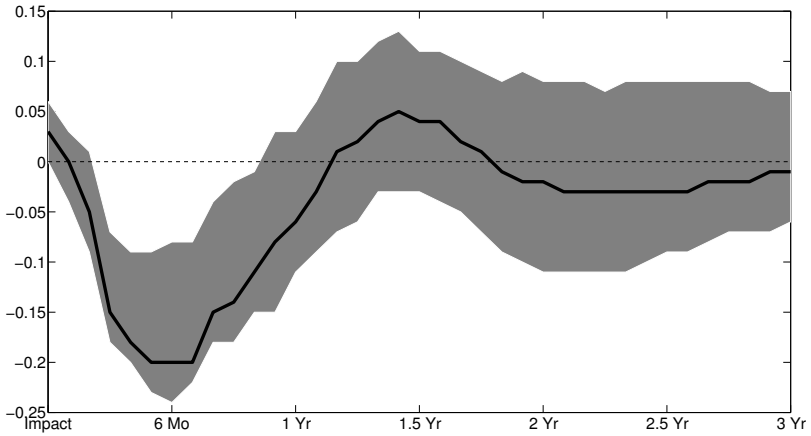


Figure: Impulse Responses: Financial Volatility Preceding Aggregate Volatility in VAR

Conclusion

- Propose macro/welfare relevance criterion for evaluating systemic risk measures
  - Only a few provide this information
- Propose (factor estimation) approach to aggregating systemic risk measures and overcoming measurement difficulties faced by individual measures
  - Systemic risk factor strongly related to future macroeconomic outcomes
- Stylized facts can guide model-building
  1. Systemic risk is strongly related to downside macro risk
  2. Policy responds to SR but has limited effectiveness
  3. Financial firms' equity volatility is most informative for future macro outcomes