Where the Risks Lie: A Survey on Systemic Risk

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New Frontiers in Systemic Risk Measures
and Extreme Risk Management

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Motivation

- Prolific research field at the crossroads of banking, macroeconomics, econometrics, network theory, mathematical finance, etc.
- Cross-fertilization between academic research and regulation.
- Regulators need measures of systemic risk that capture well-identified economic mechanisms and can be used as inputs for regulatory tools.
- Our angle differs from existing surveys (e.g. De Bandt, Hartmann and Peydro, 2012, Bisias et al., 2012) as we focus on matching (i) **sources of systemic risk**, (ii) **regulatory tools**, and (iii) **systemic risk measures**.

Definition (systemic risk)

We define **systemic risk** as the risk that many market participants are simultaneously affected by severe losses, which then spread through the system.

This definition can apply to a huge number of papers, of which we survey 205, published over the past 35 years.

Two main approaches in the literature

1. A first family of papers looks at **specific sources of systemic risk** (systemic risk taking, contagion, amplification).

2. A second family of papers derives **global measures** of systemic risk, potentially encompassing all the mechanisms studied in the first group of papers.

	Theory	Evidence/Measure	Regulation	Policy Evaluation
		I. Source-Specific Approach		
Systemic risk-taking				
Correlation risk	Acharya (2001) Farhi and Tirole (2012)	Lehar (2005) Blei and Ergashev (2014)	Sectoral capital requirements loan-to-value ratios	Ono *et al.* (2013)
Liquidity risk	Bhattacharya and Gale (1987) Brunnermeier and Oehmke (2013b)	Brunnermeier, Gorton, and Krishnamurthy (2014) Jobst (2014)	LCR, NSFR	-
Tail risk	Perotti, Ratnovski, and Vlahu (2011) Freixas and Rochet (2013)		Stress-tests	-
Leverage cycles	Bernanke and Gertler (1989) Kiyotaki and Moore (1997)	De Nicoló and Lucchetta (2011) He and Krishnamurthy (2014)	Countercyclical buffers	Aiyar, Calomiris, and Wieladek (2014) Jimenez *et al.* (2014)
Contagion				
Balance-sheet contagion	Allen and Gale (2000b) Freixas, Parigi, and Rochet (2000)	Elsinger, Lehar, and Summer (2006) Drehmann and Tarashev (2011)	Large exposure limits resolution framework	-
Payment and clearing infrastructures	Rochet and Tirole (1996a) Freixas and Parigi (1998) Duffie and Zhu (2011)	McAndrews and Potter (2002)	Mandatory clearing	Duffie, Scheicher, and Vuillemey (2015)
Informational contagion	Aghion, Bolton, and Dewatripont (2000) Dasgupta (2004)	Calomiris and Mason (1997) Bae, Karolyi, and Stulz (2003)	Stress-test disclosure	Petrella and Resti (2013) Ellahie (2013)
Amplification				
Liquidity crises	Shleifer and Vishny (1992) Brunnermeier and Pedersen (2009)	Greenwood, Landier, and Thesmar (2014) Duarte and Eisenbach (2015)	Lending of last resort	-
Market freezes	Flannery (1996) Heider, Hoerova, and Holthausen (2009)	Afonso, Kovner, and Schoar (2011) Acharya and Merrouche (2013)	Stress-test disclosure additional supervision	Petrella and Resti (2013) Ellahie (2013)
Runs	Diamond and Dybvig (1983) Martin, Skeie, and Von Thadden (2014)	Iyer and Peydró (2011) Chen, Goldstein, and Jiang (2010)	Extended deposit insurance bail-outs	-
		II. Global Approach		
	-	Acharya *et al.* (2010) Billio *et al.* (2012) Adrian and Brunnermeier (2014) Brownlees and Engle (2015)	Capital surcharge for SIFIs	Moenninghoff, Ongena, and Wieandt (2015)

Outline of the survey

1. **Sources of systemic risk**: systemic risk-taking, contagion, and amplification mechanisms.
2. **Regulation**: tools proposed to mitigate systemic risk concerns.
3. **Systemic risk measurement**: (1) current methodology of the FSB to identify SIFIs, (2) measures specific to a given source of systemic risk, and (3) global measures.
4. **Comparison of systemic risk measures**: Derive popular systemic risk measures in a unified framework and study their added value compared to standard market risk measures.
5. **Validation** of systemic risk measures.

Framework

Consider N financial institutions, each with a risk exposure x_i.

- A proportion α_i of the exposure concerns a systematic risk factor, while $1 - \alpha_i$ concerns a risk factor idiosyncratic to i.
- Denote $y_i^S = \alpha_i x_i$ the systematic exposure and $y_i^I = (1 - \alpha_i)x_i$ the idiosyncratic exposure of institution i.
- We also denote $y^S = \sum_{i=1}^N y_i^S$ the cumulative exposure to systematic risk for all institutions.

Framework (continued)

- Financial institutions have direct links among each other (interbank loans or derivatives), given by a $N \times N$ matrix B, whose elements $b_{i,j}$ denote how much i is exposed to j.
- The returns on the systematic and i's idiosyncratic factors are $\rho^S + \varepsilon^S$ and $\rho^i + \varepsilon^i$, respectively, where ρ^S and ρ^i are constants, while ε^S and all the ε^i are i.i.d.with zero mean.

Definition (benchmark payoff)

We define the benchmark payoff $\hat{\pi}_i$ as what i would receive if there were no other institutions in the system:

$$\hat{\pi}_i = \hat{\pi}_i(y_i^S, y_i^I, \varepsilon^S, \varepsilon^i)$$

Example (benchmark payoff)

For illustration, a simple specification could be:

$$\hat{\pi}_i = (\rho^S + \varepsilon^S) \times y_i^S + (\rho^i + \varepsilon^i) \times y_i^I$$

Definition (actual payoff)

Denoting π_i the actual payoff of i, $\mathcal{E}^I$, Y^S, and Y^I, the $N \times 1$ vectors of idiosyncratic shocks, systematic exposures, and idiosyncratic exposures, respectively, π_i is given by:

$$\pi_i(Y^S, Y^I, B, \varepsilon^S, \mathcal{E}^I)$$

Remark: A defining characteristic of systemic risk is that:

$$\pi_i(Y^S, Y^I, B, \varepsilon^S, \mathcal{E}^I) \neq \hat{\pi}_i(y_i^S, y_i^I, \varepsilon^S, \varepsilon^i)$$

1. Systemic risk-taking mechanisms

- These mechanisms explain the distribution of the x_i and the α_i in the system.
- Financial institutions endogenously choose a risk exposure x_i and its systematic component $\alpha_i x_i$ that differ from their welfare-maximizing values.

2. Contagion mechanisms

- The payoffs of two institutions are positively correlated, even when there is no systematic shock:

$$Cov(\pi_i, \pi_j | \varepsilon^S = 0) > 0$$

- These mechanisms work through the matrix of links B.

3. Amplification mechanisms

- Amplification mechanisms explain why small shocks can turn into large losses if they affect many institutions.
- One example is deleveraging: A small negative shock ε^S hits the institutions with a high y_i^S, they need to sell their assets and exert a price impact that worsens the losses to other market participants, and so on.
- The effect of a systematic shock ε^S is greater when the cumulative exposure to this shock y^S is larger:

$$\frac{\partial^2 \mathbb{E}(\pi_i)}{\partial \varepsilon^S \partial y^S} > 0$$

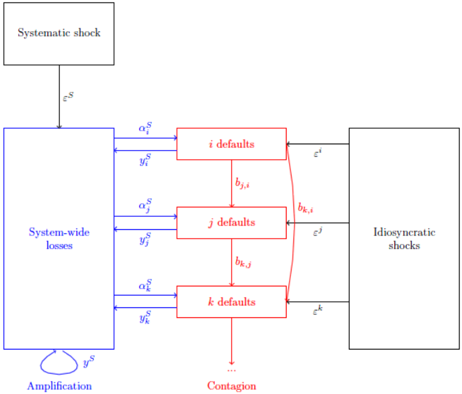
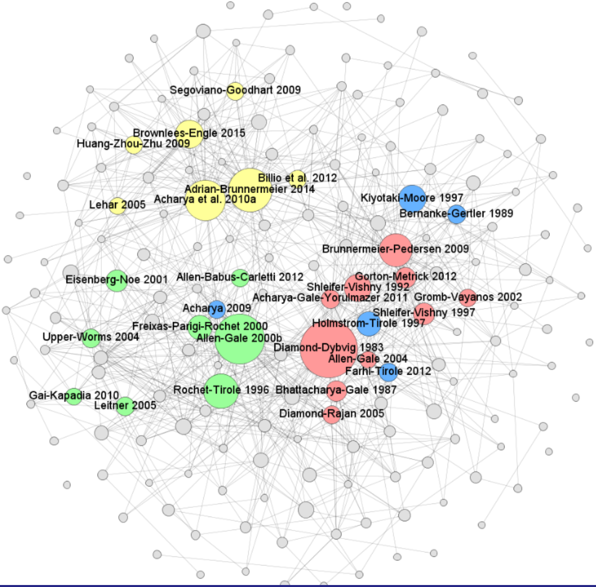


Figure 2: Systemic Loops. The red sector of the figure represents contagion mechanisms and the blue sector amplification mechanisms. Each edge represents a risk transmission channel, whose strength is given by the label on the edge. For example, the sensitivity of j to system-wide losses is measured by α_j^S, while j's contribution to system-wide losses depends on y_j^S.


Segoviano-Goodhart 2009
Brownlees-Engle 2015
Huang-Zhou-Zhu 2009
Billio et al. 2012
Adrian-Brunnermeier 2014
Acharya et al. 2010a
Lehar 2005
Kiyotaki-Moore 1997
Bernanke-Gertler 1989
Brunnermeier-Pedersen 2009
Eisenberg-Noe 2001
Allen-Babus-Carletti 2012
Gorton-Metrick 2012
Shleifer-Vishny 1992
Acharya-Gale-Yorulmazer 2011
Gromb-Vayanos 2002
Acharya 2009
Shleifer-Vishny 1997
Freixas-Parigi-Rochet 2000
Holmstrom-Tirole 1997
Upper-Worms 2004
Allen-Gale 2000b
Diamond-Dybvig 1983
Allen-Gale 2004
Farhi-Tirole 2012
Gai-Kapadia 2010
Rochet-Tirole 1996
Bhattacharya-Gale 1987
Leitner 2005
Diamond-Rajan 2005

Systemic risk measures

We review a large number of measures, classified in three groups:

1. the one currently implemented by the **regulators**,
2. structural measures that target a **specific** channel of transmission,
3. **global** measures, potentially encompassing several/all channels of transmission.

Regulatory approach

- The scoring methodology developed by the **BCBS** aggregates information about five categories of systemic importance:

size, cross-jurisdictional activity, interconnectedness,
complexity, lack of available substitutes for the services provided.

- In order not to favor any particular facet of systemic risk, the BCBS aims to give the **same importance** to each input.
- This method is currently implemented to identify the **SIFIs** and allocate them in different buckets.

Regulatory approach (continued)

- Let each bank i, for $i = 1, \ldots, N$, be characterized by K inputs or categories denoted $X_{i1}, \ldots, X_{iK}$.

Definition (systemic score)

The systemic risk score for bank i, denoted S_i, is then defined as a **simple average** of these K inputs:

$$S_i = \frac{1}{K} \sum_{j=1}^{K} \cdot x_{ij}$$

where $x_{ij} = \left(X_{ij} / \sum_{n=1}^{N} X_{nj} \right) \times 100$ corresponds to the relative value (in percentage) of input j for bank i.

Regulatory approach (continued)

- An unintended consequence is that that the resulting systemic risk score will be mechanically dominated by the **most volatile categories**.
- Scores, ranking of banks, and extra capital buffers are driven by a subset of variables only.
- BCBS (2013): "*apply a cap on the substitutability category score because this category has too high an impact on the final score*".

Solution (corrected score)

One potential correction for the above-mentioned bias is to standardize by their volatility the variables that enter into the definition of the index

$$S_i = \frac{1}{K} \sum_{j=1}^{K} \cdot \frac{x_{ij}}{\sigma_j}$$

where σ_j corresponds to the cross-sectional variance of input j.

Systemic risk measures proposed in the academia

1. Specific sources of systemic risk (contagion, bank runs, liquidity crises, etc.). This **source-specific approach** relies on qualitative models, which deliver predictions that can be confirmed by empirical analyses, often based on supervisory data (e.g. Greenwood, Landier and Thesmar, 2014).

2. Global measures of systemic risk (e.g. SRISK and ΔCoVaR), potentially encompassing all the mechanisms studied in the other group of papers.

Global measures: Pros

- Easily computed in real-time using market data (see V-Lab).
- Could replace a host of complex macroprudential tools by a simple Pigouvian systemic risk tax.

Global measures: Cons

- Not completely transparent on the causes of systemic risk.
- May appear hazardous to base regulation on global measures without a clear understanding of the risks they capture and the ones they overlook.
- Strongly related to standard market risk measures.

Framework

Consider a bivariate GARCH process for the vector of demeaned returns $r_t' = (r_{mt} \; r_{it})$:

$$r_t = H_t^{1/2} \, \nu_t$$

where $\nu_t' = (\varepsilon_{mt} \; \xi_{it})$ is i.i.d. with $E(\nu_t) = 0$ and $E(\nu_t \nu_t') = I_2$, and:

$$H_t = \begin{pmatrix} \sigma_{mt}^2 & \sigma_{it} \, \sigma_{mt} \, \rho_{it} \\ \sigma_{it} \, \sigma_{mt} \, \rho_{it} & \sigma_{it}^2 \end{pmatrix}$$

We assume that the innovations ε_{mt} and ξ_{it} are **independently distributed** at time t.

Proposition (MES)

The **MES** *of a given financial institution i is proportional to its* **systematic risk**, *as measured by its conditional* **beta**:

$$MES_{it}(\alpha) = \beta_{it}\ ES_{mt}(\alpha)$$

where $\beta_{it} = \rho_{it}\sigma_{it}/\sigma_{mt}$ *denotes the time-varying beta of firm i and* $ES_{mt}(\alpha) = E_{t-1}(r_{mt} \mid r_{mt} < C)$.

Proposition (CoVaR)

Under these assumptions, the Δ**CoVaR** *of a given financial institution i depends on its* **tail risk**, *as measured by its* **VaR**:

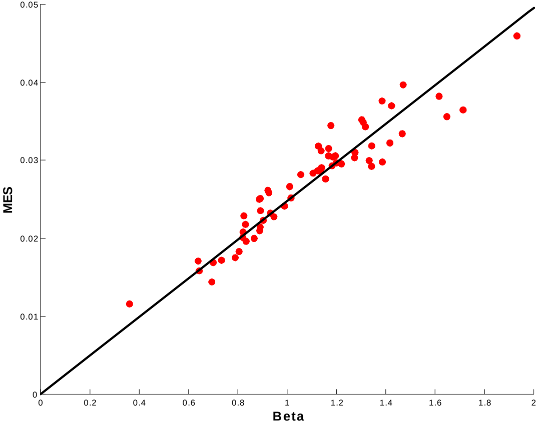
$$\Delta CoVaR_{it}(\alpha) = \gamma_{it}\ \left[VaR_{it}(\alpha) - VaR_{it}(0.5)\right]$$

where $\gamma_{it} = \rho_{it}\sigma_{mt}/\sigma_{it}$. *If the marginal distribution of the returns is symmetric around zero,* $\Delta CoVaR$ *is:*

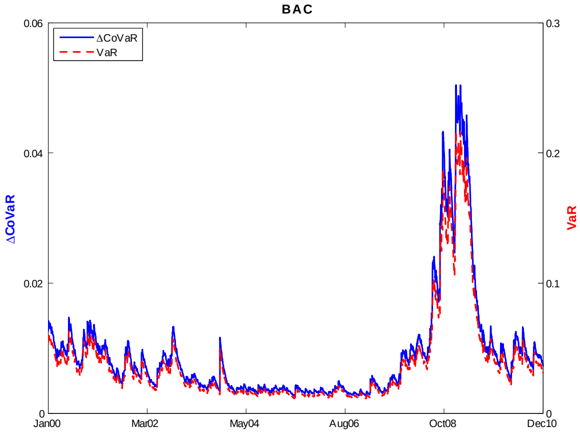
$$\Delta CoVaR_{it}(\alpha) = \gamma_{it}\ VaR_{it}(\alpha).$$

Empirical illustration

- Same estimation methods as in the original articles presenting the MES and ΔCoVaR.
- Same sample as in Acharya, Pedersen, Philippon, and Richardson (2010).
- This sample contains all US financial firms with a market capitalization greater than $5 billion as of end of June 2007.
- Sample period, January 3, 2000 - December 31, 2010.



0.05
0.04
0.03
0.02
0.01
0
MES
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Beta


BAC
ΔCoVaR
VaR
0.06
0.04
0.02
0
0.3
0.2
0.1
0
Jan00
Mar02
May04
Aug06
Oct08
Dec10
ΔCoVaR
VaR

Concluding remarks

- Many methodologies are now available to identify different sources of systemic risk and will produce new regulatory or policy tools.
- What is less clear however is how to link the measures produced by these tools to regulatory interventions.
- The quest for a global risk measure that encompasses different sources of systemic risk and yet produces a single/simple metric that can directly be used for regulation (tax or capital surcharge) is still ongoing. Could align systemic risk banks' interests with social optimum.
- Reasons to remain optimist as more data are becoming available (Data Gaps Initiative).