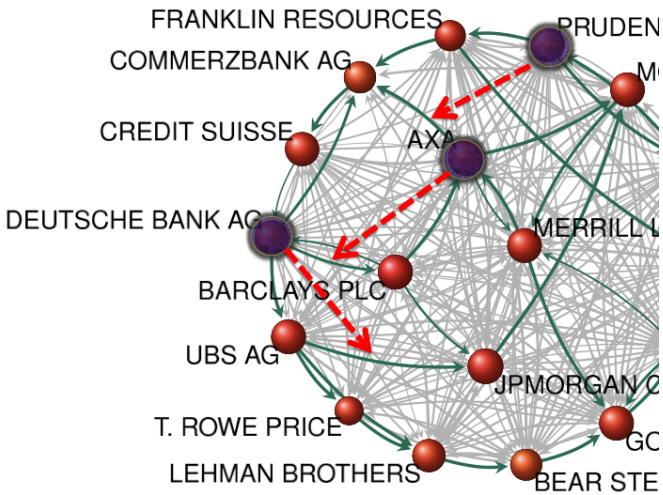
Financial Networks - III

Stefano Battiston, UZH

Les Houches-Complex Networks

April 9, 2014



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Research Agenda in Financial Networks

- Distress propagation: systemic risk vs diversification [Battiston 2012 JEDC; Battiston 2012 JFS; Vitali 2013 JEBO rev.; Tasca 2012]
- Optimal architectures vs cascades and market illiquidity [Roukny 2013 Sci Rep forth.; Tessone 2013 JOSS; Vodenska 2013 progr.]
- Indicators for policy
  - **DebtRank: identify SIFI** [Battiston 2012 Sci Rep.; Aoyama 2013 progr.]
    - vulnerability vs impact: [Puliga 2013, progr.]
  - Network controllability: identify key players for well-functioning [Delpini 2013 Sci Rep; Galbiati 2013 Nat Phys]
- Widgets: portable web applications to display indicators. Aiming at live EWS.

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DebtRank

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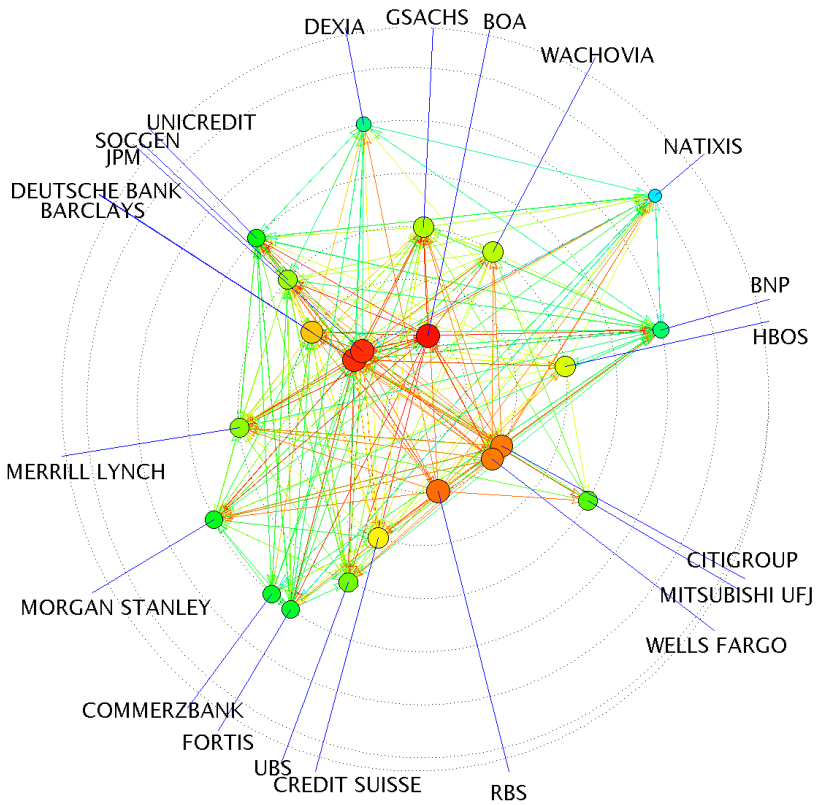

- more **central** = more systemically important
- **not just** a ranking, but **monetary value of systemic loss**
- overcome **limitations of state-of-the art**:
  1. default-only algo
  2. (2) non-specific measures (between. eigenvec., PageRank ...)
- individual and **groups**; complement to **Early Warning System**

[Battiston ea. DebtRank: Too-central-to-fail? (2012) Sci Rep. 2:541]

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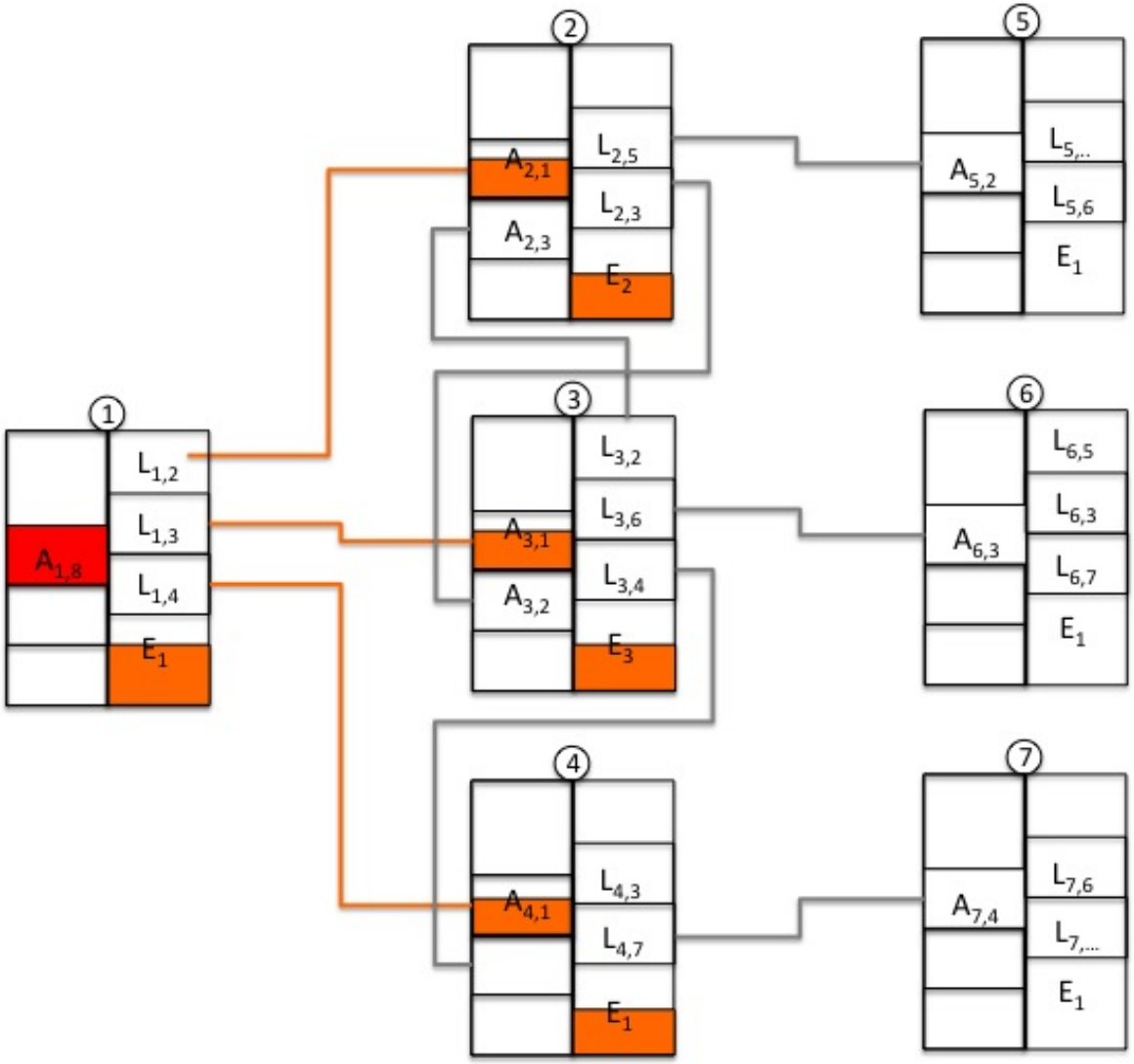
Distress Propagation: DebtRank



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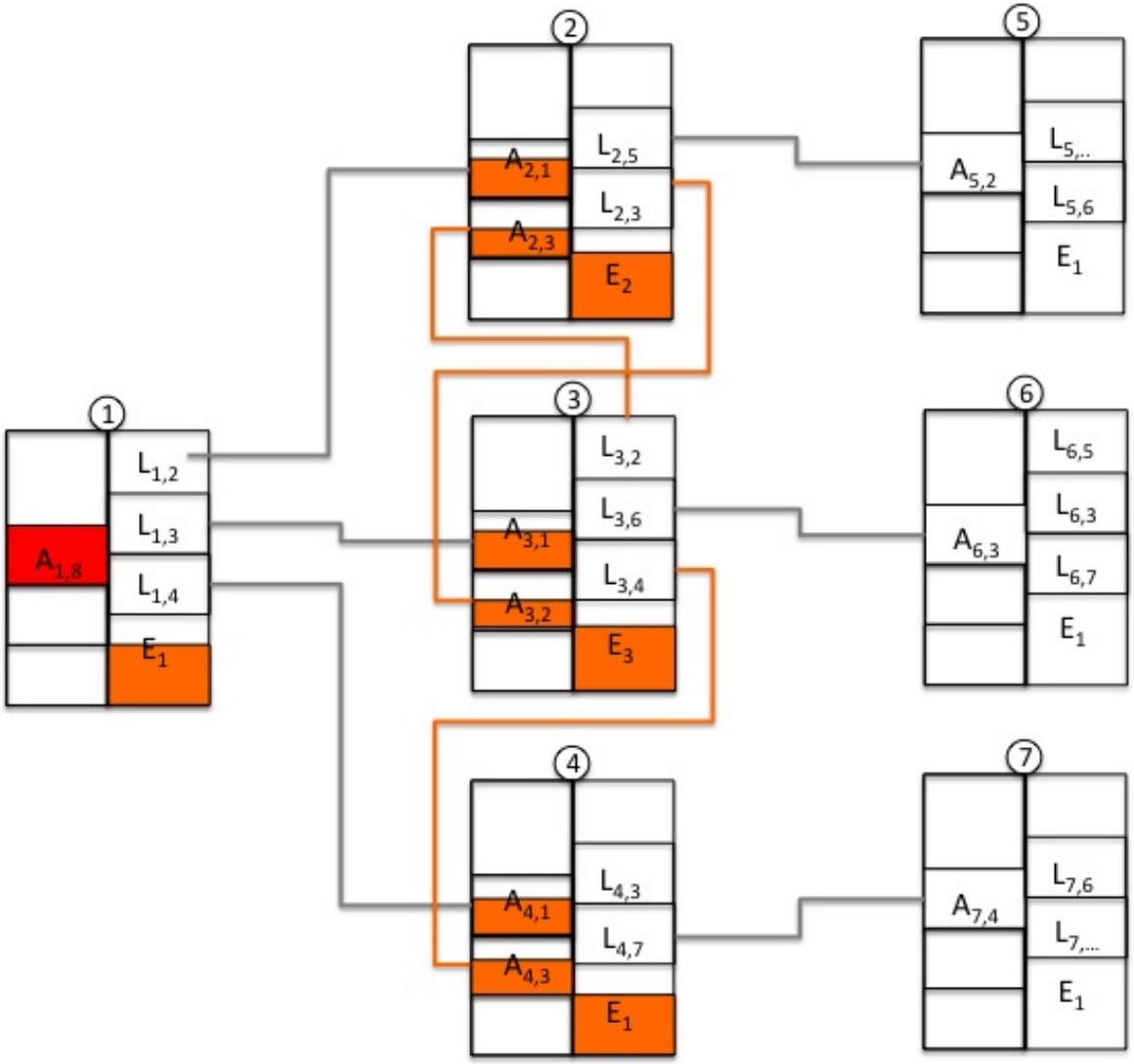

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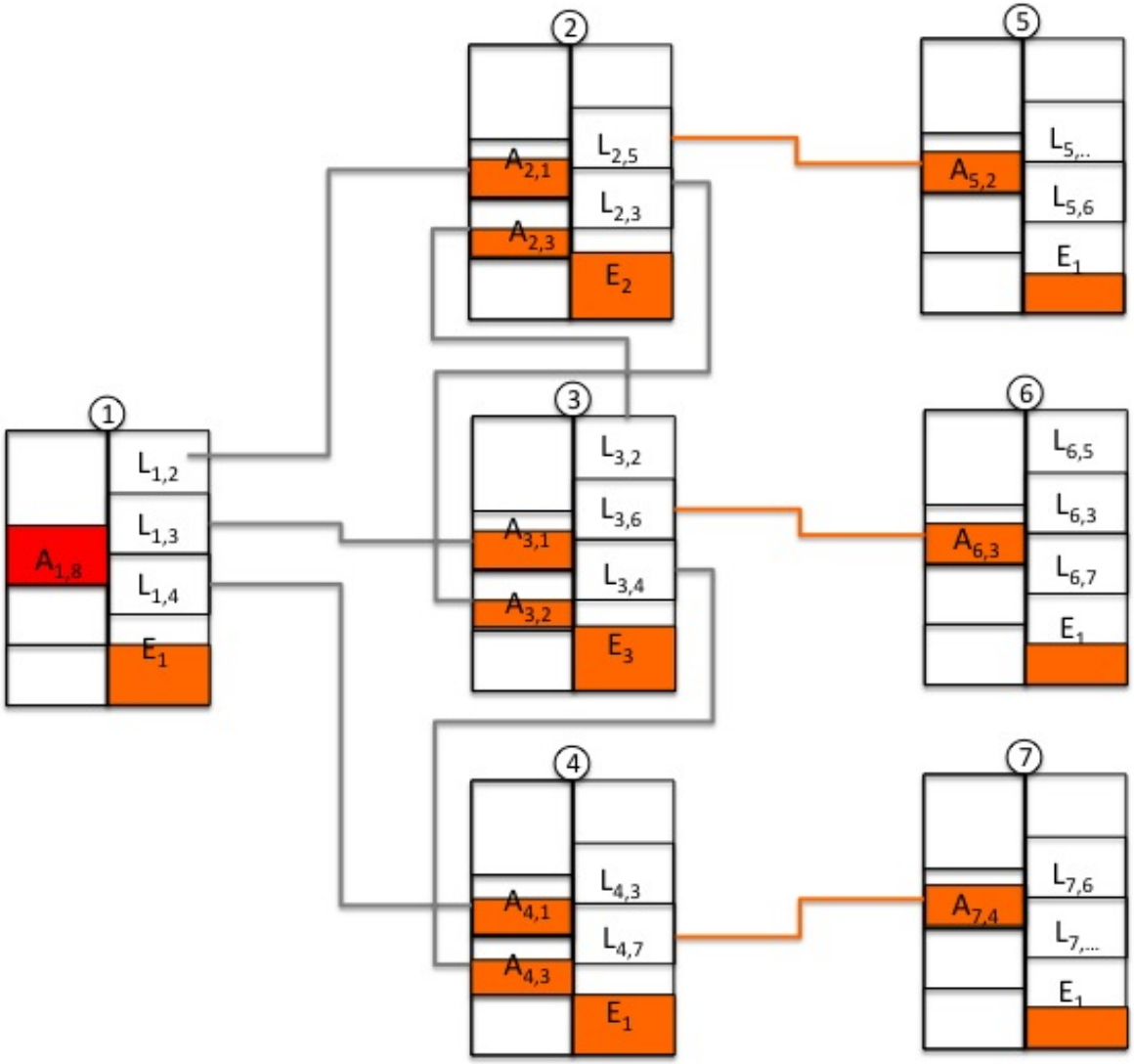

Impact Matrix and Debtrank definition

- **exposure** of i to j, A_{ij} (e.g. lending, bond, stock shares).
- **core capital** of i, E_i.

1. Relative exposure of i to j, w.r.t. core capital: $Z_{ij} = \frac{A_{ij}}{E_i}$, (sum can easily exceed 1)

- **Direct Impact** of i on j defined as the exposure that j has towards i: $W_{ij} = Z_{ji}$, $W = Z^T$

- High DebtRank: if **strong** impact (W_{ij}) on **many** other central nodes: recursive!
- Each node propagates its distress only once (we tame reverberations)
- Formulas at doi:10.1038/srep00541
- Widgets at: `http://ethz.focproject.net:8080/widget`

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Debt Rank Dynamics

- $h_i \in [0, 1]$, continuous = fraction of initial equity lost
- $s_i \in \{U, D, I\}$, 3 states: undistr., distress, inactive
- S_f: set of distressed nodes at t=1. $h_i(1) = \psi \, \forall i \in S_f$; $h_i(1) = 0 \, \forall i \notin S_f$, and $s_i(1) = D \, , \forall i \in S_f$; $s_i(1) = U \, \forall i \notin S_f$.

Cycle over time

$$h_i(t) = \min \left\{ 1, h_i(t-1) + \sum_j W_{ji} h_j(t-1) \right\}, \text{ where } j \,|\, s_j(t-1) = D$$

$$s_i(t) = \begin{cases} D & \text{if } h_i(t) > 0 \ \& \ s_i(t-1) \neq I \\ I & \text{if } h_i(t-1) > 0 \\ U & \text{otherwise,} \end{cases}$$

Final values

- $Dr_i = \sum_j h_j(T) \, E_j(0) =$ DR-Impact
- $h_i(T) =$ DR-Vulnerability

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Application: an exercise on FED data + BvD data

- Take banks' investment in each others equity share as a proxy of all **exposures**
- Focus on the largest borrowers from the FED in 2008-2010
  - 22 inst., peak lending 1.2 USD trillions, total assets 20 USD trillions)
- Incorporate dynamics of core capital (take market capitalization as a proxy of core capital)

Recipe

1. market capitalization as proxy of core capital
2. investments in equity as proxy of financial exposures
3. rescaling factor α, conservative scenario: in good the times every bank can sustain the default of at least 5 counterparties

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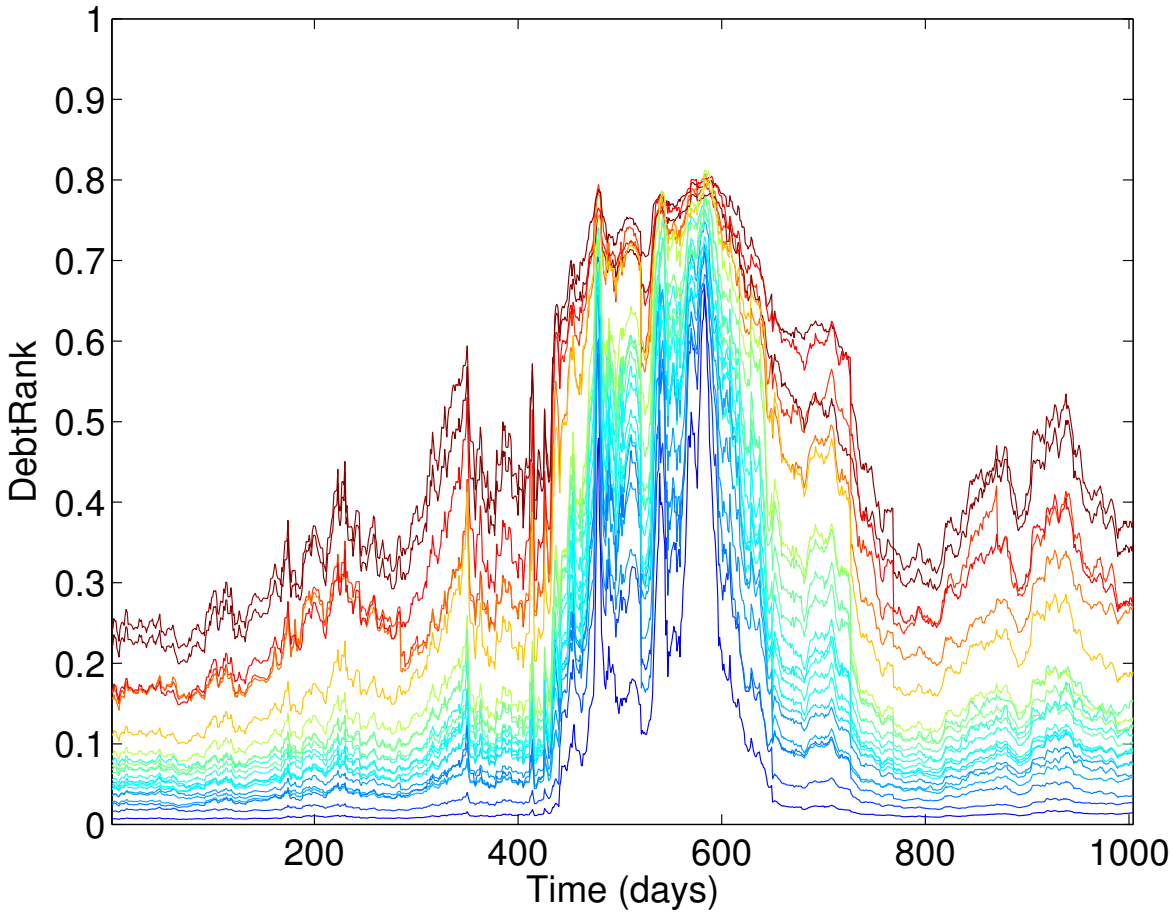
Debt Rank vs other Measures



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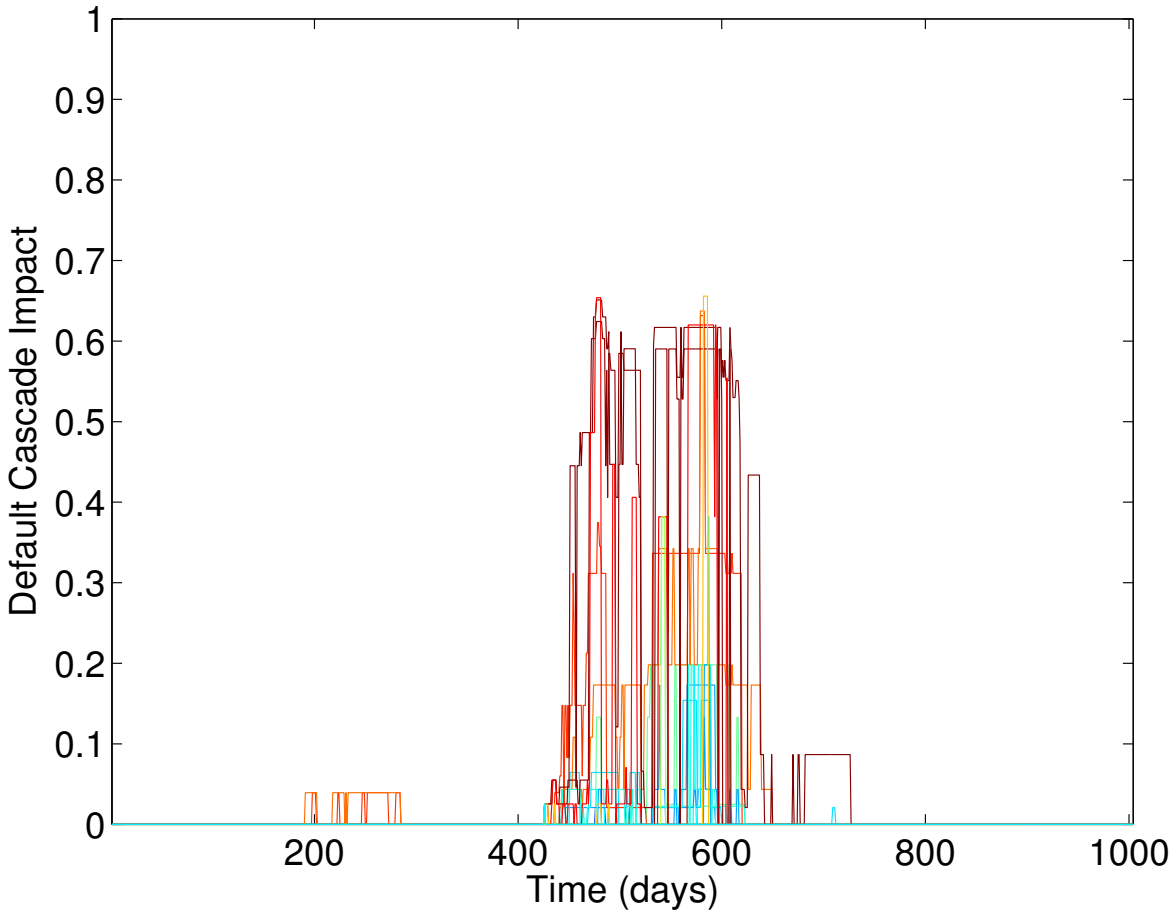

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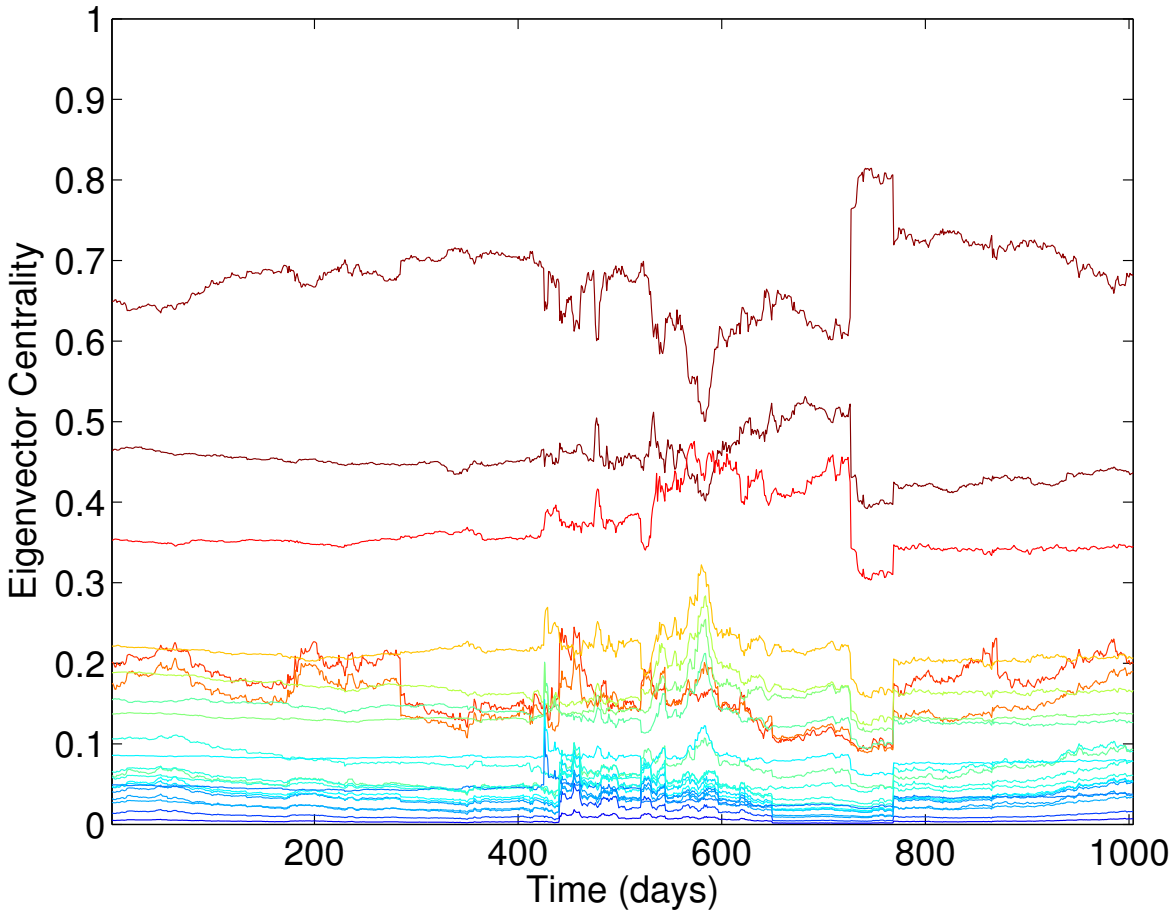

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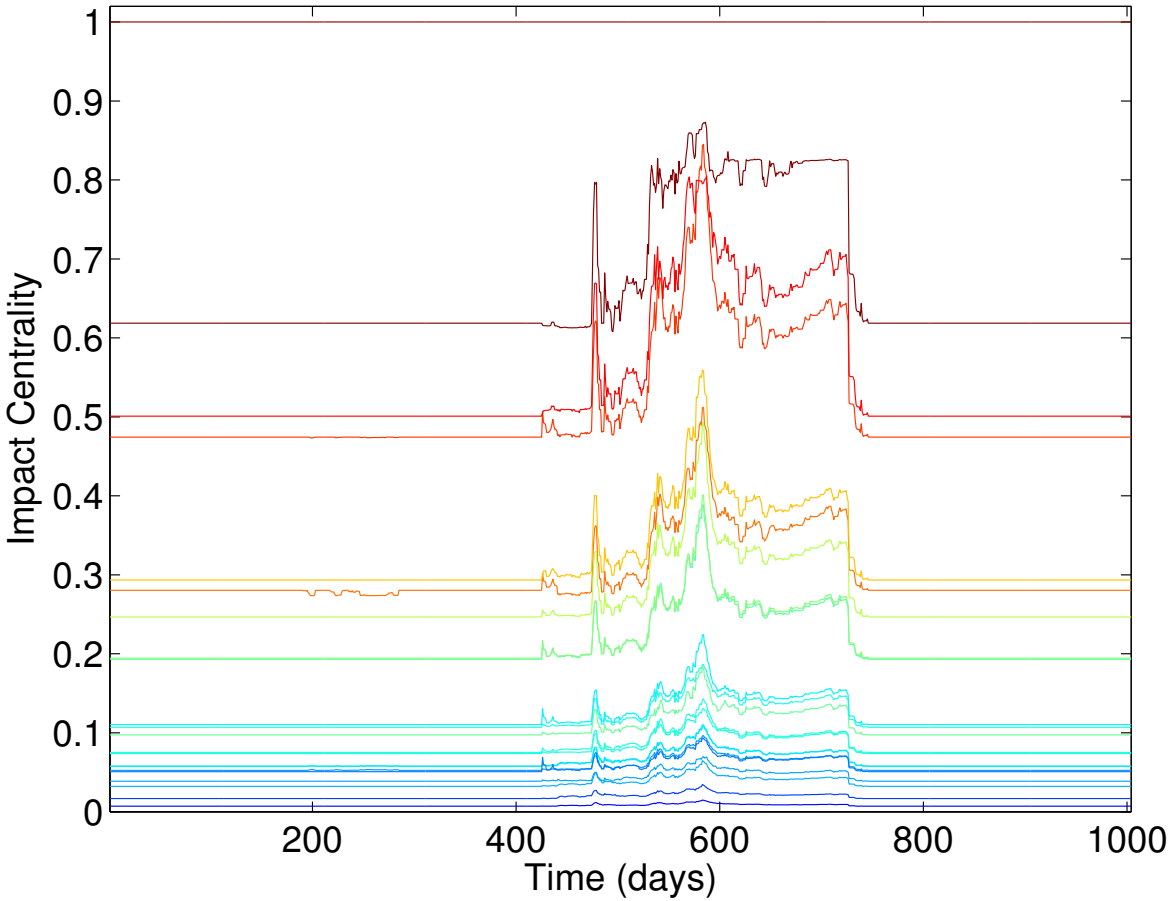
Debt Rank vs other Measures



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Group DebtRank

Recipe

1. A selected group of institutions is hit by a shock: for each a certain fraction $\phi_i < 1$ of equity vanishes
2. Propagate distress according to impact matrix as before (closed walks traversed only once)
3. Test various values of ϕ and impact scaling factor α

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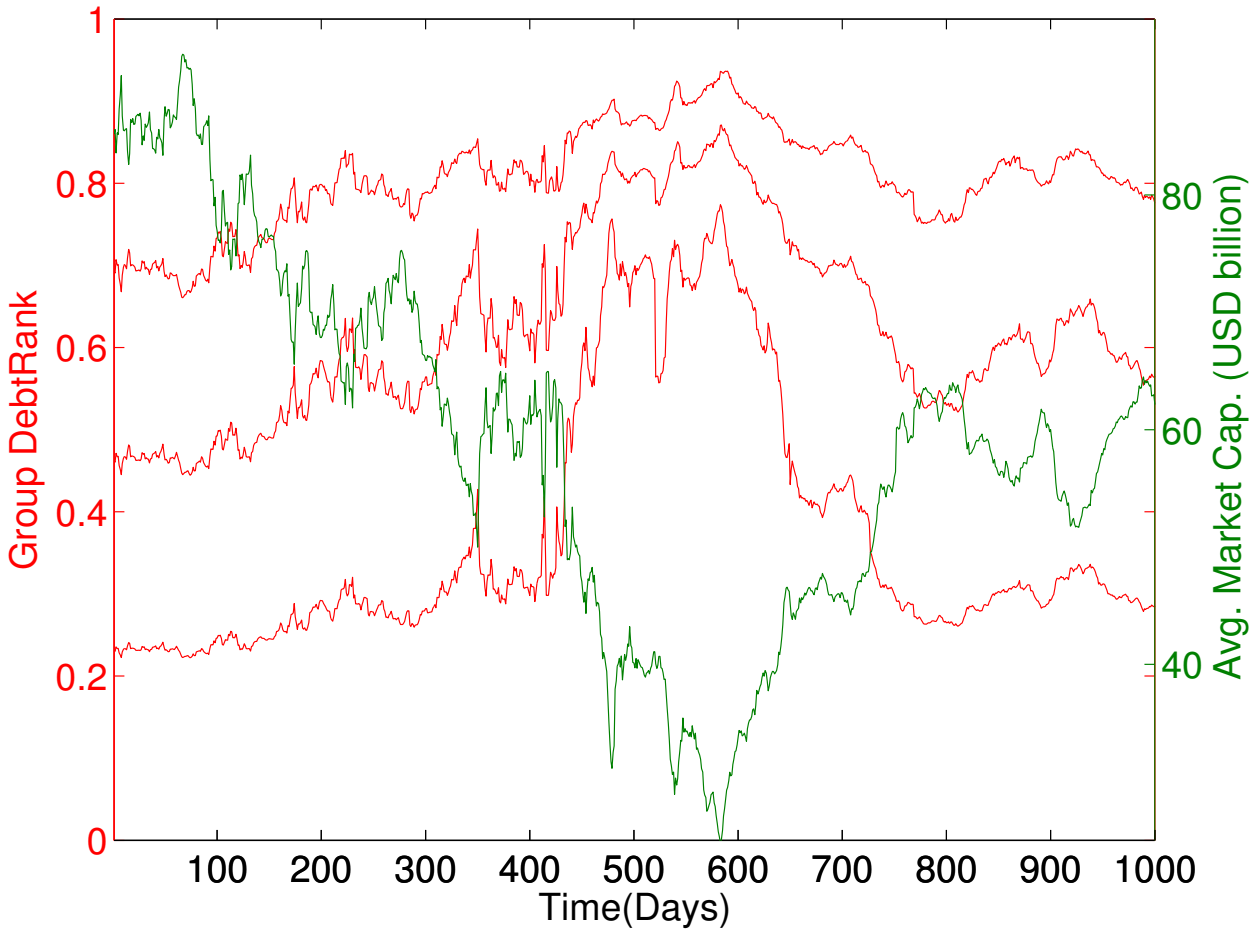
GroupDebtRank



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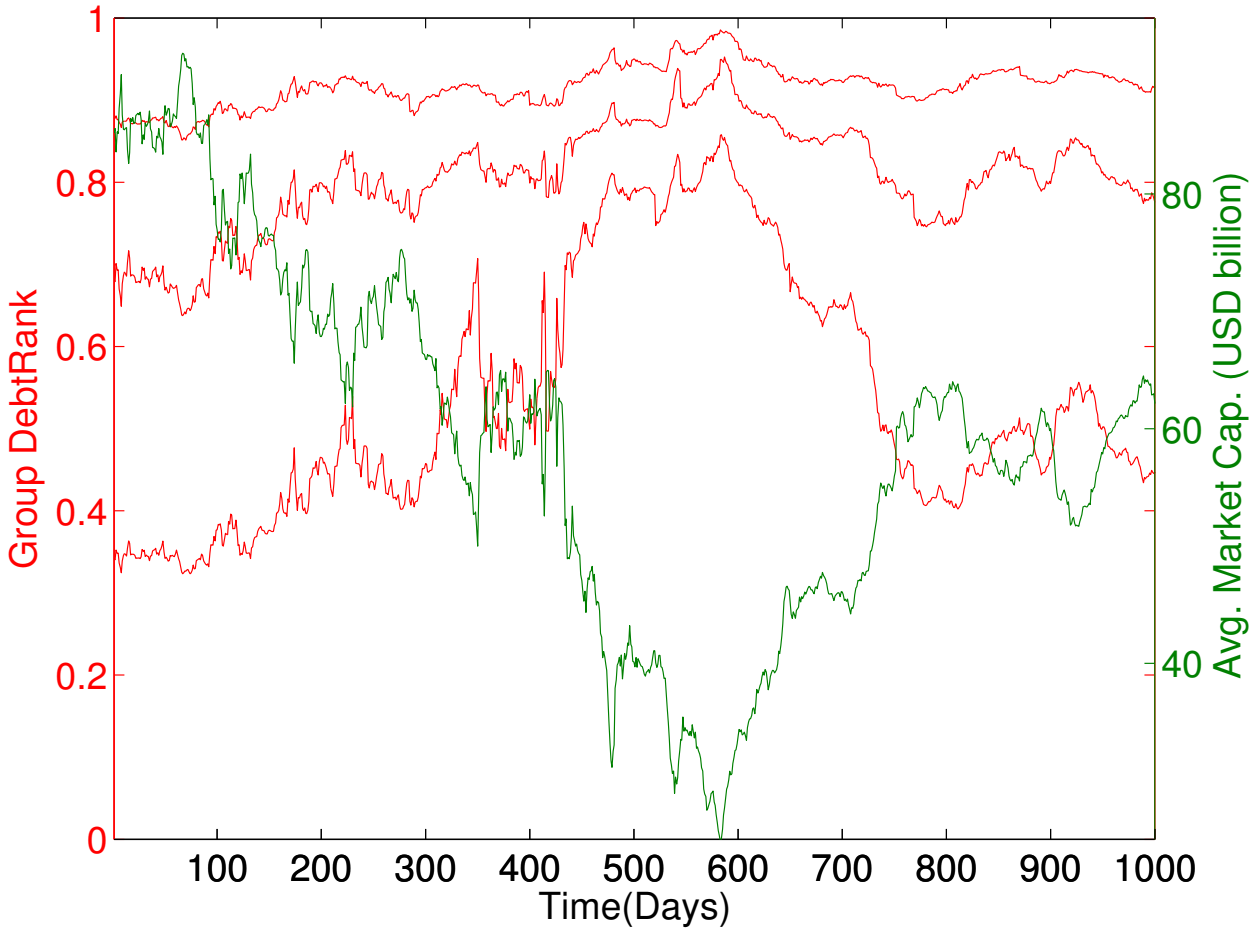
GroupDebtRank



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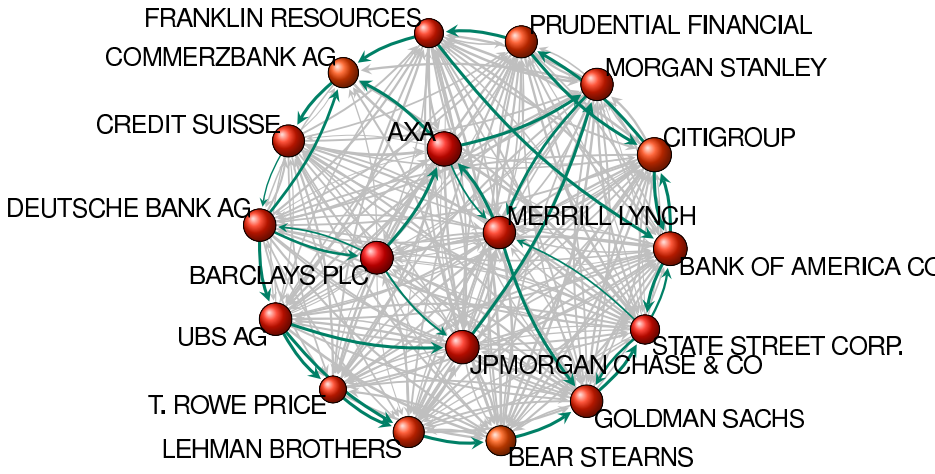
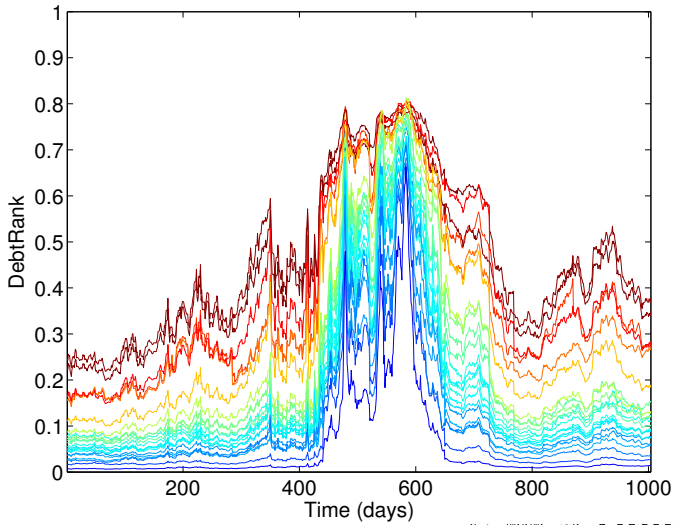
International Networks and Moral Hazard

- TBTF - too-big-too-fail
- TCTF - too-connected-to-fail
- TCTF - too-central-to-fail
- Should we regard financial institutions as an international nexus?
- Sustainability: need to cope with global moral hazard.





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Conclusions

What do we learn from investigating the financial system in terms of financia networks?

- new insights on risk diversification
- new measures of control and systemic impact
- insights on strategic interaction and systemic risk
- shed new light on issues like" inequality, systemic risk, sustainability

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References - 1

- Anand, K., Gai, P., Kapadia, S., Brennan, S. and Willison, M. A network model of financial system resilience. J. Econ. Behav. Organ. 85, 219–235 (2013).
- Battiston, S., Puliga, M., Kaushik, R., Tasca, P. and Caldarelli, G. DebtRank: Too Central to Fail? Financial Networks, the FED and Systemic Risk. Sci. Rep. 2, (2012).
- Battiston, S., Gatti, D. D., Gallegati, M., Greenwald, B. C. N. and Stiglitz, J. E. Liaisons Dangereuses: Increasing Connectivity, Risk Sharing, and Systemic Risk. J. Econ. Dyn. Control 36, 1121–1141 (2012).
- Cifuentes, R., Ferrucci, G. and Shin, H. S. Liquidity risk and contagion. J. Eur. Econ. Assoc. 3, 556–566 (2005).
- Eisenberg, L. and Noe, T. H. Systemic Risk in Financial Systems. Manage. Sci. 47, 236–249 (2001).
- Elsinger, H., Lehar, A. and Summer, M. Risk Assessment for Banking Systems. Manage. Sci. 52, 1301–1314 (2006).
- Gai, P. and Kapadia, S. Contagion in financial networks. Proc. R. Soc. A Math. Phys. Eng. Sci. 466, 2401–2423 (2010).
- Gai, P., Haldane, A., Kapadia, S. Complexity, concentration and contagion. J. Monet. Econ. 58, 453–470 (2011).
- Haldane, A. G. Rethinking Financial Networks. Speech Financial Student Assoc. Amsterdam (2009).

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References - 2

- Haldane, A. G. Rethinking Financial Networks. Speech Financial Student Assoc. Amsterdam (2009).
- Hommes C., van der Leij M., in't Veld D., Formation of a core-periphery network in OTC markets
- Kubler, F. , Schmedders, K. Stationary Equilibria in Asset-Pricing Models with Incomplete Markets and Collateral. Econometrica 71, 1767–1793 (2003).
- Roukny, T., Bersini, H., Pirotte, H., Caldarelli, G., Battiston, S. Default Cascades in Complex Networks: Topology and Systemic Risk. Sci. Rep. 3, (2013).
- Tasca, P., Battiston, S. Market Procyclicality and Systemic Risk. Submitt. earlier version ETH Risk Cent. Work. Pap. Ser. ETH-RC-12-012 (2012).
- Tasca, P., Battiston, S. Diversification and Financial Stability. Submitt. earlier version ETH Risk Cent. Work. Pap. Ser. ETH-RC-12-013 (2012).

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Recent Papers

- Debtrank: [Battiston, Puliga, Kaushik, Tasca, Caldarelli, DebtRank: Too-central-to-fail? (2012) *Sci. Rep.* 2:541]
- Complex derivatives [Battiston, Caldarelli, Georg, May, Stiglitz, *Nat. Phys.*, 2013]
- CDS and network reconstruction [Kaushik R., Battiston S., 2013 PLoS-ONE, forth], [Puliga M., Kaushik R., Battiston S., Caldarelli G., 2013 in progress]
- Estimation of systemic risk in networks from partial information: [Musmeci, Puliga, Gabrielli, Battiston, Caldarelli, JOSS 2013, forth.]
- Controllability in e-mid [Delpini, Battiston, Riccaboni, Pammolli, Gabbi, Caldarelli, *Sci. Rep.*, 2013, forth.]
- Controllability in TARGET2 [Galbiati, Delpini, Battiston, (2013) *Nat Phys*]

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Related International Activities

- **FOC** (Forecasting Financial Crises)
- MULTIPLEX (Theory of networks of networks)
- GSDP Global Systems and Policies
- GSS (Global Systems Science)
- SIMPOL (Financial Systems Simulation and Policy Modeling)
- INET - Systemic Risk Task Force: WG Fin. Nets

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