Rethinking Financial Contagion

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Joint with G. Visentin and S. Battiston
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Motivation

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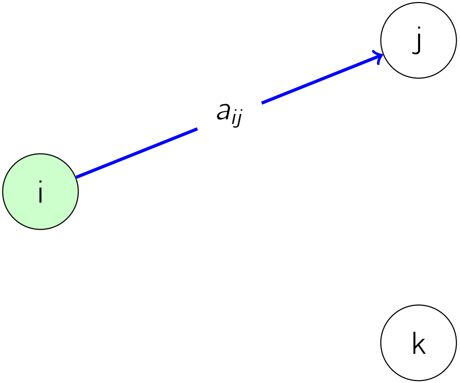
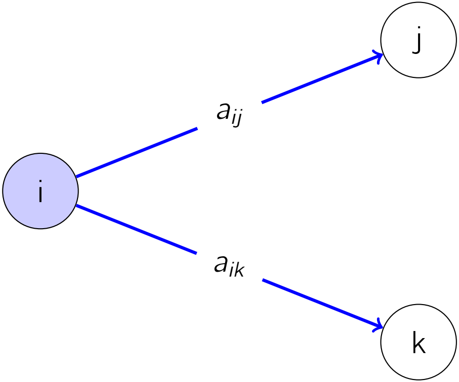
The experiment we never ran is, *suppose the government stepped aside and let these institutions fail.* **How long would it have taken to have unscrambled** *everything and figured everything out? My guess is that we are talking* **a week or two**. *[Eugene Fama]*

Default or not default?



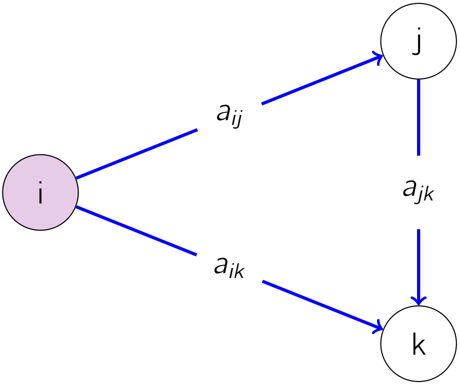
- i wants to evaluate the claim a_{ij}
- e.g. via standard structural model (Merton, 1974)
- depends on j's probability of default
- which depends on the process of its assets, $A_j(t)$

Default or not default?



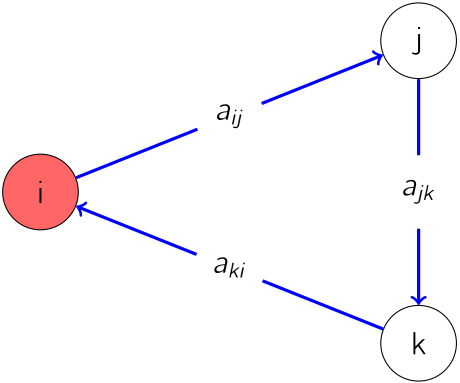
- Same thing for a_{ik}
- Will depends on j's asset process $A_k(t)$
- i tries to model **correlations** between $A_j(t)$ and $A_k(t)$

Default or not default?



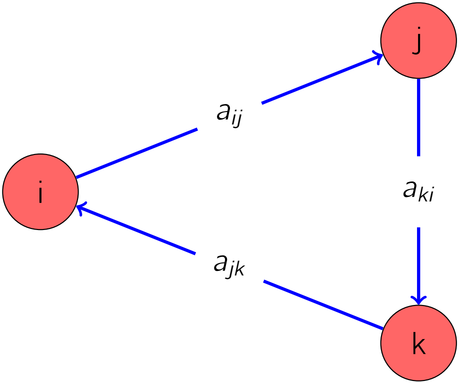
- Correlation (unknown ex-ante) between j and k increases...
- Does i even know? Can i price correctly?

Default or not default?



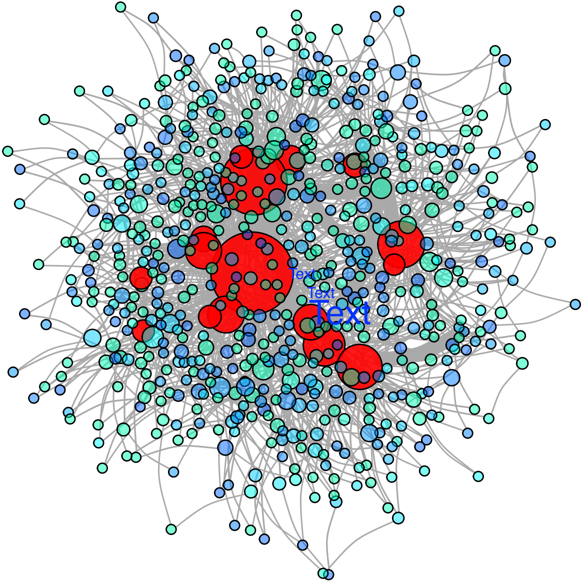
- Let us reverse a link and create a cycle...
- $p(i)$ depends on $p(j)$ which depends on $p(k)$, which depends on $p(i)$...

Default or not default?



- i, j and k need to evaluate their claims **simultaneously**
- even *clearing* is "non-trivial" (EN, 2001)

How does it look like in reality?



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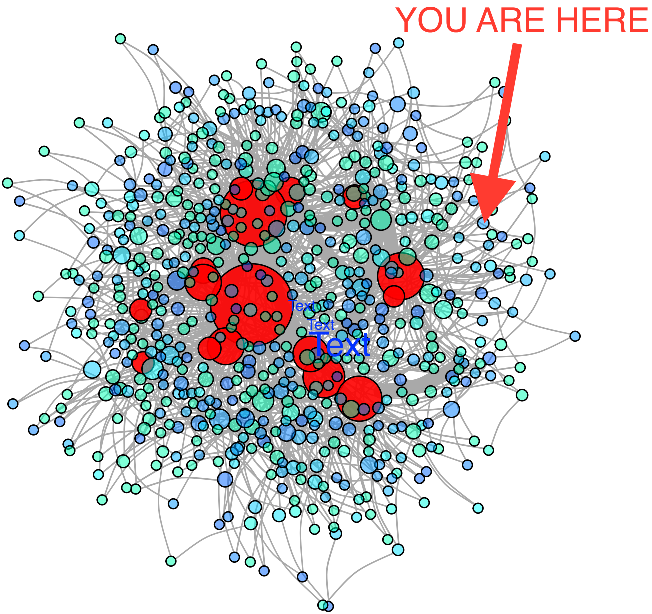

Endogeneity in finance

Interplay between:

- **Mechanics**
  - Some financial products: “mainly markets for intermediaries rather than individuals or firm” (Allen and Santomero, 2000)
  - large intrafinancial “positions” (the X-trillion OTC market) → what is the economic value/risk?

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- **Models**:
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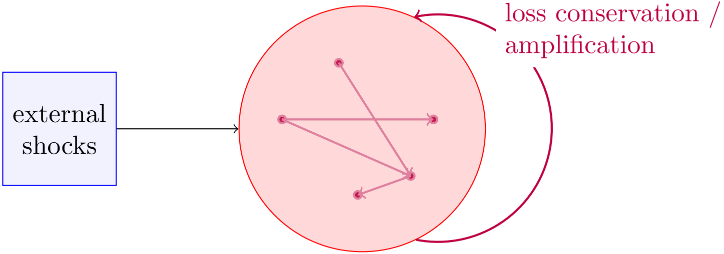
  - F. Black: people use the Black-Scholes-Merton model because they understand the (now unrealistic) assumptions...
  - Robert K. Merton: self-fulfilling prophecies and Thomas “theorem”

    If men define situations as real, they are real in their consequences.

Conservation vs amplication



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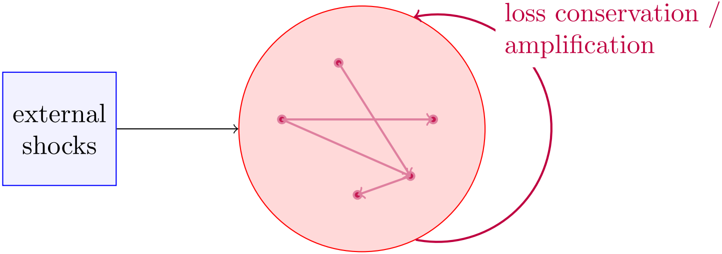
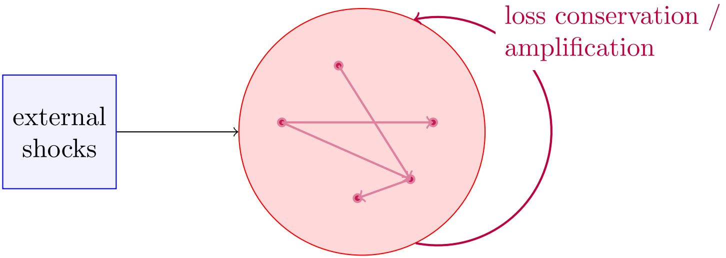


- an original shock of X euros on external assets

Conservation vs amplication



- an original shock of X euros on external assets
- the financial system is leveraged → is the original loss amplified? (intervention from CB, taxpayers)

Does interconnectedness matter?

Most work is based upon the EN framework

- Clearing payments in a network of interconnected firms (Eisenberg and Noe, 2001), several extensions
- Main claim: *existence and uniqueness* of clearing under very mild assumptions → no uncertainty about the payments due
- How to find the clearing solution? Linear programming or fixed point argument
- A number of **"hidden"** assumptions...
- Result: contagion does not matter (Elsinger et al., 2006; Glasserman and Young, 2015)

Stress-test framework

Two rounds of losses:

- **Initial loss**: shock on external assets (or selection of asset classes),
- **Final loss**: contagion process on interbank network.

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- Individual relative equity loss:

$$h_i(t) = \frac{E_i(0) - E_i(t)}{E_i(0)} = 1 - \frac{E_i(t)}{E_i(0)}$$

- Global equity loss:

$$H(t) = \sum_{i=1}^{n} w_i h_i(t)$$

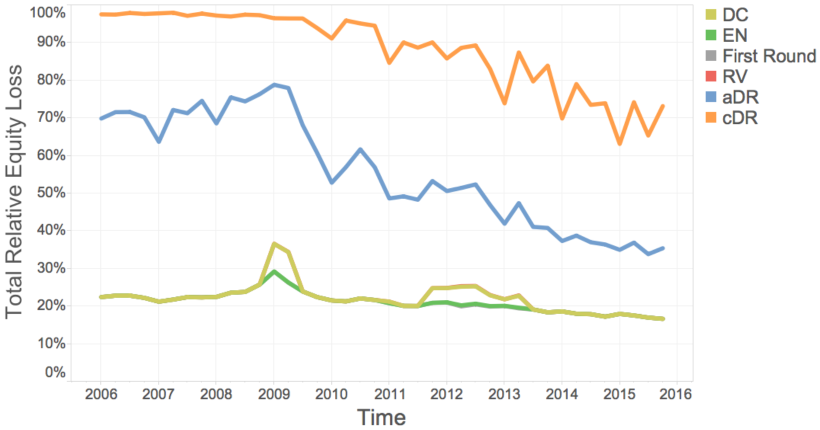
Five different propagation models

Each model must specify:

- mechanics of loss propagation (how is distress propagated?),
- set of active nodes (who can propagate losses and when?).

Model	**Mechanics**	**Active nodes**
Einserberg-Noe	Sequential defaults	Defaulted banks
Rogers-Veraart	Sequential defaults with recovery rate	Defaulted banks
Default Cascades	Sequential defaults	First-time defaulted banks
Acyclic DebtRank	MtM (CVA)	First-time distressed banks
Cyclic DebtRank	MtM (CVA)	Distressed banks

Counterfactual Stress-test - Model Comparison



- Total relative equity loss first+second-round across models, 1% shock on external assets.

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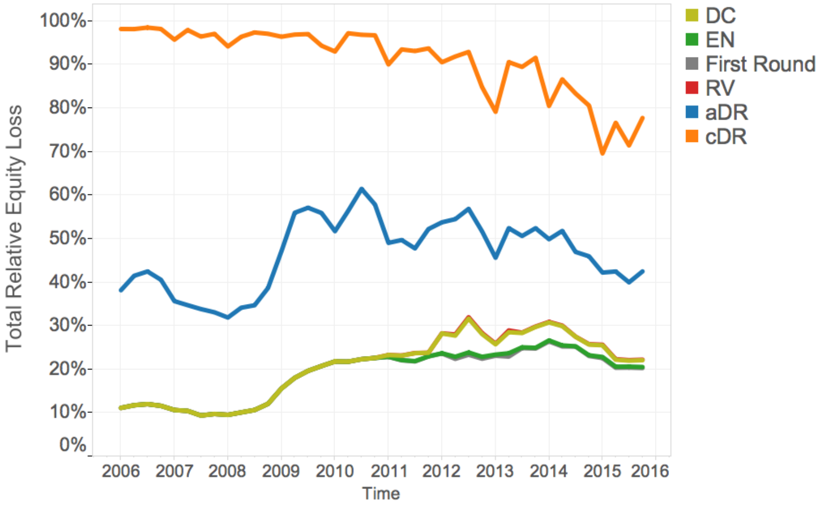
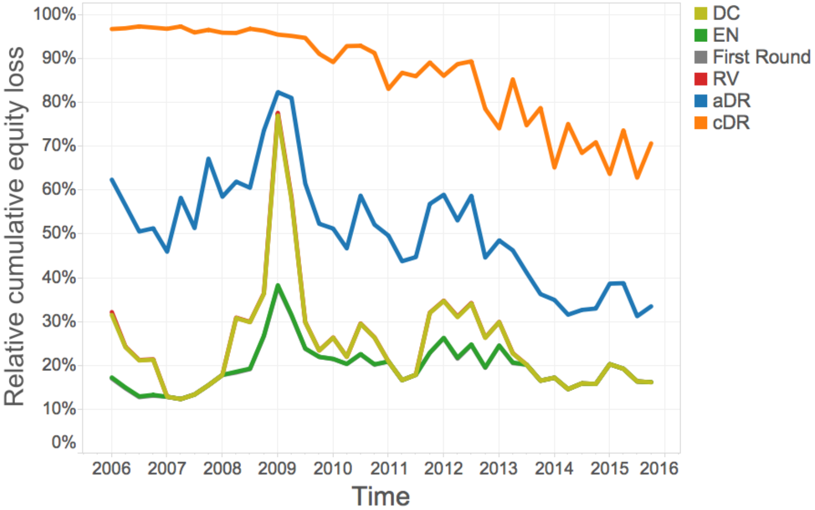


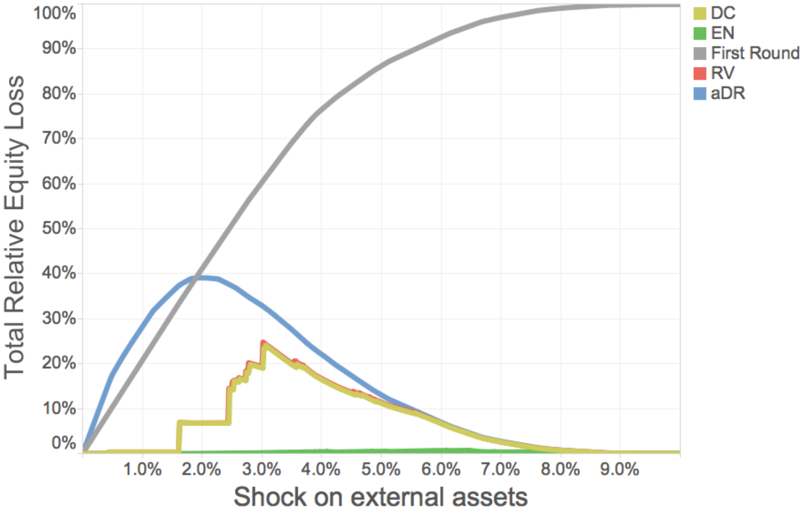
- Total relative equity loss first+second-round across models, with 40% shock on non-performing loans.Result: in aDR second round ≈ first round; in EN, RV: second round very small

Counterfactual Stress-test - Model Comparison



- Total relative equity loss first+second-round across models with 7% shock on derivatives. Result: second round in aDR larger than EN, RV except for peak in 2009

Counterfactual Stress-test - Model Comparison



- Total relative equity loss vs. varying shock size on external asset. First-round (gray); second-round-only across models. Results: **second round is non-monotone**; models tend to **coincide for large shocks**.

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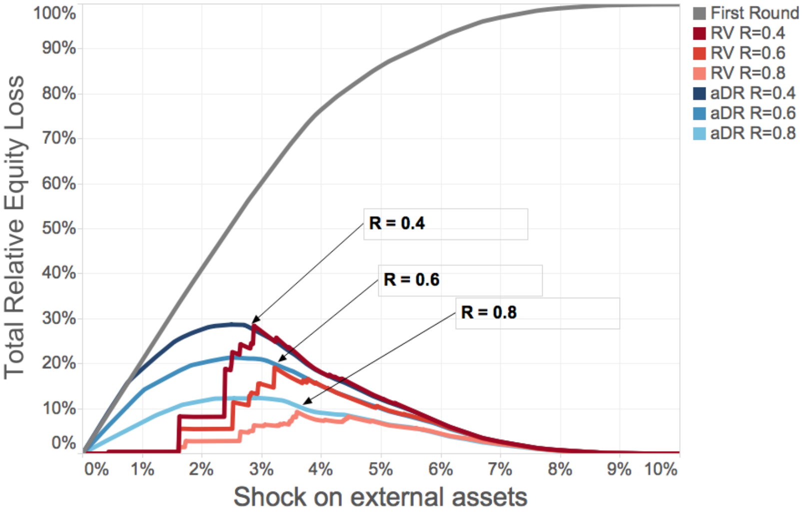

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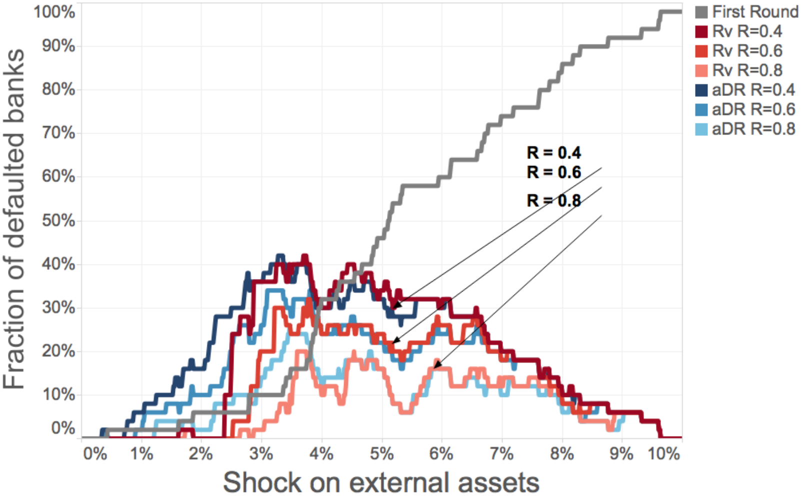

- Number of defaults vs. varying shock size on external asset. First-round (gray); second-round-only across models; models tend to **coincide for large shocks**.

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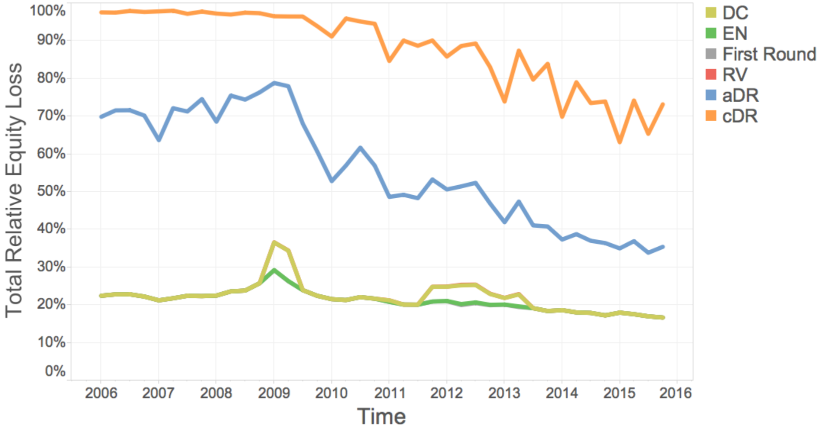


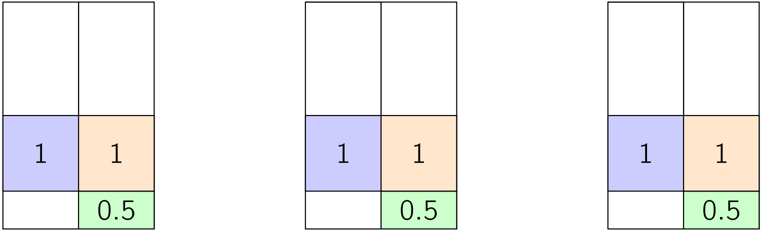
- Total relative equity loss first+second-round across models, 1% shock on external assets. Result: in aDR second round ≈ first round; in EN, RV: second round ≈ 0

Implicit assumptions of EN

Important conditions for validity, often overlooked; recent framework (Visentin et al, 2016) clarifies that:

- **Default** is the only financial event that matters. Depletion of equity does not change value of liability until default (not suitable for mark-to-market).
- **Ex-post valuation** in both EN, RV; conditional to
  - full knowledge on external assets
  - full knowledge on the network
- At default, all remaining assets are **liquidated immediately** and with certainty: "*the financial system is* **conservative**, *neither creating nor destroying value*" (EN 2001).
- Theorem: only losses in **excess of equity** are spread to counterparties

EN clearing: a system of communicating vessels



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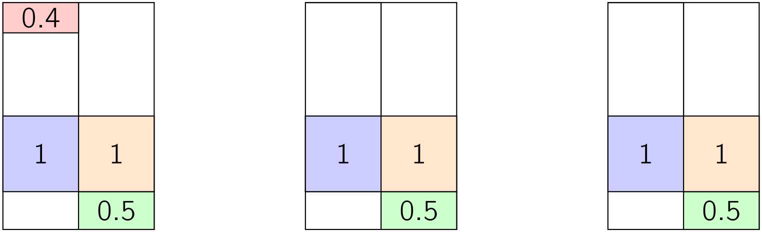

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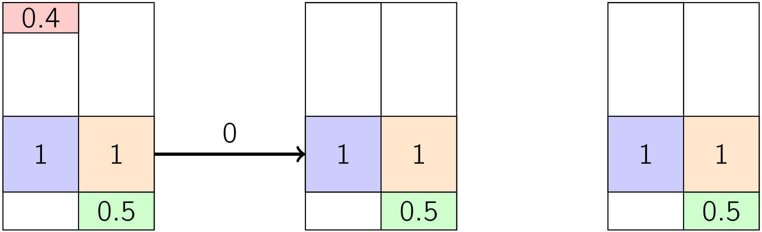

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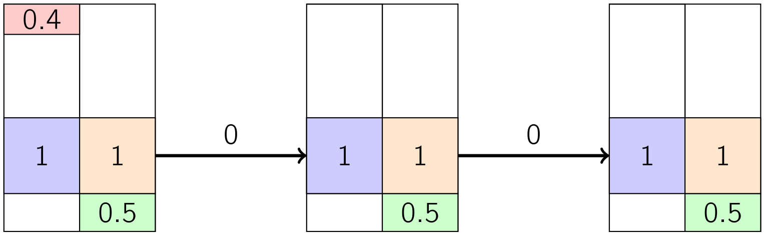

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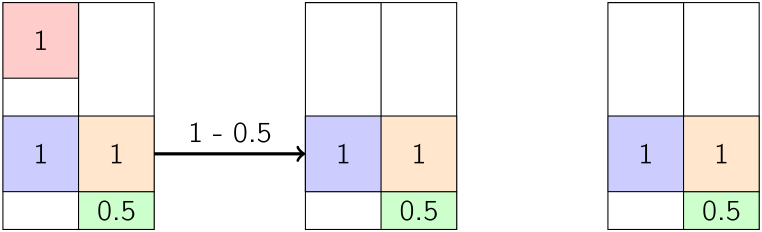

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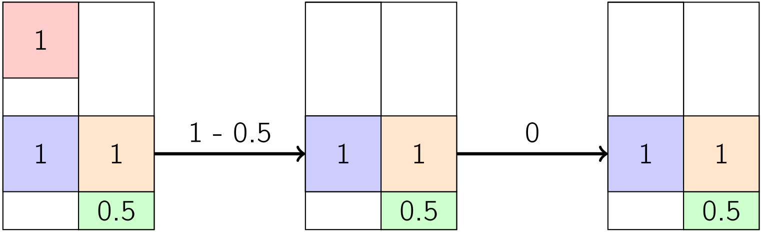

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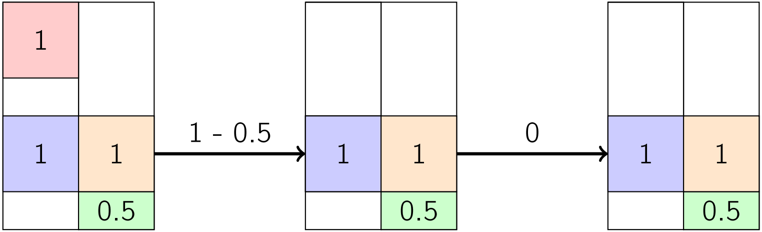
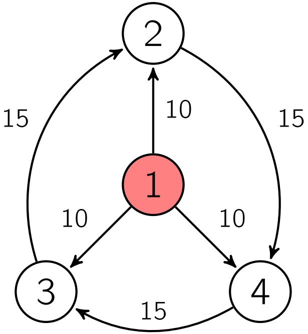


If interbank leverage $l_i^b < 1 \quad \forall i \rightarrow$ no propagation at all.

Eisenberg-Noe: mutualization of losses

How are losses mutualized?



Example: Wheel graph on n nodes (left figure, $n = 4$).
One fragile bank in the center is hit by a shock (red bank).

$$H^{EN}(\infty) = \frac{1.075}{2(n-1)+1}$$

Hence, conditional upon the default of one bank,

$$H^{\text{EN}}(\infty) \approx \frac{1}{n-1}$$

As the number of counterparties increases systemic losses are reduced (at the individual level).

$$\Longrightarrow H^{\text{EN}}(\infty) \text{ typically low.}$$

EN: Conservation of losses

Closed-form solutions given s_i, relative equity due to contagion:

$$H^{\text{EN}} = \frac{\sum_i s_i A_i^e}{\sum_{j=1}^n E_j(0)} = s l_{\text{sys}}^e$$

- Final losses in equity are **uniquely** determined as a mutualisation of initial losses in assets
- Therefore, despite formulation as recursive process on networks, in E.N. the banking system **acts as a single bank with an aggregate balance sheet and conservation of losses**.
- This implies that **network** structure does not matter in aggregate, but it matters individually

Amplification of losses

When departing from EN's assumptions, **losses can only be amplified** through the network, e.g. when

- Uncertainty about network structure
- Uncertainty about process on assets (including fire sales)
- Uncertainty about enforcement of EN
- Distress starts before default, e.g. in a mark-to-market re-evaluation (CVA and else)

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$$H^{\mathrm{EN}}(t) \leq H^{\mathrm{DC}}(t) \leq H^{\mathrm{RV}}(t) \leq H^{\mathrm{aDR}}(t) \leq H^{\mathrm{cDR}}(t).$$

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How do we price/evaluate when these sources of uncertainty are relevant and therefore we have amplification?

Implications

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- Most depends on information available to counterparties → opacity matters
- Historical analysis of the crisis

Policy

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The conservation property allows to:

$$\text{initial losses} = H^{EN} \leq H^{RV} \leq H^{\text{NEVA}}$$

- policymaker can move **during a crisis** towards the left of the inequality **only by obtaining network data and balance sheet data**
- **Very ambitious**: with right data, it is possible to run a **real-time clearing** of the financial system that tends to losses minimisation in case of defaults, even in case of uncertainty
- need for **enforcement**
- countercyclical accounting