Rethinking Financial Contagion

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Joint with G. Visentin and S. Battiston
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Motivation

- Broad agenda: is it possible (and under what conditions) to **price** systemic risk?
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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 $p(i)$...
i, j and k need to evaluate their claims \textit{simultaneously}.

- even \textit{clearing} is “non-trivial” (EN, 2001)
How does it look like in reality?
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Endogeneity in finance

Interplay between:

- **Mechanics**
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  - large intrafinancial “positions” (the X-trillion OTC market) → what is the economic value/risk?
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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 amplification

external shocks → loss conservation / amplification

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

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Conservation vs amplification

- an original shock of $X$ euros on external assets
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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)
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?).

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<th>Mechanics</th>
<th>Active nodes</th>
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<td>Defaulted banks</td>
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<td><strong>Cyclic DebtRank</strong></td>
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<td>Distressed banks</td>
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Counterfactual Stress-test - Model Comparison

- Total relative equity loss first+second-round across models, 1% shock on external assets.
Counterfactual Stress-test - Model Comparison

- 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
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
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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Counterfactual Stress-test - Model Comparison

- 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**.
Total relative equity loss first+second-round across models, 1% shock on external assets. Result: in aDR second round $\approx$ first round; in EN, RV: second round $\approx$ 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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1 1
0.5

1 - 0.5

1 1
0.5
EN clearing: a system of communicating vessels

If interbank leverage $l_i < 1 \forall i \rightarrow$ no propagation at all.
EN clearing: a system of communicating vessels

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

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

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

$\rightarrow H^{EN}(\infty)$ typically low.
Closed-form solutions given $s_i$, relative equity due to contagion:

$$H^{\text{EN}} = \frac{\sum_i s_i A^e_i}{\sum_{j=1}^n E_j(0)} = s_{\text{sys}}^e$$

- 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.
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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We prove ordering relationships:

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H^{EN}(t) \leq H^{DC}(t) \leq H^{RV}(t) \leq H^{aDR}(t) \leq H^{cDR}(t).
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How do we price/evaluate when these sources of uncertainty are relevant and therefore we have amplification?
Implications

- Does interconnectedness matter? → **No right** model of contagion
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- Most depends on information available to counterparties → opacity matters
- Historical analysis of the crisis
Despite the complexity, every cloud has a silver lining...
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The conservation property allows to:

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

- 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