Contagion Systemic Risk in Networks

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This paper

• Proposes a measure to contain systemic risk arising from direct interbank exposures.
• Considers three channels of transmission: credit risk, funding risk and runs.
• A policy proposal to contain systemic risk is derived naturally from standard limits for individual risk management.
• Compares results with proposal of limiting interbank exposures among large institutions.
Agenda

1. Definitions and simulation parameters
2. Interbank market: Risks, limits and policy proposal
3. Simulated Interbank Markets: Methodology
4. Results
5. A real-world case
6. Conclusions
1. Definitions and simulation parameters
Risks

• Upon the failure of a bank, we propose to channels it can affect others:
  • **Credit Risk:** A bank cannot pay its obligations. Impact on holders of liabilities of that bank.
  • **Funding Risk:** A bank that fails does not continue providing funds to others. Recipient banks may face losses.
• In addition, the two may combine in a single institution:
  • **Run:** As a consequence of losses suffered by a bank due to credit risk, funding risk may materialise in the form of a run.
Network: Exposures
Credit risk
Contagion
Funding risk
Funding risk
Runs
# Parameters

**Table** parameters.

<table>
<thead>
<tr>
<th>Panel A</th>
<th>Instrument</th>
<th>Contagion</th>
<th>Contagion with run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss given default</td>
<td>Derivatives in foreign currency</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Derivatives in pesos and UF</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Other intruments</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Funding replace ratio</td>
<td>All instruments</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Fire-Sales ratios</td>
<td>Cash</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Financial instruments</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Commercial loans</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Mortgages</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Consumption loans</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>$IAC &lt; 8%$</td>
<td>If $IAC$ falls under the 8% the bank is declared in default.</td>
</tr>
<tr>
<td>Runs</td>
<td>$IAC &lt; 11%$</td>
<td>If $IAC$ falls under the 11% the bank will suffer a run.</td>
</tr>
<tr>
<td>Runs*</td>
<td>Loss in capital $&gt; 5%$</td>
<td>If the the bank lost more than 5% and independent of the other conditions, the bank will suffer a run.</td>
</tr>
</tbody>
</table>

Notes: In runs scenario, if a bank defaults it will not be able to find other funding resources. Therefore, its funding replacement ratio turn to zero. For the case of fictitious exposure matrix, we create five instruments which try to replicate what we seen in the case of Chile.
2. Interbank Credit: Risks, Limits and Policy Proposal
Limits to risks in the interbank market

A

$\rightarrow$

E

Bank A

Bank B
Limits to risks in the interbank market

\[ \text{Bank A} \quad \xrightarrow{\$} \quad \text{Bank B} \]

\[ \text{A} \quad \xleftarrow{\text{E}} \quad \text{B} \]

\[ \text{r} \quad : \leq 30\% \]
Limits to risks in the interbank market

Bank A

$ \rightarrow \text{r} : \leq 5\% \\
A \\

Bank B

\text{r} : \leq 30\% \\
E
Limits to risks in the interbank market

Bank A

$ \quad r \leq 5\%$

$\sum$

Bank B

$\leq 30\%$

$\leq 40\%$
Limits to risks in the interbank market

Credit risk

$ \leq 5\%$

$ \leq 40\%$

$ \leq 30\%$

Credit risk

(problem in A)
Limits to risks in the interbank market

Bank A

Funding risk (problem in B)

Σ

Bank B

Credit risk (problem in A)

$ : ≤ 5%

: ≤ 40%

: ≤ 30%
Limits to risks in the interbank market

Bank A

$ \leq 5\%$

$\leq 40\%$

Σ

Funding risk (problem in B)

Run (problem in A)

Bank B

$\leq 30\%$

Credit risk (problem in A)
Systemic Rules – Debt with the system

- Following Cifuentes (2003), the systemic rules limit the credit or borrowing of an institution from a system perspective.

- The *Credit Risk Imposure (CRI)* is the relation between the borrowing of a bank and the equity of the rest of the system:

\[
CRI_i = \frac{\sum_{j} d_{ij}}{ERS_i} < \theta
\]

Where:
- \(d_{ij}\) represents the debt of bank \(i\) to the bank \(j\),
- \(ERS_i\) represents the equity of the rest of the system (total equity of the system minus the equity of the bank \(i\)),
- \(\theta\) indicates the regulatory limit to this measure.
Limit risk exposure of the system by limiting Credit Risk *Imposeure*
Additional shocks
- Funding
- Run
- Other
Systemic Rules – Provision of liquidity to the system

- Similarly, **Liquidity Risk Imposition (LRI)** is the relation between the aggregate provision of liquidity of a bank and the assets of the *rest of the system*.

\[
LRI_i = \frac{\sum_{j} d_{i,j}}{ARS_i} < \vartheta
\]

Where:
- \(ARS_i\) is defined as the total assets of the system minus the assets of bank \(i\).
- \(\vartheta\) is the regulatory limit.
Systemic Rules – Bilateral position (BIS)

- The systemic rules of the bilateral type \( (BR) \) limit the exposure of a systemic bank to another systemic bank in relation to its own equity.

\[
BR_j = \frac{d_{ij}}{E_j} \leq BR_{\text{max}}
\]

Where:
- \( E_j \) the equity of bank \( j \), and
- \( BR_{\text{max}} \) is the threshold.
3. Simulated interbank markets: Methodology
## Three cases

### Table: Parameters

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Panel A</th>
<th>Panel B</th>
<th>Panel C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRI</td>
<td>LRI</td>
<td>$p_{b1}$</td>
<td>$p_{b2}$</td>
</tr>
<tr>
<td>1</td>
<td>Two peaks</td>
<td>[15%-20%]</td>
<td>[2.5%-3.0%]</td>
<td>90%</td>
</tr>
<tr>
<td>2</td>
<td>Big borrower</td>
<td>[15%-20%]</td>
<td>Below 1.5%</td>
<td>90%</td>
</tr>
<tr>
<td>3</td>
<td>Big lender</td>
<td>Below 10%</td>
<td>[2.5%-3.0%]</td>
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</tr>
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**Notes:**
- CRI and LRI are the targeted values for Credit Risk Imposure and Liquidity Risk Imposition, respectively.
- Panel B shows the probability of a link between big banks (block 1), small banks (block 3) and medium banks (block 2), which include all other possible combinations.
- Panel C shows our parametrization of the size of the credit relationship in relation to its regulatory maximum. It depends on the bank's size (large, medium and small).
In each iteration, the process used to create fictitious banking systems (matrix $IM$) is the following:

- **Balance sheet**: We obtain a draw for the distribution of *total assets* from a Chi-square distribution. Both equity and current assets are defined as a percentage of total assets.

- **Regulatory matrix**: We define $R1$ ($nxn$ matrix) as the maximum credit between each pair of banks:

  \[ r_{1ij} = \min(0,05xA_i; 0,3xE_j) \]

  and $R2$ ($nx1$ vector) that defines the maximum aggregated borrowing for every bank:

  \[ r_{2i} = 0,4xA_i \]
Model simulated to create different exposure matrix

- **Link matrix:** We define $PB$ (binary matrix $n \times n$) of random links among banks ($Erdos–Renyi$), where big banks have a higher probability. For case 2 (3), we consider the lower (upper) triangular matrix of $PB$ to be zero.

- **Matrix proposed:** We define the element $im_{ij}$ of matrix $IM$ as:

  $$im_{ij} = r1_{ij} \times W^{size} \quad \text{if} \quad pb_{ij} = 1$$

  where $W^{size}$ is a weight that takes values between 0 and 1 depending on the size of the bank.
Three cases

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<tr>
<td></td>
<td></td>
<td><strong>CRI</strong></td>
<td><strong>LRI</strong></td>
<td><strong>p^{b_1}</strong></td>
</tr>
<tr>
<td>1</td>
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Model simulated to create different exposure matrix

- **Condition 1:** If $\sum_{j} im_{ij} \leq r2_i \ \forall i$, we proceed to the next condition. If not, we drop $IM$ and the process starts again.

- **Condition 2:** Depending on the simulated case, the *Credit Risk Imposure* and the *Liquidity Risk Imposure* must be consistent with the desired target. If not, we drop $IM$ and the process starts again.

- **Condition 3:** Similarly, if the implied *size of the interbank market* is consistent with the desired size, we keep $IM$. If not, we drop $IM$ and the process starts again.
## Parametrization

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° banks</td>
<td>24</td>
<td>Number of banks in Chile.</td>
</tr>
</tbody>
</table>

### Banks Balance sheet

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity</td>
<td>10%</td>
<td>Percentage of total assets of the bank.</td>
</tr>
<tr>
<td>Current assets</td>
<td>95%</td>
<td>Idem.</td>
</tr>
<tr>
<td>Risk-weighted assets</td>
<td>80%</td>
<td>Idem.</td>
</tr>
<tr>
<td>Liquid assets</td>
<td>60%</td>
<td>Idem.</td>
</tr>
</tbody>
</table>

### Limits to interbank Assets and Liabilities

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit to Credit Risk Exposure</td>
<td>30%</td>
<td>Percentage of own equity.</td>
</tr>
<tr>
<td>Maximum funding from a given bank</td>
<td>5%</td>
<td>Percentage of own current assets.</td>
</tr>
<tr>
<td>Maximum interbank funding</td>
<td>40%</td>
<td>Percentage of own current assets.</td>
</tr>
</tbody>
</table>

### Interbank Market

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of the interbank market</td>
<td>[7%, 10%]</td>
<td>Percentage of total assets of the system.</td>
</tr>
</tbody>
</table>
Interbank markets – Case 1

**Figure:** Twin peaks – Big borrowers, Big lenders (percentage of ERS and ARS, respectively)

Source: author’s simulations.
Interbank markets – Case 2

Figure: Big borrower (percentage of ERS and ARS, respectively)

Source: author’s simulations.
Interbank markets – Case 3

Figure: Big lender (percentage of ERS and ARS, respectively)

Credit Risk Imposition

Liquidity Risk Imposition

Source: author’s simulations.
4. Results
Definition of Systemic Risk

- We consider that a bank causes systemic damage if its failure causes losses in other banks above 5% of total equity of the system.
- We call “Systemic losses” those caused by all banks in a given simulated interbank market.
- We report average SL and p95.
Effectiveness of Policies

- We measure the effectiveness of a policy as the reduction in the losses described.

- Relative to initial loss: \( E1 = 100 \times \left( \frac{SL^{BP} - SL^{AP}}{SL^{BP}} \right) \)

- Relative to equity of the system:

\[
E2 = 100 \times \left( \frac{SL_t^{BP} - SL_t^{AP}}{E} \right)
\]
Case 2: Average effectiveness of Limit to CRI policy

Figure: Equity recovered as a fraction of initial systemic loss
Case 2: Reduction in interbank market of Limit to CRI policy

**Figure:** Equity recovered as a fraction of initial systemic loss
Bilateral Systemic Rule

SIFI’s

① ← ②

③
Bilateral Systemic Rule

SIFI’s

① ←→ ②

③
Bilateral Systemic Rule

SIFI’s

① ← ② ↔ ③
Case 2: Equity recovered is significant

**Figure:** Equity recovered as a fraction of total equity

![Graph showing equity recovery as a fraction of total equity](image-url)
Case 3: Average effectiveness of Limit to LRI policy

**Figure:** Equity recovered as a fraction of initial systemic loss
Case 3: On average, policy has to be more restrictive to attain results

**Figure:** Equity recovered as a fraction of initial systemic loss
Case 3: Under the parameterizations studied, damage is lower than Case 2

**Figure:** Equity recovered as a fraction of total equity
Case 1: Both limits to CRI and to LRI are relevant policies

**Figure:** Equity recovered as a fraction of initial systemic loss

![Graph showing equity recovery](image)
Figure: Equity recovered as a fraction of total equity
In order to determine the optimal combination of policies we need to do a grid search.

**Figure**: Grid search systemic rules.

(a) Reduction of losses in equity

(b) Equity recovered
Optimal policy, for a given reduction in IB market, focuses more on limiting CRI, while LRI only at end.

**Figure:** Grid search systemic rules.
Case 1 – Optimal policy combination

**Figure**: Equity recovered as a fraction of initial systemic loss

Source: authors’s simulations.
Case 1

**Figure:** Equity recovered as a fraction of total equity

Source: authors’s simulations.
6. Conclusions
Conclusions

- In order to limit systemic risk, it seems more effective to limit the overall participation of large banks in the interbank market, rather than focusing on the relations between large institutions.
- For the range of parameters described here, limit to CRI seems more effective than limits to LRI when both are relevant.
- A simulation framework can provide a rich environment for policy analysis.
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