The Role of Interbank Lending in the Predication of Individual Bank Failure during a Bank Crisis: Analysis of a Network Model of Systemic Risk

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University of Bath

Latsis Symposium Zürich
The idea

The model

The simulations

Some very preliminary empirical results

Summary
The issue

- In a banking crisis some banks struggle to survive while others are hardly affected
- Fundamentals of these banks are often very similar
- What causes these different outcomes?
The idea

The literature on predicting bank failures

- Use accounting information to predict which bank fails
- Prediction leaves a lot of room for improvement
- How does contagion spreads during a crisis has not been investigated
Our contribution

- Use a network of heterogeneous banks
- Different sizes, different interbank loans, different networks,....
- Explore what determines a bank to fail
1. The idea

2. The model

3. The simulations

4. Some very preliminary empirical results

5. Summary
## Balance sheet of banks

<table>
<thead>
<tr>
<th>Assets ($A_i$)</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cash</strong> ($R_i = \rho_iA_i$)</td>
<td><strong>Deposits</strong> ($D_i = \gamma_iA_i$)</td>
</tr>
<tr>
<td><strong>Loans</strong> ($C_i = \beta_iA_i$)</td>
<td><strong>Interbank borrowing</strong> ($L_i$)</td>
</tr>
<tr>
<td><strong>Interbank loans</strong> ($B_i$)</td>
<td><strong>Equity</strong> ($E_i = \alpha_iA_i$)</td>
</tr>
</tbody>
</table>

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The banking system

- Banks are connected via interbank loans
- Bank sizes have Powerlaw distribution
- Scale-free network of interbank loans (number of links proportional to size)
Sample banking systems
Contagion mechanism - default

<table>
<thead>
<tr>
<th>Bank 1</th>
<th>Bank 2</th>
<th>Bank 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets $A_1$</td>
<td>Liabilities</td>
<td></td>
</tr>
<tr>
<td>Cash $(R_1 = pA_1)$</td>
<td>Deposits $(D_1 = \gamma A_1)$</td>
<td></td>
</tr>
<tr>
<td>Loans $(C_1 = \beta A_1)$</td>
<td>Interbank borrowing $(L_1)$</td>
<td></td>
</tr>
<tr>
<td>Interbank loans $(B_1)$</td>
<td>Equity $(E_1 = \alpha A_1)$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bank A</th>
<th>Bank B</th>
<th>Bank C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets $A_i$</td>
<td>Liabilities</td>
<td></td>
</tr>
<tr>
<td>Cash $(R_i = pA_i)$</td>
<td>Deposits $(D_i = \gamma A_i)$</td>
<td></td>
</tr>
<tr>
<td>Loans $(C_i = \beta A_i)$</td>
<td>Interbank borrowing $(L_i)$</td>
<td></td>
</tr>
<tr>
<td>Interbank loans $(B_i)$</td>
<td>Equity $(E_i = \alpha A_i)$</td>
<td></td>
</tr>
</tbody>
</table>

Losses exceed equity, will be liquidated

Interbank loans repaid

Equity sufficient

Equity sufficient for each bank individually failing but not combined, will be liquidated
Contagion mechanism - failure

Cash reserves used, will be liquidated

Bank A

Assets ($A_i$)
- Cash ($R_i = pA_i$)
- Loans ($C_i = \beta A_i$)
- Interbank loans ($B_i$)

Liabilities
- Deposits ($D_i = yA_i$)
- Interbank borrowing ($L_i$)
- Equity ($E_i = \alpha A_i$)

Bank B

Assets ($A_i$)
- Cash ($R_i = pA_i$)
- Loans ($C_i = \beta A_i$)
- Interbank loans ($B_i$)

Liabilities
- Deposits ($D_i = yA_i$)
- Interbank borrowing ($L_i$)
- Equity ($E_i = \alpha A_i$)

Bank C

Assets ($A_i$)
- Cash ($R_i = pA_i$)
- Loans ($C_i = \beta A_i$)
- Interbank loans ($B_i$)

Liabilities
- Deposits ($D_i = yA_i$)
- Interbank borrowing ($L_i$)
- Equity ($E_i = \alpha A_i$)

Cash reserves sufficient for each bank individually failing but not combined, will be liquidated

Interbank loans called in

Bank 1

Assets ($A_i$)
- Cash ($R_i = pA_i$)
- Loans ($C_i = \beta A_i$)
- Interbank borrowing ($L_i$)

Liabilities
- Deposits ($D_i = yA_i$)
- Equity ($E_i = \alpha A_i$)

Bank 2

Assets ($A_i$)
- Cash ($R_i = pA_i$)
- Loans ($C_i = \beta A_i$)
- Interbank borrowing ($L_i$)

Liabilities
- Deposits ($D_i = yA_i$)
- Equity ($E_i = \alpha A_i$)

Bank 3

Assets ($A_i$)
- Cash ($R_i = pA_i$)
- Loans ($C_i = \beta A_i$)
- Interbank borrowing ($L_i$)

Liabilities
- Deposits ($D_i = yA_i$)
- Equity ($E_i = \alpha A_i$)

Cash reserves sufficient
Trigger mechanism

- We exogenously select one bank who we assume makes losses equal to its equity and liquidate it.
- Banks selected are biggest, second biggest and one from each size decile beyond that.
The simulations

The idea

The model

The simulations

Some very preliminary empirical results

Summary
Parameters used

- Banking system: [12; 1,000] banks
- Asset value: [100; 100,000,000,000]
- Tail index of size distribution: [1.5; 5]
- Recovery rate of loans: [0; 1]
- Fraction equity: $\alpha = [0; 0.25]$
- Fraction deposits: $[0; 1 - \alpha]$
- Fraction cash: $[0; 0.25]$
- Fraction loans to public $[0; 1]$
Factors identified in PCA

**MARKET STRUCTURE** measures how large and concentrated the banking system is

**BORROWING** measures how concentrated borrowing from other banks is (negative sign)

**BALANCE SHEET** provides a measure for the reliance of the bank on interbank loans (negative sign)

**POSITION** measures how well connected a bank is in the network

**LENDING** measures how concentrated lending to other banks is

**RECOVERY** is representing the recovery rate in case of bank failures

**TRIGGER** measures the size of the initially failing bank (negative sign)

**HUB** measures how closely integrated a bank is in its immediate neighborhood
<table>
<thead>
<tr>
<th></th>
<th>(3)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONSTANT</strong></td>
<td>-6.7455***</td>
<td>-7.0573***</td>
</tr>
<tr>
<td><strong>Individual Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(SIZE)</td>
<td>0.3119***</td>
<td>-0.2609***</td>
</tr>
<tr>
<td>EQUITY</td>
<td>0.0118</td>
<td>-0.0277**</td>
</tr>
<tr>
<td>RESERVES</td>
<td>-0.0393**</td>
<td>-0.0186</td>
</tr>
<tr>
<td>LOANS GIVEN</td>
<td>0.2134***</td>
<td>0.0783***</td>
</tr>
<tr>
<td>LOANS TAKEN</td>
<td>-0.07824***</td>
<td>-0.0100</td>
</tr>
<tr>
<td>RECOVERY</td>
<td>-0.0014</td>
<td>0.0057</td>
</tr>
<tr>
<td>log(TRIGGER)/TRIGGER</td>
<td>-1.4631***</td>
<td>-1.4822***</td>
</tr>
<tr>
<td><strong>Factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARKET STRUCTURE</td>
<td></td>
<td>0.4577***</td>
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<tr>
<td>BORROWING</td>
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<td>0.0768***</td>
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<tr>
<td>BALANCE SHEET</td>
<td></td>
<td></td>
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<tr>
<td>POSITION</td>
<td></td>
<td>-0.1593***</td>
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<tr>
<td>LENDING</td>
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<td>0.0190</td>
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<tr>
<td>HUB</td>
<td></td>
<td>0.1388***</td>
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<tr>
<td><strong>LR statistics</strong></td>
<td>13050.01***</td>
<td>16202.09***</td>
</tr>
<tr>
<td><strong>Pseudo R²</strong></td>
<td>0.2133</td>
<td>0.2649</td>
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</tbody>
</table>
## Multinomial logit regressions of a bank failing

<table>
<thead>
<tr>
<th></th>
<th>Solvency</th>
<th>Liquidity</th>
<th>Solvency</th>
<th>Liquidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTANT</td>
<td>-7.2497***</td>
<td>-7.6779***</td>
<td>-7.6799***</td>
<td>-7.8169***</td>
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<tr>
<td><strong>Individual Variables</strong></td>
<td></td>
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</tr>
<tr>
<td>log(SIZE)</td>
<td>0.3541***</td>
<td>-0.2140***</td>
<td>-0.2973***</td>
<td>-0.2768***</td>
</tr>
<tr>
<td>EQUITY</td>
<td>0.0081</td>
<td>0.0416</td>
<td>-0.0459***</td>
<td>0.0976**</td>
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<tr>
<td>RESERVES</td>
<td>-0.0651***</td>
<td>0.0736*</td>
<td>-0.0439**</td>
<td>0.1232***</td>
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<tr>
<td>LOANS GIVEN</td>
<td>0.2338***</td>
<td>0.0747</td>
<td>0.0694***</td>
<td>0.0228</td>
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<tr>
<td>LOANS TAKEN</td>
<td>-0.0983***</td>
<td>0.0334</td>
<td>-0.0117</td>
<td>0.0035</td>
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<tr>
<td>RECOVERY</td>
<td>-0.0016</td>
<td>-0.0004</td>
<td>-0.0021</td>
<td>0.0562</td>
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<tr>
<td>log(TRIGGER)/TRIGGER</td>
<td>-1.6414***</td>
<td>-0.7549***</td>
<td>-1.6686***</td>
<td>-0.7601***</td>
</tr>
<tr>
<td><strong>Factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARKET STRUCTURE</td>
<td></td>
<td></td>
<td>0.5606***</td>
<td>-0.0704</td>
</tr>
<tr>
<td>BORROWING</td>
<td></td>
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<td>0.0582***</td>
<td>0.3035***</td>
</tr>
<tr>
<td>BALANCE SHEET</td>
<td></td>
<td></td>
<td>-0.1151***</td>
<td>-0.3362***</td>
</tr>
<tr>
<td>POSITION</td>
<td></td>
<td></td>
<td>0.0320**</td>
<td>0.0067</td>
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<tr>
<td>LENDING</td>
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<td></td>
<td>0.1324***</td>
<td>0.0988***</td>
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<td>HUB</td>
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<td></td>
</tr>
<tr>
<td>LR statistics</td>
<td>13819.15***</td>
<td></td>
<td>17567.18***</td>
<td></td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
<td>0.2125</td>
<td></td>
<td>0.2702</td>
<td></td>
</tr>
</tbody>
</table>
Determinants of bank failure

- Most relevant: (trigger), network structure
- Not/less relevant: balance sheet
- Some differences between the two mechanisms for strengths of effects
Out-of-sample forecasting logit

The simulations

Type I error
Type II error

(1) All variables
(2) Size, equity reserves
(3) Size, equity, reserves, interbank loans
(4) All factors
(5) Factors and selected variables
(6) Factors without TRIGGER
Out-of-sample forecasting multinomial logit for failures only

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Predicting bank failures

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Out-of-sample forecasting comparison logit/multinomial logit for failures only
Out-of-sample forecasting multinomial logit for type of failure

The simulations

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Predicting bank failures

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Out-of-sample forecasting results

- Including network structure improves forecasting quality
- Multinomial logit outperforms logit model
Some very preliminary empirical results
Failures in the US banking system

A. Krause, S. Giansante (University of Bath)
Failures from the solvency mechanism in the model
1. The idea
2. The model
3. The simulations
4. Some very preliminary empirical results
5. Summary
Main findings

- "Too-big-to-fail" is only part of the problem
- Network structure is important determinant of whether a bank fails
- Balance sheet of limited importance
- "One-size-fits-all" capital/reserve requirements may not be appropriate
Further work under way

- Influence of minimum capital and reserve requirements
- Evaluation of actual banking systems
- Developing an index of vulnerability of a banking system
- Optimal bank responses to an unfolding crisis
- Optimization of capital/reserve requirements as a function of the variables investigated