Liquidity and Solvency Shocks in a Network Model of Systemic Risk: The Impact of Minimum Capital and Reserve Requirements

Andreas Krause    Simone Giansante

University of Bath

Financial Risk & Network Theory
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The idea

The model

The simulations

Summary
Recently proposals have been implemented to increase capital requirements for banks
Minimum liquidity requirements have also been introduced
Are these general measures effective?
Should more sophisticated requirements be developed?
The rules

- Basel II: tier 1 capital is 4% of risk weighted assets
- Basel III: tier 1 capital is 8.5% of risk weighted assets plus 2.5% discretionary countercyclical buffer
- Leverage maximum 3% of unweighed assets
- In addition requirements on liquidity to cover net cash outflows for 30 days
Our contribution

- Use a network of heterogenous banks
- Different sizes, different interbank loans, different networks,....
- Explore how capital and liquidity requirements reduce systemic risk and the risk of individual bank failure
The idea

The model

The simulations

Summary
Balance sheet of banks

<table>
<thead>
<tr>
<th>Assets ($A_i$)</th>
<th>Liabilities</th>
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</thead>
<tbody>
<tr>
<td>Cash ($R_i = \rho_i A_i$)</td>
<td>Deposits ($D_i = \gamma_i A_i$)</td>
</tr>
<tr>
<td>Minimum cash ($R_{\text{min}} = \rho_{\text{min}} A_i$)</td>
<td>Interbank borrowing ($L_i$)</td>
</tr>
<tr>
<td>Loans ($C_i = \beta_i A_i$)</td>
<td>Excess equity ($E_{\text{excess}} = \alpha_{\text{excess}} A_i$)</td>
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<tr>
<td>Interbank loans ($B_i$)</td>
<td>Minimum equity ($E_{\text{min}} = \alpha_{\text{min}} A_i$)</td>
</tr>
<tr>
<td>Excess cash ($R_{\text{excess}} = \rho_{\text{excess}} A_i$)</td>
<td>Equity ($E_i = \alpha_i A_i$)</td>
</tr>
</tbody>
</table>
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

Bank 1

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

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

Bank 2

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

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

Bank A

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

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

Losses exceed equity, will be liquidated

Bank B

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

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

Equity sufficient

Bank C

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

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

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

The model

Cash reserves used, will be liquidated
Bank A

Interbank loans called in

Cash reserves sufficient
Bank B

Bank C

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

Bank 1

Bank 2
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

1. The idea

2. The model

3. The simulations

4. 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 minimum equity: $\alpha^{\text{min}} = [0; 0.15]$
- Fraction excess equity: $\alpha_i^{\text{excess}} = [0; 0.1]$
- Fraction minimum liquidity: $\rho^{\text{min}} = [0; 0.15]$
- Fraction excess liquidity: $\rho_i^{\text{excess}} = [0; 0.1]$
- Fraction deposits: $\gamma_i = [0; 1 - \alpha_i]$
- Fraction loans to public $\beta_i = [0; 1]$
Factors identified in PCA for banking systems

**TOPOLOGY** measures the interconnectedness of the interbank loan network

**LIABILITIES STRUCTURE** measures the reliance on few interbank loans to finance the assets

**TIERING** provides a measure for the degree of tiering in the network of interbank loans

**ASSET STRUCTURE** provides a measure for how little banks invest into well diversified interbank loans

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

**TRIGGER** measures the size of the initially failing bank
## Effect of equity requirements on contagion

<table>
<thead>
<tr>
<th>Total equity</th>
<th>Excess equity</th>
<th>Minimum equity</th>
<th>Prob(contagion)</th>
<th>Fraction of banks failing</th>
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Effect of equity requirements on contagion
Effect of liquidity requirements on contagion

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<th>Total reserves</th>
<th>Excess reserves</th>
<th>Minimum reserves</th>
<th>Prob(contagion)</th>
<th>Fraction of banks failing</th>
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<tbody>
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Effect of liquidity requirements on contagion

![Graph showing the relationship between reserves and the probability of contagion, with two lines representing minimum reserves and excess reserves.](image-url)
The simulations

- Excess cash and equity is heterogeneous
- Contagion can be stopped if a bank has large buffer
- Heterogeneity can limit the extent of contagion
- Heterogeneity makes the observance of contagion more likely
Factors identified in PCA for individual banks

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

LIABILITIES STRUCTURE measures the reliance on few interbank loans to finance the assets.

ASSET STRUCTURE provides a measure for how little banks invest into well diversified interbank loans.

HUB measures how closely integrated a bank is in its immediate neighborhood.

CENTRALITY provides a measure for the importance of the bank on the interbank loan market.

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

TRIGGER measures the size of the initially failing bank.
The simulations

Effect of equity requirements on individual failures

<table>
<thead>
<tr>
<th>Total equity</th>
<th>Excess equity</th>
<th>Minimum equity</th>
<th>Prob(failing)</th>
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<th>Prob(Liquidity)</th>
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Effect of equity requirements on individual failure
Effect of equity requirements on individual failure by different contagion mechanisms
## Effect of liquidity requirements on individual failures

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<tr>
<th>Total reserves</th>
<th>Excess reserves</th>
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<th>Prob(Solvency)</th>
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</table>
1. The idea

2. The model

3. The simulations

4. Summary
Main findings

- Impact of higher minimum capital and liquidity requirements is small
- Higher common minimum requirements increases the extent of contagion
- Excess capital and liquidity has a similar impact to minimum standards
- "One-size-fits-all" capital/reserve requirements may not be appropriate and can be tailored
Future work

- What criteria should be used to tailor capital and liquidity requirements?
- Evaluation of actual banking systems
- Optimal bank responses to an unfolding crisis