Bank Networks and Systemic Risk: Micro-evidence from the National Banking Acts

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Fed System Conference on Economic and Financial History
May 25th, 2016

Views expressed in this presentation are those of the speaker(s) and not necessarily of the Office of Financial Research.
How does financial architecture affect systemic risk?

- The financial system is highly interconnected.
  - "risk of failure of large, interconnected firms must be reduced" Volcker
  - Dodd-Frank Act mandates derivatives clearing via CCPs

- Ample theories on the role of network structures on stability
How does financial architecture affect systemic risk?

- The financial system is highly interconnected.
  - “risk of failure of large, interconnected firms must be reduced” Volcker
  - Dodd-Frank Act mandates derivatives clearing via CCPs

- Ample theories on the role of network structures on stability

... yet very limited structural analysis using real data

- financial linkages are not observable
- exogenous reshaping of network structures is rare
This paper examines bank networks in 1862, 1867.

“Those who cannot learn from history are doomed to repeat it.” - Santayana
This paper examines bank networks in 1862, 1867.

- A unique historical episode
  - bank networks were simply due to reserve deposits
  - National Banking Acts (1863-1864) reshaped network structure
  - five major banking crises in the National Banking era

Our study shows that the National Banking Acts led to

- the concentration of bank linkages not only at the city level, but also at the institution level.
This paper quantifies how networks affect financial stability.

• How do such changes in network structure affect systemic risk?
  • build a model of bank reserve networks with liquidity withdrawals
  • simulate banking crises in empirical bank networks

• We find that a more centralized network is *robust-yet-fragile*
  • more robust to small shocks
  • more vulnerable to large shocks, especially to financial center banks
  • contagious withdrawals and liquidation have phase transition
Contributions

- Theoretical literature examining the relationship between financial networks and systemic risk.
  - Eisenberg, Noe 2001 MS; Elliott, Golub, Jackson 2014; Acemoglu, Ozdaglar, Tahbaz-Salehi 2015

- Empirical literature on stress-testing the resilience of networks.
  - Furfine 2003; Nier, Yang, Yorulmazer, and Alentorn 2007; Gai, Haldane, and Kapadia 2010; Glasserman and Young 2015; Gofman 2015; Stanton, Walden, and Wallace 2014

- Literature on the origin of banking crises during the National Banking era.
  - Sprague 1910; Kemmerer 1910; Calomiris and Gorton 1991; Bernstein, Hughson and Weidenmier 2010; Gorton and Tallman 2014
Outline

1 Background

2 Data and Empirical Findings

3 Model

4 Quantitative Analysis

5 Conclusion
Background
State Banking Era: 1837 - 1863

- There was no uniform currency, no central bank, no OCC.
- State-chartered banks issued their own banknotes with large dispersion in discounts.
- Banks had correspondent networks
  - shaped by interbank deposits/note-deeming + trade patterns
  🚚 core-periphery structure with local hubs (Weber 2003)
National Banking Acts: 1863 - 1864

- Lincoln needed to finance the Civil War for the federal government.

- Secretary of Treasury Chase launched National Banking Act in 1863
  - national chartered banks with regulations: buy US bonds, reserves
Lincoln needed to finance the Civil War for the federal government.

Secretary of Treasury Chase launched National Banking Act in 1863

- national chartered banks with regulations: buy US bonds, reserves
- uniform currency, the national banking system, OCC
Lincoln needed to **finance the Civil War** for the federal government.

Secretary of Treasury Chase launched National Banking Act in 1863

- national chartered banks with regulations: buy US bonds, **reserves**
- uniform currency, the national banking system, **OCC**

However, federal charters were not popular; NBA revision (1864) raised taxes on state banknotes 2% → 10% ⇒ most converted
## Transition in the Banking System

<table>
<thead>
<tr>
<th>Year</th>
<th>National</th>
<th>State</th>
<th>Savings</th>
<th>National</th>
<th>State</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1860</td>
<td>0</td>
<td>1558</td>
<td>38</td>
<td>0</td>
<td>89</td>
<td>9</td>
</tr>
<tr>
<td>1861</td>
<td>0</td>
<td>1538</td>
<td>31</td>
<td>0</td>
<td>90</td>
<td>9</td>
</tr>
<tr>
<td>1862</td>
<td>0</td>
<td>1494</td>
<td>40</td>
<td>0</td>
<td>98</td>
<td>9</td>
</tr>
<tr>
<td>1863</td>
<td>139</td>
<td>1445</td>
<td>48</td>
<td>28</td>
<td>96</td>
<td>9</td>
</tr>
<tr>
<td>1864</td>
<td>643</td>
<td>1349</td>
<td>35</td>
<td>147</td>
<td>96</td>
<td>6</td>
</tr>
<tr>
<td>1865</td>
<td>1579</td>
<td>349</td>
<td>60</td>
<td>200</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>1866</td>
<td>1644</td>
<td>297</td>
<td>96</td>
<td>203</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>1867</td>
<td>1642</td>
<td>277</td>
<td>495</td>
<td>200</td>
<td>12</td>
<td>22</td>
</tr>
<tr>
<td>1868</td>
<td>1628</td>
<td>242</td>
<td>619</td>
<td>203</td>
<td>10</td>
<td>36</td>
</tr>
<tr>
<td>1869</td>
<td>1615</td>
<td>269</td>
<td>301</td>
<td>204</td>
<td>11</td>
<td>50</td>
</tr>
</tbody>
</table>
The pyramid reserve requirements reshaped bank networks:

- classified banks into 3 tiers
- mandated reserve deposits with banks only at specific locations

<table>
<thead>
<tr>
<th>Tier</th>
<th>Banks</th>
<th>Location</th>
<th>Reserve ratio</th>
<th>Deposit in up-tiers</th>
<th>Cash in vault</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Central reserve city</td>
<td>NYC</td>
<td>25%</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Reserve city</td>
<td>PHL, PIT</td>
<td>25%</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td>3</td>
<td>Country banks</td>
<td>others</td>
<td>15%</td>
<td>3/5</td>
<td>2/5</td>
</tr>
</tbody>
</table>

Reserve networks became 3-tiered and more centralized.
Data and Empirical Results
Construct bank networks for 1862 (pre) and 1867 (post) using:

1. Bank Balance Sheets

2. Interbank Deposits

Sources:

1. Reports of the Several Banks and Savings Institutions of Pennsylvania
   - State bank balance sheet with a list of correspondents (1862, 1867)

2. National Bank Examiners’ Reports - the National Archives
   - National bank balance sheets with a list of reserve agents (1867)
   - Regulatory data from annual bank examinations
Construct Bank Networks for 1862, 1867

State bank balance sheet with detailed reserve deposits at other banks (1862, 1867)

- Reports of the Several Banks and Savings Institutions of Pennsylvania

Due to the York County Bank, from the following named solvent banks respectively, on the 4th day of November, 1862, viz:

<table>
<thead>
<tr>
<th>Bank Name</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of Commerce, New York</td>
<td>$4,654 73</td>
</tr>
<tr>
<td>Bank of Northern Liberties</td>
<td>61,276 78</td>
</tr>
<tr>
<td>Carlisle Deposit Bank</td>
<td>18 50</td>
</tr>
<tr>
<td>Jay Cook &amp; Co</td>
<td>2,072 76</td>
</tr>
<tr>
<td>Exchange Bank, Pittsburg</td>
<td>561 99</td>
</tr>
<tr>
<td>Franklin Bank, Baltimore</td>
<td>33,797 87</td>
</tr>
<tr>
<td>Girard Bank, Philadelphia</td>
<td>5,600 26</td>
</tr>
<tr>
<td>Lancaster County Bank</td>
<td>233 17</td>
</tr>
<tr>
<td>Mechanics’ Bank, Harrisburg</td>
<td>75 18</td>
</tr>
<tr>
<td>Western Bank, Baltimore</td>
<td>11,712 42</td>
</tr>
<tr>
<td>Western Bank, Philadelphia</td>
<td>2,142 72</td>
</tr>
<tr>
<td>York Bank</td>
<td>4,797 91</td>
</tr>
</tbody>
</table>

Total: $126,944 29

Figure: Detailed due-from (deposits) of York County Bank in 1862
Construct Bank Networks for 1862, 1867

National bank balance sheet with reserve deposits at approved agents (1867)

- National Bank Examiners’ Reports

Figure: Reserve deposits of York County National Bank in 1867
### Balance Sheet Statistics

<table>
<thead>
<tr>
<th></th>
<th>Philadelphia</th>
<th></th>
<th>Pittsburgh</th>
<th></th>
<th>Country Banks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Against Total Assets</strong></td>
<td>Obs</td>
<td>Mean</td>
<td>SD</td>
<td>Obs</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Cash</td>
<td>20</td>
<td>0.213</td>
<td>0.101</td>
<td>7</td>
<td>0.181</td>
<td>0.064</td>
</tr>
<tr>
<td>Liquid Securities</td>
<td>20</td>
<td>0.304</td>
<td>0.144</td>
<td>7</td>
<td>0.317</td>
<td>0.125</td>
</tr>
<tr>
<td>Due from other banks</td>
<td>20</td>
<td>0.034</td>
<td>0.042</td>
<td>7</td>
<td>0.121</td>
<td>0.043</td>
</tr>
<tr>
<td>Loans</td>
<td>20</td>
<td>0.402</td>
<td>0.118</td>
<td>7</td>
<td>0.359</td>
<td>0.118</td>
</tr>
<tr>
<td><strong>Against Total Liabilities</strong></td>
<td>Obs</td>
<td>Mean</td>
<td>SD</td>
<td>Obs</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Equity</td>
<td>20</td>
<td>0.240</td>
<td>0.055</td>
<td>7</td>
<td>0.363</td>
<td>0.071</td>
</tr>
<tr>
<td>Bank notes</td>
<td>20</td>
<td>0.133</td>
<td>0.096</td>
<td>7</td>
<td>0.391</td>
<td>0.173</td>
</tr>
<tr>
<td>Deposits</td>
<td>20</td>
<td>0.513</td>
<td>0.091</td>
<td>7</td>
<td>0.228</td>
<td>0.117</td>
</tr>
<tr>
<td>Due to other banks</td>
<td>20</td>
<td>0.091</td>
<td>0.086</td>
<td>7</td>
<td>0.006</td>
<td>0.006</td>
</tr>
</tbody>
</table>

|                                | Obs | Mean  | SD    | Obs | Mean  | SD    | Obs | Mean  | SD    |
| **Against Total Assets**       |     |       |       |     |       |       |     |       |       |
| Cash                           | 28  | 0.254 | 0.068 | 15  | 0.091 | 0.053 | 132 | 0.097 | 0.045 |
| Liquid Securities              | 28  | 0.059 | 0.053 | 15  | 0.070 | 0.128 | 132 | 0.062 | 0.093 |
| Due from other banks           | 28  | 0.055 | 0.041 | 15  | 0.066 | 0.045 | 132 | 0.099 | 0.063 |
| Loans                          | 28  | 0.395 | 0.087 | 15  | 0.488 | 0.088 | 132 | 0.404 | 0.139 |
| **Against Total Liabilities**  |     |       |       |     |       |       |     |       |       |
| Equity                         | 28  | 0.289 | 0.076 | 15  | 0.421 | 0.143 | 132 | 0.375 | 0.102 |
| Bank notes                     | 28  | 0.150 | 0.068 | 15  | 0.213 | 0.120 | 132 | 0.255 | 0.098 |
| Deposits                       | 28  | 0.490 | 0.117 | 15  | 0.347 | 0.205 | 132 | 0.337 | 0.162 |
| Due to other banks             | 28  | 0.062 | 0.078 | 15  | 0.018 | 0.031 | 132 | 0.026 | 0.034 |
Reserve Networks: Concentration of bank linkages at the institutional level

It has been well documented that the NBA caused the immediate concentration of bank linkages at the city level.

The NBA caused the concentration of bank linkages at the institution level.

- in-degree for NYC banks doubled: 2.7 → 5.4
Model
Model: a network of interbank deposits

- Environment
  - N banks, household depositors, risk-neutral, no discounting
  - Banks have demand deposit, invest in long-term loan, and are subject to liquidity risk.

- Key features
  - Interbank liability linkages
  - Endogenous liquidity withdrawal
  - Two periods of clearing equilibrium

- Builds on Eisenberg and Noe (2001 MS); Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015 AER).
Model: timeline

\[ t = 0 \] \hspace{5cm} \[ t = 1 \] \hspace{5cm} \[ t = 2 \]

Balance sheet \{C, I, L, K, D\}

Expected loan return \( R_1 \)

Loan return \( R_2 \)
Model: timeline

\[ t = 0 \quad t = 1 \quad t = 2 \]

Balance sheet

\{ C, I, L, K, D \}

Expected loan return \( R_1 \)

Loan return \( R_2 \)

- Bank \( i \)'s balance sheet is

<table>
<thead>
<tr>
<th>Asset</th>
<th>Liability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash ( C_i )</td>
<td>Capital ( K_i )</td>
</tr>
<tr>
<td>Loan ( I_i )</td>
<td>Deposit ( D_i )</td>
</tr>
<tr>
<td>Due-from ( \sum_k L_{ik} )</td>
<td>Due-to ( \sum_j L_{ji} )</td>
</tr>
</tbody>
</table>

- Interbank deposit network is \( L \).

- \( L_{ij} > 0 \) denotes bank \( i \) deposits at \( j \).
Model: timeline

\[ t = 0 \quad \rightarrow \quad t = 1 \quad \rightarrow \quad t = 2 \]

Balance sheet \{C, I, L, K, D\}

Expected loan return \( R_1 \)

Withdrawal \( W^L, W^D \)

Payment \( I^l, I^{d1}, X^L, X^D \)

Loan return \( R_2 \)

• Loan return \( \log R_{t+1} = \log R_t + \epsilon_{t+1}, \epsilon_{t+1} \sim N(\nu_t, \sigma_t, \rho_t) \).

• Clearing payment among banks \( X^L \), to households \( X^D \).

• Early withdrawals by bank depositors \( W^L \), by households \( W^D \).

• Early liquidation \( I^l \): reserve + cash < withdrawals.

• Early default \( I^{d1} \): reserve + cash + loan liquidation < withdrawals.
Model: timeline

### t = 0

- Balance sheet \(\{C, I, L, K, D\}\)
- Loan return \(R_2\)
- Payment \(I^l, I^{d1}, X^L, X^D\)
- Early liquidation \(\mathbb{I}^l\): reserve + cash < withdrawals
- Early default \(\mathbb{I}^{d1}\): reserve + cash + loan liquidation < withdrawals

### t = 1

- Expected loan return \(R_1\)
- Withdrawal \(W^L, W^D\)

### t = 2

- Loan return \(R_2\)
- Payment \(I^l, I^{d1}, X^L, X^D\)

---

\[ \log R_{t+1} = \log R_t + \varepsilon_{t+1}, \quad \varepsilon_t \sim N(\nu_t, \sigma_t, \varrho_t). \]
Model: timeline

$t = 0$

Balance sheet
{$C, I, L, K, D$}

$t = 1$

Expected loan return $R_1$
Withdrawal $W^L, W^D$
Payment $I^l, I^{d1}, X^L, X^D$

$t = 2$

Loan return $R_2$
Payment $I^{d2}, Y^L, Y^D$
Model: timeline

\[ t = 0 \quad \rightarrow \quad t = 1 \quad \rightarrow \quad t = 2 \]

Balance sheet \( \{C, I, L, K, D\} \)
Expected loan return \( R_1 \)
Loan return \( R_2 \)
Withdrawal \( W^L, W^D \)
Payment \( I^l, I^{d1}, X^L, X^D \)
Payment \( I^{d2}, Y^L, Y^D \)

- If not liquidated, loan returns \( IR_2 \).
- Clearing payment among banks \( Y^L \), to households \( Y^D \)
- Default \( I^{d2} \): reserve + cash + loan return < deposits
Early Withdrawal Scenarios: fundamentals

(A). Depositors withdraw when holder bank has low expected return.

\[ \text{Pr} ( i \text{ defaults at } t_2 \mid R_{i,1}) > \bar{p} \Rightarrow \text{all of } i \text{'s depositors withdraw.} \]
Early Withdrawal Scenarios: vertical contagion

(B). $i$ withdrawals from $k$ if $i$ has illiquidity due to withdrawals.

(C). If $k$ defaults on $i$, all of $i$’s depositors withdraw.
Early Withdrawal Scenarios: horizontal contagion

(Д). $j$ withdrawals from $i$ if other depositors of bank $i$ withdraw.

\[
\Pr (i \text{ defaults at } t_2 | R_k, 1) > \bar{p}, \text{ all of } i\text{'s depositors withdraw.}
\]
Early Withdrawal Clearing Equilibrium

- Given balance sheet \( \{C, I, K, D, L\} \), expected loan returns \( R_1 \), withdrawal \( W^L \) and \( W^D \), early liquidation and default \( \mathbb{I}^l \) and \( \mathbb{I}^{d1} \), total cash flow of \( i \) (who has withdrawals) at \( t = 1 \) is

\[
H^1_i = C_i + \sum_k W^L_{ik}X^L_{ik} + \mathbb{I}^l_iI_i(1 - \xi_l).
\]
Early Withdrawal Clearing Equilibrium

- Given balance sheet \( \{C, I, K, D, L\} \), expected loan returns \( R_1 \), withdrawal \( W^L \) and \( W^D \), early liquidation and default \( \mathbb{I}^l \) and \( \mathbb{I}^{d1} \), total cash flow of \( i \) (who has withdrawals) at \( t = 1 \) is

\[
H_i^1 = C_i + \sum_k W_{ik}^L X_{ik}^L + \mathbb{I}_i^l I_i (1 - \xi_l).
\]

- If \( H_i^1 < i \)'s withdrawal demand, \( i \) defaults and pays \( X_{i}^L \) and \( X_{i}^D \) to depositors pro rata.
Early Withdrawal Clearing Equilibrium

- Given balance sheet \{C, I, K, D, L\}, expected loan returns \( R_1 \), withdrawal \( W^L \) and \( W^D \), early liquidation and default \( \Pi^l \) and \( \Pi^{d1} \), total cash flow of \( i \) (who has withdrawals) at \( t = 1 \) is

\[
H^1_i = C_i + \sum_k W^L_{ik} X^L_{ik} + \Pi^l_i I_i (1 - \xi_l).
\]

- If \( H^1_i < i \)'s withdrawal demand, \( i \) defaults and pays \( X^L_i \) and \( X^D_i \) to depositors pro rata.

- Interbank reserve deposit payment \( X^L \) + household deposit payment \( X^D \) form an early withdrawal clearing equilibrium of the bank network at \( t = 1 \).

- The clearing equilibrium exists and is unique. (Eisenberg Noe 2001)
Final Date Clearing Equilibrium

- For all banks with no early withdrawals, loan returns $R_2$ realize, total cash flow of $i$ at $t = 2$ is

$$H^2_i = C_i + I_i R_{i,2} + \sum_k \left( W_{ik}^L X_{ik}^L + (1 - W_{ik}^L) Y_{ik}^L \right)$$

- If $H^2_i < i$’s deposits, $i$ defaults and pays $Y_i^L$ and $Y_i^D$ to depositors *pro rata*.

- Interbank reserve deposit payment $Y^L +$ household deposit payment $Y^D$ form a **final date clearing equilibrium** of the bank network at $t = 2$.

- The clearing equilibrium exists and is unique.
Quantitative Analysis
Quantitative Analysis

- Construct banking systems using real data
  - \{C, I, K, D, L\} from bank balance sheets in 1862 and 1867

- Top-to-bottom crises: correlated return shocks $R_1$ to NYC banks

- Bottom-to-top crises: correlated liquidity shocks $W^D$ to country banks

- Measures for systemic risk
  - joint probability of liquidation/default
  - expected costs from liquidation/default
  - liquidation/default due to contagion
"It was the suspension of cash payments and not bank runs nor bank failures through which the public in the rest of the country experienced the effects of banking panics.” (Wicker, 2000)

- 4 out of 5 major banking panics began due to investment loss in NYC and spread to the rest of the country.

- 1873: failure of Jay Cooke
- 1884: failure of Grant and Ward
- 1890: failure of Decker Howell and Co.
- 1907: failure of knickerbocker trust
Quantitative Analysis: Top-to-Bottom Crises

Negative shock to $R_{k,1}$

$\Rightarrow$ Withdrawals from $i$, $m$ and $k$’s household depositors

$\Rightarrow$ $k$ liquidates and defaults.

$\Rightarrow$ $j$ and $n$ withdraw from $i$ and $m$.

$\Rightarrow$ $i$ and $m$ liquidate and default, etc.
Top-to-Bottom Crises: phase-transition

1867 network is robust to small shocks but not to large shocks

“robust-yet-fragile”, knife-edge dynamics as in Haldane (2013)

![Graph showing the probability of percentage liquidation exceeding θ1%](attachment:graph1.png)

![Graph showing the probability of percentage default exceeding θd%](attachment:graph2.png)
Mechanism: downward withdrawal contagion

Small shocks: diversification limits downward contagion

Large shocks: centralized linkages act as a mechanism for contagion

a. $E[\text{Pct. downward withdrawal contagion}]\%$

b. $E[\text{Pct. upward withdrawal contagion}]\%$
Quantitative Analysis: Bottom-to-Top crises

“A withdrawal of reserves by the bottom of the pyramid during a panic could thus result in a rapid depletion of reserves within the banking system.” (Bankers’ Magazine 1907 July)

- Due to agricultural cycles, country banks experienced farmers’ withdrawal in the spring and fall and thus liquidity shortages.

- 1893: bank suspensions occurred outside NYC, mainly in the South and the West.
Quantitative Analysis: Bottom-to-Top crises

Shocks to $W_j^D$ and $W_n^D$

$\Rightarrow j$ and $n$ withdraw from $i$ and $m$.

$\Rightarrow i$ and $m$ withdraw from $k$.

$\Rightarrow$ Household depositors of $i$, $m$, and $k$ withdraw.

$\Rightarrow k$ liquidates and defaults.

$\Rightarrow i$ and $m$ liquidate and default, etc.
1867 network is generally more robust to illiquidity of country banks

NYC banks held more cash

**a. Prob(Pct. liquidation > \( \theta_l \))%**

**b. Prob(Pct. default > \( \theta_d \))%**

---

**c. \( E[\text{Pct. liquidation}] \)%**

**d. \( E[\text{Pct. default}] \)%**

**e. \( E[\text{Liquidation costs/total bank value}] \)%**

**f. \( E[\text{Default costs/total bank value}] \)%**
Conclusion

An important topic: bank networks and systemic risk

A unique historical and quantitative approach

- examine bank networks in 1862 and 1867
- quantify effect of networks on systemic risk

Key findings

- The Acts reshaped the bank reserve networks to be more centralized.
- Such more centralized network is robust-yet-fragile to liquidity crises.
### Benchmark Parameter Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity loss threshold to trigger liquidation</td>
<td>$\kappa$</td>
<td>0.3</td>
</tr>
<tr>
<td>Liquidation cost proportional to loan size</td>
<td>$\xi_l$</td>
<td>0.2</td>
</tr>
<tr>
<td>Default cost proportional to shortfall</td>
<td>$\xi_d$</td>
<td>1.5</td>
</tr>
<tr>
<td>Average loan return rate</td>
<td>$\bar{e}$</td>
<td>0</td>
</tr>
<tr>
<td>Volatility of loan return rate</td>
<td>$\sigma_e$</td>
<td>0.1</td>
</tr>
<tr>
<td>Systemic threshold for fraction of bank liquidation</td>
<td>$\theta_l$</td>
<td>20%</td>
</tr>
<tr>
<td>Systemic threshold for fraction of bank defaulting</td>
<td>$\theta_d$</td>
<td>20%</td>
</tr>
<tr>
<td>Liquidation event</td>
<td>$-\Delta \text{assets} &gt; \kappa \times \text{equity}$</td>
<td></td>
</tr>
<tr>
<td>Default event</td>
<td>$h_i &lt; \sum_j L_{ji} + d_i$</td>
<td></td>
</tr>
<tr>
<td>Systemic liquidation event</td>
<td>$&gt; \theta_l$ of banks liquidate</td>
<td></td>
</tr>
<tr>
<td>Systemic default event</td>
<td>$&gt; \theta_d$ of banks default</td>
<td></td>
</tr>
</tbody>
</table>