Network Analysis of Convertible Debt Systemic Risk

Yueliang LU
Quant Finance & Risk Analytics

Adviser: Prof. Aparna Gupta

Lally School of Management, Rensselaer Polytechnic Institute

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Outline

1. Research Background
2. Motivation & Objectives
3. Model & Methodology
4. Network Model for Banking System
5. Calibration & Simulation & Results
6. Summary
2007/08 Financial Crisis

Fourth Largest Investment Bank before 2008
Too-big-to-fail

- Financial institutions, are so **large** and so **interconnected**
- Their failure would be disastrous to the greater economic system
- They therefore must be supported by government when they face potential failure.
Should they be saved?

- If they’re too big to fail, they’re too big

Alan Greenspan
Outline

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Contingent Convertible Debt

- A form of debt that automatically converts into equity when gets triggered
- Self-saving financial instrument
- Trigger criteria: single or dual?
- Conversion mechanism: fully or partial?
- How they are held before triggering: bonds
Research Objectives

- Evaluate the buffer effect of CoCo in controlling systemic risk
Outline

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What is a Balance Sheet?

### Springfield Psychological Services

#### Balance Sheets
December 31, 2004 and 2003

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current assets:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>$12,597</td>
<td>$8,173</td>
</tr>
<tr>
<td>Short-term investments</td>
<td>5,003</td>
<td>3,517</td>
</tr>
<tr>
<td>Accounts receivable</td>
<td>2,315</td>
<td>3,750</td>
</tr>
<tr>
<td>Prepaid Rent</td>
<td>3,000</td>
<td>3,000</td>
</tr>
<tr>
<td><strong>Total current assets</strong></td>
<td><strong>22,915</strong></td>
<td><strong>18,440</strong></td>
</tr>
<tr>
<td>Property, plant and equipment:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land and building</td>
<td>65,553</td>
<td>28,369</td>
</tr>
<tr>
<td>Machinery and equipment</td>
<td>5,000</td>
<td>3,511</td>
</tr>
<tr>
<td>Less accumulated depreciation</td>
<td>5,775</td>
<td>4,321</td>
</tr>
<tr>
<td><strong>Property and equipment, net</strong></td>
<td><strong>64,778</strong></td>
<td><strong>27,559</strong></td>
</tr>
<tr>
<td>Long-term investments</td>
<td>1,353</td>
<td>4,587</td>
</tr>
<tr>
<td>Other assets</td>
<td>283</td>
<td>211</td>
</tr>
<tr>
<td><strong>Total assets</strong></td>
<td><strong>$89,329</strong></td>
<td><strong>$50,797</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liabilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current liabilities:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note payable</td>
<td>$4,200</td>
<td>$4,752</td>
</tr>
<tr>
<td>Accounts payable</td>
<td>375</td>
<td>15</td>
</tr>
<tr>
<td>Accrued wages</td>
<td>1,579</td>
<td>1,149</td>
</tr>
<tr>
<td>Taxes payable</td>
<td>5,386</td>
<td>4,722</td>
</tr>
<tr>
<td><strong>Total current liabilities</strong></td>
<td><strong>11,540</strong></td>
<td><strong>10,638</strong></td>
</tr>
<tr>
<td>Long-term debt</td>
<td>50,000</td>
<td>20,000</td>
</tr>
<tr>
<td><strong>Owner’s Equity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total owners’ equity</td>
<td><strong>27,789</strong></td>
<td><strong>20,159</strong></td>
</tr>
<tr>
<td><strong>Total liabilities and owners’ equity</strong></td>
<td><strong>$89,329</strong></td>
<td><strong>$50,797</strong></td>
</tr>
</tbody>
</table>

(Lally, RPI)
Balance Sheet Construction

Equities = Assets - Liabilities

**Assets**
- Cash & Equivalents
- Government Securities
- Total Loans
- Equity Securities Holdings

**Liabilities**
- Deposits
- Common Debt
- CoCo Debt
Evolution of Asset Items

- **Cash & Equivalents (Bank \( i \) at time \( t \))**

\[
dC_{it} = u_i C_{it} dt + \sigma_i C_{it} dZ_t, \quad \forall i = 1 \text{ to } N.
\]

\( dZ_t \) is a Wiener Process

- **Government Securities, Total Loans**

\[
\frac{dG_{it}}{G_{it}} = k_i^G dt, \quad \forall i = 1 \text{ to } N
\]

- **Equity Holdings (Network): Interbank Holdings + Non-Financial Holdings**
Evolution of Liability Items

Bond Price/Yield

Coupon Rate = 6%

10-Year Bond

Convexity Adjustment:
Note that the adjustment is greater on the upside...

... than on the downside...

... and the size of the adjustment is proportional to the change in interest rates
Evolution of Liability Items

- **Interest Rate & Credit Spreads**

\[ dr_t = \alpha_r (r - r_t) dt + \sigma_r \sqrt{r_t} dW_t \]
\[ ds_t = \alpha_s (s - s_t) dt + \sigma_s \sqrt{s_t} dW_t \]
\[ r^l_t = r_t + \alpha^l s_t \]

- **Common Debt & CoCo Debt**

\[ dL^b_{it} = -D^b_i L^b_{it} dr^l_t + \frac{1}{2} C_i^b L^b_{it} dr^{l2}_t, \quad \forall i = 1 \text{ to } N. \]

- **Deposits**

\[ \frac{dD_{it}}{D_{it}} = k^D_i dt, \quad \forall i = 1 \text{ to } N \]
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Network of Daily Transaction

Equity Holdings: Non-Financial Holdings

Industries

- Financial
- Energy
- Health Care

Banks

- JPM
- GS
- BOA
- NBT
- SEI
Network of Daily Transaction

Equity Holdings: Interbank Holdings
Network of Tail Dependencies

Stress Testing: Industrial Sectors Conditional Correlations
Network of Tail Dependencies

Stress Testing: US Banks Conditional Correlations
Measurement of Systemic Risk?

- The number of banks that go bankrupt
- Expected Default Frequency
- Conditional Value at Risk

KMV model
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Data & Model Calibration

- 10 Years: Quarterly or Daily
- Equity Holdings: SEC 13-F filings
- Balance Sheet Items: Call Reports
- Industrial Evolution: Dow Jones Index Sectors
Simulation

Scenario Settings:

- 36 Banks: 4 Super Large, 6 Large, 16 Medium and 10 Small
- 11 Sectors: Correlated Geometric Brownian Motions
- Trigger: Equity/Asset ratio drop down 40%
- Conversion: Full conversion once triggered
- Simulation Times: 10,000 times
- Simulation Steps: 365 days
Financial Shocks

Liquidity Shocks:
- Frequency: 0.5-year
- Severity: \( U \sim N(-0.2, 0.05) \& 0.8*U \)

Industrial Shocks:
- Frequency: 5-year
- Severity: \( U \sim N(-0.4, 0.1) \& 0.6*U \)
The Distribution of Bankrupt Banks

Without CoCo

With CoCo

(Lally, RPI)

Frontiers of Network Science 2017
Dec 4, 2017
The Distribution of Bankrupt Banks

Table: Statistics of Bankrupt Banks

<table>
<thead>
<tr>
<th></th>
<th>Banking System (36)</th>
<th>Large (10)</th>
<th>Medium (16)</th>
<th>Small (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without CoCo</td>
<td>Mean</td>
<td>2.3854</td>
<td>1.2326</td>
<td>1.0128</td>
</tr>
<tr>
<td></td>
<td>S.d</td>
<td>2.5082</td>
<td>1.3943</td>
<td>0.9704</td>
</tr>
<tr>
<td>With CoCo</td>
<td>Mean</td>
<td>0.2854</td>
<td>0.1334</td>
<td>0.152</td>
</tr>
<tr>
<td></td>
<td>S.d</td>
<td>1.0543</td>
<td>0.5896</td>
<td>0.5218</td>
</tr>
</tbody>
</table>
CoCo Mechanics

![Graphs of Inusdustrial Sectors, Equity Value, Firm-Holdings, Interbank-Holdings](image-url)
CoCo Mechanics

Equity Evolution without CoCo conversion

Equity Evolution with CoCo conversion

Without CoCo

With CoCo Conversion

(Lally, RPI)
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Summary

- Banks are connected through Balance Sheet Items
- Contingent Convertible Debt: A debt that automatically converts into equity when triggered
- Holding CoCo Debt can significantly reduce systemic risk exposure due to industrial shock and liquidity stress
- Further work:
  - Industrial Shock $\implies$ Liquidity Stress
  - Industrial Shock $\implies$ Credit Rating Downgrading
  - Liquidity Stress $\implies$ Credit Rating Downgrading
  - Credit Rating Downgrading $\implies$ Liquidity Stress
References


