Addressing Systemic Risk Using Contingent Convertible Debt - A Network Analysis

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Contingent Convertible Debt

- Financial Crisis (2008)
  - Too-big-to-fail & Systemic Risk: Lehman Brothers, Bear Stearns
  - Too-connected-to-fail: the Federal Reserve re-proposed to limit business ties among Wall Street banks (2011 & 2016)
- Dodd-Frank Act (2010) & Basel III (2013)
  - Regulation: strengthen capital positions
  - Debate: increasing capital $\xrightarrow{???}$ "Too-big-to-fail"

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  - More than €125 billion CoCo bonds in Europe with more than 60% of them as tax-deductible

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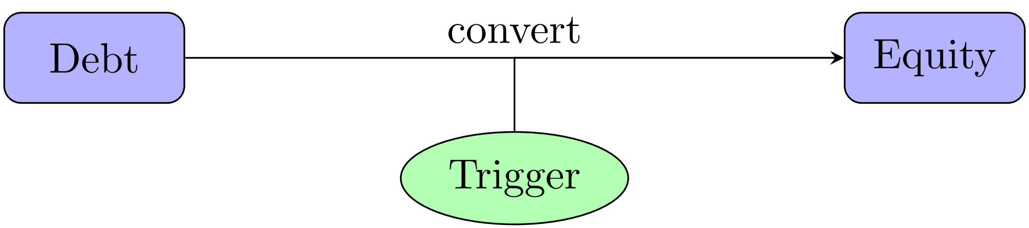
- Contingent convertible (CoCo) debt
  - More than €125 billion CoCo bonds in Europe with more than 60% of them as tax-deductible
  - Satisfying regulatory capital requirement & a Self-saving instrument



Motivation

Contingent convertible debt with,

1. **Trigger criteria** [Glasserman and Nouri, 2012]
    - Single trigger
        - Regulatory ratio: [Credit Suisse, 2011], [Rabobank, 2010], [Lloyd, 2009]
        - Stock price/ equity ratio/ CDS prices ...
    - Dual-trigger
        - [Allen and Tang, 2016], [Pennacchi et al., 2014], [McDonald, 2013]

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     - [Allen and Tang, 2016], [Pennacchi et al., 2014], [McDonald, 2013]
2. **Network Model**
   - Researchers have applied network science for studying systemic risk.
     - [Allen and Gale, 2000] (first)
     - [Anand et al., 2013] (balance sheet network model for European banks)
     - [Brunetti et al., 2018] (SEC: systemic risk & portfolio concentration)
   - **However**,
     - Network model calibration is a challenge due to the lack of data
     - No research has combined network analysis with CoCo debt

Questions, Contributions & Findings

Research Questions

- Impact of CoCo debt conversion on individual banks & banking system
- Effect of two designs of CoCo debt trigger: single trigger & dual-trigger

Contributions

- It's the first work to combine the network analysis with the CoCo debt by developing a reduced form balance sheet network model.
- Estimate the impact of different types of CoCo debts on banking system stability with the network model
- Calibrate a real world banking network with 13-F filings data and find consistent result

Questions, Contributions & Findings

Findings

- Theoretically, CoCo debt controls the spread of local stress to the banking system
  - Both # of bank failures and ΔCoVaR are significantly reduced
  - Design of CoCo triggers reflects a trade-off in systemic risk management
    - Single trigger is better at saving stressed individual banks
    - Dual trigger outperforms in improving banking system stability
  - CoCo debt performs better in the situation of lower financial stability
    - Lower the Basel III leverage ratio, the better the protective effects.
    - The dual trigger CoCo outperforms the single trigger CoCo

- Empirically,
  - Faster propagation of financial shocks along linkage of large BHCs
  - # of bank failures and ΔCoVaR are consistent with theoretical findings

Balance Sheet Construction

- Assuming that CoCo debt is allocated from common debt

$$C_{it} + G_{it} + M_{it} + A^B_{it} + A^I_{it} = D_{it} + L^B_{it} + L^C_{it} + E_{it} \tag{1}$$

Table 1: Captured key financial ratios

Key Statistics	Value
Leverage Ratio[1]	10%
Debt to Deposit Ratio	7.5%
Average Liability Duration	1.5
Long Term Base Interest Rate	1.47%
Long Term BBB Debt Risk Premium	3.43%

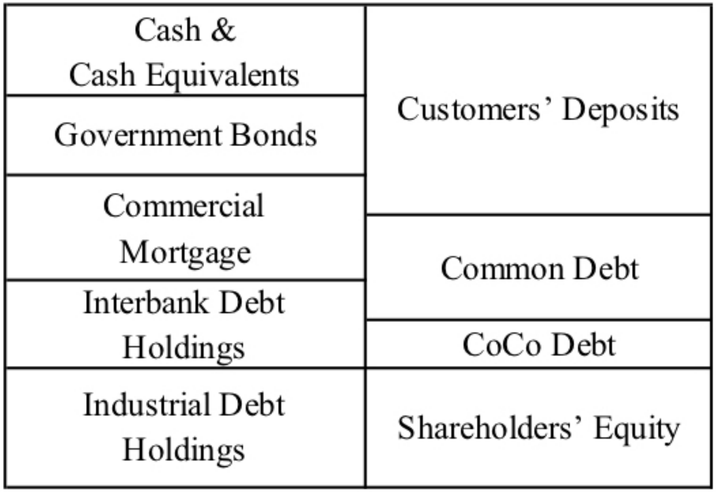

Figure 1: A sample balance sheet

Banking Network: N banks and M sectors

Channel 1: interbank debt holdings

- w_{ij}, the percentage of bank j's common debt held by bank i

$$A_i^B = \sum_{j=1}^{N} w_{ij} L_j^B, \quad \forall i, j = 1 \ to \ N, \tag{2}$$

where L_j^B is the inter-bank debt issuance of a bank j.

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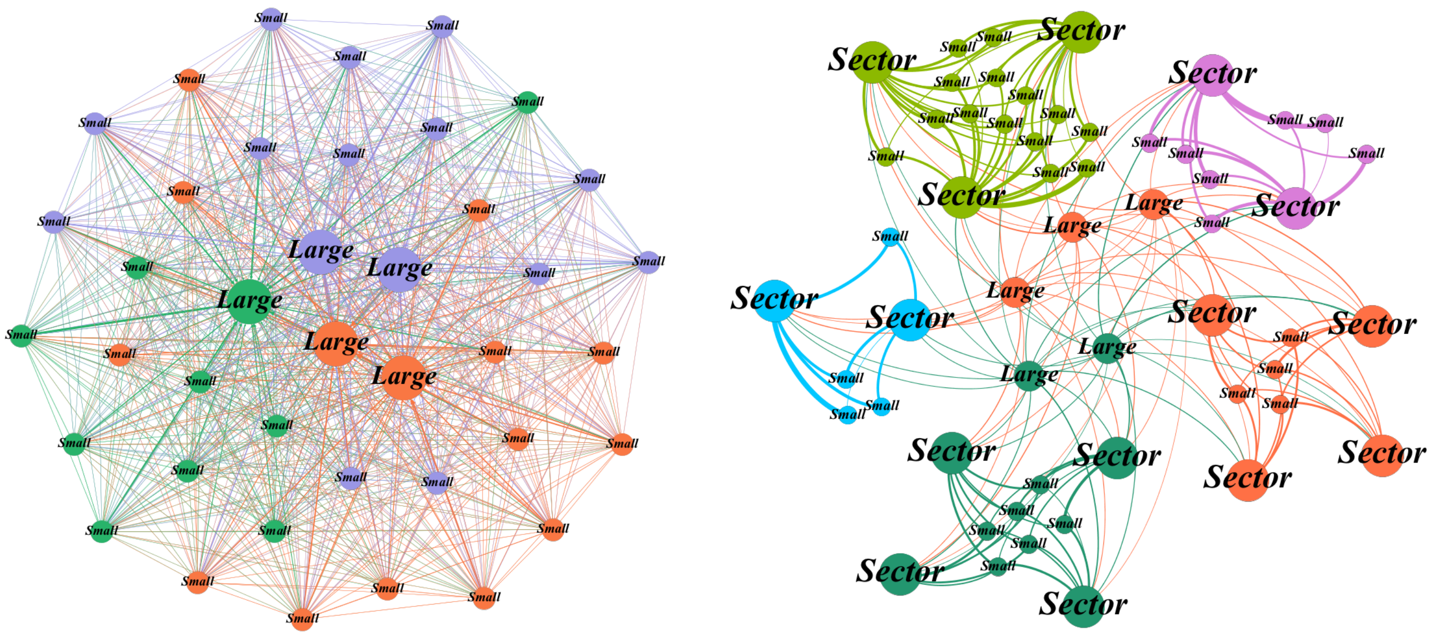
Channel 2: common debt exposures

- s_{ij}, the fraction of a bank i's debt exposure to a sector j.

$$A_i^I = \sum_{j=1}^{M} s_{ij} I_j, \quad \forall i = 1 \ to \ N, \tag{3}$$

where I_j represents the value of a singe share invested in a sector j.

Visualization: Theoretical Networks



(a) (b)

Figure 2: (a) Interbank Holdings (b) Commmon Exposures

Dynamism of Balance Sheet

- Interbank debt holdings
  $A^B_{it} = \sum_{j=1}^N w_{ij} L^B_{jt}$
- Industrial debt holdings:
  $A^I_{it} = \sum_{j=1}^M s_{ij} I_{jt}$
- Cash & cash equivalents:
  $dC_{it} = C_{it} dY_{it}$ (with jumps)

- Common debt:
  $dL^B_{it} = -D^b_i L^B_{it} dr^l_t + \frac{1}{2} C^b_i L^B_{it} (dr^{l2}_t)^2$
- CoCo debt:
  $dL^C_{it} = -D^c_i L^C_{it} dr^l_t + \frac{1}{2} C^c_i L^C_{it} (dr^l_t)^2$

- Index value of industrial sectors
  - $dI_{jt} = \alpha(I_{j\mu} - I_{jt})dt + \sigma_j I_{jt} dW_{jt} + I_{jt} dJ_{jt}$ (with jumps)
- Interest rate: for bank with credit rating l,
  - $r^l_t = r_t + \alpha^l s_t$
  - $dr_t = \alpha_r(\bar{r} - r_t)dt + \sigma_r \sqrt{r_t} dW^r_t$ (Base Rate)
  - $ds_t = \alpha_s(\bar{s} - s_t)dt + \sigma_s \sqrt{s_t} dW^s_t$ (Credit Spread)

CoCo trigger design

1. **Single trigger:** only bank-level trigger
   - bank-level trigger: individual bank equity ratio

$$\frac{E_{it}}{TA_{it}} \leq \alpha_i \tag{4}$$

2. **Dual-trigger:** bank-level trigger + systemic trigger
   - bank-level trigger: individual bank equity ratio

$$\frac{E_{it}}{TA_{it}} \leq \alpha_i \tag{5}$$

   - systemic trigger: average of all individual bank equity ratios

$$\left\langle \frac{E_{it}}{TA_{it}} \right\rangle_t \leq \beta \tag{6}$$

   - systemic trigger MUST be activated for the conversion of CoCo debt

3. **Two-tranches CoCo:** in sensitivity analysis

Stress Test & Measure of Systemic Risk

- We designed two types of shocks
  1. industrial shocks

     exogenous shock that spreads from industrial to the banking system
  2. cash shocks

     endogenous shock that starts within the banking system

- Measure of Systemic Risk
  1. The # of Bank Failures
  2. $\Delta CoVaR$ [Adrian and Brunnermeier, 2016]
     - $CoVaR$

$$Pr(X_i \leq CoVaR_q^{Shock} | Shock) = q\%. \tag{7}$$

     - $\Delta CoVaR$

$$\Delta CoVaR_q = VaR_q - CoVaR_q^{Shock} \tag{8}$$

One-year Forward Daily Simulation

Algorithm 1 pseudo algorithm for dual-trigger simulation (one path)

1: Initialization
2: **for** $t = 0$ to $T - 1$ **do**
3: $\quad r^l_{i,t+1} \leftarrow r^l_t$, $L^B_{i,t+1} \leftarrow L^B_t$, $L^C_{i,t+1} \leftarrow L^C_t$, $\triangleright$ update interest rate and debt
4: $\quad C_{i,t+1} \leftarrow C_{i,t} + (shock)$, $\triangleright$ update cash, if shocks, choose random # of banks
5: $\quad I_{j,t+1} \leftarrow I_{j,t} + (shock)$, $\triangleright$ update sectors, if shocks, choose random # of sectors

One-year Forward Daily Simulation

Algorithm 2 pseudo algorithm for dual-trigger simulation (one path)

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2: **for** $t = 0$ to $T-1$ **do**
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6: $\quad A^B_{i,t+1} \leftarrow \sum_{j=1}^{N} w_{ij} L^B_{j,t+1}$, ▷ update interbank holdings
7: $\quad A^I_{i,t+1} \leftarrow \sum_{j=1}^{M} s_{ij} I_{j,t+1}$, ▷ update industrial holdings
8: $\quad x_{i,t+1} \leftarrow \frac{E_{i,t+1}}{TA_{i,t+1}}$, ▷ update the equity ratio

One-year Forward Daily Simulation

Algorithm 3 pseudo algorithm for dual-trigger simulation (one path)

Initialization

for $t = 0$ to $T - 1$ **do**

  $r^l_{i,t+1} \leftarrow r^l_t$, $L^B_{i,t+1} \leftarrow L^B_t$, $L^C_{i,t+1} \leftarrow L^C_t$, ▷ update interest rate and debt

  $C_{i,t+1} \leftarrow C_{i,t} + (shock)$, ▷ update cash, if shocks, choose random # of banks

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  $x_{i,t+1} \leftarrow \frac{E_{i,t+1}}{TA_{i,t+1}}$, ▷ update the equity ratio

  for all $x_{i,t+1} \leq \alpha_i$, $i = 1, 2, ..., N$ **do**

    if $\langle x_i \rangle \leq \beta$ **then**

      $E_{i,t+1} \leftarrow E_{i,t+1} + L^c_{i,t+1}$, ▷ CoCo debt conversion

      $L^c_{i,t+1} \leftarrow 0$, ▷ update CoCo debt

  if $E_{i,t+1} \leq 0$ **then**

    $E_{i,t+1} \leftarrow 0$, ▷ bank failures

One-year Forward Daily Simulation

Algorithm 4 pseudo algorithm for dual-trigger simulation (one path)

Initialization

for $t = 0$ to $T - 1$ **do**

  $r^l_{i,t+1} \leftarrow r^l_t$, $L^B_{i,t+1} \leftarrow L^B_t$, $L^C_{i,t+1} \leftarrow L^C_t$, ▷ update interest rate and debt

  $C_{i,t+1} \leftarrow C_{i,t} + (shock)$, ▷ update cash, if shocks, choose random # of banks

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  $A^I_{i,t+1} \leftarrow \sum_{j=1}^{M} s_{ij} I_{j,t+1}$, ▷ update industrial holdings

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      $L^c_{i,t+1} \leftarrow 0$, ▷ update CoCo debt

  if $E_{i,t+1} \leq 0$ **then**

    $E_{i,t+1} \leftarrow 0$, ▷ bank failures

return

$E_{i,T}$, $i = 1, 2, ..., N$

Theoretical Simulation Result I

Table 2: One Industrial Shock

A: Systemic Risk Measures	Banking System			Large Banks			Medium Banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CoCo design	None	Single	Dual	None	Single	Dual	None	Single	Dual
Mean of bank failures	1.8817	0.1752	0.9160	0.0001	0	0	1.8816	0.1752	0.9160
Equity $\Delta CoVaR_{0.05}$	0.1629	0.0830	0.0735	0.1218	0.1035	0.1052	0.1948	0.0717	0.0619

B: Significance Test	Banking System			Large Banks			Medium Banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Difference	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single
Mean of bank failures	-1.7064***	-0.9657***	0.7408***	-0.0001	-0.0001	0.0000	-1.7063***	-0.9656***	0.7408***
	(-46.52)	(-24.38)	(36.98)	(-1.00)	(-1.00)	(.)	(-46.53)	(-24.38)	(36.98)
Equity $\Delta CoVaR_{0.05}$	-0.0799***	-0.0894***	-0.0095*	-0.0183**	-0.0166**	0.0017	-0.1232***	-0.1329***	0.-0097*
	(11.10)	(12.61)	(1.88)	(2.75)	(2.54)	(-0.27)	(13.48)	(15.54)	(1.70)

Note: Bootstrap t-statistics are reported in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Theoretical Simulation Result II

Table 3: Two Industrial Shocks

A: Systemic Risk Measures	Banking System			Large Banks			Medium Banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CoCo design	None	Single	Dual	None	Single	Dual	None	Single	Dual
Mean of bank failures	4.6103	0.6965	1.7784	0	0	0	4.6103	0.6965	1.7784
Equity $\Delta CoVaR_{0.05}$	0.3138	0.1942	0.1586	0.2574	0.2017	0.1996	0.3660	0.1915	0.1282

B: Significance Test	Banking System			Large Banks			Medium Banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Difference	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single
Mean of bank failures	-3.9138***	-2.8319***	1.0819***	0.0000	0.0000	0.0000	-3.9138***	-2.8319***	1.0819***
	(-68.90)	(-48.05)	(34.22)	(.)	(.)	(.)	(-68.90)	(-48.05)	(34.22)
Equity $\Delta CoVaR_{0.05}$	-0.1195***	-0.1552***	-0.0356***	-0.0557***	-0.0578***	-0.0021	-0.1744***	-0.2378***	-0.0633***
	(16.46)	(21.72)	(6.28)	(9.09)	(9.77)	(0.39)	(19.90)	(27.37)	(9.46)

Note: Bootstrap t-statistics are reported in parentheses

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Theoretical Simulation Result III

Table 4: Industrial & Cash Shocks

A: Systemic Risk Measures	Banking System			Large Banks			Medium Banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CoCo design	None	Single	Dual	None	Single	Dual	None	Single	Dual
Mean of bank failures	2.0508	0.1910	0.8026	0.1840	0.0008	0.0111	1.8668	0.1902	0.7915
Equity $\Delta CoVaR_{0.05}$	0.3447	0.1682	0.1817	0.5645	0.2984	0.4154	0.2008	0.0726	0.0503

B: Significance Test	Banking System			Large Banks			Medium Banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Difference	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single
Mean of failures	-1.8598***	-1.2482***	0.6116***	-0.1832***	-0.1729***	0.0103***	-1.6766***	-1.0752***	0.6014***
	(-46.21)	(-29.42)	(31.44)	(-25.88)	(-24.04)	(7.63)	(-45.87)	(-27.64)	(31.12)
Equity $\Delta CoVaR_{0.05}$	-0.1765***	-0.1630***	0.0135***	-0.2661***	-0.1490***	0.1171***	-0.1282***	-0.1505***	-0.0223***
	(21.87)	(20.42)	(-2.52)	(34.32)	(18.29)	(-16.61)	(13.94)	(17.79)	(3.98)

Note: Bootstrap t-statistics are reported in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Sensitivity Analysis: Two Tranches CoCo

1. single & systemic triggers $\Longrightarrow$ all converts
2. only single trigger $\Longrightarrow$ first tranche converts
   - second tranche converts only when two triggers both activated
3. first tranche, 100% $\Longrightarrow$ single trigger; 0 $\Longrightarrow$ dual trigger

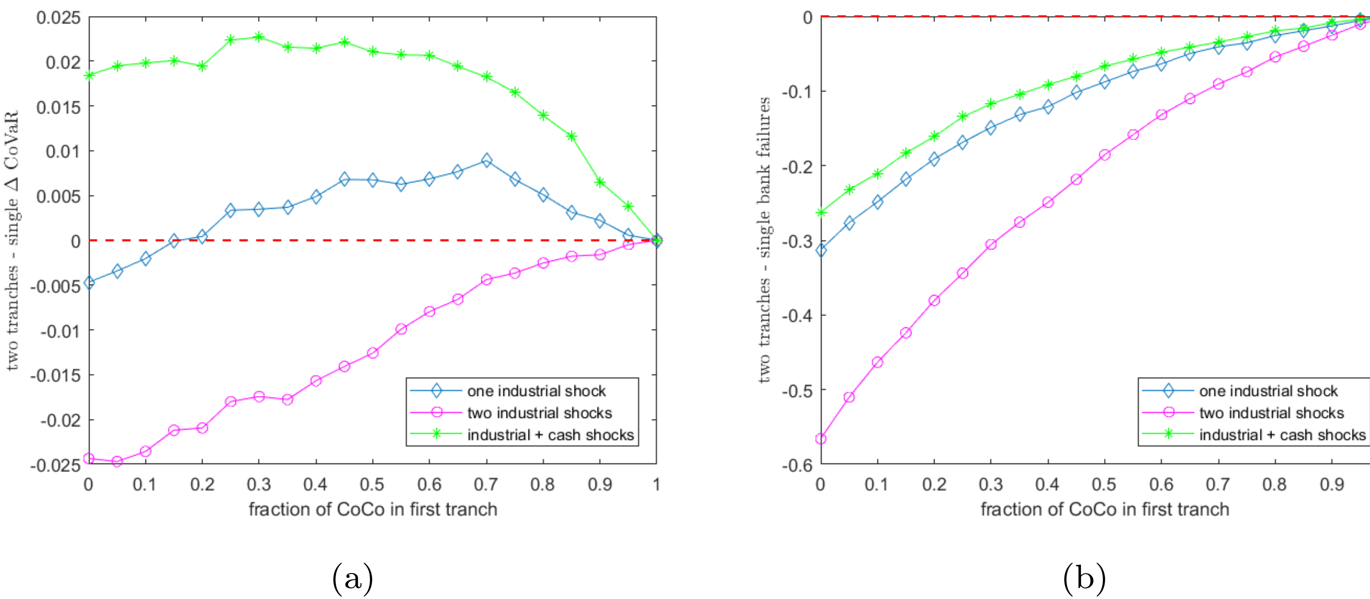
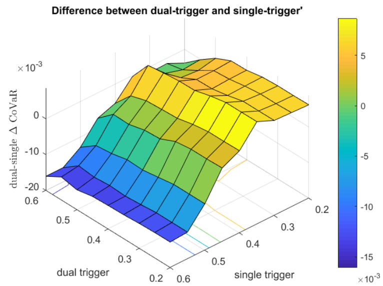
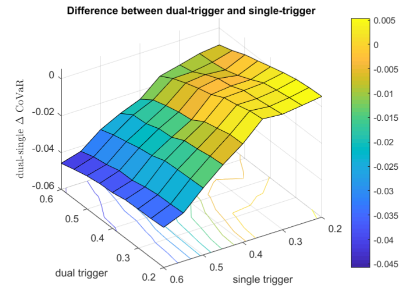


Figure 3: (a) Δ CoVaR (b) Δ Bank Failures

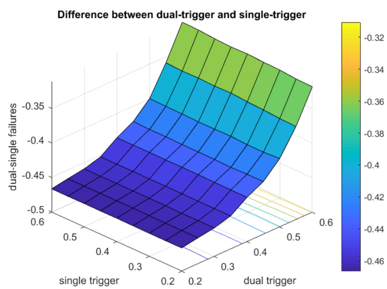
Sensitivity Analysis: Trigger Level



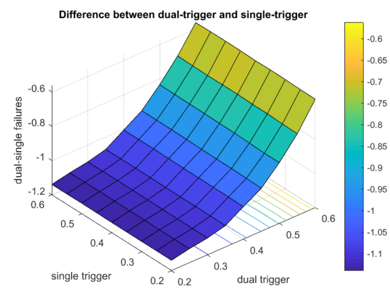
(a)



(b)



(c)



(d)

Figure 4: (a) Δ CoVaR (1 shock) (b) Δ CoVaR (2 shocks) (c) bank falures (1 shock) (d) bank falures (2 shocks)

Data

- *13-F Filings* from SEC EDGAR System
- *Call reports* from Federal Financial Institutions Examination Council
- Interest rates, OAS, credit ratings, etc, from a Bloomberg terminal

Table 5: 36 Major US BHCs

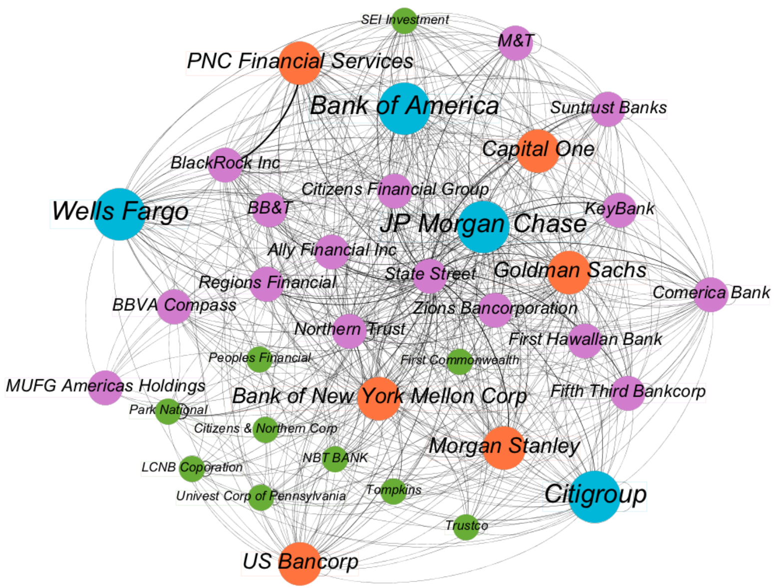
BHC Size ⋆	Total Assets	Number
Super Large BHCs	Greater than $1000 Billion	4
Large BHCs	Greater than $250 Billion & Less than $1000 Billion	6
Medium BHCs	Greater than $10 Billion & Less than $250 Billion	16
Small BHCs	Less than $10 Billion	10

⋆ Size definition is from [MBCA, 2013]

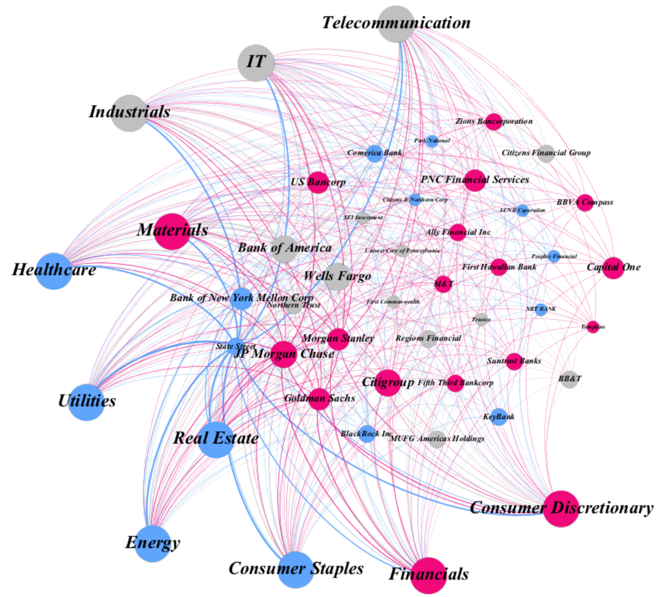
Table 6: Real-world Network Property

Network	Avg. Degree	Diameter	Path Len.	**Betweenness**	Cluster Coef.	Components
36 US BHCs	17.47	4	1.54	16.39	0.71	1 weak ; 6 strong
10 Large & Super	9.6	2	1.03	0.30	0.97	1 weak ; 1 strong

Visualization: Real-world Networks



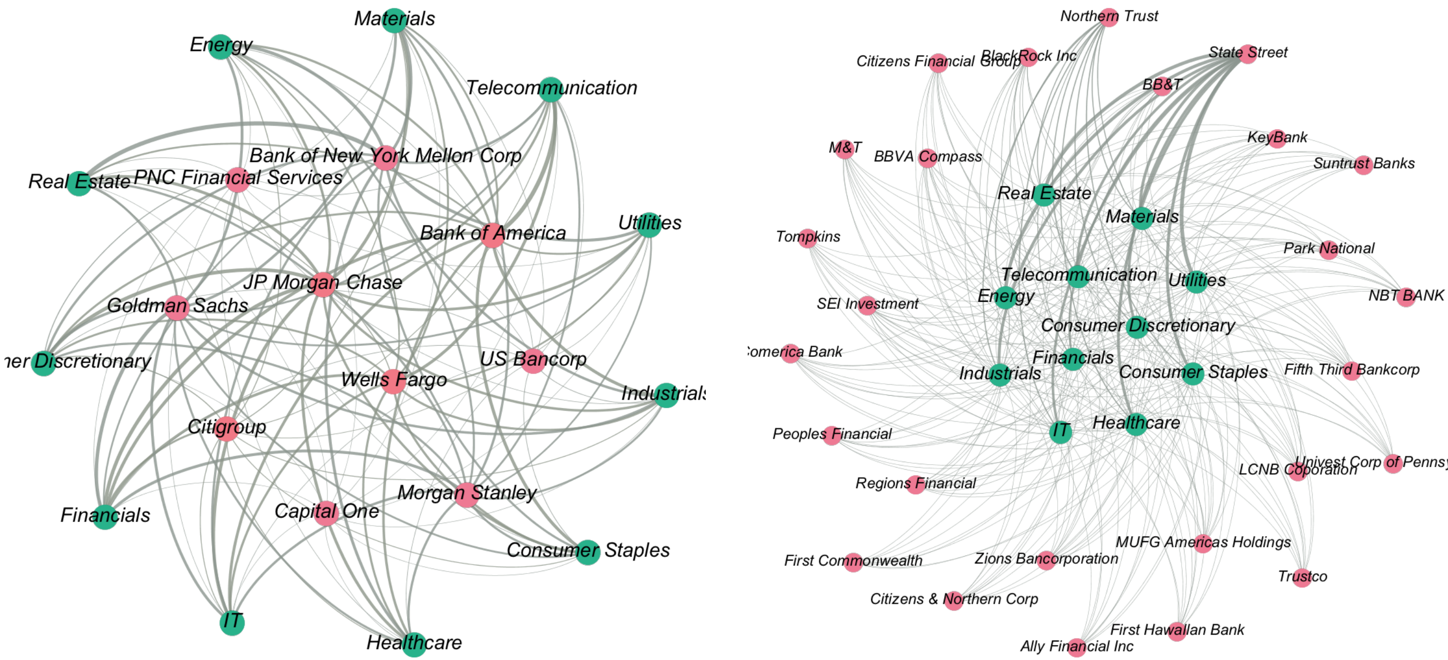
(a)



(b)

Figure 5: (a) Interbank Holdings (b) Commmon Exposures

Visualization: Common Exposures



(a) (b)

Figure 6: (a) Large & Super Large (b) Medium & Small

Empirical Simulation Result I

Table 7: Two Industrial Shocks

A: Systemic Risk Measures	Banking System			Large & Super Large BHCs			Medium & Small BHCs		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CoCo design	None	Single	Dual	None	Single	Dual	None	Single	Dual
Mean of bank failures	3.3417	2.1583	3.1469	1.7489	1.0608	1.5921	1.5928	1.0975	1.5548
Equity $\Delta CoVaR_{0.05}$	0.1162	0.0950	0.0842	0.1510	0.1202	0.1053	0.0447	0.0443	0.0437

B: Significance Test	Banking System			Large & Super Large BHCs			Medium & Small BHCs		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Difference	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single
Mean of bank failures	-1.1834***	-0.1948**	0.9886***	-0.6881***	-0.1568*	0.5313***	-0.4953***	-0.0380	0.4573***
	(-9.2413)	(-1.7020)	(7.6684)	(-9.7149)	(-1.8935)	(8.4882)	(-7.4704)	(-1.3339)	(6.5160)
Equity $\Delta CoVaR_{0.05}$	-0.0213***	-0.0320***	-0.0108*	-0.0312***	-0.0461***	-0.0149**	-0.0007	-0.0011	-0.0005
	(3.5251)	(4.9057)	(1.7147)	(3.9337)	(6.1343)	(2.0871)	(0.2660)	(0.3623)	(0.2054)

Note: Bootstrap t-statistics are reported in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Empirical Simulation Result II

Table 8: Industrial & Cash Shocks

A: Systemic Risk Measures	Banking System			Large & Super Large BHCs			Medium & Small BHCs		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CoCo design	None	Single	Dual	None	Single	Dual	None	Single	Dual
Mean of bank failures	3.3751	2.1636	3.1621	1.7590	1.0636	1.5961	1.6161	1.1000	1.5660
Equity $\Delta CoVaR_{0.05}$	0.1322	0.1074	0.0950	0.1722	0.1374	0.1193	0.0466	0.0466	0.0459

B: Significance Test	Banking System			Large & Super Large BHCs			Medium & Small BHCs		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Difference	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single	Single-None	Dual-None	Dual-Single
Mean of bank failures	-1.2115***	-0.2130**	0.9985***	-0.6954***	-0.1629**	0.5325***	-0.5161***	-0.0501*	0.4660***
	(-7.8084)	(-2.6679)	(6.2456)	(-9.6613)	(-2.4686)	(8.4566)	(-8.7689)	(-1.8033)	(6.4194)
Equity $\Delta CoVaR_{0.05}$	-0.0250***	-0.0373***	-0.0125**	-0.0351***	-0.0531***	-0.0183***	-0.0003	-0.0009	-0.0006
	(4.4387)	(6.2811)	(2.1167)	(4.9412)	(6.3115)	(2.7287)	(0.1047)	(0.2998)	(0.2422)

Note: Bootstrap t-statistics are reported in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Summary

- CoCo debt controls the spread of systemic risk of the banking system.
- A trade-off in CoCo debt trigger designs,
  - Single trigger better protects individual stressed banks.
  - Dual trigger outperforms when targeting the banking system.
  - These is no universally correct answer to this choice.
- The results are robust to simulation parameters.
- Calibrated real-world banking network gives consistent results.

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