

Market Structure, Counterparty Risk, and Systemic Risk

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Counterparty Risk

- *Counterparty*: other side of ongoing financial agreement.
 - A bank enters into a swap with you on the S&P 500.
- Counterparty Risk
 - Risk resulting from default/bankruptcy of a counterparty.
 - Strictly: Risk to you from one of your counterparties.
 - Broadly: Includes effects on overall market (our concern).
- This broad definition we refer to as *systemic risk*.

Counterparty Risk to Systemic Risk

- Counterparty risk affects market when large failure looms:
 - Near-bankruptcy of Bear Stearns (May 2008)
 - Bankruptcy of Lehman Brothers (Sep 2008)
 - Bankruptcy of Refco Inc? (Oct 2005, owned #1 CME broker)
- Outstanding notional at CME before ceasing trading:

Bear	Lehman	Refco LLC
\$761 BB	\$1,150 BB	\$130 BB

- N.B. No defaults or trade halts at CME for these events.
- Other bankruptcies: Askin (1994), LTCM (1998, why I care).
- Is counterparty risk an “accelerant” in financial crises?

Systemic Risk

- Distress increases volatility sharply and significantly.
 - Widens spreads: transactions costs \uparrow ; market liquidity \downarrow .
 - Volatility is pushed onto the survivors (externality).
- Crisis bankruptcies have real costs:
 - Virtuous, vicious circles of market and funding liquidity².
 - Reduced funding liquidity affects non-financial firms also.
 - Less invested in risky assets; allocative inefficiency?
 - Higher unemployment: harder job searches, lower tax revenue.
 - Bernanke (1983): affects credit markets; possible depression.

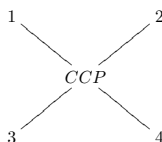
²Brunnemeier and Pedersen (2009).

Results Preview

- Market structure affects contagion and exposure to defaults.
- Specifically: complete networks magnify systemic risk.
 - Disagrees with Allen and Gale (2000), Nier et al (2007).
 - Difference due to differing creation of complete networks.
 - Also: financial, banking networks differ (cf Acemoglu).
- Market fragility estimable with a few metrics of market core.
- Can price distress volatility of differing structures.

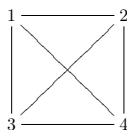
Model: Market Structures

- Investigate two extremes of n -counterparty networks.



Star network

(Market with CCP³)



Complete network

(Bilateral "OTC" market)

- Each node is a counterparty (capital K , risk aversion λ).
- Each edge is a contract⁴ linking counterparties i and j
- Contract exposure: $q_{ij} = -q_{ji}$; $q_{i<j} \stackrel{iid}{\sim} N(0, \eta^2)$
- Counterparty i 's net exposure: $Q_i = \sum_{j \neq i} q_{ij}$.
- Same net exposures (Q_i 's) in both networks.

³Central counterparty.

⁴A swap or forward on a risky asset.

Model: Event Timing

To study counterparty risk, events occur at discrete times.

$t = 0$: Bankruptcy of counterparty n occurs.

- All contracts with counterparty n are invalidated.
- Pushes unwanted exposure onto other $n - 1$ counterparties.

$t = 1$: Living counterparties trade in response to bankruptcy.

$t = 2$: Living counterparties close out bankruptcy-induced exposure.

Order of trading in a period is random, not strategic.

Model: Price Impact of Trading

- Each counterparty i trades x_i shares at time $t = 1$.
- Huberman and Stanzl (2004) arbitrage-free price impact.
 - Impact has linear permanent component⁵.
 - Permanent component impacts prices for later traders.
- Trade ordering, price impact create low and high prices.
- Time periods are very short; two simplifying assumptions:
 - ① Prices have no drift other than price impact due to trading.
 - ② Price diffusion is Gaussian (not log-normal).
- Defer handling crisis-related adverse selection.

⁵Price impact could arise from inventory risk cost, non-crisis adverse selection.

Effects of Invalidated Contracts

- Suppose counterparty A is net long the market.
- \Rightarrow Other counterparties are net short the market.
- These are their preferred equilibrium positions.
- Thus when counterparty A defaults:
 - Survivors must re-create exposure from counterparty A.
 - Survivors become net sellers.
- CCP market: only CCP trades; net sell.
- OTC market: some counterparties will sell, some will buy.
- However, counterparties trade in own interest.
 - Do they re hedge immediately? Push market further?

Large Bankruptcy

- Consider bankruptcy of a large financial firm.
- Assume large market move r_0 at $t = 0$ induces bankruptcy.
- Net exposure Q_n probably large; estimate via EVT⁶.

$$\hat{Q}_n = \frac{-K}{r_0} + \frac{\eta\sqrt{n-1}}{c_n(1 - e^{-e^{-c_n\kappa_1-d_n}})} \sum_{k=1}^{\infty} \frac{(-1)^{k+1} e^{-k(c_n\kappa_1+d_n)}}{kk!} \quad (1)$$

where $\kappa_1 = \frac{-K}{r_0\eta\sqrt{n-1}}$ (minimum exposure causing death),

$$c_n = \frac{1}{\sqrt{2\log(n)}}, \text{ and } d_n = \sqrt{2\log(n)} - \frac{\log\log(n) + \log(16\tan^{-1}(1))}{2\sqrt{2\log(n)}}.$$

⁶Equivalent: endow all counterparties with perfect information, examine most likely $Q_n|r_0$.

Large Bankruptcies

- For large Q_n , trading at $t = 1, 2$ will move market a lot.
- Move will be further in direction that caused bankruptcy.
- This raises two distressing possibilities:
 - Contagion: move may cause other counterparties to fail; or,
 - Checkmate: hedging may bankrupt the hedger.
- Counterparties anticipate these, respond selfishly.
- For bilateral OTC market, all counterparties may trade.
 - All hedge anticipated follow-on bankruptcy exposure \hat{Q}_f .
 - Trouble: $\nu > 1$ (overtrading at $t = 1$) to be expected.
 - Longs, shorts may largely self-segregate re hedge timing.
- Thus network structure matters.

Large Bankruptcy: Equilibrium CCP Trade

- CCP anticipates follow-on bankruptcies; equilibrium yields
- Follow-on bankruptcy exposure \hat{Q}_f (**distress exposure**):

$$\hat{Q}_f = (n-1)^{3/2} \eta \frac{\phi(\kappa_2) - \phi(\kappa_1)}{\Phi(\kappa_1)} \quad \text{where} \quad (2)$$

$$\kappa_2 = \frac{-Kp_0 / [\eta \sqrt{n-1}]}{p_0 r_0 - \pi(\hat{Q}_n + \hat{Q}_f)} = \text{min exposure for follow-on death.}$$

- # follow-on bankruptcies \hat{b} (**distress pervasiveness**):

$$\hat{b} = (n-1) \frac{\int_{\kappa_2}^{\kappa_1} \phi(z) dz}{\int_{-\infty}^{\kappa_1} \phi(z) dz} = (n-1) \left(1 - \frac{\Phi(\kappa_2)}{\Phi(\kappa_1)} \right) \quad (3)$$

Large Bankruptcy: Equilibrium OTC Net Trade

- OTC traders anticipate one another, follow-on bankruptcies.
- However: those most at-risk re hedge quickly, others delay.
- Random trade sequence \Rightarrow uncertain low of rehedging \underline{S}_{n-1} .
- Use these to solve for equilibrium OTC net trade.

$$\kappa_2 = \frac{-Kp_0}{\eta\sqrt{n-1}(p_0r_0 + \pi E(\underline{S}_{n-1}|\nu))}, \quad (4)$$

$$\hat{Q}_f = (n-1)^{3/2}\eta \frac{\phi(\kappa_2) - \phi(\kappa_1)}{\Phi(\kappa_1)}. \quad (5)$$

- Important to note that $\nu \geq 1$ (in $E(\underline{S}_{n-1})$).
- Finding ν is hard: n -player (random) game; usually c1.75.

Bad Behavior? Checkmate and Hunting

Proposition (Checkmate)

A large enough initial bankruptcy may yield a follow-on bankruptcy in expectation — despite any finite effort by the troubled counterparty.

Proposition (Hunting)

For a complete network of 3 or more counterparties and a large enough initial bankruptcy, two or more other counterparties may profit by driving a survivor into (follow-on) bankruptcy.

The Other Extreme: A Separating Equilibrium?

- Another (extreme) possibility exists in bilateral OTC markets:
 - Buyers and sellers may separate when they trade.
- Those who are same side as net rehedger rush to hedge first.
- Those on other side wait to allow maximum distress.
- If net rehedger makes sellers panic, net sale in period 1 is:

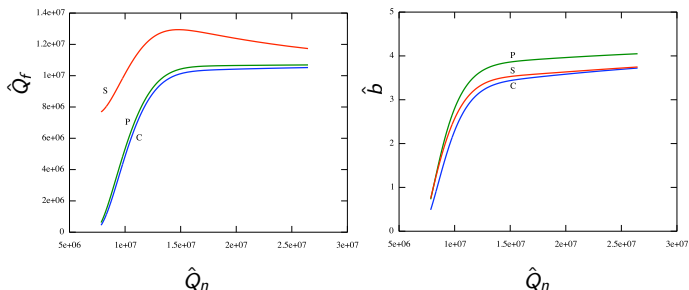
$$- E\left(\sum_{i=1}^{n-1} [x_i]^- \mid \sum_{i=1}^{n-1} x_i = -\hat{Q}_n - \hat{Q}_f\right) \quad (6)$$

$$\approx -(n-1)^{3/2} \eta \phi(\mu^*) - (\hat{Q}_n + \hat{Q}_f)(1 - \Phi(\mu^*)) \quad (7)$$

where $\mu^* = \frac{\hat{Q}_n + \hat{Q}_f}{(n-1)^{3/2} \eta}$ (net rehedger in std devs/survivor)
and ϕ, Φ are standard normal pdf, cdf.

Large Bankruptcies: Indicative Distress

- Consider large bankruptcy for $n = 10$ counterparties⁷.
- Std deviation of bilateral contract exposure $\eta = 1,000,000$.
- Distress exposure \hat{Q}_f and pervasiveness \hat{b} vs. \hat{Q}_n .



Lines: (P)ooled OTC; (S)eparated OTC; (C)CP

P – S: Envelopes of distress exposure, pervasiveness

⁷Price impact parameters are as in Almgren and Chriss (2001).

Large Bankruptcies: Example of Market Impact

- Suppose $\hat{Q}_n = 10,000,000$; GARCH variance decay of 0.9.
- For CCP market:
 - Expected market impact: $-\$30$.
 - Effective annual volatility goes from 30% to 38%.
- If pooled OTC buyers, sellers overtrade $1.75\times$ at $t = 1$.
 - Expected market impact: $-\$31$.
 - Annual volatility \uparrow to 328% (instant.), 146% (effective).
- If OTC buyers and sellers separate, at $t = 1$:
 - Expected market impact: $-\$41$.
 - Annual volatility \uparrow to 596% (instant.), 268% (effective).

Large Bankruptcies: Example of Real Effects

- Suppose $\hat{Q}_n = 10$ MM, market size of \$40 MM⁸.
- If 8% equity premium and mean risk aversion of $\hat{\lambda} = 3$:
 - Equilibrium allocation to risky asset: 29% (71% cash).
 - Post-crisis: 19% (CCP), 1.2% (OTC pool), 0.4% (OTC sep).
- Cost of distress externality:
 - \$3.2MM (CCP), \$123 MM (OTC pool), \$425 MM (OTC sep).
 - Cost of OTC market distress is 3–11× market size.
- Given 2–3 bankruptcies; mean employees, compensation:
 - 260,000–400,000 unemployed; \$33–\$49 billion pay loss.
 - At 40% total taxes: revenue loss of \$13–\$20 billion.
- Also affects credit markets, overall macroeconomy.

⁸Approximately $2(\hat{Q}_n + \hat{Q}_f)$.

Large Bankruptcies: Not So Random

- Complete networks admit two destabilizing events:
 - Checkmate: weak counterparty may have no beneficial trade.
 - Hunting: counterparties force others into bankruptcy.
- Worse, hunting is a full equilibrium behavior.
 - Market may be pushed far beyond one follow-on bankruptcy.
- Are counterparties selfishly amoral/evil? Maybe not.
 - Trade amount may pre-hedge expected follow-on bankruptcies.
 - This reduces surprise need for trading in period 2.
- CCP markets have fewer such destabilizing events.
 - Suggests central clearing reduces OTC market volatility.

Difference from Allen and Gale (2000)

- Allen and Gale (2000): complete networks are more robust.
- I disagree: complete networks are more fragile.
- Why? Differing methods of network construction.
- Allen and Gale approach: top-down.
 - Net exposure: $Q_i \stackrel{iid}{\sim} N(0, (n-1)\eta^2)$
 - Contract exposure: $q_{ij} = Q_i / (n-1)$. (all same sign)
- My approach: bottom-up.
 - Contract exposure: $q_{i < j} \stackrel{iid}{\sim} N(0, \eta^2)$; $q_{ij} = -q_{ji}$;
 - Net exposure: $Q_i = \sum_{j \neq i} q_{ij}$; $Q_i \stackrel{iid}{\sim} N(0, (n-1)\eta^2)$.
- Same net exposures Q_i 's, different contract exposures q_{ij} 's.
- Strategic separation of buyers, sellers unlikely in A&G.

Conclusion

- Even small bankruptcies temporarily increase volatility.
- For a large bankruptcy in a bilateral OTC market:
 - Counterparties may be unable to save themselves (checkmate).
 - Counterparties may hunt their weakest peers for profit.
 - Volatility externality (and thus cost) higher than CCP market.
- Self-segregating buyers, sellers in OTC markets can be nasty:
 - Externality distress cost \gg market size. (market failure?)
- Suggests benefits to centralized clearing in OTC markets⁹.
- Volatility externality cost \Rightarrow when to move markets to CCP.
- May be able to measure when markets are more/less brittle.
 - n, η, \bar{K} for part of market like complete network.

⁹Biais, Heider, Hoerova (2011) suggests CCP is capital efficient.