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 refere 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?

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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 liquidity[2].
  - 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.

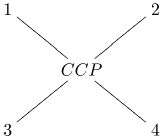
[2] Brunnemeier and Pedersen (2009).

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.

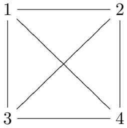
Model: Market Structures

- Investigate two extremes of *n*-counterparty networks.



Star network

(Market with CCP[3])



Complete network

(Bilateral "OTC" market)

- Each node is a counterparty (capital K, risk aversion λ).
- Each edge is a contract[4] linking counterparties i and j
- Contract exposure: $q_{ij} = -q_{ji}$; $q_{i<j} \overset{iid}{\sim} N(0, \eta^2)$
- Counterparty i's net exposure: $Q_i = \sum_{j \neq i} q_{ij}$.
- Same net exposures (Q_i's) in both networks.

[3]Central counterparty.

[4]A swap or forward on a risky asset.

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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.

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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 component[5].
  - 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.

[5] Price 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 rehedge 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 EVT[6].

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

where $\kappa_1 = \frac{-K}{r_0\eta\sqrt{n-1}}$ (minimum exposure causing death),
$c_n = \frac{1}{\sqrt{2\log(n)}}$, and $d_n = \sqrt{2\log(n)} - \frac{\log\log(n) + \log(16\tan^{-1}(1))}{2\sqrt{2\log(n)}}$.

[6] Equivalent: 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 rehedge timing.
- Thus network structure matters.

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Large Bankruptcy: Equilibrium CCP Trade

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

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

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

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

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

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Large Bankruptcy: Equilibrium OTC Net Trade

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

$$\kappa_2 = \frac{-Kp_0}{\eta\sqrt{n-1}(p_0 r_0 + \pi E(\underline{S_{n-1}}|\nu))}, \quad (4)$$

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

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

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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 rehedge rush to hedge first.
- Those on other side wait to allow maximum distress.
- If net rehedge makes sellers panic, net sale in period 1 is:

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

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

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

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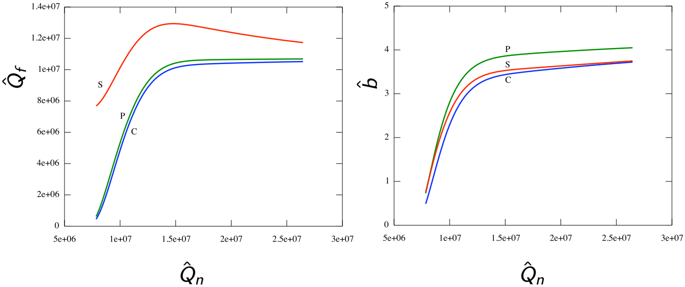
Large Bankruptcies: Indicative Distress

- Consider large bankruptcy for $n = 10$ counterparties[7].
- 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

[7]Price 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 MM[8].
- 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.

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

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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: $Q_i \overset{iid}{\sim} N(0, (n-1)\eta^2)$
  - Contract exposure: $q_{ij} = Q_i/(n-1)$. (all same sign)
- My approach: bottom-up.
  - Contract exposure: $q_{i<j} \overset{iid}{\sim} N(0, \eta^2)$; $q_{ij} = -q_{ji}$;
  - Net exposure: $Q_i = \sum_{j \neq i} q_{ij}$; $Q_i \overset{iid}{\sim} N(0, (n-1)\eta^2)$.
- Same net exposures Q_i's, different contract exposures q_{ij}'s.
- Strategic separation of buyers, sellers unlikely in A&G.

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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 markets[9].
- 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.

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

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