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: $761 BB
  - Lehman: $1,150 BB
  - Refco LLC: $130 BB

- N.B. No defaults or trade halts at CME for these events.


- Is counterparty risk an “accelerant” in financial crises?
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.

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Market structure affects contagion and exposure to defaults.

Specifically: complete networks magnify systemic risk.
  - 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.

\[
\begin{align*}
\text{Star network} & \quad \text{Complete network} \\
\text{(Market with CCP$^3$)} & \quad \text{(Bilateral “OTC” market)}
\end{align*}
\]

- Each node is a counterparty (capital $K$, risk aversion $\lambda$).
- Each edge is a contract$^4$ linking counterparties $i$ and $j$.
- Contract exposure: $q_{ij} = -q_{ji}$; $q_{i<j} \sim iid N(0, \eta^2)$
- 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.
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 $t = 1$.
  - 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.
Suppose counterparty A is net long the market.
⇒ 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?
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\(^6\).

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

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.
Large Bankruptcy: Equilibrium CCP Trade

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

\[
\hat{Q}_f = (n - 1)^{3/2} \eta \frac{\phi(\kappa_2) - \phi(\kappa_1)}{\Phi(\kappa_1)}
\]

where

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

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

\[
\hat{b} = (n - 1) \frac{\int_{\kappa_2}^{\kappa_1} \phi(z) dz}{\int_{-\infty}^{\kappa_1} \phi(z) dz} = (n - 1) \left( 1 - \frac{\Phi(\kappa_2)}{\Phi(\kappa_1)} \right)
\]
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 $S_{n−1}$.
- Use these to solve for equilibrium OTC net trade.

\[
\begin{align*}
\kappa_2 &= \frac{-Kp_0}{\eta\sqrt{n - 1}(p_0 r_0 + \pi E(S_{n-1}|\nu))}, \\
\hat{Q}_f &= (n - 1)^{3/2} \frac{\phi(\kappa_2) - \phi(\kappa_1)}{\Phi(\kappa_1)}.
\end{align*}
\]

- Important to note that $\nu \geq 1$ (in $E(S_{n-1})$).
- Finding $\nu$ 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.
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:

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

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

where $$\mu^* = \frac{\hat{Q}_n + \hat{Q}_f}{(n-1)^{3/2} \eta}$$ (net rehedge in std devs/survivor)

and $$\phi, \Phi$$ are standard normal pdf, cdf.
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 ↑ to 328% (instant.), 146% (effective).
- If OTC buyers and sellers separate, at $t = 1$:
  - Expected market impact: $-\$41$.
  - Annual volatility ↑ 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:
  - $3.2$ MM (CCP), $123$ MM (OTC pool), $425$ MM (OTC sep).
  - Cost of OTC market distress is $3–11 \times$ 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.

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$^8$Approximately $2(\hat{Q}_n + \hat{Q}_f)$. 
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.
- 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: \( q_{ij} \overset{iid}{\sim} N(0, \eta^2); q_{ij} = -q_{ji}; \)
  - 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.
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.
  - $n$, $\eta$, $\bar{K}$ for part of market like complete network.

\(^9\)Biais, Heider, Hoerova (2011) suggests CCP is capital efficient.
Further Commentary

Since we are under Chatham House Rules... further thoughts.  

- What about collateral, MTM, global netting?  
  - We used all of these at LTCM; it wasn’t enough.  
  - Say A, B swap; C does many swaps: all swaps now riskier.  

- Transition to CCP: slow? 6 mos. to flatten LTCM IRSwaps.  

- Fixed income structured products are nastier to analyze.  
  - Rosenthal: Crises accelerate defaults $\Rightarrow$ correlated.  

- Thus there is a need for full information and coordination.  

- Tax OTC trades? May be macroprudential.  
  - Tax on-exchange trades? No. (Rosenthal and Thomas)  

- Stable/unstable spirals: market liq affects funding liq?  
  - Market-based funding responds faster (TED=40 bp vs 80 bp).  

10 And some shameless plugs.  
11 Brunnermeier and Pedersen (2009)