Lecture 22: Bank Runs

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Financial Crisis

- Proximate cause of 2008-2009 recession was a cascading sequence of interlinked financial crises beginning the previous year with the subprime housing crisis and reaching a crescendo with the bankruptcy of Lehman Bros in 2008 and its aftermath.

- Have already discussed at some length the monetary policy response.

- In this class and next we will dig a bit deeper into the underlying issues.

Outline

1. Trends in banking before the financial crisis

Securitization and structured finance
Leverage — amplifying boom and bust
Liquidity mismatch

2. Bank runs

Diamond-Dybvig model: bank runs as coordination failure
The run on repo

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Securitization and Structured Finance

- Securitization
  - pool of underlying assets
    (mortgages, bank loans, corporate debt, etc)
  - pooling cash flows creates more homogeneous product

- Structured finance
  - adds capital structure, i.e., prioritization of claims to cash flows

Structured Finance

- Begin with diversified portfolio of underlying assets.

- Add *prioritized capital structure* of claims to cash flows (tranches)

$$\begin{array}{rcl} \text{senior tranche} & \leftrightarrow & \text{least risky} \\ \vdots & & \\ \text{mezzanine tranche} & & \\ \vdots & & \\ \text{junior tranche} & \leftrightarrow & \text{most risky} \end{array}$$

- Sell different tranches to investors with different attitudes to risk (e.g., pension funds vs. hedge funds)

CDO Example

- Two bonds. Each pays cash $\{0, 1\}$.
- Probability of cash $= 1$ is 0.9 *independent across bonds*.
- Sell junior j and senior s claims to cash flow

realization	$\{0,0\}$	$\{0,1\}$	$\{1,0\}$	$\{1,1\}$
probability	0.01	0.09	0.09	0.81
payment $\{j, s\}$	$\{0,0\}$	$\{0,1\}$	$\{0,1\}$	$\{1,1\}$

- Senior claim paid with prob 0.99, junior claim with prob 0.81.
- Senior claim can be more highly rated than underlying.

Layers of Securitization

- Do not have to stop at one round of securitization.
- Apply same logic to pools of junior tranches.

CDO-Squared Example

- Two *pools*, each of two bonds as in first example.
  Each bond pays $\{0,1\}$, independent across bonds, prob 0.9.

- Each pool has senior s and junior j claims as in first example

realization	$\{0,0\}$	$\{0,1\}$	$\{1,0\}$	$\{1,1\}$
probability	0.01	0.09	0.09	0.81
payment $\{j,s\}$	$\{0,0\}$	$\{0,1\}$	$\{0,1\}$	$\{1,1\}$

- Combine j tranches from each pool, sell j_j and s_j claims.

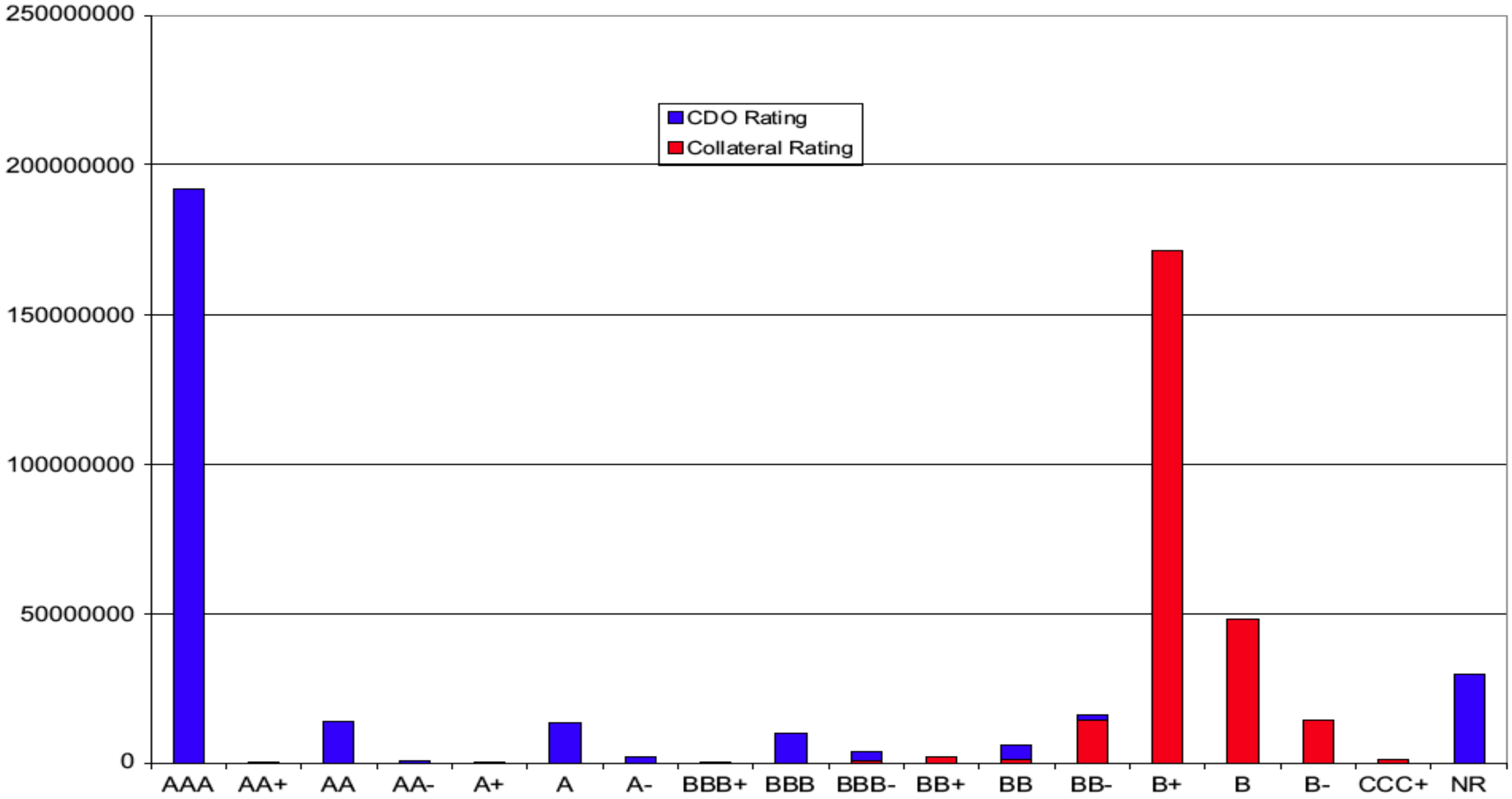
realization $\{j_1,j_2\}$	$\{0,0\}$	$\{0,1\}$	$\{1,0\}$	$\{1,1\}$
probability	0.0361	0.1539	0.1539	0.6561
payment $\{j_j,s_j\}$	$\{0,0\}$	$\{0,1\}$	$\{0,1\}$	$\{1,1\}$

Credit Ratings

- Many institutional investors only buy high-rated products.

- *Rating at the edge*, structure tranche to ensure particular ratings.

Alchemy of CDO Credit Ratings



CDO vs underlying collateral credit ratings. Compares the credit rating of CDO tranches with average credit rating of the underlying collateral pools backing them. Source: Benmelech and Dlugosz (2009).

Correlation

- Benefits of securitization diminished by *positive correlation* across cash flows of underlying assets.

- In fact, underlying pools of mortgages were highly similar in geographic location and in vintage, etc.

CDO Example With Correlation

- Two bonds. Each pays cash $\{0, 1\}$.

- Prob of cash $= 1$ is 0.9 but *perfectly correlated across bonds*.

realization	$\{0,0\}$	$\{1,1\}$
probability	0.10	0.90
payment $\{j, s\}$	$\{0,0\}$	$\{1,1\}$

- Cannot use prioritization to protect a senior claim.

- No credit enhancement.

Sensitive to Parameter Estimates

- Valuing structured products harder than for single-name securities.

- Need to take stand on *joint distribution* of cash flows across pools of underlying assets.

- Valuations highly sensitive to parameter estimates.

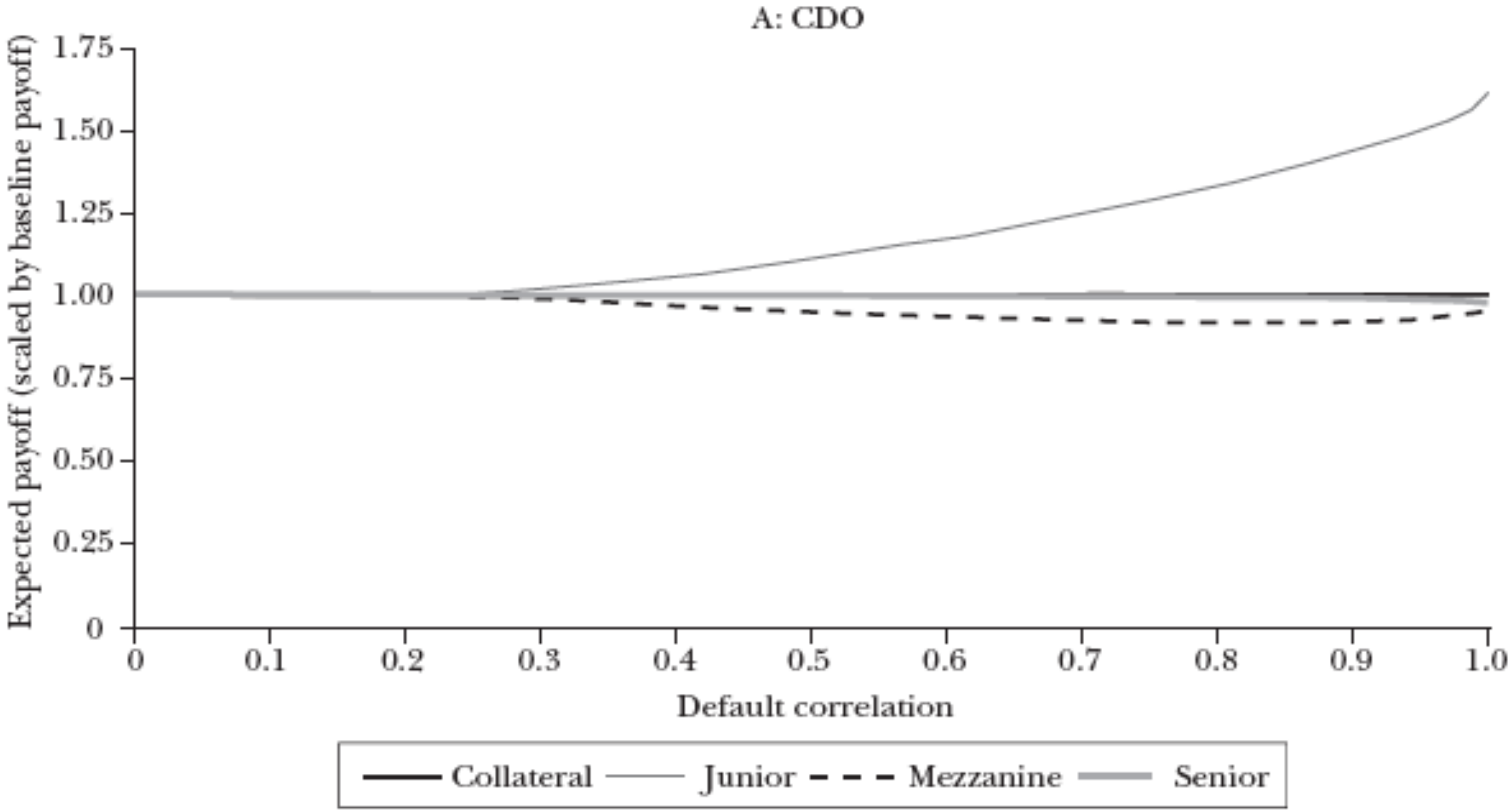
- Over-optimistic scenarios

  - data with modest and/or only regional house price falls

  - highly parametric statistical models used to fill-in for limited data

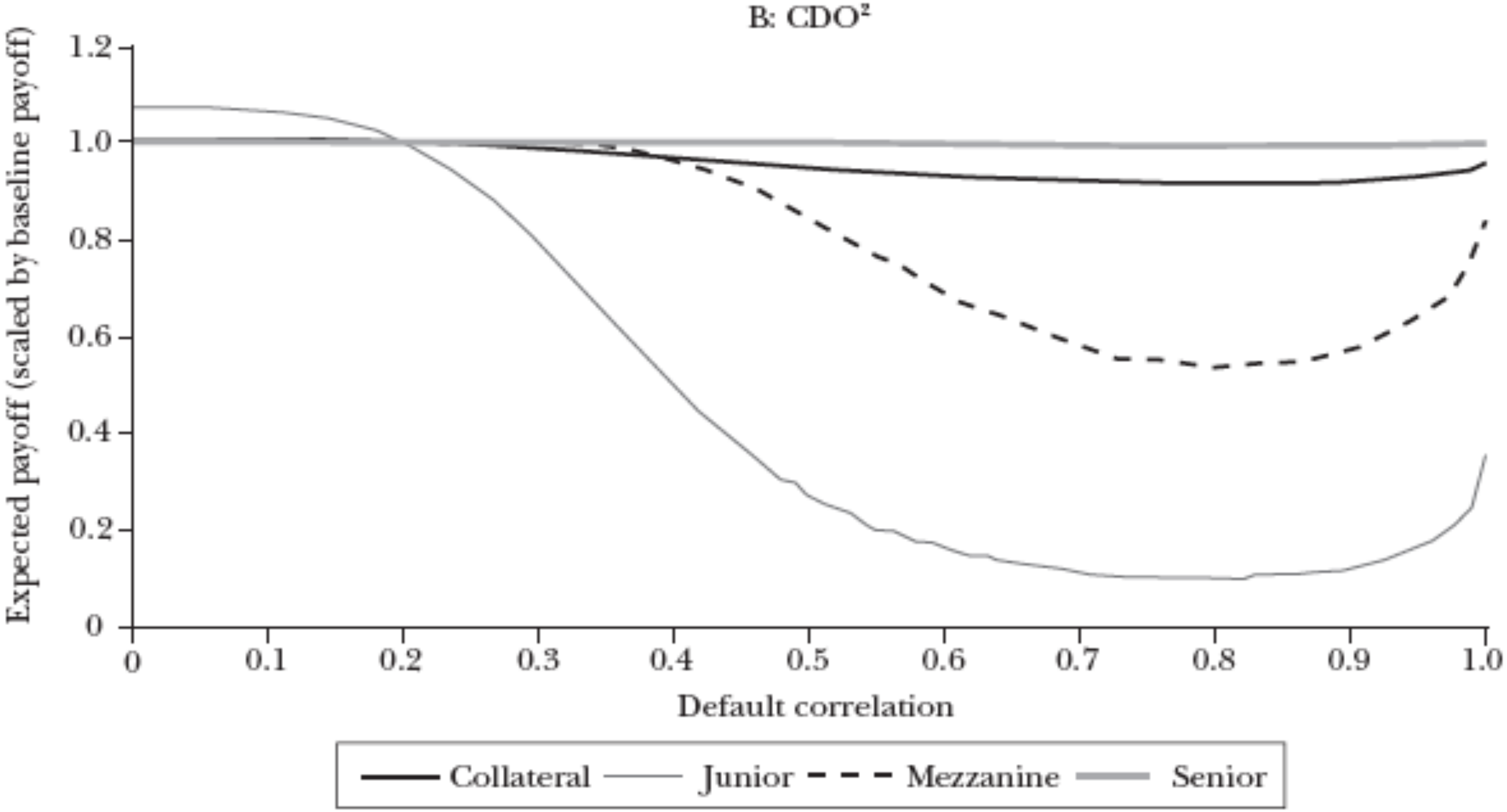
- Problems amplified for CDO-squared and by rating-at-the-edge.

Sensitivity of CDO to Default Correlation



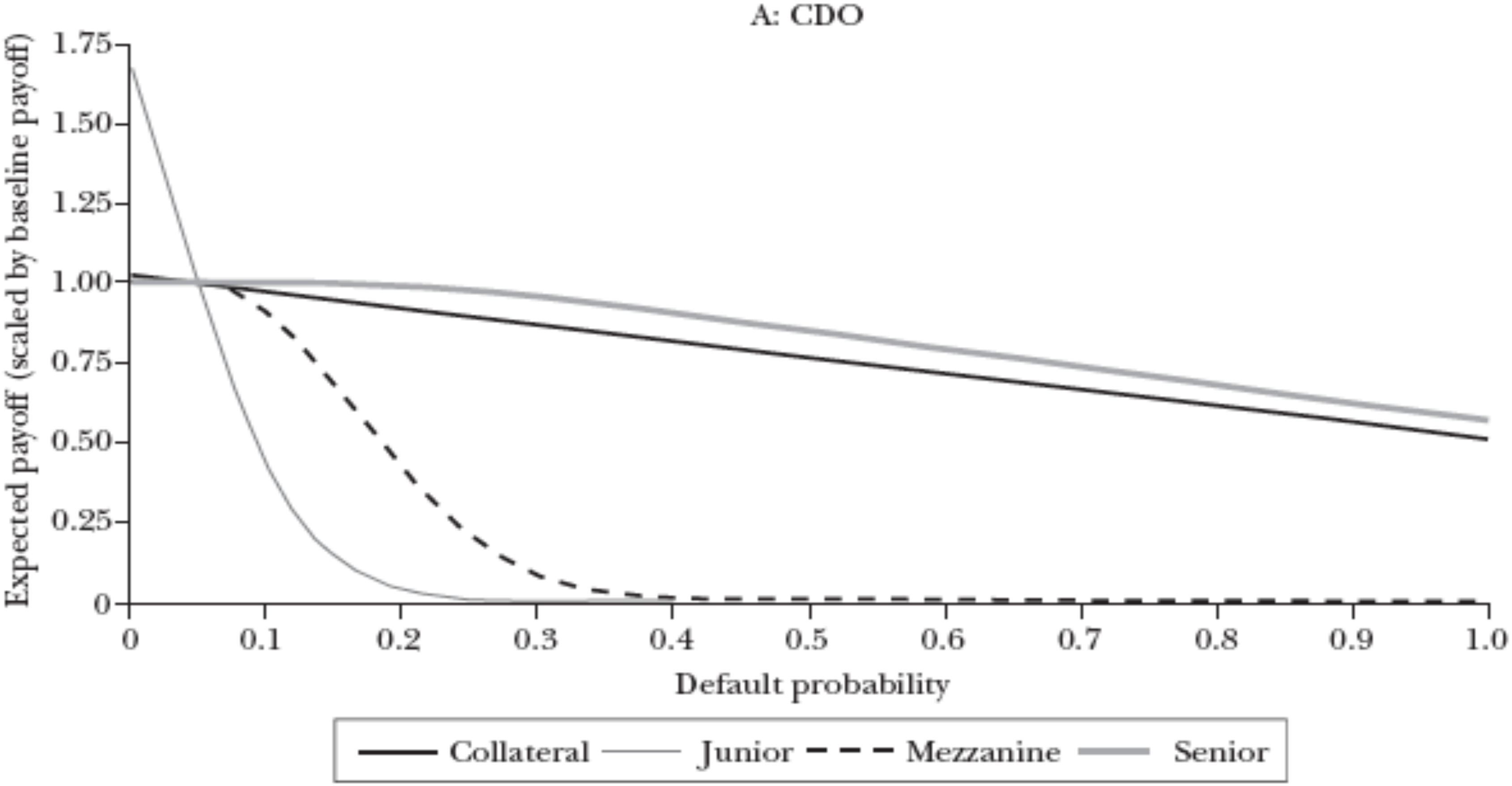
Normalized expected payoff as function of correlation *within* given pool. As correlation increases, risk shifts from junior to senior tranche. Non-monotonic effect on mezzanine tranche, rises for high correlation as risk shifted to senior tranche. Source: Coval, Jurek and Stafford (2009).

Sensitivity of CDO^2 to Default Correlation



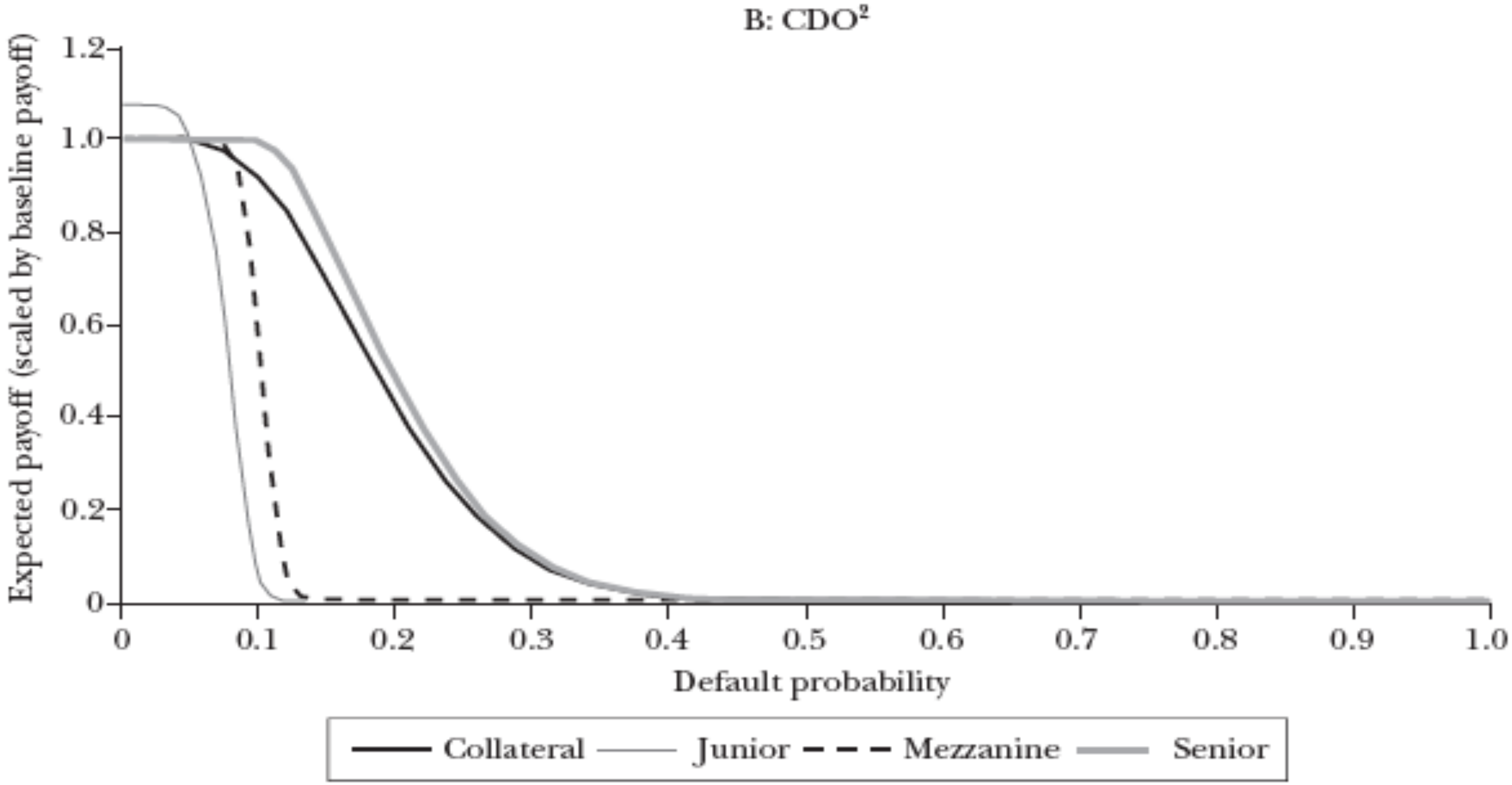
Amplification of sensitivity for CDO^2. In practice, subprime exposure was in this form. CMOs re-securitized from subordinated tranches of subprime mortgage- backed securities. Source: Coval, Jurek and Stafford (2009).

Sensitivity of CDO to Default Probability



Normalized expected payoff as function of default probability. Payoffs decline monotonically. Sensitivity highest for junior tranche. Source: Coval, Jurek and Stafford (2009).

Sensitivity of CDO^2 to Default Probability



Amplification of sensitivity for CDO^2. Regions of extremely high sensitivity to small errors in estimated default probabilities. Source: Coval, Jurek and Stafford (2009).

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   Liquidity mismatch

2. **Bank runs**
   Diamond-Dybvig model: bank runs as coordination failure
   The run on repo

Leverage

- A powerful amplifying mechanism

$$\text{leverage ratio} = \frac{\text{total assets}}{\text{equity}}$$

- **Mortgage Example:** Buy \$500k house with \$100k down, \$400k debt.

Assets	Liabilities
House 500	Debt 400
	Equity 100

Here the leverage ratio is $500/100 = 5$.

- With *mark-to-market* accounting, changes in asset values directly change balance sheets and hence change net worth (i.e., equity).

Leverage

- Leverage *magnifies risk and return* to equity.

- **Good year:** house price appreciates by \$50k

  - return on investment $= (550 - 500)/500 = 0.10$ or 10%

  - return on homeowner's equity $= (150 - 100)/100 = 0.50$ or 50%

- **Bad year:** house price depreciates by \$50k

  - return on investment $= (450 - 500)/500 = -0.10$

  - return on homeowner's equity $= (50 - 100)/100 = -0.50$

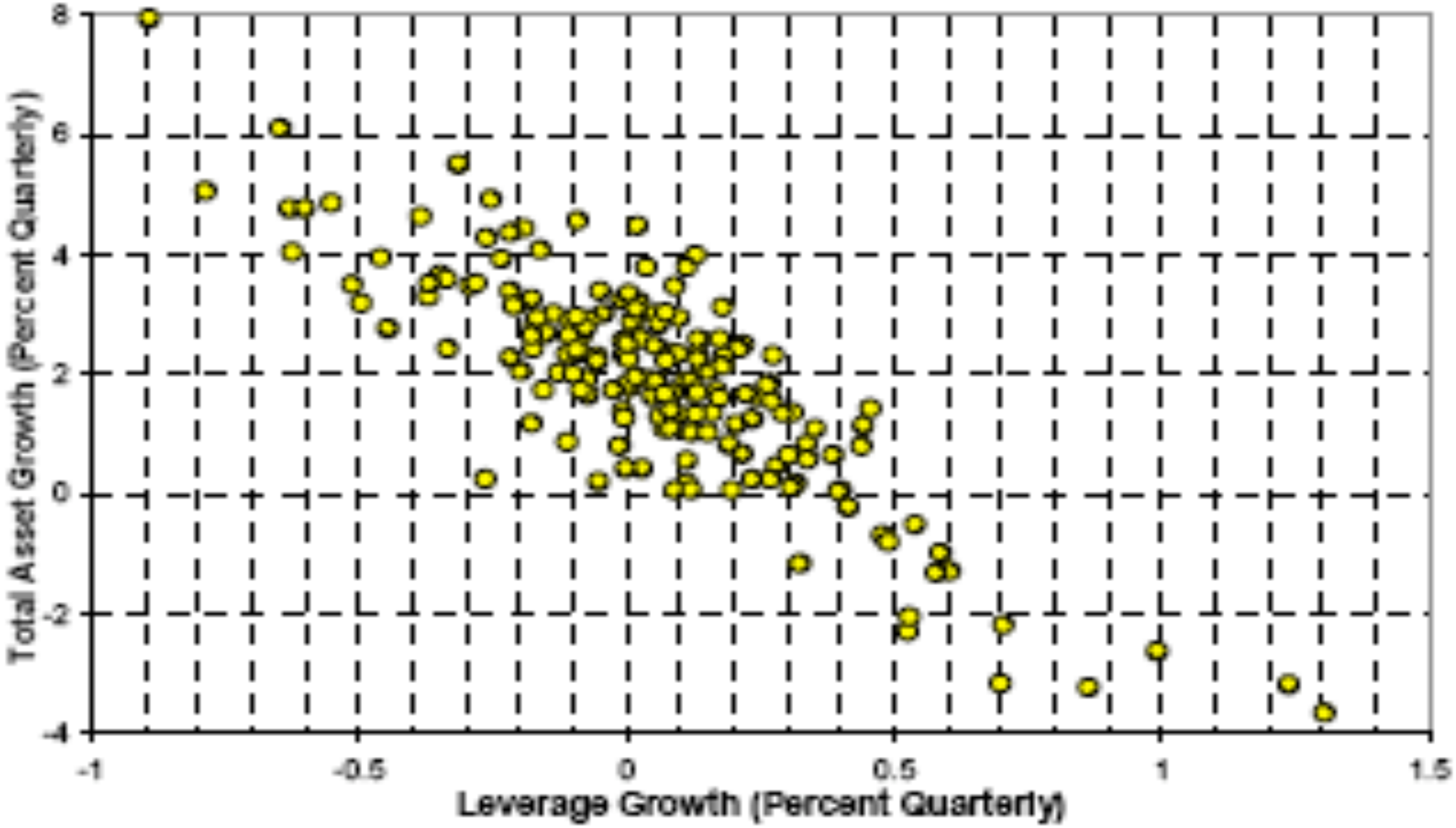
- The more levered you are, the easier it is for falling house prices to take you "underwater". If levered $10:1$ (so \$50k down), exact same fall in house prices would wipe out all equity.

Balance Sheet Management

- Households
  - relatively *passive* balance sheet management
    increase in asset value not matched by proportionate increase in debt
  - countercyclical leverage ratio

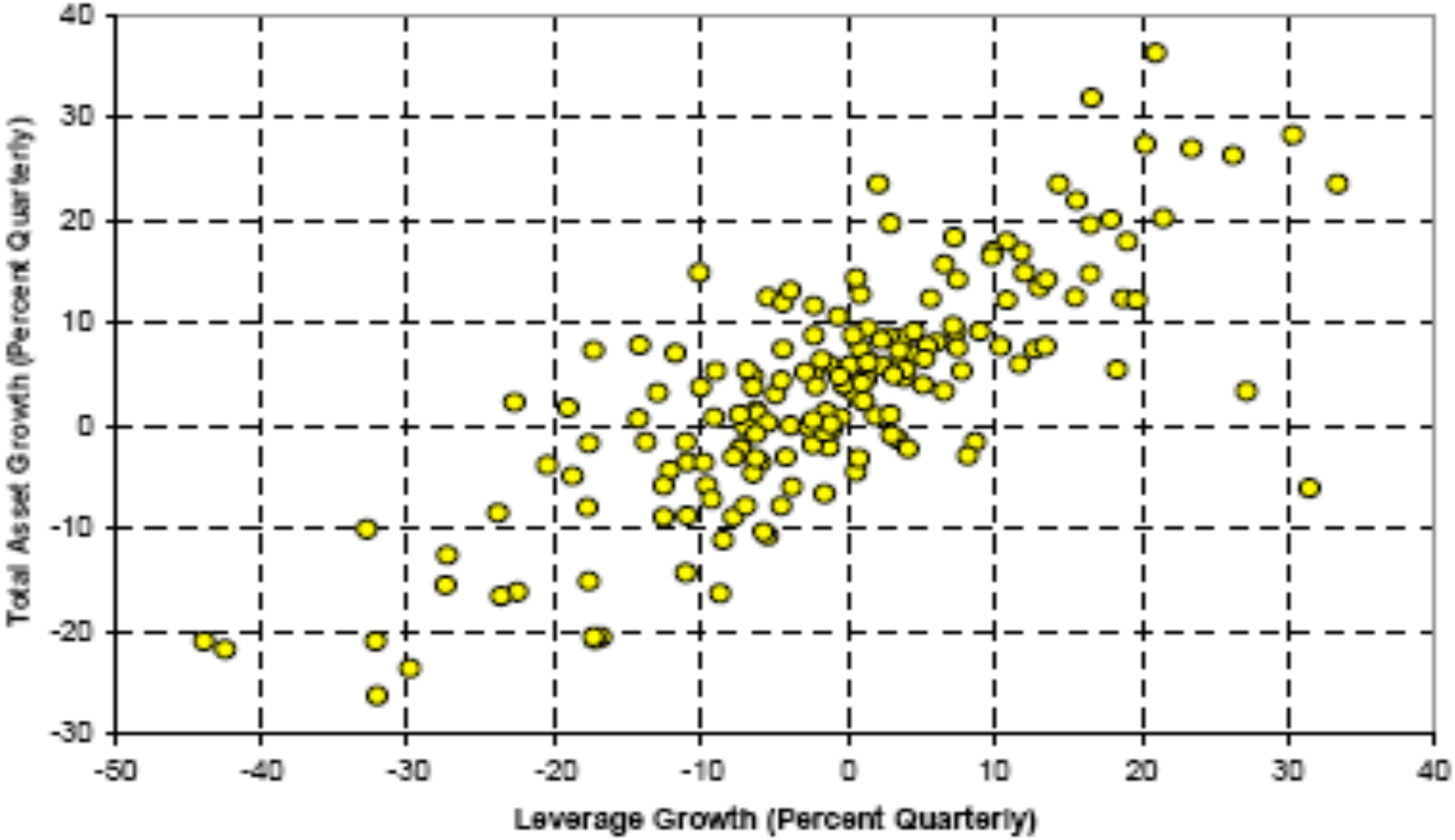
- Financial intermediaries
  - relatively *active* balance sheet management
    increase in asset value matched by increase in debt
  - commercial banks, proportionate increase in debt, constant leverage ratio
  - investment banks, more-than-proportionate increase, procyclical leverage

Households: *Passive* Balance Sheets



Increase in asset value not matched by proportionate increase in debt. Countercyclical leverage. Source: Adrian and Shin (2010).

Investment Banks: *Active* Balance Sheets



For investment banks, increase in asset value more than matched by increase in debt. Procyclical leverage. Source: Adrian and Shin (2010).

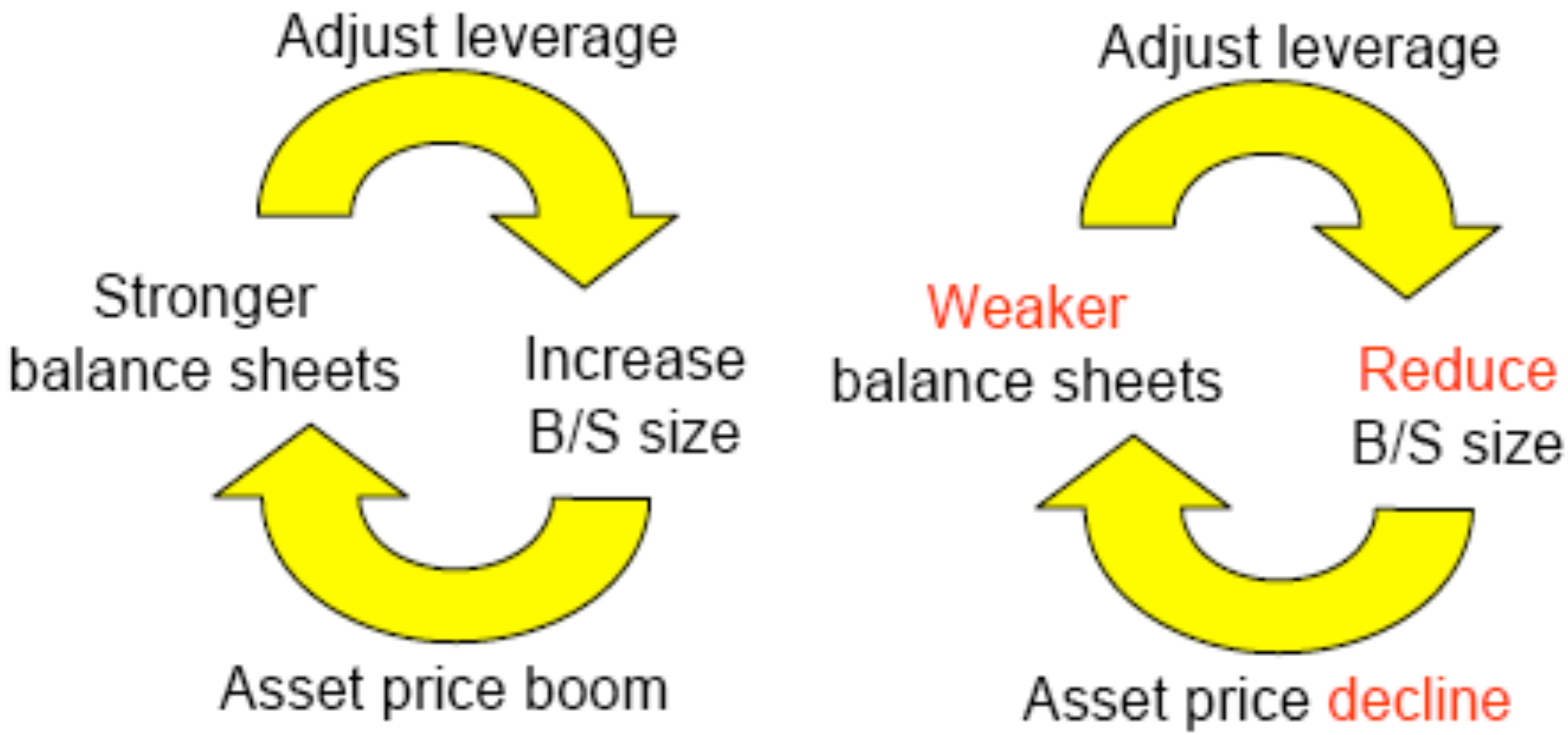
Feedback to Asset Prices

- In boom, banks issue debt to buy more securities
  - but buying more securities puts upward pressure on securities prices
  - increase in prices allows further balance sheet expansion . . .

- In bust, banks attempt to sell securities to retire debt
  - but selling securities puts downward pressure on securities prices
  - decrease in prices contracts balance sheets further . . .

- Self-reinforcing cycles.

Leverage Cycles



Consequences of deleveraging made worse by *liquidity mismatch*.

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Liquidity Mismatch

- **Example:** a typical big commercial bank

Assets		Liabilities	
Loans	1000	Deposits	1000
Investments	900	Short-term debt	400
Cash and reserves	100	Long-term debt	400
Total assets	2000	*Total liabilities*	1800
		Equity	200

- Here, the leverage ratio is $2000/200 = 10$.

- Overall, liabilities generally *much less liquid* than assets.

Liquidity Mismatch

- Suppose fall in house prices reduces value of bank's investments.

- At market prices, value of investments is now 700 down from 900.
  - no equity left, on brink of insolvency

- Exposed to *bank run*
  - depositors may want money back
  - but bank does not not have enough liquid assets

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Bank Runs

- **Classic bank run:** fear of insolvency, depositors to demand money back
  - in previous example, bank owes 1000 to depositors
  - only has 100 cash and reserves, some depositors cannot be repaid
  - hard to convert illiquid assets into cash
  - fire-sale deleveraging, spillovers to other banks, systemic failure

  - FDIC *deposit insurance* as safeguard

- **Modern bank run:** short-term debt plays role of deposits
  - in tranquil times, rolling-over short-term debt is easy
  - in run, rolling-over short-term debt is hard

- Basic problem in both cases is *liquidity mismatch*: short-term liquid liabilities but long-term illiquid assets.

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Diamond-Dybvig Model

Q. *Why are bank liabilities more liquid than their assets?*

A. Liquid liabilities allow for efficient risk-sharing. Investors who may need liquidity prefer to invest in bank rather than hold illiquid asset directly.

Q. *Why are banks subject to runs?*

A. Coordination failure. Implementing efficient risk-sharing with liquid liabilities is one equilibrium. But also *another* equilibrium where investors panic and run to withdraw deposits.

Diamond-Dybvig Model

- Three dates $\{0, 1, 2\}$.

- Unit mass of ex ante identical investors, representative bank.

- Each investor has endowment 1 to invest at date $t = 0$.

- Type of investor revealed at date $t = 1$

  – fraction α are *impatient*, consume at $t = 1$ only
  – fraction $1 - \alpha$ are *patient*, consume at either $t = 1$ or $t = 2$

  – individual type is *private information*, but aggregate fraction α is known

- Risk averse, utility function

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}, \qquad \sigma \geq 1$$

Asset Structure

- Each asset described by pair of *known* returns r_1, r_2
  - there is no asset return risk, only liquidity risk

- Key asset types

  (i) *illiquid asset*

$$1 = r_1 < r_2 = R$$

  (ii) *liquid asset*

$$1 < r_1 < r_2 < R$$

Efficient Risk Sharing (Planner's Problem)

- Planner chooses consumption for the impatient c_1 and consumption for the patient c_2 to maximize ex ante expected utility

$$\alpha\, u(c_1) + (1-\alpha)\, u(c_2)$$

subject to the *resource constraint*

$$\alpha\, c_1 + (1-\alpha)\, \frac{c_2}{R} \leq 1$$

and the *incentive compatibility constraint*

$$u(c_1) \leq u(c_2)$$

- The incentive compatibility constraint ensures that patient types have no incentive to mimic impatient types.

Planner's Problem

- Lagrangian

$$\mathcal{L} = \alpha u(c_1) + (1-\alpha)u(c_2) + \lambda\left[1 - \alpha c_1 - (1-\alpha)\frac{c_2}{R}\right] + \eta\left[u(c_2) - u(c_1)\right]$$

- First order conditions

$$c_1: \quad \alpha u'(c_1) - \lambda\alpha - \eta u'(c_1) = 0$$

and

$$c_2: \quad (1-\alpha)u'(c_2) - \lambda(1-\alpha)\frac{1}{R} + \eta u'(c_2) = 0$$

Planner's Problem

- Guess and verify incentive constraint is slack ($\eta = 0$).

- If so, we have the planner's consumption Euler equation

$$u'(c_1) = u'(c_2)R \qquad \Leftrightarrow \qquad c_2 = c_1 R^{1/\sigma} > c_1$$

$\therefore\ u(c_2) > u(c_1)$, verifies incentive constraint is slack

- Now use resource constraint to solve for c_1^*, c_2^*

$$c_1^* = \frac{1}{\alpha + (1-\alpha)R^{\frac{1-\sigma}{\sigma}}} \geq 1$$

$$c_2^* = \frac{R^{\frac{1}{\sigma}}}{\alpha + (1-\alpha)R^{\frac{1-\sigma}{\sigma}}} \leq R$$

These contingent payments provide optimal insurance given the resource and incentive constraints.

Numerical Example

- Let $\alpha = 0.25$, $R = 2$, $\sigma = 2$
- Gives payments to each type

$$c_1^* = \frac{1}{0.25 + 0.75 \times 2^{-0.5}} = 1.28 > 1$$

$$c_2^* = \frac{2^{0.5}}{0.25 + 0.75 \times 2^{-0.5}} = 1.81 < 2$$

Implementing Risk Sharing with Deposits

- Bank takes deposits (liquid liabilities) and invests them in project (illiquid asset) with payoff R at date $t = 2$.

- *Deposit contract*

  - take deposit of 1 at time $t = 0$

  - pay r_1 to investors who withdraw at $t = 1$ (early)
  - pay r_2 to investors who withdraw at $t = 2$ (late)

- Check feasibility

  - at $t = 1$, fraction α make withdrawal get r_1
  - bank needs to liquidate αr_1 funds

  - remaining $1 - \alpha r_1$ funds earn R, divided amongst patient investors

$$r_2 = \max \left[0,\ R \frac{1 - \alpha r_1}{1 - \alpha} \right]$$

Implementing Risk Sharing with Deposits

- *Sequential service constraint*

$$r_2 = \max\left[0,\ R\frac{1-\alpha r_1}{1-\alpha}\right]$$

- Now take $r_1 = c_1^*$ from the efficient risk-sharing problem. Rearrange the resource constraint to get

$$c_2^* = R\frac{1-\alpha c_1^*}{1-\alpha} > c_1^* > 0$$

- Therefore we can set

$$r_2 = \max\left[0,\ c_2^*\right] = c_2^*$$

- So we can implement efficient risk-sharing with deposit contracts.

Good News and Bad News

- *Good news*
  - implementation of optimal insurance is ***a*** Nash equilibrium of deposit game

- *Bad news*
  - bank runs are ***also*** a Nash equilibrium
  - all investors can panic and try to withdraw early, not just impatient types but patient types too

Bank Runs

- Suppose some fraction f withdraw at date $t = 1$.
- Return at date $t = 2$ then depends on f

$$r_2(f) = \max\left[0,\ R\frac{1 - fr_1}{1 - f}\right]$$

- Impatient types always withdraw, so $f \geq \alpha$.
- Patient types withdraw if

$$r_2(f) < r_1 \qquad \Leftrightarrow \qquad f \geq f^* \equiv \frac{1}{r_1}\frac{R - r_1}{R - 1}$$

[note "tipping point" $f^* < 1 \Leftrightarrow r_1 > 1$]

- If $r_1 > 1$ (deposit contract), then *two Nash equilibria in pure strategies*: (i) $f = \alpha$ and $r_2(\alpha) = c_2^*$ as above, and (ii) $f = 1$ and $r_2(1) = 0$.

Deposit Insurance

- Government promise to guarantee r_1, r_2 backed by tax powers.

- Rule-based deposit insurance also avoids discretionary "bailouts".

- Often supplemented by central bank acting as *lender-of-last-resort*
  - discount window loans, etc
  - in other words, *public liquidity*

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Modern Securitized Banking

- Deposit insurance capped, so of less value to institutional investors.

- Instead of demand deposits, raise funds in the market for "sale and repurchase agreements" — *repo*, for short.

  (and other similar forms of short-term finance)

- No deposit insurance, investors protect funds by taking *collateral*.

- What makes for acceptable collateral? This is where highly-rated tranches of structured finance products come back into the picture.

Modern Securitized Banking

- Mortgages and loans securitized.
- Funds raised from investors via repo, collateralized by securities.
- In short, *outputs* of securitization process are also *inputs* in the form of collateral to repo financing.
- So how does this repo financing work?

Repo Transactions

- Borrower raises funds by selling security at spot price to lender who provides cash. Borrower agrees to repurchase security at future date (perhaps tomorrow) at forward price.

- Effectively, security is collateral for a cash loan from the lender.

Credit Risk and Haircuts

- If repurchase does not happen (borrower defaults), lender keeps security. But may not be able to recover face value, implying loss to lender.

- As protection against this *credit risk*, amount of loan typically less than market value of collateral.

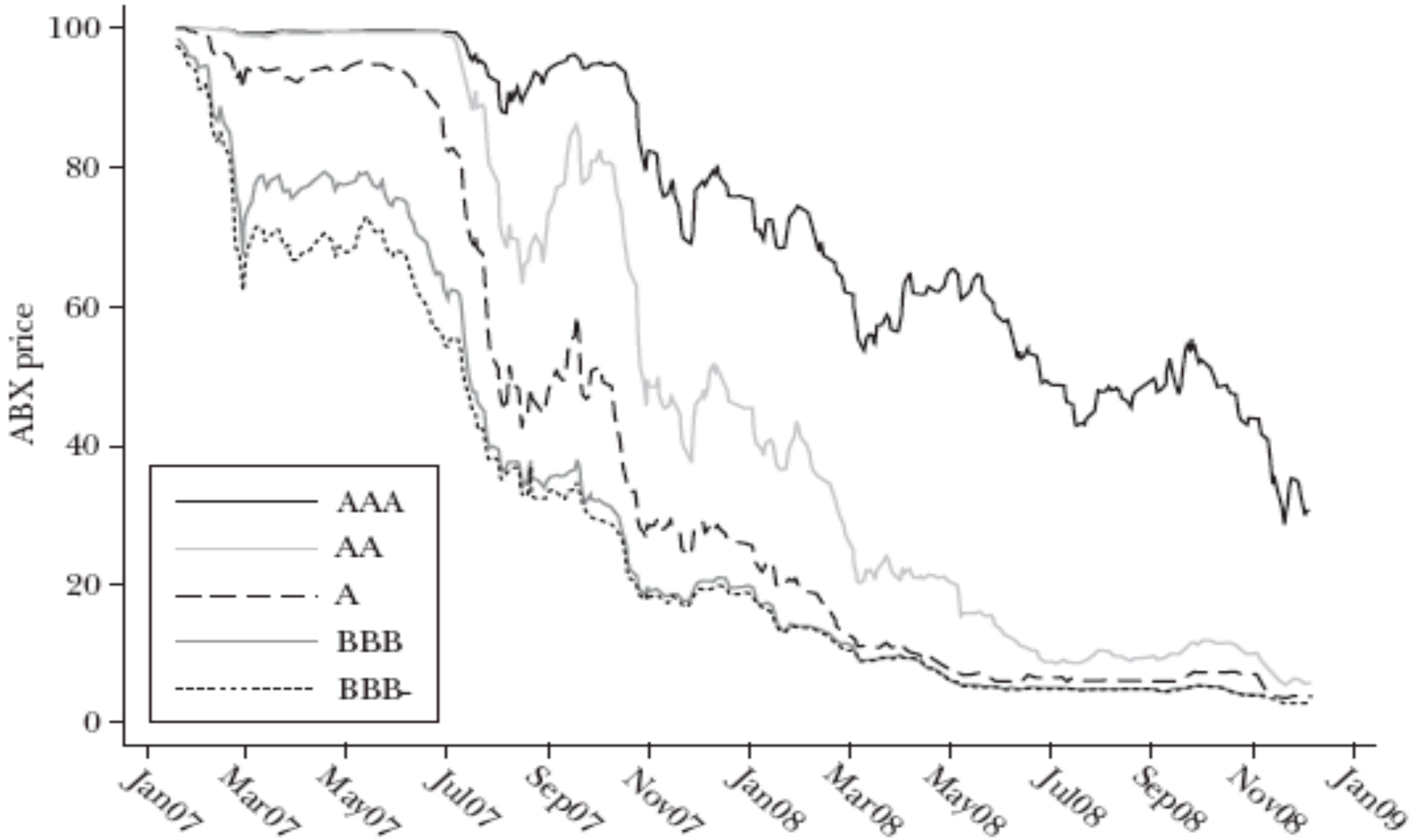
- **Example:** if asset has market value 100 and amount of loan is 95, then *haircut* (initial margin) is $(100 - 95)/100 = 5\%$.

- No consequences ex post if borrower repays, but ex ante limits amount of funds borrower can raise against inventory of securities.

- A "margin call" is then a tightening of borrowing conditions, reducing the amount that can be borrowed against a given inventory of securities.

New Information: ABX Indices

Decline in Mortgage Credit Default Swap ABX Indices
(the ABX 7-1 series initiated in January 1, 2007)



To buy protection against default, pay upfront fee of 100−ABX price. Previous sellers of CDS suffer losses as index falls. Source: Brunnermeier (2009).

Run on Repo

- *Margin calls*, massive "withdrawal" of repo finance in the form of large increases in haircuts. As haircuts increase, banks have funding shortfalls.

- **Example:** raise \$95 via repo with \$100 collateral (5% haircut). As haircut rises to 15%, can only raise \$85, shortfall \$10.

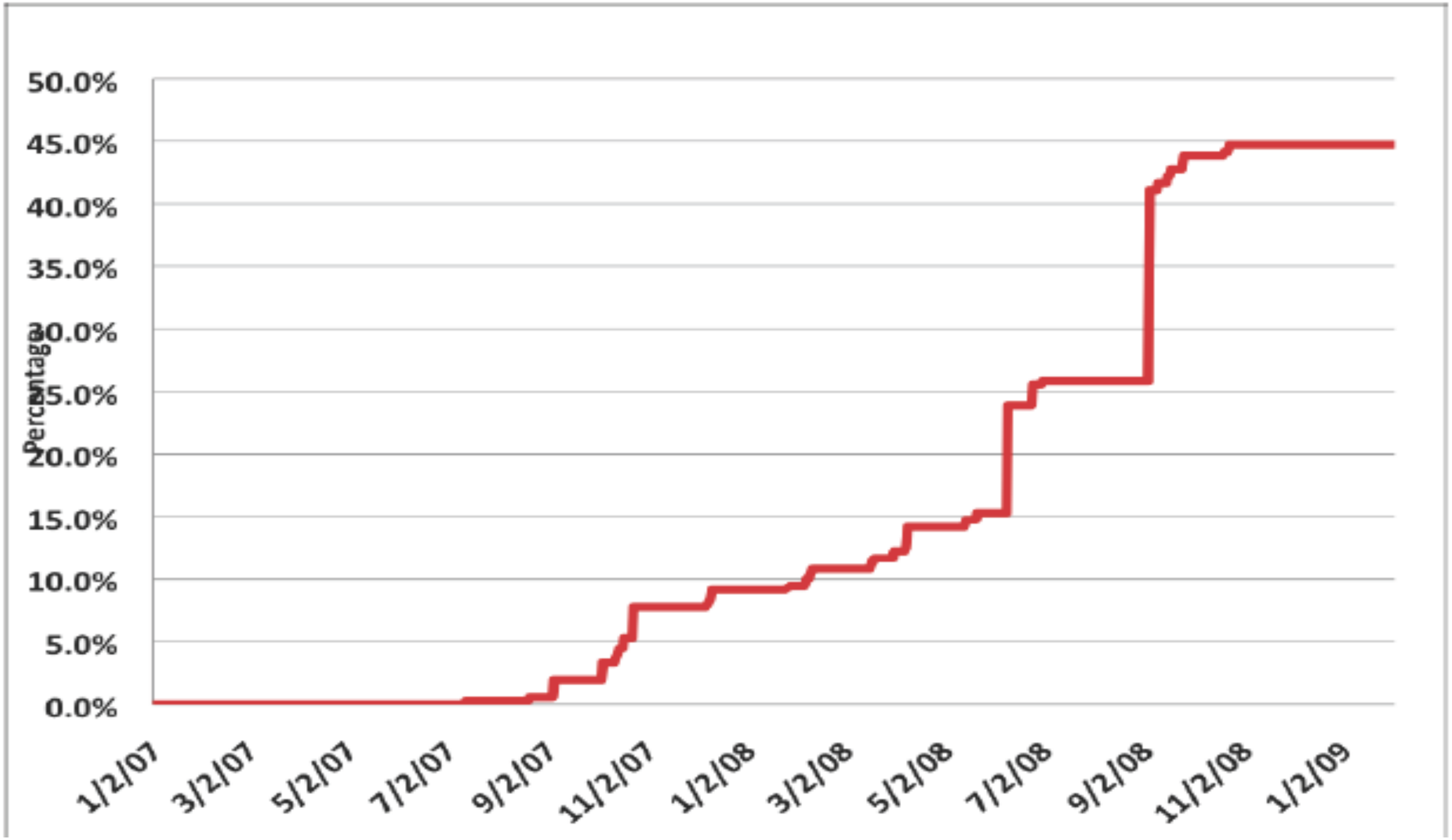
- May be unable to meet new margin if highly levered — the liquidity mismatch problem again.

- *Full-blown crisis*:

  - all investors raise haircuts on all borrowers
    (most banks both investors and borrowers at same time)

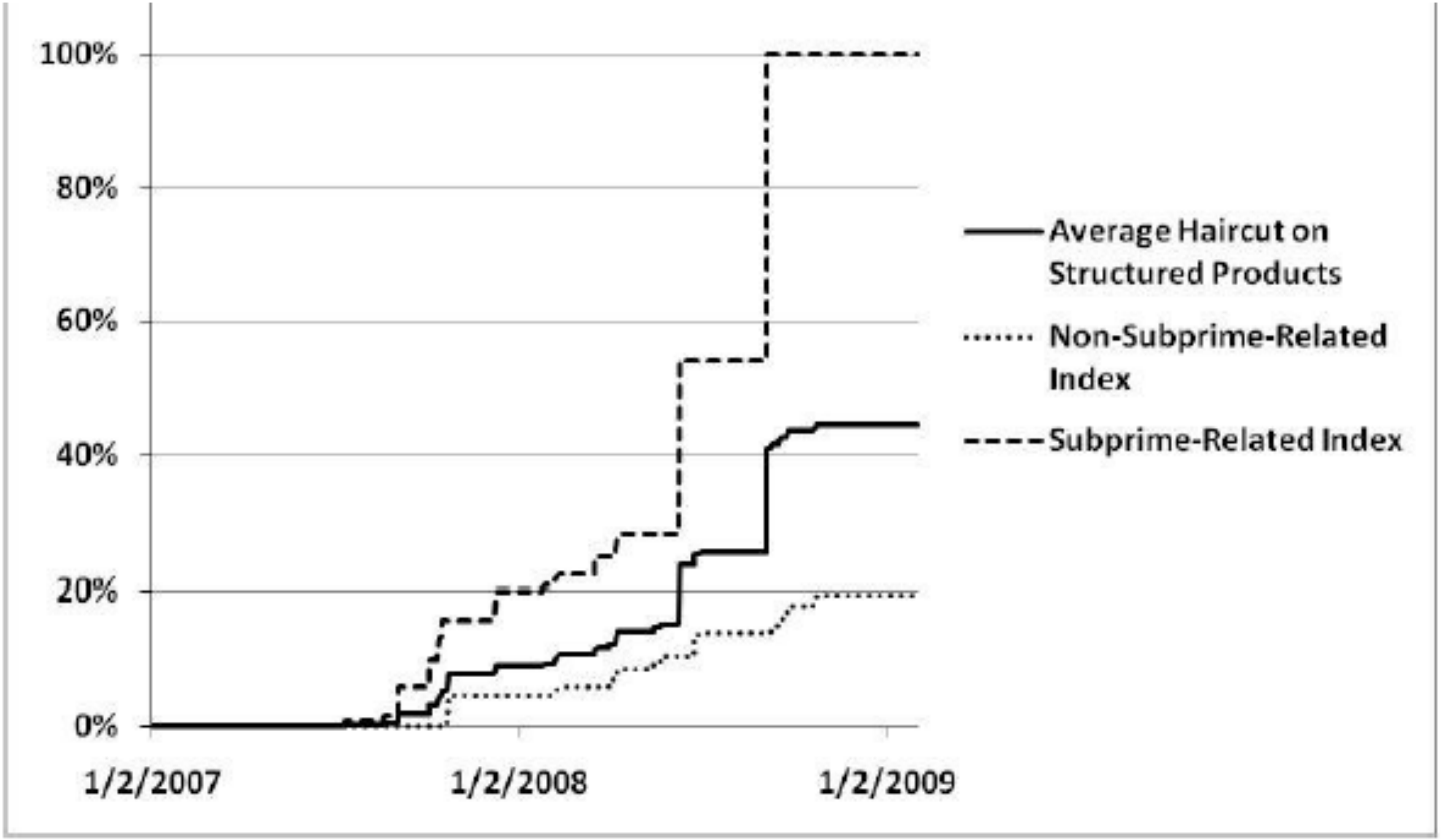
  - systemic deleveraging as all banks try to sell assets to bridge shortfalls

Repo Haircut Index



Repo-haircut index is equally-weighted average haircut for nine asset classes. Source: Gorton and Metrick (2009).

Repo Haircuts on Different Market Segments



Source: Gorton and Metrick (2009b)

Next Class

- Financial crisis, part two.

- Heterogeneous beliefs and the leverage cycle.

- Last lecture before second midterm.