Advanced Macroeconomics

Lecture 21: financial crises, part one

Chris Edmond

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This class

- Beginning of lectures on financial crises
- Diamond-Dybvig model of bank runs. The run on repo.
- Further reading
  - Diamond and Dybvig (1983): Bank runs, deposit insurance, and liquidity, *Journal of Political Economy*.

This lecture

- Diamond-Dybvig model of bank runs
  - tension between efficient risk-sharing/liquidity provision and exposure to a run
- Securitized banking and the run on repo
  - increased repo ‘haircuts’ as a form of modern bank run

Diamond-Dybvig

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

A. Issuing liquid liabilities allows 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 only one equilibrium. Also *another* equilibrium where investors panic and run to withdraw deposits

Diamond-Dybvig

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

- Unit mass of ex ante identical investors, single 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 realized type is *private information*, but aggregate fraction α is known

- CRRA preferences $u(c)$ with coefficient $\sigma \geq 1$

Asset structure

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

(i) *illiquid asset*

$$1 = r_1 < r_2 = R$$

(ii) *liquid asset*

$$1 < r_1 < r_2 < R$$

Optimal insurance (*risk-sharing*) contract

Maximize ex ante expected utility

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

subject to *resource constraint*

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

and *incentive compatibility constraint*

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

(patient types will not want to mimic impatient types)

Optimal insurance contract

- 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

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

Optimal insurance contract

- Guess and verify incentive constraint is slack ($\eta = 0$)
- If so, with CRRA utility we have

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

$\therefore u(c_2) > u(c_1)$, 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

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

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

Implementing the optimal contract 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 the optimal contract 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 optimal insurance contract. Rearrange the resource constraint to get

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

- Therefore we can set

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

We can implement the optimal insurance contract with deposits.

- *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 $f^* < 1 \Leftrightarrow r_1 > 1$]

- If $r_1 > 1$ (deposit contract), *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*

Traditional banking in practice

- Lend long (mortgages, bank loans) to borrowers
- Raise funds from investors through demand deposits, these funds can be withdrawn any time
- Bank holds assets (mortgages, bank loans) on its balance sheet
- Small fraction of deposits retained as *reserves*
- *Deposit insurance* in the United States:

  Since 1933, FDIC guarantees deposits at *commercial banks*. Regulates capitalisation of member banks. Insured to cap of $250k
- *Lender-of-last-resort*: prime loans from the Federal Reserve

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 good collateral?

Modern securitized banking

- Pass-through 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)
- Higher tranches can be used as collateral

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

Modern securitized banking

- Mortgages and loans securitized
- Funds raised from investors via repo, collateralized by securities
- *Outputs* of securitization process are also *inputs* in the form of collateral to repo financing

Repo transactions

- Borrower (say, bank) raises funds by selling security at spot price to investor 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 investor

Haircuts

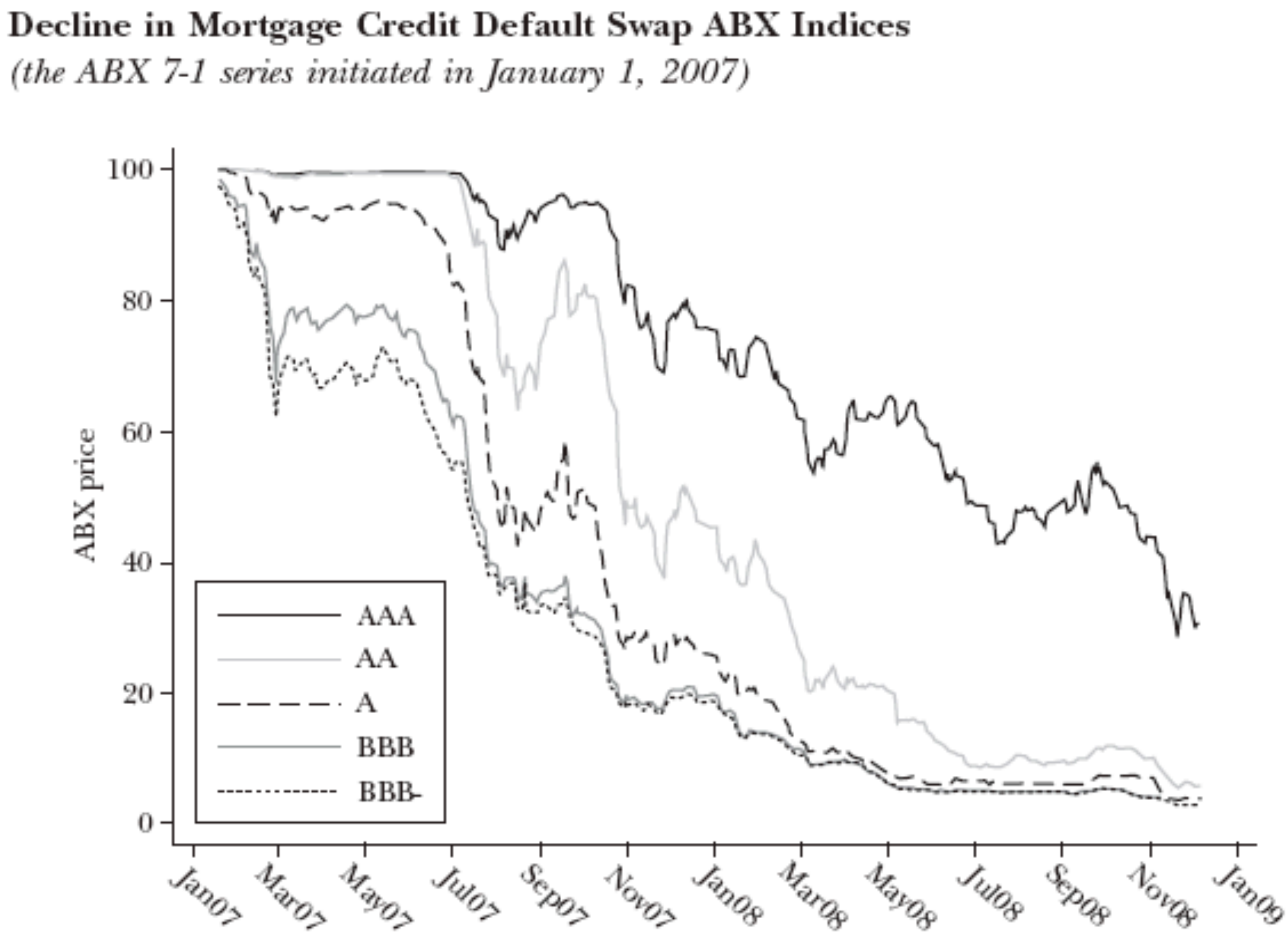
- *Credit risk.* If repurchase does not happen (borrower defaults), investor keeps security. But may not be able to recover face value, implying loss to investor

- As protection against 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

New information: ABX indices



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’

- Massive ‘withdrawal’ of repo finance in the form of large increases in haircuts (*margin calls*)

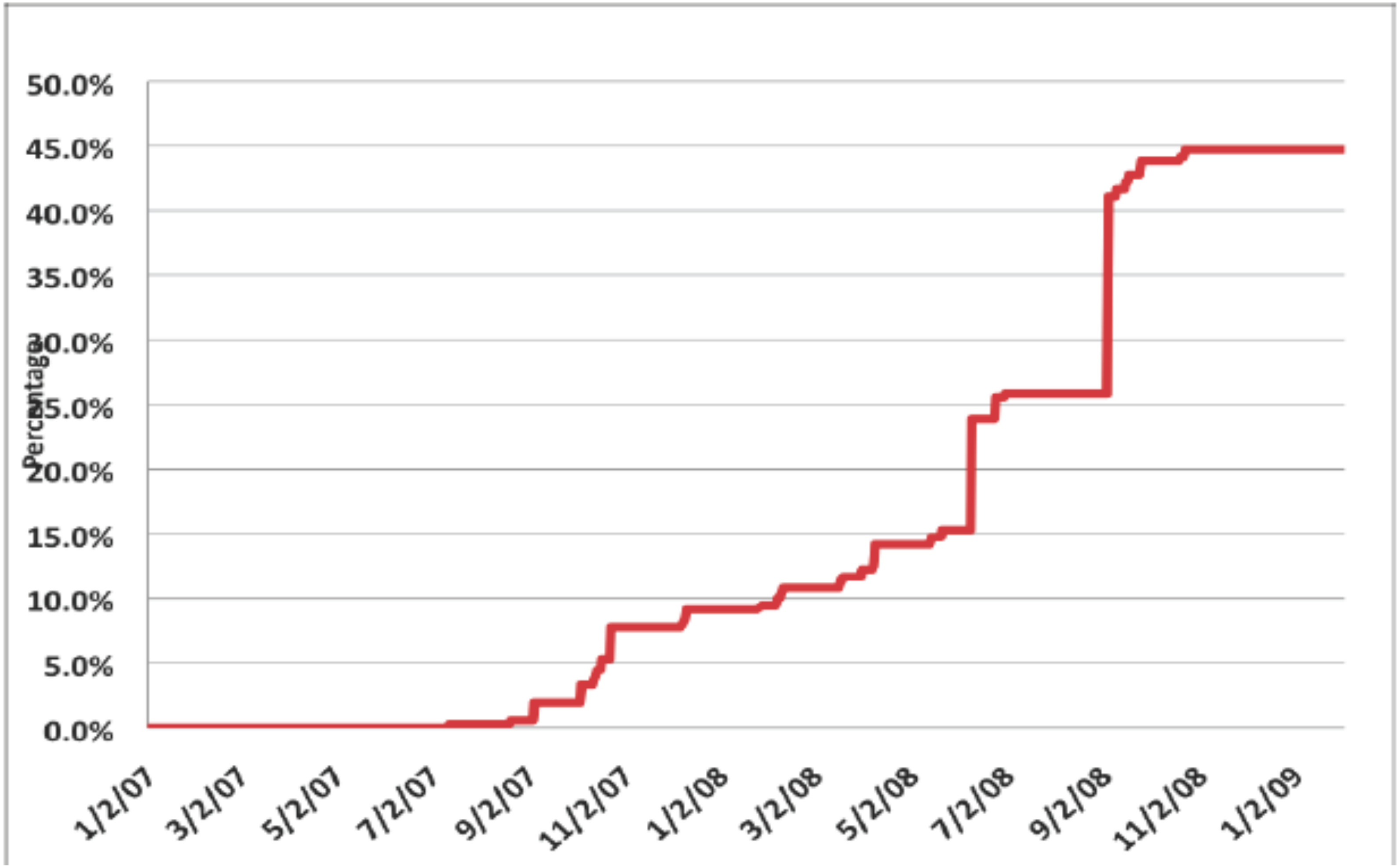
- As haircuts increase, banks have funding shortfall

  Example: bank raises \$95 via repo with \$100 collateral (5% haircut). As haircut rises to 15%, bank can only raise \$85 funds, now shortfall of \$10

  May be unable to meet new margin if highly levered

- *Systemic crisis*: all investors raise haircuts on all borrowers (most institutions both investors and borrowers at same time). Massive de-leveraging as banks try to sell assets to bridge shortfalls

Repo haircut index



Repo haircuts on different market segments