Lecture 2
Securitisation and Financial Stability

Hyun Song Shin
Princeton University

Clarendon Lectures in Finance
Oxford, June 2nd - 4th, 2008
Acknowledgements

Adrian and Shin (2007) “Liquidity and Leverage” paper for 6th BIS annual conference


Some History

Some History

US Home Mortgage Holdings
Market versus Bank Finance

US Home Mortgage holdings

Trillion Dollars

- Market-based
- Bank-based
Two Pieces of Received Wisdom (Old and New)

- Securitisation enhances financial stability by dispersing credit risk.
  - Implicitly assumes that instability arises through defaults
  - “Domino Hypothesis”

- Securitisation allows “hot potato” of bad debts to pass down chain.
  - Chain of agency problems
  - There is a greater fool next in the chain
  - Final investor (e.g. pension fund) is the greatest fool.
  - “Hot Potato Hypothesis”
• Channel of financial contagion is chain of defaults.
  – Passive players, who stand by while others fail
  – No role for prices
  – Only implausibly large shocks generate any contagion in simulations

In 2007/8 crisis, direction of contagion has been reversed.

Bear Stearns and Northern Rock crises were **runs** on the liabilities side.
Hot Potato Hypothesis

Securitisation chain:

Sub-prime borrower $\rightarrow$ mortgage broker $\rightarrow$ originating bank $\rightarrow$ mortgage pools $\rightarrow$ commercial/investment bank $\rightarrow$ rating agency $\rightarrow$ special purpose vehicles (SPV) $\rightarrow$ final investors
Hot Potato Hypothesis

Distinguish between:

- Selling bad loans down the chain (passing hot potato)
- Issuing liabilities backed by bad loans (keeping hot potato)

Originating bank sells the loan, but the SPV holds the loan and issues securities against the loans.

Banks sponsor (and hold liabilities of) SPVs.

⇒ Hot potato stays in the financial system, and is not passed to final investor.
• In a consolidated sense, the hot potato of bad loans sits on the balance sheets of the large, sophisticated banks.

• Final investor makes losses, but losses for securitising bank can wipe out its equity.

• The banking system is the greatest fool.
### Subprime Exposures

<table>
<thead>
<tr>
<th></th>
<th>Total reported sub-prime exposure</th>
<th>Percent of reported exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Investment Banks</td>
<td>75</td>
<td>5%</td>
</tr>
<tr>
<td>US Commercial Banks</td>
<td>250</td>
<td>18%</td>
</tr>
<tr>
<td>US GSEs</td>
<td>112</td>
<td>8%</td>
</tr>
<tr>
<td>US Hedge Funds</td>
<td>233</td>
<td>17%</td>
</tr>
<tr>
<td>Foreign Banks</td>
<td>167</td>
<td>12%</td>
</tr>
<tr>
<td>Foreign Hedge Funds</td>
<td>58</td>
<td>4%</td>
</tr>
<tr>
<td>Insurance Companies</td>
<td>319</td>
<td>23%</td>
</tr>
<tr>
<td>Finance Companies</td>
<td>95</td>
<td>7%</td>
</tr>
<tr>
<td>Mutual and Pension</td>
<td>57</td>
<td>4%</td>
</tr>
<tr>
<td>US Leveraged Sector</td>
<td>671</td>
<td>49%</td>
</tr>
<tr>
<td>Other</td>
<td>697</td>
<td>51%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,368</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Note: The total for U.S. commercial banks includes $95 billion of mortgage exposures by Household Finance, the U.S. subprime subsidiary of HSBC. Moreover, the calculation assumes that US hedge funds account for four-fifths of all hedge fund exposures to subprime mortgages.

Source: Goldman Sachs. Authors’ calculations.

Greenlaw, Hatzius, Kashyap and Shin (2008)
Questions to be addressed

• Why did apparently sophisticated banks act as the “greatest fool”? 

• What are the economic conditions that are conducive for the formation of bubbles?

• What are the crisis dynamics:
  – On the way up?
  – On the way down?
Balance Sheet Size and Leverage: Households

[Graph showing the relationship between leverage growth and total asset growth for households. The x-axis represents leverage growth (percent quarterly), and the y-axis represents total asset growth (percent quarterly). The data points are scattered across the graph, indicating a positive correlation between the two variables.]
Non-Financial, Non-Farm Corporations
Security Dealers and Brokers
Total Assets and Leverage

Lehman Brothers

Merrill Lynch

Morgan Stanley

Bear Sterns

Goldman Sachs

Citigroup Markets 98-04

Total Asset Growth vs. Leverage Growth for different firms and time periods.
Leverage and Total Assets Growth
Asset weighted, 1992Q3-2008Q1, Source: SEC

![Graph showing the relationship between Leverage and Total Assets Growth. The graph includes data points for years 1998Q4, 2007Q3, 2007Q4, and 2008Q1. The y-axis represents Total Assets (log change), and the x-axis represents Leverage (log change). The data points are marked with red dots for 1998Q4, 2007Q3, 2007Q4, and 2008Q1.]
Explaining Leverage

Capital $K$ is set to total value at risk (VaR)

$$K = V \times A$$

Hence, leverage $L$ satisfies:

$$L = \frac{A}{K} = \frac{1}{V}$$

Procyclical leverage arise from counter-cyclical nature of value at risk. Measured risk is low during booms and high during busts.
VaR/Equity and Leverage

**Log VaR/Equity**

**Log Leverage**

- Log VaR to Equity (log)
- Log Leverage

2001-1
2002-1
2003-1
2004-1
2005-1
2006-1
2007-1
2008-1

Date

Bear Sterns
Goldman Sachs
Lehman Brothers
Merrill Lynch
Morgan Stanley
Stylized Financial System

end-user borrowers \[\rightarrow\] loans \[\rightarrow\] financial intermediaries

\[\rightarrow\] equity

\[\rightarrow\] debt claims

outside claim holders
Pricing Assets in a Financial System

Loans are claims against other parties in the financial system.

- Value of my claim against $A$ depends on value of $A$’s claims against $B$, $C$, etc.

- Strength of $A$’s balance sheet depends on strength of $B$’s and $C$’s balance sheets.

Housing $\Rightarrow$ mortgages $\Rightarrow$ CDOs (collateralized debt obligations) $\Rightarrow$ claims against CDO holders . . .
Modeling Strategy

Financial system is a network of interlinked balance sheets

- **Ex Post Analysis**
  - Solve for ex post allocation for known realizations
  - Priority of debt over equity

- **Ex Ante Analysis**
  - Pricing uncertainty over final values
  - Everything is marked to market, risk-neutrality in pricing

- **Comparative Statics**
  - Shifts in fundamental risk have implications for leverage and credit availability
## Claims Matrix

<table>
<thead>
<tr>
<th>bank 1</th>
<th>bank 2</th>
<th>...</th>
<th>bank n</th>
<th>outside</th>
<th>debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$\bar{x}_{12}$</td>
<td>...</td>
<td>$\bar{x}_{1n}$</td>
<td>$x_{1,n+1}$</td>
<td>$\bar{x}_1$</td>
</tr>
<tr>
<td>$\bar{x}_{21}$</td>
<td>0</td>
<td>...</td>
<td>$\bar{x}_{2n}$</td>
<td>$x_{2,n+1}$</td>
<td>$\bar{x}_2$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$\bar{x}_{n1}$</td>
<td>$\bar{x}_{n2}$</td>
<td>...</td>
<td>0</td>
<td>$x_{n,n+1}$</td>
<td>$\bar{x}_n$</td>
</tr>
<tr>
<td>$\bar{y}_1$</td>
<td>$\bar{y}_2$</td>
<td>...</td>
<td>$\bar{y}_n$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total assets**

$\bar{a}_1$ $\bar{a}_2$ $\bar{a}_n$
Credit Risk

Two dates, 0 and 1. Loans made at date 0, repaid at date 1.

Bank $i$ has face value of end-user loans $\tilde{y}_i$.

Credit risk follows Vasicek (2002) one factor model (backbone of Basel II regulations).

End-user borrower $j$ of bank $i$ repays the loan when $Z_{ij} \geq 0$, where

$$Z_{ij} = -\Phi^{-1}(p_i) + \sqrt{\rho} Y + \sqrt{1-\rho} X_{ij}$$

$\Phi(.)$ is the c.d.f. of the standard normal, $Y$ and $\{X_{ij}\}$ are mutually independent standard normal random variables. $Y$ is common across all banks and is common factor that drives the aggregate credit loss.
Ex ante probability of default by borrower $j$ of bank $i$ is $p_i$

$$
\Pr (Z_{ij} < 0) = \Pr \left( \sqrt{\rho} Y + \sqrt{1 - \rho} X_{ij} < \Phi^{-1} (p_i) \right)
= \Phi \left( \Phi^{-1} (p_i) \right) = p_i
$$

Conditional on common factor $Y$, defaults are independent across borrowers.

Say portfolio consists of $N$ loans each with face value $\bar{y}_i/N$. Let $N \to \infty$.

By law of large numbers, repayment $w_i$ on loan book of $\bar{y}_i$ is deterministic function of $Y$
\[ w_i(Y) \equiv \bar{y}_i \Pr(Z_{ij} \geq 0|Y) \]
\[ = \bar{y}_i \Pr \left( Y \sqrt{\rho} + X_{ij} \sqrt{1-\rho} \geq \Phi^{-1}(p_i) \right) \]
\[ = \bar{y}_i \Phi \left( \frac{Y \sqrt{\rho} - \Phi^{-1}(p_i)}{\sqrt{1-\rho}} \right) \]

The c.d.f. over the repayment on bank \( i \)’s loan book is

\[ F_i(z) = \Pr(w_i(Y) \leq z) \]
\[ = \Pr(Y \leq w^{-1}_i(z)) \]
\[ = \Phi \left( \frac{\Phi^{-1}(p_i) + \sqrt{1-\rho}\Phi^{-1}\left(\frac{z}{y_i}\right)}{\sqrt{\rho}} \right) \quad (1) \]
\[ F_i(z) = \Phi \left( \frac{\Phi^{-1}(p_i) + \sqrt{1-\rho} \Phi^{-1} \left( \frac{z}{y_i} \right)}{\sqrt{\rho}} \right) \] (2)

Change in \( p_i \) implies \textbf{first degree} stochastic dominance shift in density

Change in \( \rho \) implies \textbf{second degree} stochastic dominance shift in density
Repayment density: \( \bar{y} = 1, \ p = 0.1 \)

\[ \rho = 0.01 \]

\[ \rho = 0.1 \]

\[ \rho = 0.2 \]
Realized Values

\[ \bar{x}_i \]

\[ \hat{x}_i \]

\[ \bar{\alpha}_i \]
Realized values of debt satisfy:

\[
\begin{align*}
\hat{x}_1 &= \min (a_1(\hat{x}), \bar{x}_1) \\
\hat{x}_2 &= \min (a_2(\hat{x}), \bar{x}_2) \\
&\quad \vdots \\
\hat{x}_n &= \min (a_n(\hat{x}), \bar{x}_n)
\end{align*}
\]

where \( \hat{x} = (\hat{x}_1, \hat{x}_2, \cdots, \hat{x}_n) \). So, there is non-decreasing function \( F(.) \) that maps realized asset values to the realized asset values that result when debts are settled. Ex post allocation is fixed point of \( F(.) \)
Unique Solution

There is unique profile of realized debt values $\hat{x}$ that solves $\hat{x} = F(\hat{x})$

Result follows from

- Tarski’s fixed point theorem
- Fact that realized value of equity is (weakly) increasing in the realized value of $i$’s assets

Eisenberg and Noe (Management Science 2001), Milgrom and Roberts (AER 1994))
Comparative Statics of Unique Solution

Denote by $\hat{x}_i(\hat{y})$ the realized value of $i$’s debt given realizations $\hat{y} = (\hat{y}_1, \cdots, \hat{y}_n)$ of payoffs to banks 1 to $n$.

**Lemma 1.** $\hat{x}_i$ is weakly increasing in $\hat{y}_j$ for any $j$.

Lemma follows from comparative statics on lattices (Milgrom and Roberts (AER 1994)).

The realized values $\{\hat{y}_i\}$ are deterministic functions of $Y$. Hence,

$$\hat{a}_i (Y) = \hat{y}_i (Y) + \sum_j \pi_{ji} \hat{x}_j (\hat{y}_j (Y)).$$

**Lemma 2.** For each bank $i$, the realized value of its assets $\hat{a}_i$ is a well-defined, increasing function of $Y$. 

32
Market Values

Market values are expected values at date 0.

$y_i$ (without any hats or bars) is expected value of $\hat{y}_i$.

$x_i$ the expected value of $\hat{x}_i$, and so on.

Marked to market value of total assets of bank $i$

$$a_i = y_i + \sum_j x_j \pi_{ji}$$

Marked to market liabilities

$$e_i + x_i$$

Leverage of bank $i$ is $\lambda_i$.

$$\frac{a_i}{a_i - x_i} = \lambda_i$$
For $\delta_i = 1 - \frac{1}{\lambda_i}$

$$x_i = \delta_i \left( y_i + \sum_j x_j \pi_{ji} \right)$$

$$= \delta_i y_i + \begin{bmatrix} x_1 & \cdots & x_n \end{bmatrix} \begin{bmatrix} \delta_i \pi_{1i} \\ \vdots \\ \delta_i \pi_{ni} \end{bmatrix}$$

(3)

Let $x = \begin{bmatrix} x_1 & \cdots & x_n \end{bmatrix}$, $y = \begin{bmatrix} y_1 & \cdots & y_n \end{bmatrix}$, and

$$\Delta = \begin{bmatrix} \delta_1 & \cdots \\ & \ddots \\ & & \delta_n \end{bmatrix}$$
Write (3) in vector form as:

\[ x = y \Delta + x \Pi \Delta \]

Solving for \( x \),

\[
x = y \Delta (I - \Pi \Delta)^{-1} \\
= y \Delta \left( I + \Pi \Delta + (\Pi \Delta)^2 + (\Pi \Delta)^3 + \cdots \right)
\]

(4)

The matrix \( \Pi \Delta \) is given by

\[
\Pi \Delta = \begin{bmatrix}
0 & \delta_{2\pi_{12}} & \cdots & \delta_{n\pi_{1n}} \\
\delta_{1\pi_{21}} & 0 & \cdots & \delta_{n\pi_{2n}} \\
\vdots & \vdots & \ddots & \vdots \\
\delta_{1\pi_{n1}} & \delta_{2\pi_{n2}} & \cdots & 0
\end{bmatrix}
\]

(5)
Infinite series in (4) converges since the rows of $\Pi \Delta$ sum to a number strictly less than 1. Hence, the inverse $(I - \Pi \Delta)^{-1}$ is well-defined.
Value at Risk

For bank $i$ its value at risk at confidence level $c$ relative to the face value of its assets $\bar{a}_i$, is the smallest non-negative number $V_i$ such that

$$\Pr(\hat{a}_i < \bar{a}_i - V_i) \leq 1 - c$$
Value at risk $V_i$ is the “approximately” worst case loss, where “approximately worst case” is defined so that anything worse happens with probability smaller than benchmark $1 - c$.

- 1996 Market Risk Amendment of the Basel Accord
- Basel II regulations
Balance Sheet Management

Bank aims to set market equity $e_i$ to its value at risk $V_i$

$$e_i = V_i$$

Consequences for desired leverage $\lambda_i^*$:

$$\lambda_i^* = \frac{a_i}{V_i}$$

- $x$ initial profile of debt
- $x'$ after shock, but before adjustment of face values
- $x^*$ debt profile implied by desired leverage ratios $\{\lambda_i^*\}$
Comparative Statics

$\mathbf{x}^*$

debt which equates equity with value at risk

$\mathbf{x}'$

after shock, before adjustment of debt

$\mathbf{x}$

initial profile of debt
Comparative Statics

Value at Risk and Leverage
**Liquidity**

Debt values $x'$ after shock

\[ x' = y \Delta' \left( I + \Pi \Delta' + (\Pi \Delta')^2 + (\Pi \Delta')^3 + \cdots \right) \]  

(6)

where $\Delta'$ is diagonal matrix of leverage after shock

\[ \lambda_i' = \frac{a_i'}{e_i'} \]

Let $\Delta^*$ be diagonal matrix implied by the *desired* leverage ratios $\lambda_i^*$, where

\[ \lambda_i^* = \frac{a_i'}{V_i'} \]
Define $x^*$ as

$$x^* = y \Delta^* \left( I + \Pi \Delta^* + (\Pi \Delta^*)^2 + (\Pi \Delta^*)^3 + \cdots \right)$$

(7)

Since

$$e_i' > e_i > V_i'$$

we have

$$\lambda_i^* = \frac{a_i'}{V_i'} > \frac{a_i'}{e_i'} = \lambda_i'$$

Hence $\Delta^* > \Delta'$, so that

$$x^* - x' > 0$$
Liquidity

\( x^* \) is not an equilibrium profile of debt - only indicates direction of desired adjustment.

- Large \( x^* - x' \) implies ready availability of credit - high liquidity
- Low (negative) \( x^* - x' \) indicates reluctance to lend - “liquidity dries up”.

Examine the impact of a fall in the parameter \( \rho \) of the Vasicek model.

The fall in \( \rho \) can be interpreted as a moderation of the business cycle volatility - such as the “Great Moderation”
## Credit Availability for End-Users

The table below illustrates the credit availability for end-users across different banks and the relationship between end-user loans and total assets:

<table>
<thead>
<tr>
<th>Bank 1</th>
<th>Bank 2</th>
<th>⋯</th>
<th>Bank n</th>
<th>Outside</th>
<th>Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$x_{12}$</td>
<td>⋯</td>
<td>$x_{1n}$</td>
<td>$x_{1,n+1}$</td>
<td>$x_1$</td>
</tr>
<tr>
<td>$x_{21}$</td>
<td>0</td>
<td>⋯</td>
<td>$x_{2n}$</td>
<td>$x_{2,n+1}$</td>
<td>$x_2$</td>
</tr>
<tr>
<td>⋮</td>
<td>⋮</td>
<td>⋯</td>
<td>⋮</td>
<td>⋮</td>
<td>⋮</td>
</tr>
<tr>
<td>$x_{n1}$</td>
<td>$x_{n2}$</td>
<td>⋯</td>
<td>0</td>
<td>$x_{n,n+1}$</td>
<td>$x_n$</td>
</tr>
</tbody>
</table>

- **End-user loans**: $y_1$, $y_2$, ⋯, $y_n$
- **Total assets**: $a_1$, $a_2$, ⋯, $a_n$
Initial Situation

- Conventional banks
- Shadow banking system
- Long-only sector

Household borrowers

Diagram showing the relationships between conventional banks, shadow banking system, and long-only sector.
Example with Two Banks

Conventional bank

Shadow banking system

$y_1$

$e_1$

$x_1$

$e_2$

$x_1$

$x_2$
Fall in $\rho$

Conventional bank

Shadow banking system

$y_1$  
$e_1$  
$x_1$

$e_2$  
$x_1$  
$x_2$
Originate and Distribute

Conventional bank

Shadow banking system
Initial Situation

<table>
<thead>
<tr>
<th>conventional banks</th>
<th>shadow banking system</th>
<th>long-only sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>conventional banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shadow banking system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>household borrowers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Impact of Great Moderation

Red indicates expanding items
“Inflating Balloon” View of the Subprime Crisis

- Great Moderation increases the marked-to-market value of liabilities
- Shadow banking system is prime beneficiary of increased marked-to-market equity
- Shadow banking system expands its balance sheet due to greater lending capacity
- Shadow banking system is an *inflating balloon* looking for assets to fill up its expanding balance sheets
- Demand for extra assets entails scouring for borrowers - even sub-prime ones
Feedback

- Two types of borrowers:
  - prime: constant prob. $p$ of loss
  - sub-prime: prob. $q$ of loss that depends on house prices.
  - rising house prices reduces (i) probability of default (ii) loss given default

- House price $v$ is increasing in $\sum_i \bar{y}_i$
  - Credit constrained households buy their homes from landlords
  - Landlords submit passive supply curve

- Probability of default $q$ is declining in $v$. 
• Two types of banks
  – Conventional bank (savings institutions, credit unions) holds only end-user loans to prime household borrowers, and face probability of loss of $p$.
  – “Shadow banking system” of institutions in the securitization chain - investment banks, GSEs, securitization vehicles run by commercial banks, etc.

• The pool of prime borrowers are already borrowing from the conventional banking system.

• But the pool of sub-prime borrowers are credit constrained, and do not have access to mortgage financing.
Feedback and Credit Cycles

Credit risk declines with total credit.

Total credit decreases with $q$.

$$\sum_i y_i$$
Housing Boom

\[ q = 0 \sum_{i} \bar{y}_i \]
Housing Crash

![Graph showing the impact of a house price shock on the housing market, indicating a shift from an initial point to a new point, illustrating the concept of a housing crash.](image-url)
Texas 1984 - 1996

*4-quarter moving average.
Source: Mortgage Bankers Association. OFHEO.
California 1991 - 2000

Source: Mortgage Bankers Association. OFHEO.

* 4-quarter moving average.
Massachusetts 1990 - 1998

Massachusetts:
- Home Prices (left)
- Foreclosure Rate* (right)

* 4-quarter moving average.

Source: Mortgage Bankers Association. OFHEO.
Where are we now?

Foreclosure Rate Indexed to 100 at Start of Housing Bust:
- US Current Episode
- California
- Massachusetts
- Texas

Source: Mortgage Bankers Association.