Securitisation and Financial Stability

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Some History

Some History

US Home Mortgage Holdings
Market versus Bank Finance

US Home Mortgage holdings

- Market-based
- Bank-based

Securitisation and Financial Stability
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”
Domino 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, there has (so far) been no major bank failure. But crisis has been potent.
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.

Hot potato stays in the financial system, and is not passed to final investor.

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

The banking system is the greatest fool.

Securitisation and Financial Stability
### 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>
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<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>1,368</td>
<td>100%</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?
\textbf{Pricing Assets in a Financial System}

Many assets (e.g. loans) are claims against other parties in the financial system.

Balance sheet strength, spreads, asset prices fluctuate together.

- 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 . . .
Stylized Financial System

end-user borrowers \[\rightarrow\] loans \[\rightarrow\] financial intermediaries \[\leftarrow\] equity \[\leftarrow\] debt claims

financial intermediaries

outside claim 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
Framework

$n + 1$ entities in financial system

- $n$ leveraged institutions (“banks”)
- outside claim holders (indexed by $n + 1$)

Balance sheet of bank $i \in \{1, \cdots, n\}$ in face values

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{y}_i$</td>
<td>$\bar{e}_i$</td>
</tr>
<tr>
<td>$\sum_{j=1}^{n} \bar{x}<em>j \pi</em>{ji}$</td>
<td>$\bar{x}_i$</td>
</tr>
</tbody>
</table>

$\bar{y}_i$ is face value of loans to end-users such as firms and households.
\( \bar{x}_i \) is the face value of bank \( i \)'s debt

\( \pi_{ji} \) is the proportion of bank \( j \)'s debt held by \( i \).

\( \bar{e}_i \) is the book value of bank \( i \)'s equity

The balance sheet identity in terms of face values:

\[
\bar{y}_i + \sum_{j=1}^{n} \bar{x}_j \pi_{ji} = \bar{x}_i + \bar{e}_i
\]
# Claims Matrix

<table>
<thead>
<tr>
<th></th>
<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>bank 1</td>
<td>0</td>
<td>$\bar{x}_{12}$</td>
<td>⋮</td>
<td>$\bar{x}_{1n}$</td>
<td>$\bar{x}_{1,n+1}$</td>
<td>$\bar{x}_1$</td>
</tr>
<tr>
<td>bank 2</td>
<td>$\bar{x}_{21}$</td>
<td>0</td>
<td>⋮</td>
<td>$\bar{x}_{2n}$</td>
<td>$\bar{x}_{2,n+1}$</td>
<td>$\bar{x}_2$</td>
</tr>
<tr>
<td>⋮</td>
<td>⋮</td>
<td>⋮</td>
<td>⋮</td>
<td>⋮</td>
<td>⋮</td>
<td>⋮</td>
</tr>
<tr>
<td>bank $n$</td>
<td>$\bar{x}_{n1}$</td>
<td>$\bar{x}_{n2}$</td>
<td>⋮</td>
<td>0</td>
<td>$\bar{x}_{n,n+1}$</td>
<td>$\bar{x}_n$</td>
</tr>
<tr>
<td>end-user loans</td>
<td>$\bar{y}_1$</td>
<td>$\bar{y}_2$</td>
<td>⋮</td>
<td>$\bar{y}_n$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total assets</td>
<td>$\bar{a}_1$</td>
<td>$\bar{a}_2$</td>
<td>⋮</td>
<td>$\bar{a}_n$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 $\bar{y}_i$.

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 $Y$.
\[ w_i(Y) \equiv \bar{y}_i \Pr(Z_{ij} \geq 0|Y) \]
\[ = \bar{y}_i \Pr(Y \sqrt{\rho} + X_{ij} \sqrt{1 - \rho} \geq \Phi^{-1}(p_i)) \]
\[ = \bar{y}_i \Phi\left(\frac{Y \sqrt{\rho} - \Phi^{-1}(p_i)}{\sqrt{1 - \rho}}\right) \]

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

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

Change in \( p_i \) implies **first degree** stochastic dominance shift in density.

Change in \( \rho \) implies **second degree** stochastic dominance shift in density.
Repayment density: $\bar{y} = 1, \rho = 0.1$
Realized Values

Use the hat notation “^” to denote realized values at date 1.

- \( \hat{y}_i \) is the realized repayment on bank \( i \)'s loans to end-users
- \( \hat{x}_i \) is the realized repayment by bank \( i \) and so on.
- All debt is of equal seniority. If \( \hat{x}_i < \bar{x}_i \), bank \( j \) receives share \( \pi_{ij} \) of \( \hat{x}_{ij} \).

Regularity condition. Entity \( n + 1 \) holds a piece of every bank’s debt: \( \pi_{i,n+1} > 0 \) for all \( i \). (This regularity condition is stronger than necessary, but will do for now)
Realized Values

\[ \hat{x}_i \]

\[ \bar{x}_i \]

Securitisation and Financial Stability
System

Realized values of debt satisfy:

\[
\hat{x}_1 = \min\left( a_1(\hat{x}), \bar{x}_1\right) \\
\hat{x}_2 = \min\left( a_2(\hat{x}), \bar{x}_2\right) \\
\vdots \\
\hat{x}_n = \min\left( a_n(\hat{x}), \bar{x}_n\right)
\]

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 \( F(.) \)
Iterative approach

“Pessimistic” case

\[
\hat{x}^1 = F(0) \\
\hat{x}^{t+1} = F(\hat{x}^t)
\]

Increasing sequence, but bounded above \(\Rightarrow\) convergence. The limit is a fixed point of \(F(.).\) But how many fixed points?
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)
Argument for Uniqueness

Suppose there are distinct solutions $\hat{x}, \hat{x}'$.

By Tarski, $\hat{x} \leq \hat{x}'$ and $\hat{x}_i < \hat{x}'_i$ for some $i$.

Asset value of entity $n + 1$ (from regularity condition) is strictly higher under $\hat{x}'$ than under $\hat{x}$.

Since equity values are non-decreasing in asset values,
(i) equity value of $n + 1$ under $\hat{x}'$ is strictly higher than under $\hat{x}$
(ii) equity value of all others are no lower under $\hat{x}'$

Equity value of the system under $\hat{x}$ is strictly lower than under $\hat{x}'$

But equity value of the system is total value of fundamental assets, $\sum_i \hat{y}_i$

Contradiction.
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 $j$. If there is a path from $j$ to $i$ through debt holdings, then $\hat{x}_i$ is strictly increasing in $\hat{y}_j$.

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

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

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

Lemma 2. For each bank $i$, the realized value of its assets $\hat{a}_i$ is a well-defined, increasing function of $Y$. 
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 $\delta_i = 1 - \frac{1}{\lambda_i}$

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

$$= \delta_i y_i + \begin{bmatrix} x_1 & \cdots & x_n \end{bmatrix} \begin{bmatrix} \delta_i \pi_{1i} \\ \vdots \\ \delta_i \pi_{ni} \end{bmatrix} \tag{3}$$

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

$$\Delta = \begin{bmatrix} \delta_1 & \cdots \\ \vdots \\ \delta_n \end{bmatrix}$$
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

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

$$\Pr (\hat{a}_i < \bar{a}_i - V_i) \leq 1 - c$$

![Graph showing probability density over $i$'s realized assets with $1-c$, $V_i$, and $\bar{a}_i$ labeled.](image)
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 $1 - c$.

- Concept of value at risk has been adopted widely, both by private sector and regulators
  - 1996 Market Risk Amendment of the Basel Accord
  - Basel II regulations

- Important open question: What is the microeconomic foundations of value at risk in terms of contracting problem?

Here, simply recognize the widespread use of the value at risk and investigate the consequences of such actions.
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

Initial profile of debt

\[ x \]

After shock, before adjustment of debt

\[ x' \]

Debt which equates equity with value at risk

\[ x^* \]
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

$$x^* = y \Delta^* \left( I + \Pi \Delta^* + (\Pi \Delta^*)^2 + (\Pi \Delta^*)^3 + \cdots \right)$$  \hspace{1cm} (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”.
Impact of Great Moderation

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”

- Conventional bank assets undergo second-degree stochastic dominance shift

- Shadow banking system assets undergo first-degree stochastic dominance shift
Credit Availability for End-Users

<table>
<thead>
<tr>
<th></th>
<th>bank 1</th>
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</tr>
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<tr>
<td>bank 1</td>
<td>0</td>
<td>$x_{12}$</td>
<td>...</td>
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<td>...</td>
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<td>...</td>
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<td>...</td>
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<tr>
<td>bank $n$</td>
<td>$x_{n1}$</td>
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<td>0</td>
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end-user loans

<table>
<thead>
<tr>
<th></th>
<th>$y_1$</th>
<th>$y_2$</th>
<th>...</th>
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</tr>
</thead>
</table>

total assets

<table>
<thead>
<tr>
<th></th>
<th>$a_1$</th>
<th>$a_2$</th>
<th>...</th>
<th>$a_n$</th>
</tr>
</thead>
</table>
Initial Situation

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

Household borrowers
Example with Two Banks

Conventional bank

Shadow banking system bank

Securitisation and Financial Stability
Fall in $\rho$

Conventional bank

Shadow banking system bank

$y_1$

$x_1$

$e_1$

$e_2$

$x_1$

$x_2$
**Originate and Distribute**

Conventional bank  

<table>
<thead>
<tr>
<th>$y_1$</th>
<th>$x_1$</th>
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</table>

Shadow banking system bank  

<table>
<thead>
<tr>
<th>$y_2$</th>
<th>$e_2$</th>
</tr>
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</table>

<table>
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Securitisation and Financial Stability
## Initial Situation

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<td>shadow banking system</td>
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</tr>
<tr>
<td>household borrowers</td>
<td></td>
<td></td>
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</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 $q$.

$\sum_i \bar{y}_i$
Housing Boom

$\sum_i y_i$
Housing Crash

\[
\sum_{i} y_i
\]

new point

initial point

house price shock
Texas 1984 - 1996

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

* 4-quarter moving average.

Source: Mortgage Bankers Association, OFHEO.
Massachusetts 1990 - 1998

* 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.