# Securitization and Financial Stability

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"Global Financial Crisis of 2007 – 2009:
Theoretical and Empirical Perspectives"

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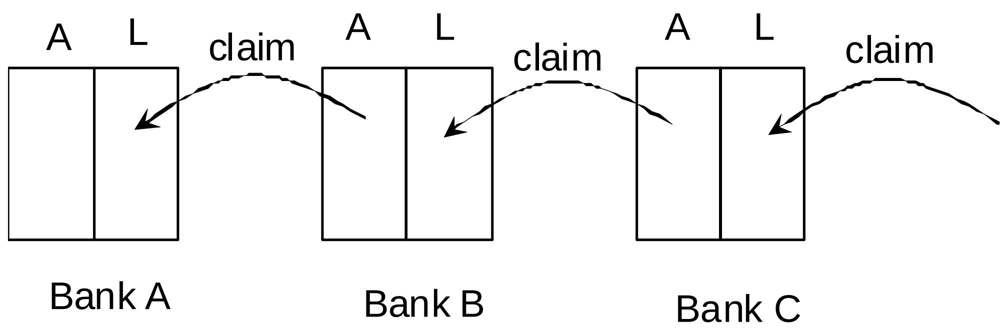
# Two Pieces of Received Wisdom (Old and New)

- Securitization enhances financial stability by dispersing credit risk.
  - Implicitly assumes that instability arises through defaults
  - "Domino Hypothesis"
- Securitization 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, direction of contagion has been reversed.

Bear Stearns, Lehman Brothers and Northern Rock crises were **runs** on the liabilities side.

# Hot Potato Hypothesis

Securitization chain:

Sub-prime borrower $\longrightarrow$ mortgage broker $\longrightarrow$ originating bank $\longrightarrow$ mortgage pools $\longrightarrow$ commercial/investment bank $\longrightarrow$ rating agency $\longrightarrow$ special purpose vehicles (SPV) $\longrightarrow$ 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.

$\Rightarrow$ 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 sheet 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

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

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?

# Main Idea

- Claims of the leveraged sector as a whole (when inter-entity claims are netted out) must be financed by
  - Equity of leveraged institutions
  - Borrowing from outside the leveraged sector
- Securitization enables tapping of new outside creditors
  - Domestic pension funds, insurance companies, mutual funds
  - Foreign central banks
- Decline of credit risk implies combination of
  - Greater capacity to bear risk (lower value at risk per dollar of assets)
  - Increased marked to market equity

## "Expanding Balloon" View of Subprime Crisis

- The result is an expanding balloon that searches for new assets.
- Once all prime borrowers have mortgages but still the ballon needs to expand, lending standards must be lowered.
- Subprime borrowers receive credit.

# 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 . . .

# Modeling Strategy

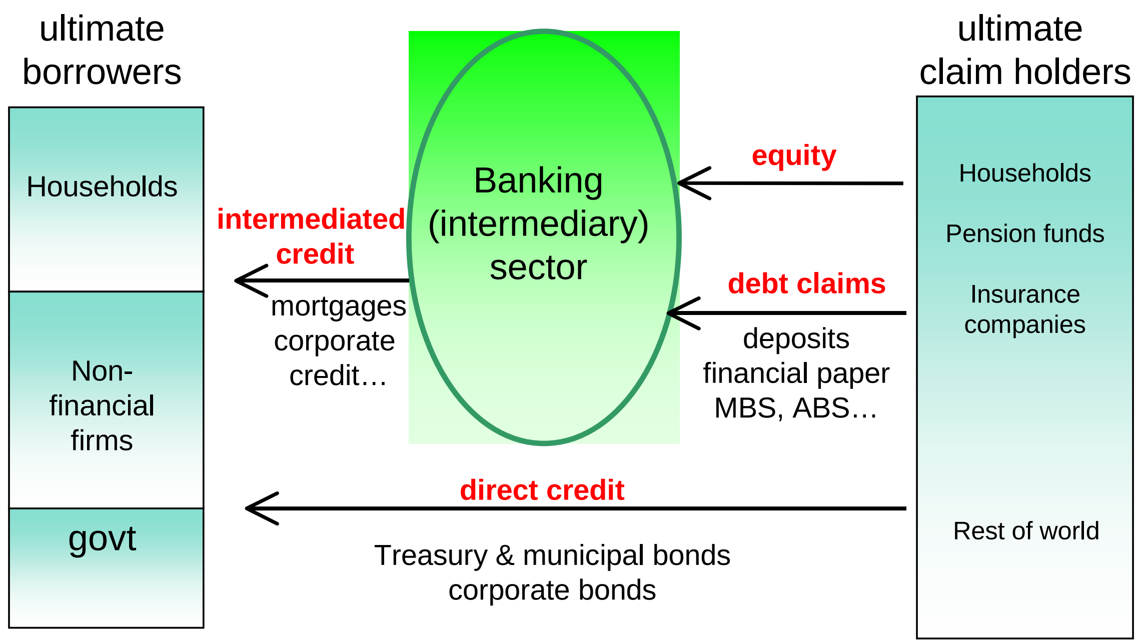
Financial system is a network of interlinked balance sheets

- **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

# Stylised Financial System



# 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

| Assets | Liabilities |
|---|---|
| $\bar{y}_i$ | $\bar{e}_i$ |
| $\sum_{j=1}^{n} \bar{x}_j \pi_{ji}$ | $\bar{x}_i$ |

$\bar{y}_i$ 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

$$
\begin{array}{r|cccc|c|c}
 & \text{bank } 1 & \text{bank } 2 & \cdots & \text{bank } n & \text{outside} & \text{debt} \\
\hline
\text{bank } 1 & 0 & \bar{x}_{12} & \cdots & \bar{x}_{1n} & \bar{x}_{1,n+1} & \bar{x}_1 \\
\text{bank } 2 & \bar{x}_{21} & 0 & & \bar{x}_{2n} & \bar{x}_{2,n+1} & \bar{x}_2 \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \\
\text{bank } n & \bar{x}_{n1} & \bar{x}_{n2} & \cdots & 0 & \bar{x}_{n,n+1} & \bar{x}_n \\
\hline
\text{end-user loans} & \bar{y}_1 & \bar{y}_2 & \cdots & \bar{y}_n & & \\
\cline{2-5}
 & & & & & & \\
\text{total assets} & \bar{a}_1 & \bar{a}_2 & & \bar{a}_n & &
\end{array}
$$

# 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 $p_i$

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

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 determinstic function of $Y$

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

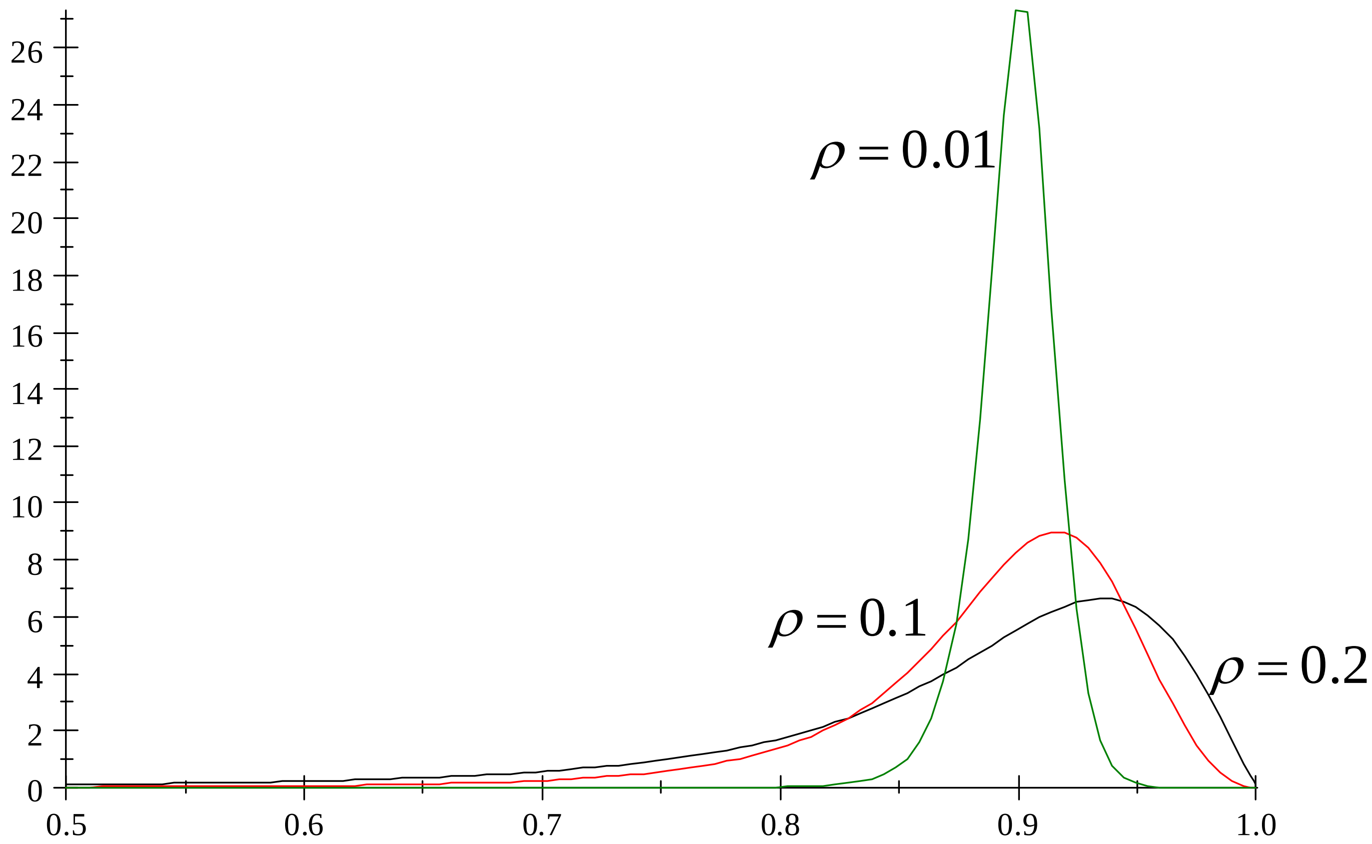
The c.d.f. over the repayment on bank $i$'s loan book is

$$
\begin{aligned}
F_i(z) &= \Pr(w_i(Y) \leq z) \\
&= \Pr\left(Y \leq w_i^{-1}(z)\right) \\
&= \Phi\left(\frac{\Phi^{-1}(p_i) + \sqrt{1-\rho}\,\Phi^{-1}\left(\frac{z}{\bar{y}_i}\right)}{\sqrt{\rho}}\right) \qquad (1)
\end{aligned}
$$

$$F_i\left(z\right) = \Phi\left(\frac{\Phi^{-1}(p_i)+\sqrt{1-\rho}\,\Phi^{-1}\left(\frac{z}{\bar{y}_i}\right)}{\sqrt{\rho}}\right) \tag{2}$$

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: $\bar{y} = 1,\ p = 0.1$

## Realized Values

Use the hat notation "ˆ" to denote realized values at date $1$.

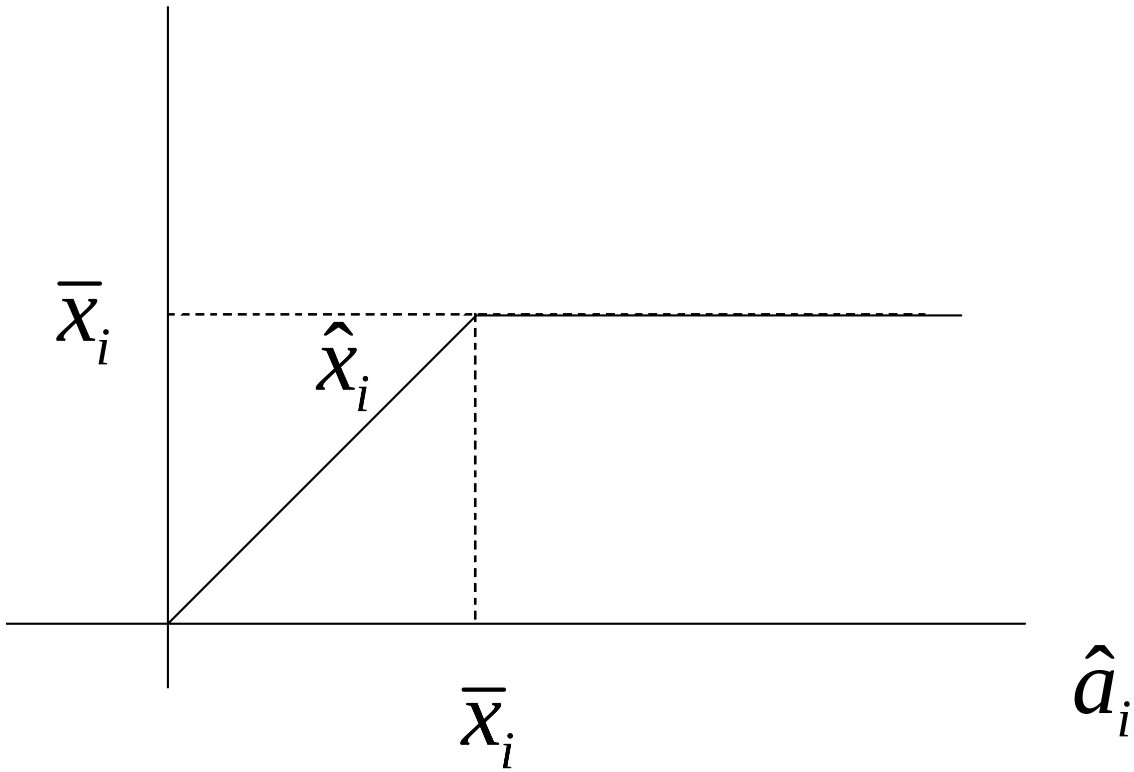
- $\hat{y}_i$ is the realized repayment on bank $i$'s loans to end-users

- $\hat{x}_i$ 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



# System

Realized values of debt satisfy:

$$\begin{aligned}
\hat{x}_1 &= \min\left(a_1\left(\hat{x}\right), \bar{x}_1\right) \\
\hat{x}_2 &= \min\left(a_2\left(\hat{x}\right), \bar{x}_2\right) \\
&\vdots \\
\hat{x}_n &= \min\left(a_n\left(\hat{x}\right), \bar{x}_n\right)
\end{aligned}$$

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

# Iterative approach

"Pessimistic" case

$$\begin{aligned}\hat{x}^1 &= F(0)\\ \hat{x}^{t+1} &= F\left(\hat{x}^t\right)\end{aligned}$$

$$0 \lneqq \hat{x}^1 \lneqq \hat{x}^2 \lneqq \hat{x}^3 \lneqq \cdots$$

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 $\hat{x}_i\left(\hat{y}\right)$ the realized value of $i$'s debt given realizations $\hat{y} = \left(\hat{y}_1, \cdots, \hat{y}_n\right)$ 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 determinstic functions of $Y$. Hence,

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

**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.

Balance sheet identity of bank $i$

$$y_i + \sum_j x_j \pi_{ji} = e_i + x_i$$

| | bank 1 | bank 2 | $\cdots$ | bank $n$ | outside | debt |
|---|---|---|---|---|---|---|
| bank 1 | $0$ | $x_{12}$ | $\cdots$ | $x_{1n}$ | $x_{1,n+1}$ | $x_1$ |
| bank 2 | $x_{21}$ | $0$ | | $x_{2n}$ | $x_{2,n+1}$ | $x_2$ |
| $\vdots$ | $\vdots$ | $\vdots$ | $\ddots$ | $\vdots$ | $\vdots$ | |
| bank $n$ | $x_{n1}$ | $x_{n2}$ | $\cdots$ | $0$ | $x_{n,n+1}$ | $x_n$ |
| end-user loans | $y_1$ | $y_2$ | $\cdots$ | $y_n$ | | |
| total assets | $a_1$ | $a_2$ | | $a_n$ | | |

Write $\Pi$ as $n \times n$ matrix where the $(i, j)$th entry is $\pi_{ij}$.

$$[x_1, \cdots, x_n] = [x_1, \cdots, x_n] \begin{bmatrix} & & \\ & \Pi & \\ & & \end{bmatrix} + [y_1, \cdots, y_n] - [e_1, \cdots, e_n]$$

$$x = x\Pi + y - e$$

Recursive nature of debt in a financial system: each bank's debt value is increasing in the debt value of other banks.

$$y = e + x\,(I - \Pi)$$

Leverage of bank $i$

$$\lambda_i \equiv \frac{a_i}{e_i}$$

$$y = e + e\,(\Lambda - I)\,(I - \Pi)$$

Define the vector $z$ as

$$z \equiv (I - \Pi)\,u \quad \text{where} \quad u \equiv \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}$$

Aggregate lending is

$$\sum_{i=1}^{n} y_i = \sum_{i=1}^{n} e_i + \sum_{i=1}^{n} e_i z_i\,(\lambda_i - 1)$$

## Securitization and Credit Contraction

$$\sum_{i=1}^{n} y_i = \sum_{i=1}^{n} e_i \left(1 + z_i \left(\lambda_i - 1\right)\right)$$

High levels of securitization (high values of $\{z_i\}$) amplify the credit contraction due to

- credit losses (decreases in $\{e_i\}$)
- deleveraging (decreases in $\{\lambda_i\}$)

## Leverage of Financial System

Given degree of leverage for financial system is consistent with (almost) any leverage level for individual banks.

Financial system in face values is array $(\bar{e}, \bar{y}, \bar{x}, \Pi)$ that satisfies the balance sheet identity:

$$\bar{x} = \bar{x}\Pi + \bar{y} - \bar{e}$$

For positive constant $\phi$, construct financial system $(\bar{e}', \bar{y}', \bar{x}', \Pi')$ where $\bar{e}' = \bar{e}$, $\bar{x}' = \phi\bar{x}$ and $\Pi'$ is any matrix of interbank claims whose $i$th row sum to $1 - z_i/\phi$.

Finally, $\bar{y}'$ is defined as

$$\bar{y}' = \bar{e}' + \bar{x}'\left(I - \Pi'\right)$$

Aggregate lending is

$$\begin{aligned}
\sum_{i=1}^{n} \bar{y}_i' &= \bar{e}'u + \bar{x}'\left(I - \Pi'\right)u \\
&= \sum_{i=1}^{n} \bar{e}_i' + \sum_{i=1}^{n} \bar{x}_i' \frac{z_i}{\phi} \\
&= \sum_{i=1}^{n} \bar{e}_i + \sum_{i=1}^{n} \bar{x}_i z_i \\
&= \sum_{i=1}^{n} \bar{y}_i
\end{aligned}$$

Aggregate notional leverage in both financial systems is $\sum_{i=1}^{n} \bar{y}_i / \sum_{i=1}^{n} \bar{e}_i$.

However, by construction, the debt to equity ratio of all individual banks is $\phi$ times larger in the second financial system.

(only restriction on the constant $\phi$ comes from the feature that the $i$th row of $\Pi'$ sums to $1 - z_i/\phi$, implying a lower bound).

The same construction holds for market values, but there is also upper bound for $\phi$. Market value of debt $x_i$ cannot be larger than the market value of assets $a_i$, and the market value of assets is underpinned by the value of fundamental assets $\{y_k\}$.

Leverage of the aggregate banking sector itself is related to the leverage of individual banks in the following way.

$$\begin{aligned} L &= \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} e_i} \\ &= 1 + \frac{\sum_{i=1}^{n} e_i z_i \left(\lambda_i - 1\right)}{\sum_{i=1}^{n} e_i} \end{aligned}$$

**Proposition 1.** For given profile of leverage for individual banks, leverage of financial intermediary sector is increasing in $z$.

# Value at Risk

Up to this point, we have just manipulated balance sheet identities.

Decisions of banks follow 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

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

Value at risk $V_i$ is the "approximately" worst case loss that can be suffered by the bank, where "approximately worst case" is defined so that anything worse happens with probability smaller than the benchmark $1 - c$.

(backbone of Basel regulations).

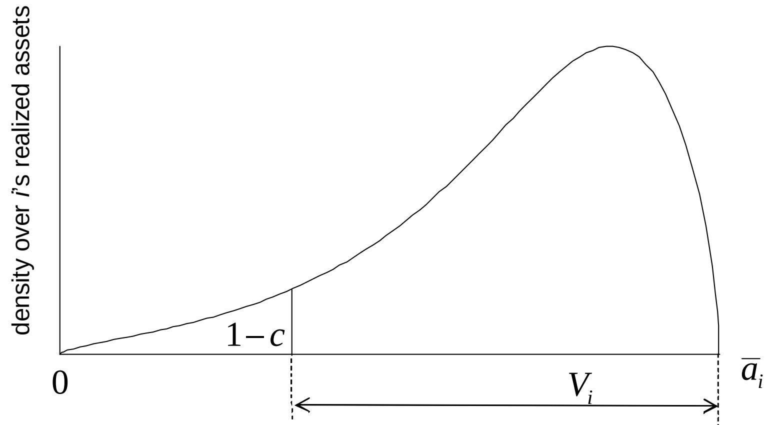
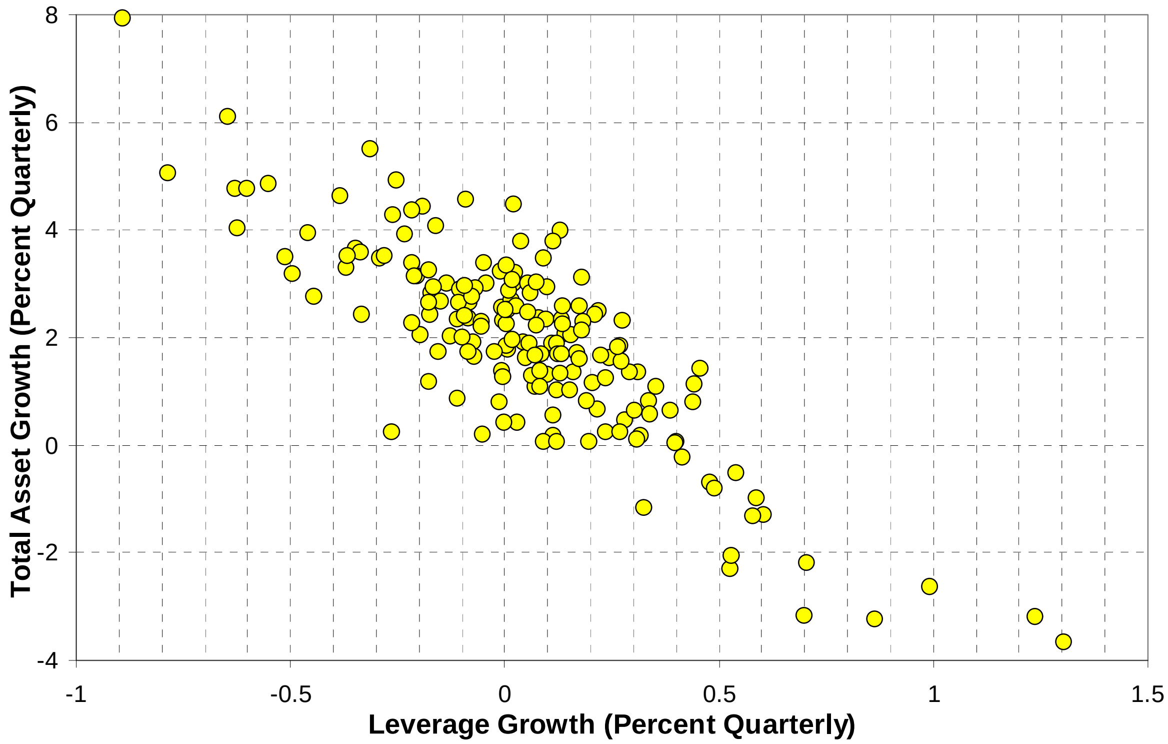



Figure 1: Value at Risk

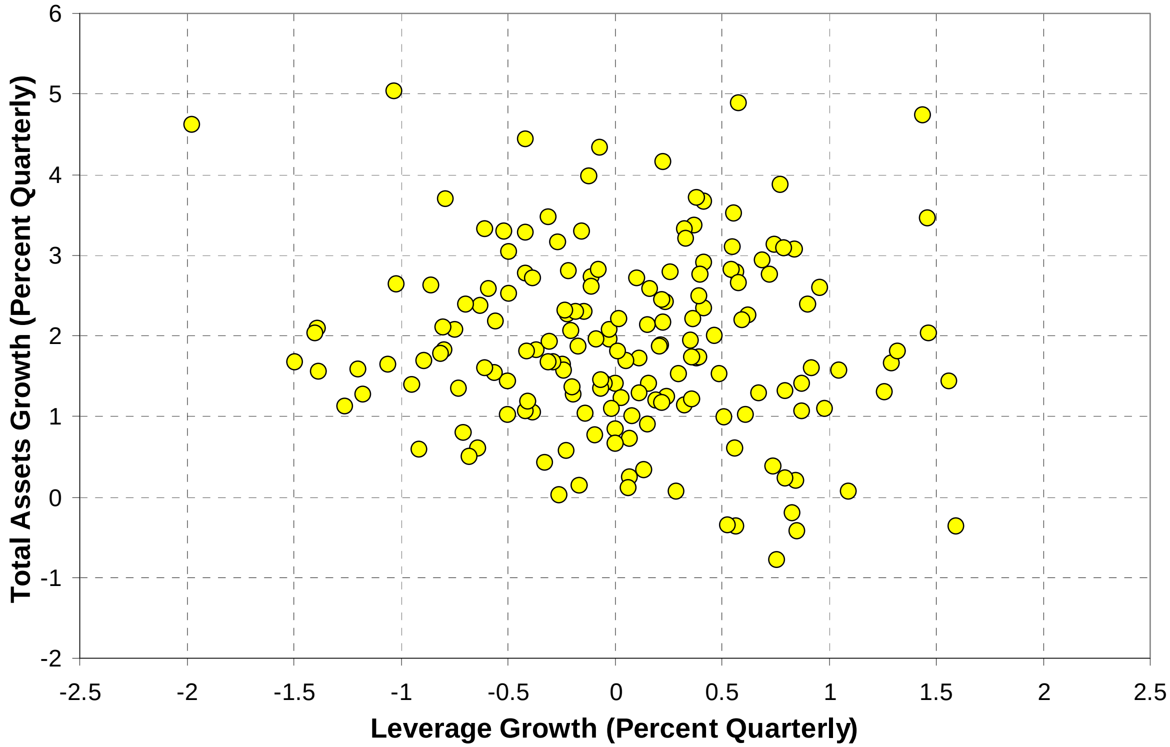
Assume bank $i$ aims to set market equity $e_i$ to its value at risk $V_i$, so that

$$e_i = V_i$$

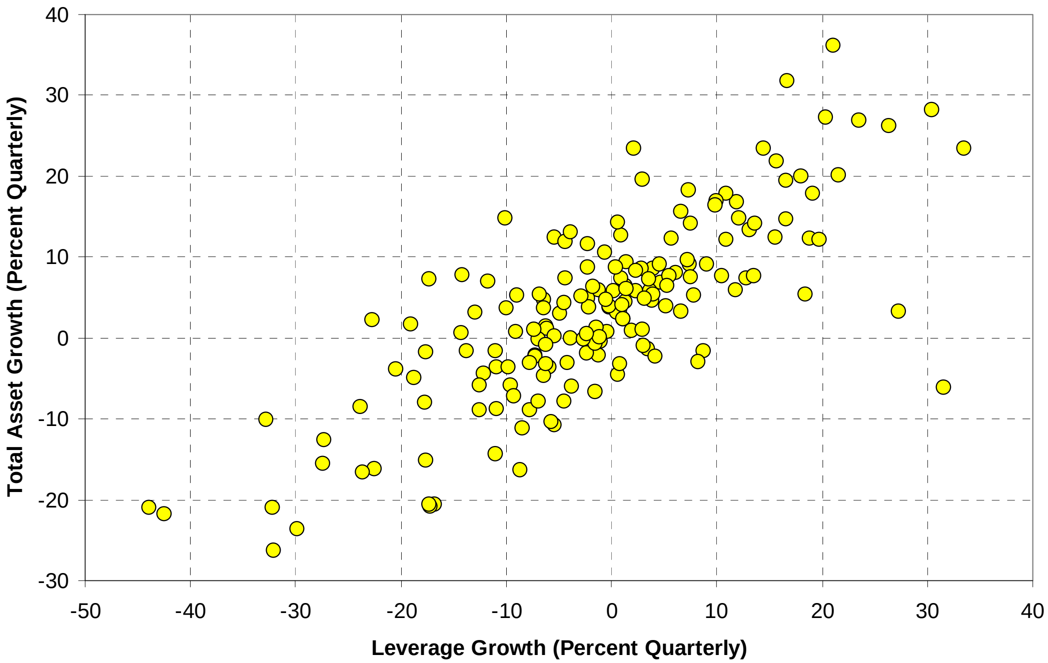
# Balance Sheet Size and Leverage: Households



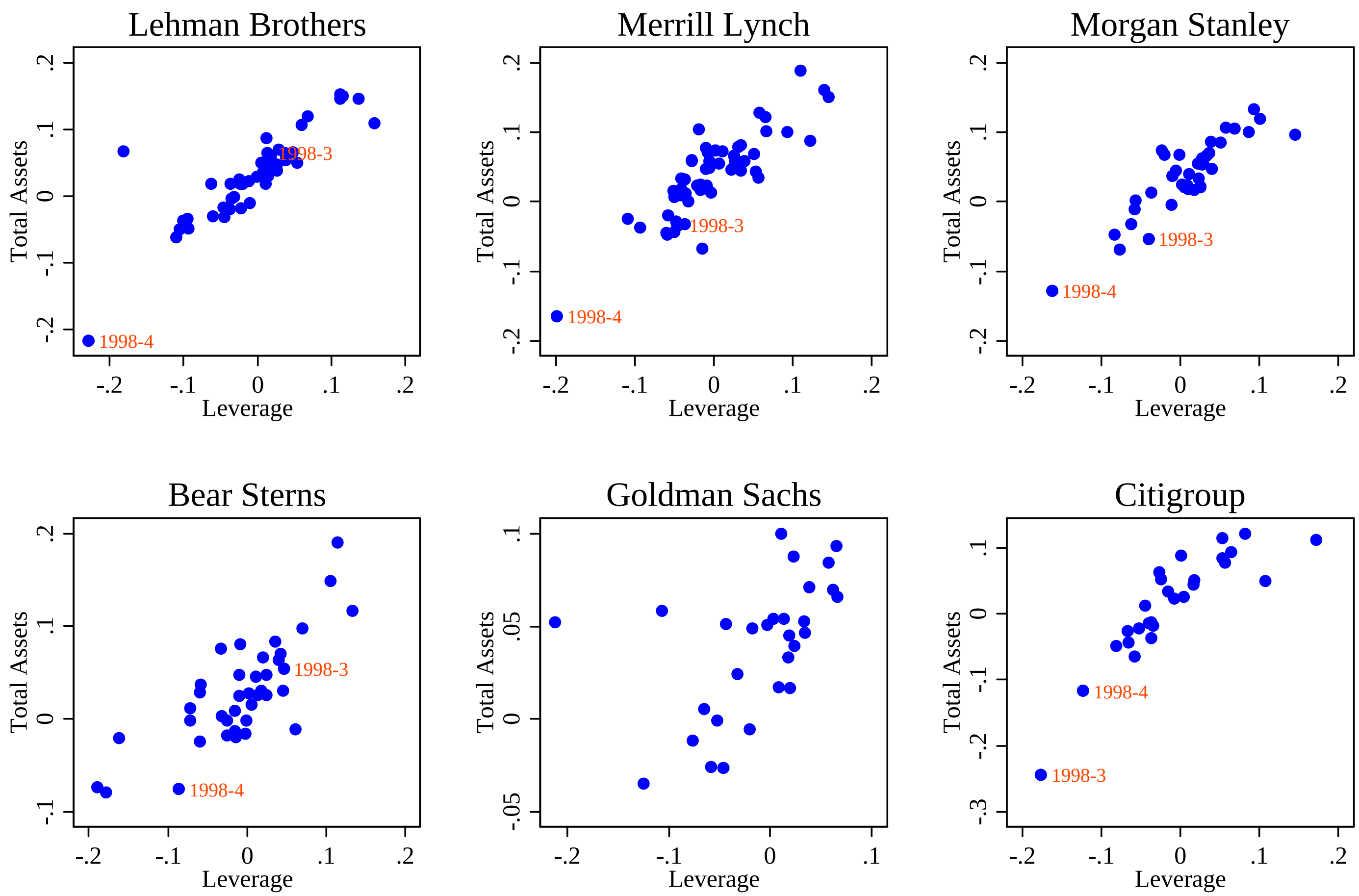
# Non-Financial, Non-Farm Corporations

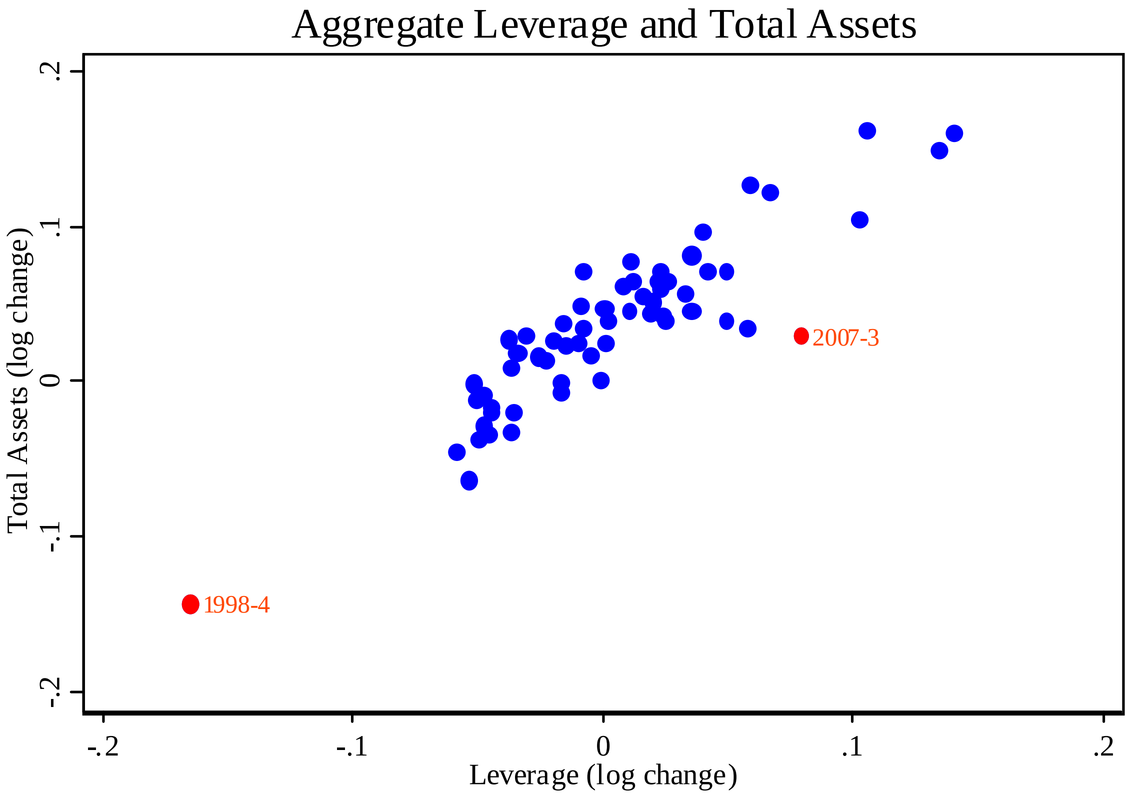


# Security Dealers and Brokers



# Total Assets and Leverage




Aggregate Leverage and Total Assets
Total Assets (log change)
.2
.1
0
-.1
-.2
-.2
-.1
0
.1
.2
Leverage (log change)
2007-3
1998-4

# Explaining Leverage

Equity capital $E$ is set to total value at risk (VaR)

$$E = V \times A$$

Hence, leverage $L$ satisfies:

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

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

Scenario: decline of default probabilities $\{p_i\}$ in the Vasicek one-factor model. For simplicity, let $p_i = p$ for all $i$.

Fall in $p$ implies FDSD shift in repayment density

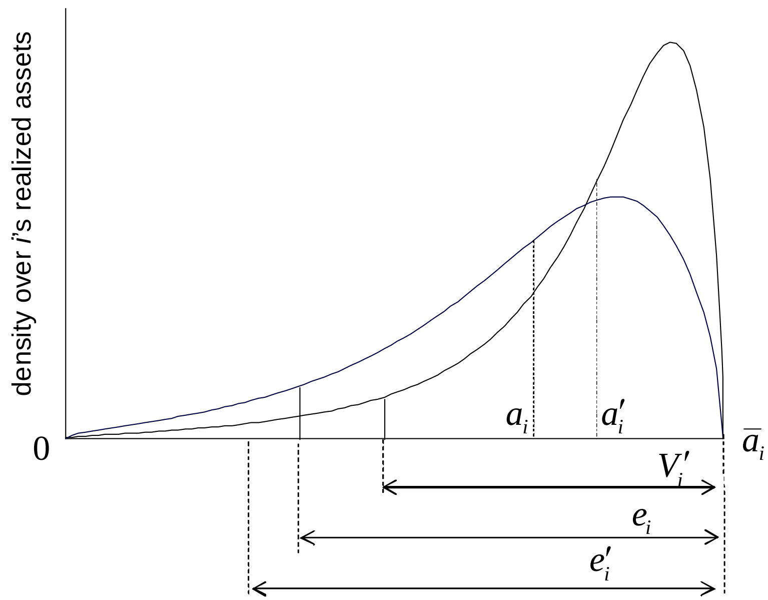



Figure 2: Value at Risk and Leverage

Following the decline in $p$,

$$e'_i > e_i > V'_i$$

**Assumption 1.** When $e'_i > V'_i$ after the decline in $p$, bank $i$ increases the face value of its debt $\bar{x}_i$.

Milgrom and Roberts (1994, theorem 3): fixed point of increasing functions on complete lattices is monotonic.

$$x^*_i \geq x_i \text{ for all } i$$

**Assumption 2.** When banks increase notional debt in response to a fall in $p$, the proportion of funding raised from the outside creditor sector is non-decreasing.

$$(I - \Pi^*)\, u \geq (I - \Pi)\, u$$

**Proposition 2.** When $p$ falls, the value of aggregate lending to end-users increases, both in notional values and in market values.

$$\begin{aligned} \bar{y} &= \bar{e} + \bar{x}\,(I - \Pi) \\ \bar{y}^* &= \bar{e}^* + \bar{x}^*\,(I - \Pi^*) \end{aligned}$$

where $^*$ indicates variables after the change. Face value of equity remains unchanged ($\bar{e}^* = \bar{e}$), so

$$\begin{aligned} (\bar{y}^* - \bar{y})\, u &= (\bar{x}^* - \bar{x})\,(I - \Pi)\, u + \bar{x}^*\,(\Pi - \Pi^*)\, u \\ &> 0 \end{aligned}$$

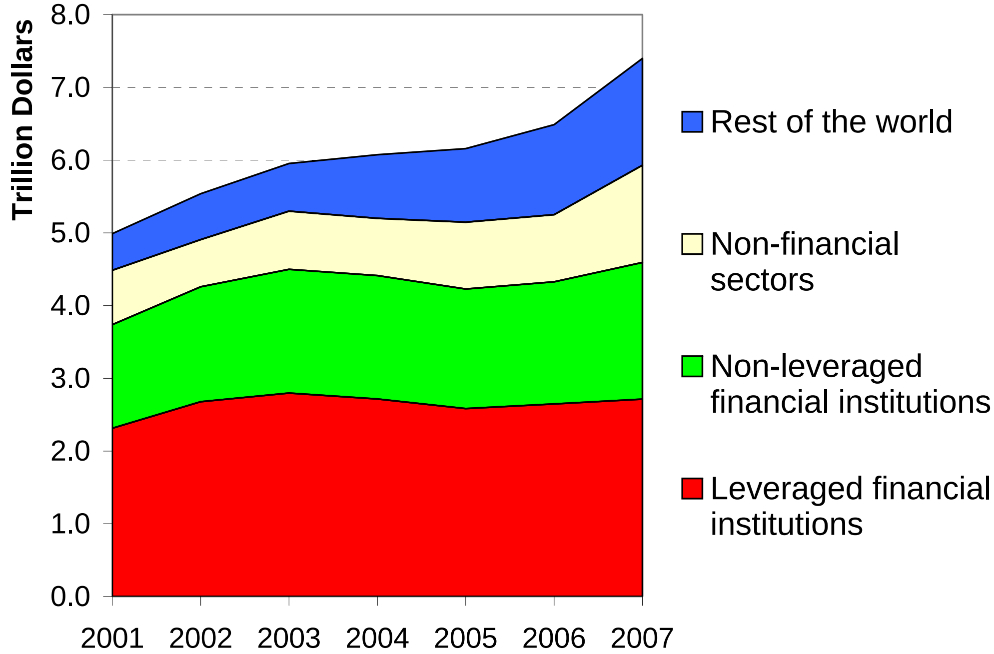
In market values,

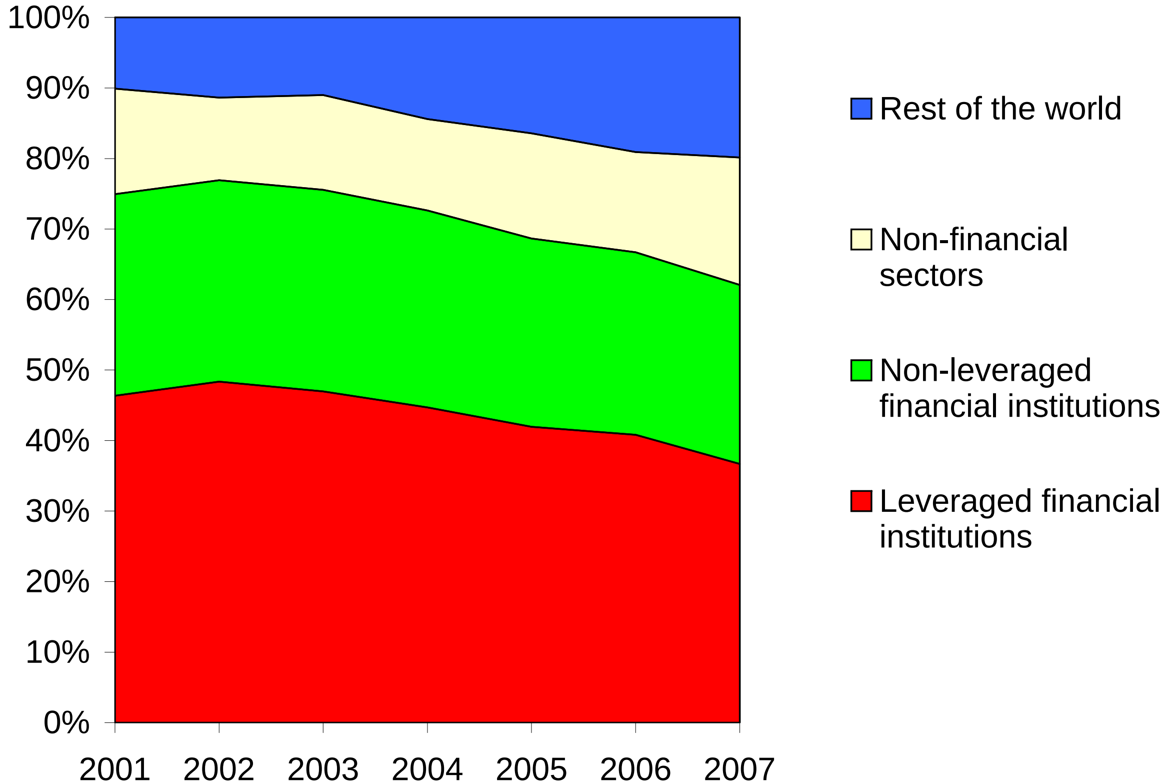
$$
\begin{aligned}
y &= e + x\,(I - \Pi) \\
y^* &= e^* + x^*\,(I - \Pi^*)
\end{aligned}
$$

Hence,

$$
\begin{aligned}
(y^* - y)\,u &= (e^* - e)\,u + (x^* - x)\,(I - \Pi)\,u + x^*\,(\Pi - \Pi^*)\,u \\
&> 0
\end{aligned}
$$

# Holding of US Agency and GSE-Backed Securities




100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2001
2002
2003
2004
2005
2006
2007
Rest of the world
Non-financial sectors
Non-leveraged financial institutions
Leveraged financial institutions

# US Debt Liabilities to Foreigners (by Sector)

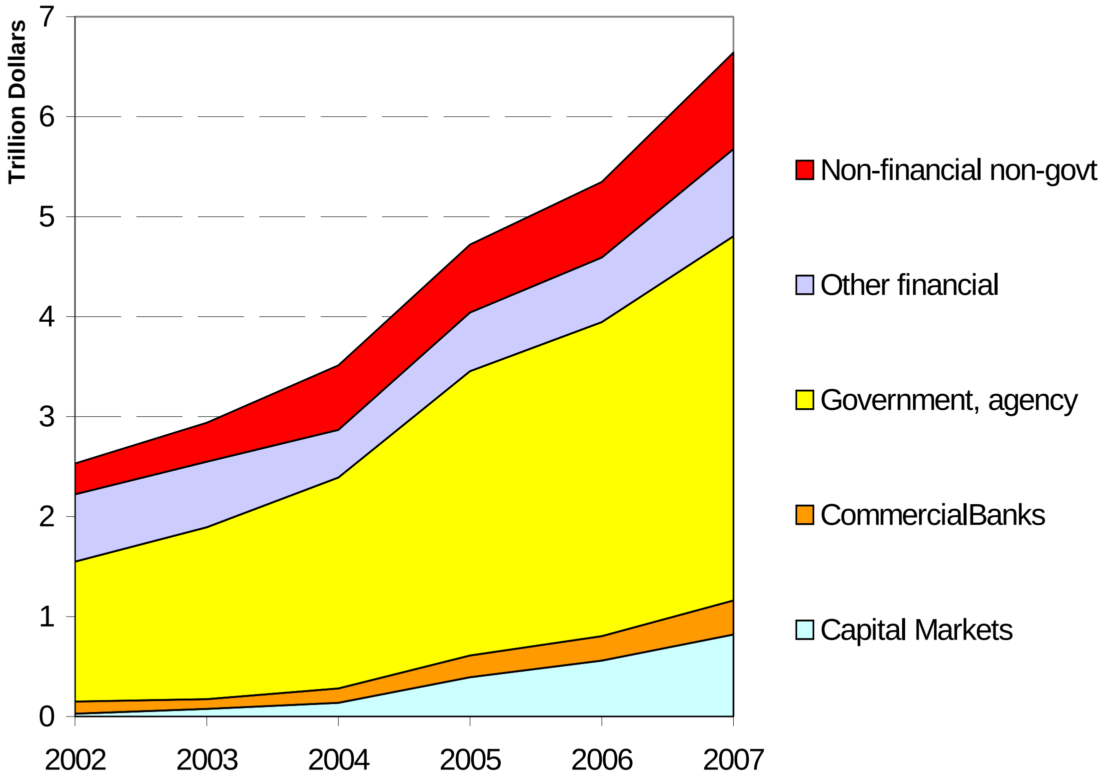

Trillion Dollars
7
6
5
4
3
2
1
0
2002
2003
2004
2005
2006
2007
Non-financial non-govt
Other financial
Government, agency
CommercialBanks
Capital Markets

Figure 3:

# US Debt Liabilities to Foreigners (by Sector)

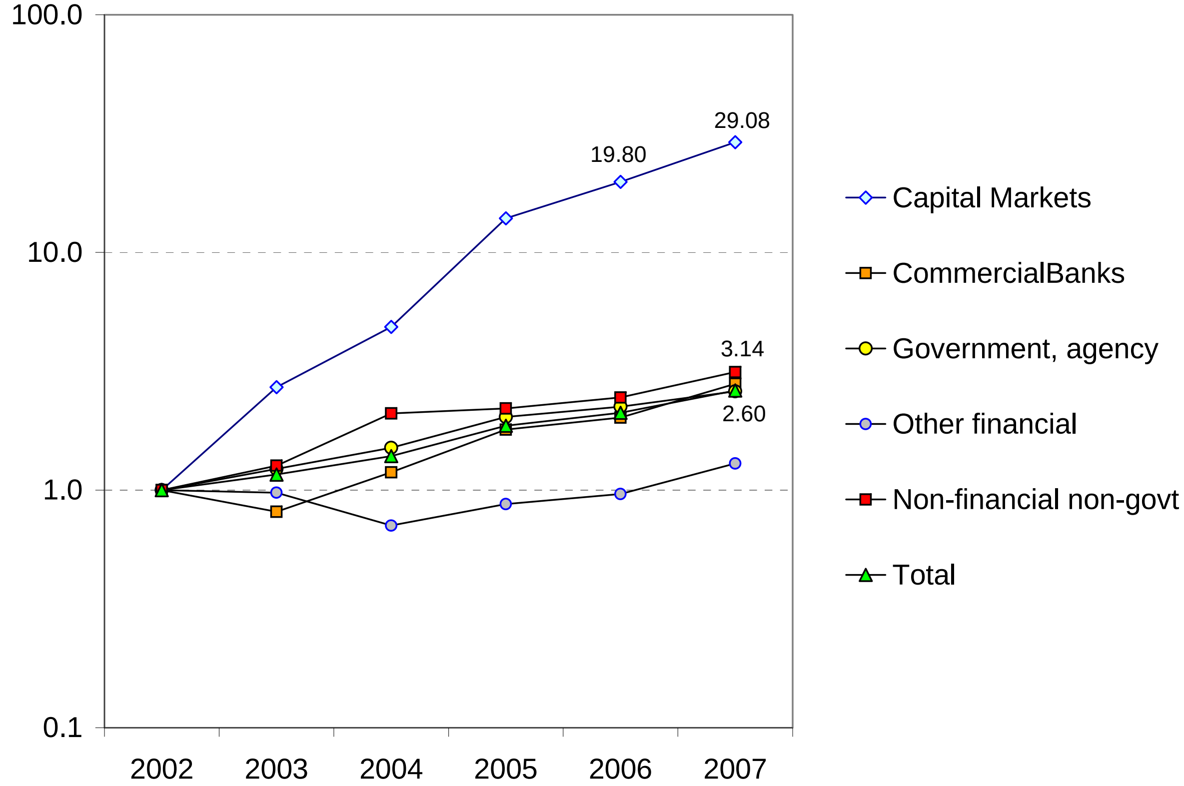
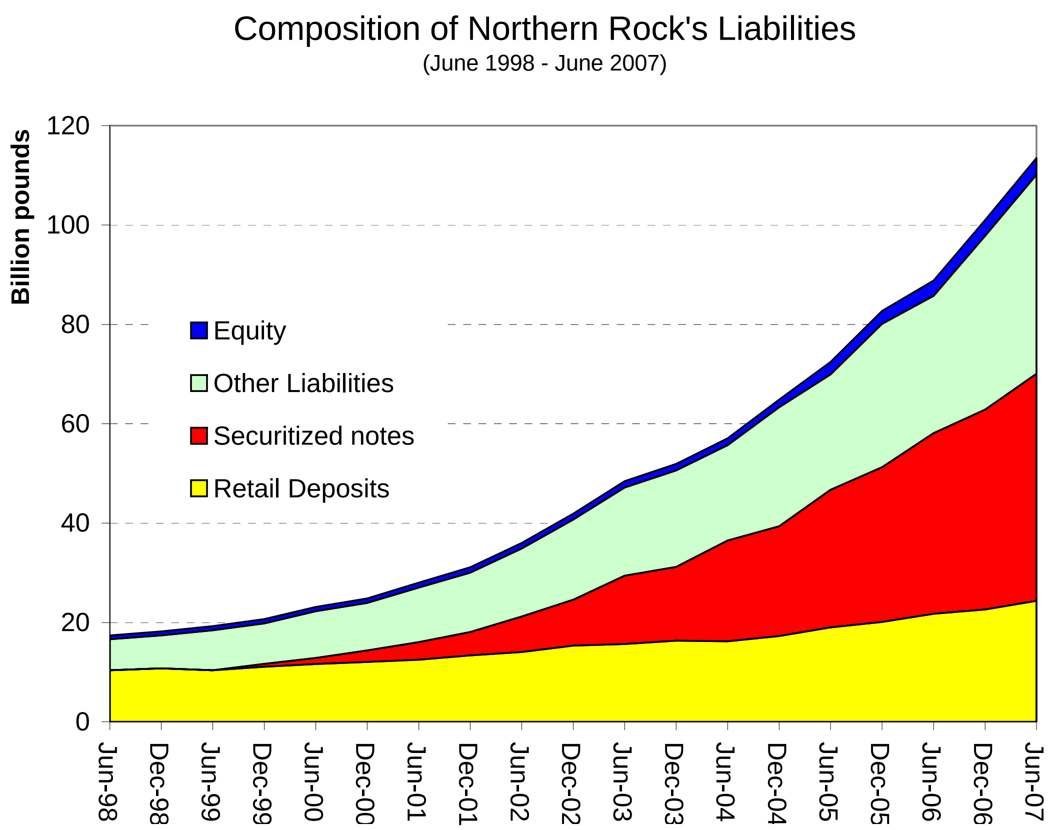

100.0
10.0
1.0
0.1
2002
2003
2004
2005
2006
2007
29.08
19.80
3.14
2.60
Capital Markets
CommercialBanks
Government, agency
Other financial
Non-financial non-govt
Total

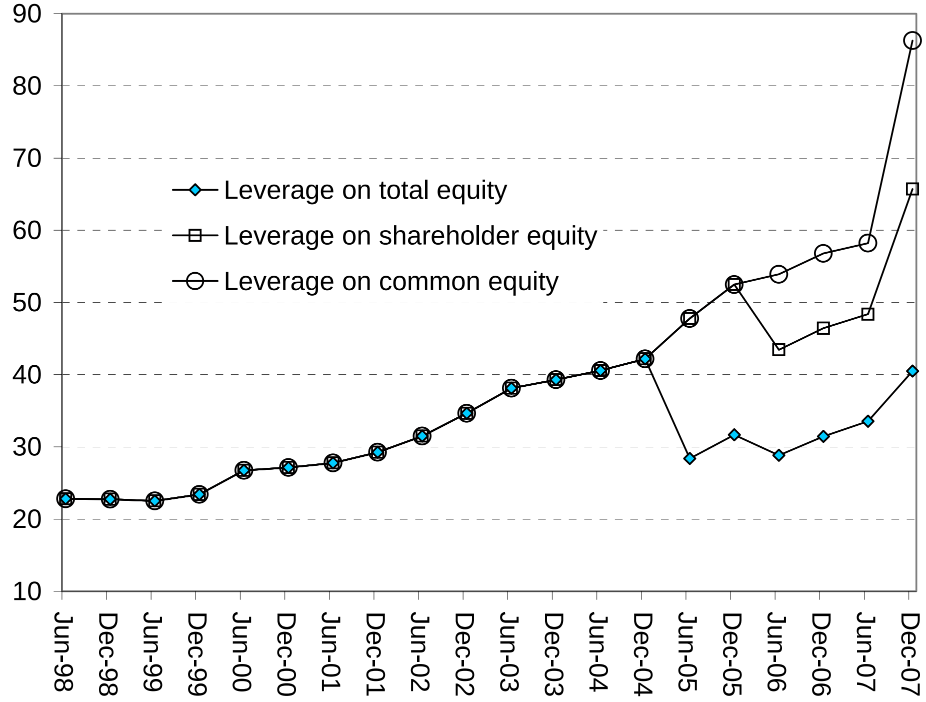
Figure 4:

# Northern Rock



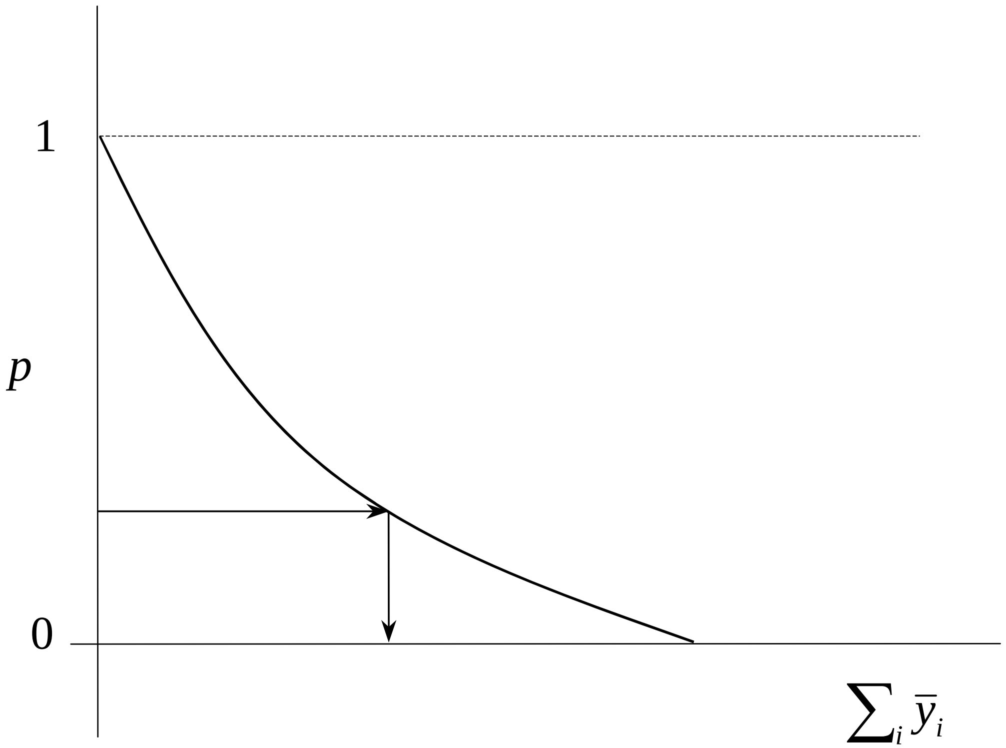
Northern Rock's Leverage

June 1998 - December 2007

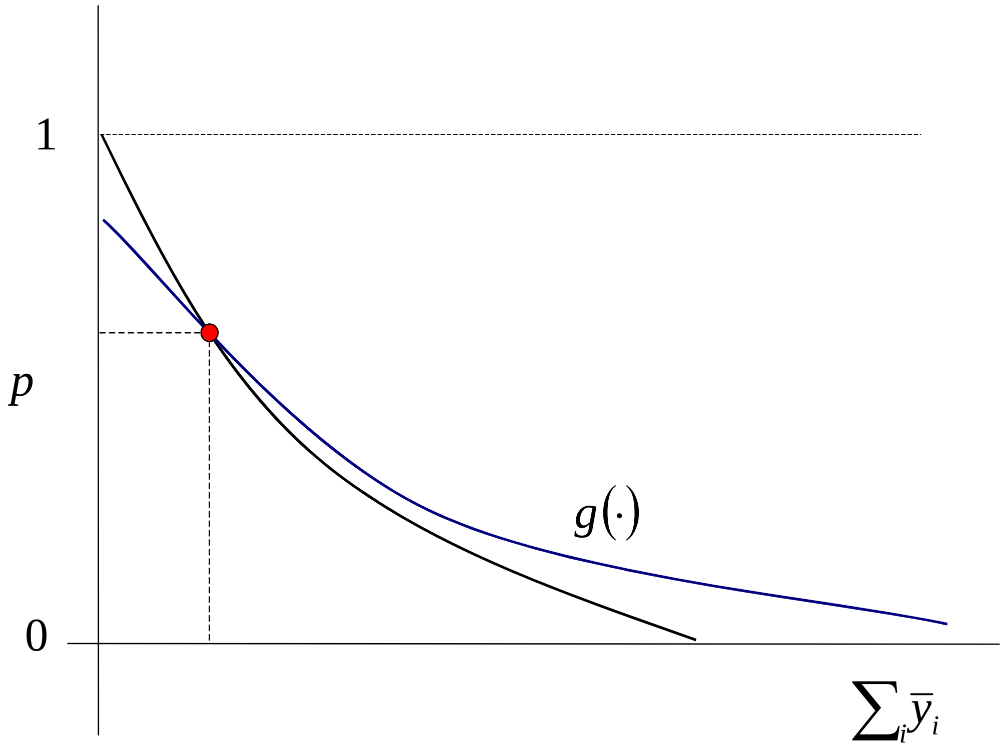


# Lending Boom

Supply of credit curve



Suppose loan supply feeds through to more buoyant aggregate conditions. Function $g$ maps aggregate lending $\sum_i \bar{y}_i$ to the probability of default $p$.



Securitization shifts credit supply curve.