Wholesale Banking and Bank Runs in Macroeconomic Modelling of Financial Crises

Mark Gertler, Nobuhiro Kiyotaki and Andrea Prespitino
NYU, Princeton, Federal Reserve Board
A key feature of the recent crisis is banking crisis

Slow run on shadow banks from Summer 2007, followed by fast run after Lehman failure in Fall 2008

Spreads rose and investments fell

Wholesale funding by financial intermediaries expanded significantly before the crisis

What are the driving forces?

Efficiency gain?

Possibility of run in wholesale funding market?

Why should we care about run?
<table>
<thead>
<tr>
<th>Retail Sector</th>
<th>Private Depository Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money Market Mutual Funds</td>
<td>Mutual Funds</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale Sector</td>
<td><strong>Originate</strong>: Financing Companies</td>
</tr>
<tr>
<td>Real Estate Investment Trusts</td>
<td><strong>Securitize</strong>: Government Sponsored Enterprises</td>
</tr>
<tr>
<td>Security Brokers Dealers</td>
<td></td>
</tr>
<tr>
<td>ABS Issuers</td>
<td></td>
</tr>
<tr>
<td><strong>Hold</strong>: GSE Mortgage Pools</td>
<td>Funding Companies</td>
</tr>
<tr>
<td>Holding Companies</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1: Modes of Financial Intermediation

Figure 2: Wholesale Intermediation
The graph shows the evolution of credit intermediated by the three different sectors. Nominal data from the flow of funds are deflated using the CPI and normalized so that the log of the normalized value of real wholesale intermediation in 1980 is equal to 1. The resulting time series are then multiplied by 100.
Leverage is given by the ratio of total assets over equity. Equity is computed from the flow of funds by subtracting liabilities other than "holding companies equity investment" from total assets. The net position leverage computes assets by netting out long and short positions in REPO and Security Credit.
Figure 5: Short Term Wholesale Funding

The graph shows the logarithm of the real value outstanding. Nominal values from Flow of Funds are deflated using the CPI
Figure 6: Retail short term Funding

The graph shows the logarithm of the real value outstanding. Nominal values from Flow of Funds are deflated using the CPI and normalized so that the log of the normalized value of retail short term funding in 2001 is equal to 100.
We develop a macro model of wholesale and retail banks and households

Wholesale banks are better at making business loans

Banks are better in monitoring other banks than households

Financial innovation: better monitoring of other banks $\rightarrow$ wholesale banks borrow more from retail banks

leverage of each bank $\uparrow\uparrow >$ net leverage of banking sector $\uparrow$

Improve efficiency: larger steady state output and smaller financial accelerator

But wholesale banks are more vulnerable to roll-over risk, or "bank run"
Figure 7: Investment Collapse

Spreads and Investment

Percentage Points

Billions of (2009) Dollars

2003 2004 2005 2006 2007 2008 2009 2010 2011
Basic Model

Capital is either intermediated by banks or held by households

\[ K_t^w + K_t^r + K_t^h = \overline{K} \]

\[ date t \]
\[ K_t^j \text{ capital} \]
\[ F^j(K_t^j) \text{ goods} \]
\[ date t+1 \]
\[ K_t^j \text{ capital} \]
\[ Z_{t+1}K_t^j \text{ output} \]

\[ F^j(K_t^h) = \frac{\alpha^h}{2} (K_t^j)^2 : \text{management cost} \]
\[ \alpha^h > \alpha^r > \alpha^w = 0 \]

Retail bank pays \( f_t^r = F^{r'}(K_t^j) \) fee per unit of capital to households who provide management service
Retail deposit and interbank loan contracts

Short term

Promised rates of returns $\bar{R}_{t+1}$ and $\bar{R}_{bt+1}$ are non-contingent

With run, the return to the creditor is the minimum of the promised return and total realized debtor bank assets per outstanding credit

In Basic Model, bank run is unanticipated
Households maximize

\[
U_t = E_t \left( \sum_{i=0}^{\infty} \beta^i \ln C_{t+i}^h \right)
\]

subject to:

\[
C_t^h + D_t + Q_t K_t^h + F^h(K_t^h)
\]

\[
= Z_t W^h + R_t D_{t-1} + (Z_t + Q_t) K_{t-1}^h + f_t K_t^r - F^r(K_t^r)
\]

\[
\rightarrow
\]

\[
1 = E_t \left( \beta \frac{C_t}{C_{t+1}} \right) R_{t+1}
\]

\[
1 = E_t \left( \beta \frac{C_t}{C_{t+1}} \cdot \frac{Z_{t+1} + Q_{t+1}}{Q_t + F^{h'}(K_t^h)} \right)
\]
Many bankers of type $j = w, r$

Each has an i.i.d. survival probability of $\sigma^j$

Banker consumes wealth upon exit: $c_t^j = n_t^j$

Preferences are linear in "terminal" consumption

$$V_t^j = E_t \left[ \sum_{i=1}^{\infty} \beta^i (\sigma^j)^{i-1}(1 - \sigma^j)c_{t+i}^j \right]$$

Each exiting banker replaced by a new banker with an endowment $w^j = n_t^j$

Net worth $n_t^j$ of surviving bankers

$$n_t^j = (Z_t + Q_t)k_{t-1}^j - R_t d_{t-1}^j - R_{bt} b_{t-1}^j$$
$Z_t$ is realized B/S of Bank j

<table>
<thead>
<tr>
<th>Asset: $(Q_t + f_t)k_t$</th>
<th>Deposit: $d_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interbank loan: $b_t$</td>
<td></td>
</tr>
<tr>
<td>Net worth: $n_t$</td>
<td></td>
</tr>
</tbody>
</table>

Date $t$

Continue: $V_t$

θ[$d_t + n_t + \omega \max(b_t, 0)$]

Bankrupt

Repay $R_{t+1}d_t$ and $R_{bt+1}b_t$
Retain $n_{t+1}$
Exit or continue

Incentive constraint

$\theta[d_t + n_t + \omega \max(b_t, 0)] \leq V_t$
Consider a bank with \( n_t^j = 1 \). The bank chooses \((Q_t + f_t^j)k_t^j\) and \(d_t^j\) to maximize

\[
V_t^j = \beta E_t \left\{ \left( 1 - \sigma^j + \sigma^j \frac{V_{t+1}^j}{n_{t+1}^j} \right) n_{t+1}^j \right\}
\]

\[
= \beta E_t \Omega_{t+1}^j \left[ \left( R_{kt+1}^j - R_{bt+1}^j \right) (Q_t + f_t^j)k_t^j + (R_{bt+1}^j - R_{t+1}^j)d_t^j + R_{bt+1}^j \right]
\]

\[
= \mu_{kt}^j (Q_t + f_t^j)k_t^j + \mu_{bt}^j d_t^j + \nu_{bt}^j, \text{ where } R_{kt+1}^j = \frac{Q_{t+1}^j + Z_{t+1}^j}{Q_t + f_t^j}
\]

subject to

\[
V_t^j \geq \theta \left[ 1 + d_t^j + \omega \text{Max} \left( (Q_t + f_t^j)k_t^j - d_t^j - 1, 0 \right) \right]
\]
Wholesale banks

\[ D_t^w = 0, \text{ if } \omega \mu_{bt}^w < (1 - \omega)\mu_{kt}^w \]

\[ Q_t K_t^w = \phi_t^w N_t^w = N_t^w + B_t \]

\[ \phi_t^w = \frac{\nu_{bt}^w - \theta(1 - \omega)}{\theta \omega - \mu_{kt}^w} \]

Retail banks

\[ (Q_t + f_t^r) K_t^r + B_t = \phi_t^r N_t^r = N_t^r + D_t^r \]

\[ \phi_t^r = \frac{\nu_{bt}^r - \mu_{bt}^r}{\theta - \mu_{bt}^r} \]

\[ N_t^j = \sigma^j \left[ (Z_t + Q_t) K_t^{j-1} - R_t D_t^{j-1} - R_{bt} B_t^{j-1} \right] + (1 - \sigma^j) w^j \]
\[ Q_t K^w_t = N^w_t + B_t \]
<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>discount rate</td>
<td>.99</td>
</tr>
<tr>
<td>$\alpha^h$</td>
<td>Intermediation cost</td>
<td>.03</td>
</tr>
<tr>
<td>$W^h$</td>
<td>Endowment</td>
<td>.006</td>
</tr>
<tr>
<td>Retail Banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma^r$</td>
<td>Survival Probability</td>
<td>.95</td>
</tr>
<tr>
<td>$\alpha^r$</td>
<td>Intermediation cost</td>
<td>.0075</td>
</tr>
<tr>
<td>$W^r$</td>
<td>Endowment</td>
<td>.0008</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Divertable proportion of assets</td>
<td>.25</td>
</tr>
<tr>
<td>Wholesale Banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma^w$</td>
<td>Survival Probability</td>
<td>.9</td>
</tr>
<tr>
<td>$\alpha^w$</td>
<td>Intermediation cost</td>
<td>0</td>
</tr>
<tr>
<td>$W^w$</td>
<td>Endowment</td>
<td>.0004</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Shrinkage of divertable proportion of assets</td>
<td>.5</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>std of dividends</td>
<td>.05</td>
</tr>
<tr>
<td>$\rho_z$</td>
<td>autocorrelation of dividends</td>
<td>.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEADY STATE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q^r$</td>
<td>price of capital</td>
<td>1</td>
</tr>
<tr>
<td>$K^r$</td>
<td>retail intermediation</td>
<td>.4</td>
</tr>
<tr>
<td>$K^w$</td>
<td>wholesale intermediation</td>
<td>.4</td>
</tr>
<tr>
<td>$R^b$</td>
<td>Annual interbank rate</td>
<td>1.052</td>
</tr>
<tr>
<td>$R$</td>
<td>Annual deposit rate</td>
<td>1.04</td>
</tr>
<tr>
<td>$R^w$</td>
<td>Annual wholesale return on capital</td>
<td>1.064</td>
</tr>
<tr>
<td>$\phi^w$</td>
<td>wholesale leverage</td>
<td>25</td>
</tr>
<tr>
<td>$\phi^r$</td>
<td>retail leverage</td>
<td>10</td>
</tr>
<tr>
<td>$Y$</td>
<td>output</td>
<td>.0225</td>
</tr>
<tr>
<td>$C^h$</td>
<td>consumption</td>
<td>.0168</td>
</tr>
<tr>
<td>$N^r$</td>
<td>retail banks networth</td>
<td>.0785</td>
</tr>
<tr>
<td>$N^w$</td>
<td>wholesale banks networth</td>
<td>.0160</td>
</tr>
</tbody>
</table>
Financial Innovation: A Permanent Fall in ω

Wholesale banks borrow more from retail banks with higher leverage

Retail banks reduce business loans

Leverage multiples of individual bank is higher, but

\[
\frac{Q_tK_t^w + (Q_t + f_t^r)K_t^r}{N_t^w + N_t^r} < \frac{(Q_t + f_t^r)K_t^r + B_t}{N_t^r} < \frac{Q_tK_t^w}{N_t^w}
\]

Economy becomes more efficient with larger net output

Financial accelerator becomes SMALLER
Figure 9: Low Frequency Dynamics in Financial Intermediation

$k_w$

Proportion of total intermediation

0.2 0.25 0.3 0.35 0.4 0.45

$k_f$

Proportion of total intermediation

0.35 0.4 0.45 0.5 0.55 0.6 0.65

$B/D$

Ratio between WS and Retail short term funding

0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75
Figure 11: A recession before and after financial innovation (NO RUN EQUILIBRIUM)
Wholesale Bank Runs

Ex ante, zero probability of a run

If retail banks do not roll over their interbank credit ("run"), the wholesale banks sell their capital to households and retail banks who are less efficient in managing capital.

In addition to an equilibrium without run, bank run equilibrium exists if:

\[(Z_t + Q_t^*) K_{t-1}^w < R_{bt} B_{t-1}\]

\[Q_t^* \equiv \text{the liquidation price of the bank’s assets}\]
After a bank run at $t$:

$$K^h_t + K^r_t = \bar{K},$$

$$N_{t+1}^w = (1 - \sigma^w)w^w + \sigma^w(1 - \sigma^w)w^w$$

$$N_s^w = \sigma^w \left[ (Z_s + Q_s) K_{s-1}^w - R_{bs} B_{s-1} \right] + (1 - \sigma^w)w^w, \quad \forall \ s \geq t+2$$

Household condition for direct capital holding →

$$Q^*_t = E_t \left\{ \sum_{i=1}^{\infty} \wedge_{t,t+i} [Z_{t+i} - \alpha^h K^h_{t+i}] \right\} - \alpha^h K^h_t$$
Figure 13: A recession followed by a run on wholesale bankers only
Anticipated Bank Runs

Deposit returns $R_{bt+1} = \begin{cases} 
R_{bt+1} & \text{if no bank run} \\
x_{bt+1}R_{bt+1} & \text{if bank run} 
\end{cases}$

$x_{bt+1} = \text{Min} \left[ 1, \frac{(Q^*_t + Z_{t+1}) K^w_t}{R_{bt+1} B_t} \right]$}

Household attaches the probability of bank run as

$p_t = p(E_t(x_{bt+1})), \ p(1) = 0, \ p'(\cdot) < 0$

FONC for interbank loan is

$E_t[(1-p_t)\Omega_{t+1}^r (R_{kt+1}^r - \overline{R}_{bt+1}) + p_t\Omega_{t+1}^{r*} (R_{kt+1}^{r*} - x_{bt+1} \overline{R}_{bt+1})] = 0$
Figure 14: A recession in the model with anticipated runs
Figure 15: A recession followed by a run in the model with anticipated runs
Figure 16: Total credit spreads and interbank spreads

![Graph of Total Finance Premium (ER^k-R)](image)

![Graph of Financial CP Spread](image)

Legend:
- Blue: Model
- Red: Data
Some Remarks About Policy

Capital requirement on all the large banks reduces likelihood of bank run

Can reduce the efficiency of intermediation

Lender-of-last resort stabilizes liquidation price

May reduce the likelihood of run

But increases the leverage multiple ex ante and the financial accelerator