Learning in Bank Runs

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What we know...

- Runs occur because of:
  - Signals about fundamental solvency risk (Chari and Jagannathan, 1988; Gorton, 1988)
  - Coordination problems among depositors (Diamond and Dybvig, 1983)
  - Fundamentals act as a mechanism to coordinate beliefs (Goldstein and Pauzner, 2005).

- But...
  - Bank runs do not (only) occur overnight: **Increasing withdrawals** ramp up into a panic (Iyer, Puri, and Ryan, 2016)
  - Investors are not homogeneous: Early withdrawals characterized by **information advantage** (O Grada and White, 2003)
This paper

Analyzes **time dimension** of investor-level responses to solvency risk when investors have different **levels of information**

- Information has two benefits
  - Timing benefit: **withdraw early** from bad assets
  - Screening benefit: **avoid liquidation** losses of good assets
- Uninformed investors can:
  - **Learn**: wait to free-ride on information at cost of claim juniority
  - **Run preemptively**, based on incomplete knowledge ⇒ highest welfare costs
Key Results

• (Real) option to learn **accelerates** uninformed withdrawals
  • **Slow motion runs**: learning results in fundamental runs
  • Future fundamental run triggers panic runs: likelihood of preemptive runs **increases**
• More informed agents **increase** likelihood of preemptive runs
  • Smaller residual value after early informed withdrawals **decreases** benefits of waiting (learning)
• Surplus may be **non-linear in information** held by investors
  • An intermediate level of information may be worse than having all investors informed or all uninformed
• Investors endogenously choose to **over-invest** in information
The Model

- Risk neutral investors hold **short-term debt claims** of bank
  - If bank remains solvent, debt claim pays $B \leq R_H$ at $t = 3$
  - Insolvency: residual value allocated evenly among investors
  - Investors can “withdraw” before at penalty rate $D < B$

- Bank invested in **risky asset** returning at $t = 3$:
  - $R_H$ (high quality asset) with probability $p(\theta)$
  - $R_L < R_H$ (low quality asset) otherwise.

- Prob $p(\theta)$ strictly increases in **economic state** $\theta$
  - $\theta$ is uniformly distributed in interval $[0, 1]$

- Premature **liquidation is costly** (at $t = 1, 2$)
  - Factor $\lambda < 1$ of final return
The Timing

$t=0$ Bank has high (low) quality asset with $p(\theta)$ (with $(1−p(\theta))$).
Uninformed depositors observe a private noisy signal $\theta_i$.
Informed depositors observe the asset quality directly.

$t=1$ All depositors decide to withdraw or wait (observable).
Bank liquidates fraction of the asset to serve any withdrawals.

$t=2$ All remaining depositors decide to withdraw or wait.
Bank liquidates fraction of the asset to serve any withdrawals.

$t=3$ The fraction remaining of the asset matures.
The bank repays remaining deposits if solvent.
The Assumptions

- **Assumption 1:** \( \lambda R_H \geq D > R_L \)
  - Individually optimal to run on low quality but wait for high quality asset, if quality is known.
- **Assumption 2:** \( pR_H + (1-p)\lambda R_L > D \)
  - Without additional information, it is optimal to delay withdrawal decision if all others wait
- **Assumption 3:** \( pR_H < pD + (1-p)\lambda R_L \)
  - Without additional information, withdrawal at \( t = 1 \) is optimal if all others run

\[ \Rightarrow \text{Strategic complementarity among uninformed investors} \]
Backwards Induction

At $t = 2$
- Investors don’t withdraw if they know asset quality is high
- Investors withdraw if they know the asset has low quality

At $t = 1$
- If asset has high quality, informed investors wait till maturity
- If asset has low quality, informed investors withdraw at $t = 1$

Uninformed learn asset quality at $t = 2$ from informed withdrawal:
No inference problem if $\lim \varepsilon \to 0$
Uninformed Investors’ Trade-off at $t = 1$

$$\Pi^{\text{WAIT}}(N(\theta_i), p(\theta_i)) = p(\theta_i)R_H + (1 - p(\theta_i)) \max \left[ \frac{\lambda R_L - N(\theta_i)D}{1 - N(\theta_i)}, 0 \right]$$

$$\Pi^{\text{RUN}}(N(\theta_i), p(\theta_i)) = p(\theta_i)D + (1 - p(\theta_i)) \min \left[ D, \frac{\lambda R_L}{N(\theta_i)} \right]$$

**Strategic Complementarity**

$$\Pi^{\text{RUN}}(1, p) > \Pi^{\text{WAIT}}(1, p) \text{ but } \Pi^{\text{RUN}}(0, p) < \Pi^{\text{WAIT}}(0, p)$$

**Dominance Regions**

$$\Pi^{\text{RUN}}(0, p(\theta)) > \Pi^{\text{WAIT}}(0, p(\theta)) \text{ and } \Pi^{\text{RUN}}(1, p(\bar{\theta})) < \Pi^{\text{WAIT}}(1, p(\bar{\theta}))$$

Global game $\rightarrow$ Preemptive run if signal (fundamental) is low
Global Game among Uninformed Investors

- Uninformed investor with signal $\theta^*(\pi)$ is indifferent between waiting and running at $t = 1$

$$\int_{\pi}^{\lambda R_L D} \{ p(\theta) R_H + (1 - p(\theta)) \frac{\lambda R_L - N_1(L)D}{(1 - N_1(L))} - D \} dN_1(L)$$

$$+ \int_{\lambda R_L D}^{1} \{ p(\theta) R_H - p(\theta) D - (1 - p(\theta)) \frac{R_L \lambda}{N_1(L)} \} dN_1(L) = 0$$

- Signal determines critical probability of high quality asset:

$$p(\theta^*)|_{\varepsilon \to 0} = \frac{\Phi(\pi)}{(1 - \pi)(\frac{R_H}{D} - 1) + \Phi(\pi)}$$

with $\Phi(\pi) := -\frac{\lambda R_L}{D} \log \left( \frac{\lambda R_L}{D} \right) - (1 - \frac{\lambda R_L}{D}) \left( \log \left( 1 - \frac{\lambda R_L}{D} \right) - \log (1 - \pi) \right)$
More informed investors - More preemptive runs

Proposition

*The signal threshold \( p(\theta^*) \) is increasing in \( \pi \).*

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*Parameterization \( D = 1, R_H = 1.5, R_L = 0.9, \lambda = 0.8 \)
The Ambiguous Surplus Effect of Information

(a) Ambiguous effect.
The parameters used are $D = 1$, $R_H = 1.3$, $R_L = 0.9$, and $\lambda = 0.9$.

(b) Learning harms surplus.
The parameters used are $D = 1$, $R_H = 1.5$, $R_L = 0.9$, and $\lambda = 0.9$.

Option to learn

\[ S^I - S^{NI} = - (1 - \lambda)R_L \int_{\theta^{NI}}^1 (1 - p(\theta)) \, d\theta - (1 - \lambda) \frac{D}{\lambda} \int_{\theta^{NI}}^{\theta^*(0)} p(\theta) \, d\theta \]

Loss from run on $R_L$

More pre-emptive runs

\[ - (1 - \lambda) \frac{D}{\lambda} \int_{\theta^*(0)}^{\theta^*(\pi)} p(\theta) \, d\theta + \pi (1 - \lambda) \frac{D}{\lambda} \int_{0}^{\theta^*(\pi)} p(\theta) \, d\theta \]

Amplification: Fear of missing out

Fewer uninformed withdrawals
Endogenous Information Choice

The information gain is positive for all feasible $\pi$.

$$\Delta(\pi) = \int_{0}^{\theta^*(\pi)} p(\theta)(R_H - D) \, d\theta + \int_{\theta^*(\pi)}^{1} (1 - p(\theta)) \left( \frac{D - \lambda R_L}{1 - \pi} \right) \, d\theta$$

- **Keep high asset despite preemptive run**
- **Seniority absent preemptive run**

**Lemma**

The gain $\Delta(\pi)$ from learning the actual asset quality at $t = 1$ is positive and increasing in $\pi$ for all feasible $\pi \in (0, \hat{\pi})$.

- More informed agents reduce the utility of uninformed agents
- More preemptive runs make information more valuable
Lemma

If $\Delta(\hat{\pi}) < \hat{\pi}$, there exists a fixed point solving $\Delta(\pi^*) = \pi^*$ in $\pi \in (0, \hat{\pi})$. 

![Graph showing the relationship between $\Delta(\pi)$ and $\pi$]
Optimal Information

\[ \pi^S = \arg \max_{\pi} S^l(\pi) - \int_0^\pi c \, dc \]

**Proposition**

*Depositors choose to over-invest in information relative to the surplus maximizing information choice \( \pi^* > \pi^S \).*

- Surplus contains only one of the two individual benefits:
  - First mover advantage does not affect surplus
- Negative Externality:
  - Depositors do not consider the effect on the decisions of the others to run pre-emptively.
Higher asset liquidity - Ambiguous effect

Proposition

A higher asset liquidity ($\lambda$) decreases the incidence of preemptive runs if there are only few informed investors and increases otherwise.

- Remaining fraction of assets to be liquidated in second period is high and the higher liquidation value outweighs benefits of immediate withdrawal
- Many informed investors: immediate withdrawal becomes more attractive with a higher liquidation value as the fraction of low quality assets remaining in the second period is low.
Conclusion

• Depositor learning exacerbates panic-based bank runs:
  • The (real) option to learn from previous withdrawals leads to costly liquidation in bad states, which increases incentive to run ex-ante.
  • When informed depositors learn the bank’s asset quality early, remaining depositors have a fear of missing out, which makes pre-emptive runs more likely.

• More information may thus lead to more panic runs and welfare may be non-monotonic in the amount of information available.

• Investors over-invest in information: Negative externalities of information choice

• Higher asset liquidity may reduce (increase) incidence of runs if only few (many) investors are informed
Literature

- Chari & Jagannathan (1988, JF): uninformed investors may run on a bank after observing high withdrawals
- He & Manela (2016, JF): endogenous acquisition of information may shorten bank’s survival time
- Ahnert & Kakhbod (2017, RFS): higher signal precision increases (efficient) run probability of less informed investors
- Santos & Suarez (2018, JFE): optimal policy response to information shocks that cause slow (exogenous) liquidity outflow from banks even with high quality assets.

Our contribution: Information may harm welfare as the menace of a fundamental-based run can trigger a panic-based run.
Asset quality dependent debt payoffs at time $t$

$N_t = $ Investors withdrawing at time $t$

<table>
<thead>
<tr>
<th>Quality</th>
<th>Aggregate Withdrawals</th>
<th>$t=1$</th>
<th>$t=2$</th>
<th>$t=3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>$D$</td>
<td>$D$</td>
<td></td>
<td>$R_H$</td>
</tr>
<tr>
<td>L</td>
<td>(1) $\frac{\lambda R_L}{D} &gt; (N_1 + N_2)$</td>
<td>$D$</td>
<td>$D$</td>
<td>$\frac{R_L - (N_1 + N_2) D}{\lambda (1 - N_1 + N_2)}$</td>
</tr>
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<td></td>
<td>(2) $N_1 &lt; \frac{\lambda R_L}{D} &lt; (N_1 + N_2)$</td>
<td></td>
<td>$\frac{\lambda R_L - N_1 D}{N_2}$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3) $N_1 &gt; \frac{\lambda R_L}{D}$</td>
<td>$\frac{\lambda R_L}{N_1}$</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Option to Learn Increases Likelihood of Preemptive Run

Proposition

The option of investors to wait until \( t = 2 \) and discover the realization of the bank asset value increases the probability of a preemptive run on the bank in the first period.

\[
p(\theta^*(0)) > p(\theta_0)
\]

- Allowing investors to delay withdrawal decision, leads to fundamental runs at \( t = 2 \)
- Fundamental runs decrease, ex ante, the benefit from waiting \( \Rightarrow \) increase the incentive to withdraw early with incomplete knowledge
Ambiguous Welfare Effect

Increase in $\pi$ (more informed agents) has two opposing welfare effects

- Increases the **likelihood** of preemptive runs
- Decreases the **size** of preemptive runs (less inefficient liquidation)

$$W^{IA} = pR_H + (1 - p)\lambda R_L - (1 - \pi)D \left(\frac{1}{\lambda} - 1\right) \int_0^{\theta^*(\pi)} p(\theta) \, d\theta$$

Preemptive Liquidation Cost

**Proposition**

*If the proportion of informed investors is small, an increase in information decreases welfare.*

- For small $\pi$, the higher likelihood of preemptive runs outweighs the reduced size of a panic run.
Endogenous Information Choice

The information gain is positive for all feasible $\pi$.

$$\Delta(\pi) = \int_0^{\theta^*(\pi)} p(\theta)(R_H - D) \, d\theta + \int_{\theta^*(\pi)}^1 (1 - p(\theta)) \left( \frac{D - \lambda R_L}{1 - \pi} \right) \, d\theta$$

- Keep high asset despite preemptive run
- Seniority absent preemptive run

![Graph showing $\Delta(\pi)$ and $\pi$]
Lemma

The information gain is increasing in $\pi$

- More informed agents reduce the utility of uninformed agents
- Higher likelihood of preemptive runs makes information more valuable

$$\frac{\partial \Delta(\theta^*(\pi), \pi)}{\partial \pi} = \int_{\theta^*(\pi)}^{1} (1 - p(\theta)) \frac{D - \lambda R_L}{(1 - \pi)^2} \, d\theta$$

$$+ \frac{\partial \theta^*(\pi)}{\partial \pi} \left( p(\theta^*(\pi))(R_H - D) - (1 - p(\theta^*(\pi)) \frac{D - \lambda R_L}{1 - \pi} \right) > 0$$
Inference Problem

\[ N_1(L) = \begin{cases} 
1 & \text{if } \theta < \theta^*(\pi) - \varepsilon \\
\pi + (1 - \pi) \left( \frac{1}{2} + \frac{\theta^*(\pi) - \theta}{2\varepsilon} \right) & \text{if } \theta^*(\pi) - \varepsilon < \theta < \theta^*(\pi) + \varepsilon \\
\pi & \text{if } \theta^*(\pi) + \varepsilon < \theta
\end{cases} \]

\[ N_1(H) = \begin{cases} 
(1 - \pi) & \text{if } \theta < \theta^*(\pi) - \varepsilon \\
(1 - \pi) \left( \frac{1}{2} + \frac{\theta^*(\pi) - \theta}{2\varepsilon} \right) & \text{if } \theta^*(\pi) - \varepsilon < \theta < \theta^*(\pi) + \varepsilon \\
0 & \text{if } \theta^*(\pi) + \varepsilon < \theta
\end{cases} \]