Systemic bank runs in a DSGE model

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Very Preliminary. Comments Welcome.

Financial crisis of 2007-2009

- What happened in the financial crisis of 2007-2009 can be interpreted as bank runs on various forms of short-term debt (Gorton and Metrick, 2010).
  - runs on the repurchase agreements (repo) market:
    - Gorton and Metrick (2009), Lucas and Stokey (2011), etc.
  - runs on commercial paper:
    - Arteta, Carey, Correa, and Kotter (2010), Covitz, Liang, and Suarez (2009), Kacperczyk and Schnabl (2010), etc.
  - runs on dealer banks:
    - Duffie (2011).
- Also, it was a “systemic event” in the sense that the financial intermediary sector became insolvent as a whole (Gorton and Metrick, 2009).
- It triggered the “Great Recession.”

Repos and commercial paper

Adrian and Shin (2010)

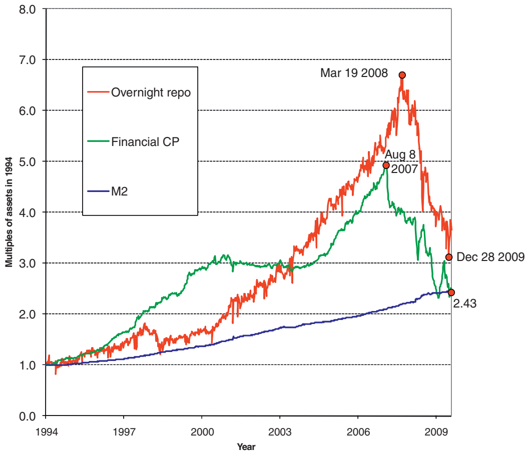


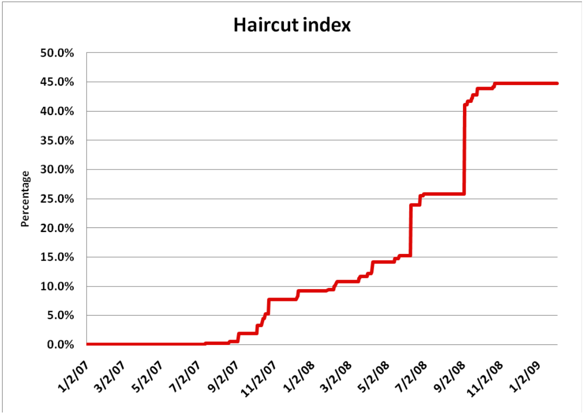
Figure 11

Overnight repurchase agreements (repos) and M2. All data have been normalized to equal 1 on July 6, 1994. CP, commercial paper. Data taken from the Federal Reserve, 1994W1–2010W5.

Haircut index

Gorton and Metrick (2010)

Figure 4: The Repo-Haircut Index



Notes: The repo-haircut index is the equally-weighted average haircut for all nine asset classes included in Table I, Panel D.

What we do in this paper

- develop a DSGE model with bank runs.
- focus on
  - "fundamental bank runs" instead of "sunspot bank runs," and
  - "systemic bank runs" rather than "idiosyncratic bank runs."
- analyze how a systemic bank run amplifies a negative productivity shock:

  a sufficiently negative productivity shock

  $\Longrightarrow$ a systemic bank run

  $\Longrightarrow \downarrow$ supply of liquidity

  $\Longrightarrow \downarrow$ working capital

  $\Longrightarrow \uparrow$ labor wedge (gap between MPL and MRS)

  $\Longrightarrow \downdownarrows$ output.

Our model: Banks

- Our modeling of banks follows Diamond and Rajan (2001).
    - Banks have superior loan collection skills, which are relation specific.
        - Holdup problem: Banks may threaten to withdraw their skills in order to get more rents.
    - Demand deposits make banks susceptible to runs, but prevent them from behaving opportunistically.
- Liquidity creation by banks:
    - Banks obtain funds in the form of demand deposits and make loans to firms;
    - they collect loan payments from firms and provide the economy with liquidity.

$$\text{depositors} \quad \begin{array}{c} \xrightarrow{\text{deposits}} \\ \xleftarrow[\text{liquidity}]{} \end{array} \quad \text{banks} \quad \begin{array}{c} \xrightarrow{\text{loans}} \\ \xleftarrow[\text{repayment}]{} \end{array} \quad \text{firms}$$

Our model: Systemic bank runs

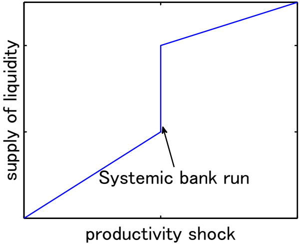
- A systemic bank run is caused by a sufficiently negative productivity shock:
  - A negative technology shock lowers the surplus generated by firms, which lowers the repayments collected by banks.

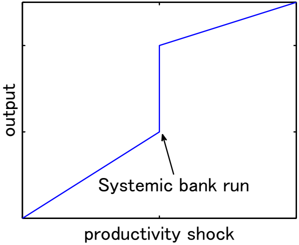
$$\text{depositors} \quad \begin{array}{c} \xrightarrow{\text{deposits}} \\ \xleftarrow[\downarrow\text{liquidity}]{} \end{array} \quad \textit{banks} \quad \begin{array}{c} \xrightarrow{\text{loans}} \\ \xleftarrow[\downarrow\text{repayment}]{} \end{array} \quad \downarrow \text{firms}$$

  - If the shock is bad enough, all banks would become insolvent, which leads to a systemic bank run, and damages the economy's capacity to create liquidity.

$$\text{depositors} \quad \begin{array}{c} \xrightarrow{\text{deposits}} \\ \xleftarrow[\downarrow\downarrow\text{liquidity}]{} \end{array} \quad \cancel{\text{banks}} \quad \begin{array}{c} \xrightarrow{\text{loans}} \\ \xleftarrow[\downarrow\downarrow\text{repayment}]{} \end{array} \quad \downarrow \text{firms}$$

Our model: Propagation and amplification





- A systemic bank run reduces the supply of liquidity.

  $\Longrightarrow$ lowers the amount of working capital available to firms.

  $\Longrightarrow$ decreases employment and hence output further.

- A bank run distorts the economy by enlarging the gap between MPL and MRS (the labor wedge).
  - consistent with what happened during the Great Recession.

Households

- a continuum of identical households.
- Each household consists of
  - a (standard) infinitely-lived consumer/worker, and
  - overlapping generations of two-period lived firms and banks.
- In every period a firm and a bank are born in each household.

Firms and banks

- A new born firm needs funds to purchase physical capital and to hire labor.
  - It must obtain loans from a bank in a different household.
- A new born bank must raise funds in the form of demand deposits.
  - It should obtain them from other households.
- New born firms and banks in different households are matched randomly in each period.

Match between a firm and a bank

- Consider a match formed in period t.
- The bank:
  - $b_t =$ amount of funds that the bank obtains by issuing demand deposits.
  - acquires relation-specific loan-collection skills.
- The firm:
  - in period t:
    - borrows b_t from the bank.
    - purchases physical capital k_t in period t.
    - deposits the rest, $d_t^F \equiv b_t - k_t$, which becomes the working capital.
  - in period $t+1$:
    - hires labor from other households and produces output:

$$y_{t+1} = A_{t+1} k_t^{\alpha} l_{t+1}^{1-\alpha}$$

where $A_{t+1} =$ economy-wide productivity shock.

Repayment of the loan

- Let Π_{t+1} = total surplus generated by the firm in period $t+1$.
- The repayment of the loan is a constant fraction of Π_{t+1}.
- The bank has superior loan-collection skills.
  - $\Theta\Pi_{t+1}$ = the amount that the bank can take as the repayment of the loan;
  - But if someone else negotiates with the firm on the repayment, it reduces to $\theta\Pi_{t+1}$, where $\theta < \Theta$.
- In particular if a run against the bank occurs,
  - the depositors of the bank become a collective owner of its loans to the firm and they collectively negotiate with the firm on the repayment.
  - As a result, the depositors obtain $\theta\Pi_{t+1}$ from the firm, which is shared equally.

Bank runs

- Let s_{t+1} denote the occurrence of a systemic bank run in period $t+1$.

$$s_{t+1} = \begin{cases} 1, & \text{if a systemic bank run occurs in period } t+1, \\ 0, & \text{otherwise.} \end{cases}$$

- $1 + r_t$ = interest rate on demand deposits between periods t and $t+1$.
  - When a bank run occurs, however, it is reduced to $\xi_{t+1}(1 + r_t)$.
  - Define $\tilde{\xi}_{t+1}$ by

$$\tilde{\xi}_{t+1} = \begin{cases} 1, & \text{if } s_{t+1} = 0, \\ \xi_{t+1}, & \text{if } s_{t+1} = 1. \end{cases}$$

Problem of the firm born in period t

- Profit earned by the firm born in period t is

$$\pi_{t+1}^F = (1 - \tilde{\theta}_{t+1})\Pi_{t+1}$$

where

$$\Pi_{t+1} = A_{t+1} k_t^{\alpha} l_{t+1}^{1-\alpha} - w_{t+1} l_{t+1} + \tilde{\xi}_{t+1}(1 + r_t) d_t^F + (1 - \delta) k_t$$

$$\tilde{\theta}_{t+1} = \begin{cases} \Theta, & \text{if } s_{t+1} = 0, \\ \theta, & \text{if } s_{t+1} = 1. \end{cases}$$

- The firm chooses $\{k_t, d_t^F, l_{t+1}\}$ to maximize:

$$\max_{\{k_t, d_t^F, l_{t+1}\}} E_t \frac{\beta \lambda_{t+1}}{\lambda_t} \pi_{t+1}^F,$$

$$\text{s.t.} \quad k_t + d_t^F \leq b_t,$$

$$w_{t+1} l_{t+1} \leq \tilde{\xi}_{t+1}(1 + r_t) d_t^F,$$

where $\beta^t \lambda_t$ = stochastic discount factor.

Problem of the bank born in period t

- Profit earned by the bank born in period t is

$$\pi^B_{t+1} = \max\left\{\tilde{\pi}^B_{t+1}, 0\right\},$$

where

$$\tilde{\pi}^B_{t+1} = \Theta\Pi_{t+1} - (1 + r_t)b_t + T_{t+1},$$

where T_{t+1} denotes the transfer from the government.

- It chooses b_t to solve

$$\max_{b_t} E_t \frac{\beta\lambda_{t+1}}{\lambda_t}\pi^B_{t+1}.$$

Here, The bank takes into account the fact that the paired firm chooses $\{k_t, d^F_t, l_{t+1}\}$ as a function of b_t by solving its profit-maximization problem.

Bank run

- If a bank run occurs in period $t+1$, it does so after A_{t+1} has been realized but before the production process starts.
  - $\bar{A}_{t+1}$ = threshold level of productivity below which a bank run occurs.
- The firm born chooses l_{t+1} given $(d_t^F, k_t, A_{t+1}, r_t, w_{t+1}, \tilde{\xi}_{t+1})$ to solve

$$\max_{l_{t+1}} A_{t+1} k_t^{\alpha} l_{t+1}^{1-\alpha} - w_{t+1} l_{t+1}$$
$$\text{s.t.} \quad w_{t+1} l_{t+1} \leq \tilde{\xi}_{t+1}(1+r_t) d_t^F$$

- Given $(d_t^F, k_t, r_t, w_{t+1})$, consider the hypothetical problem for each $A' > 0$:

$$l_{t+1}^*(A') \equiv \arg\max_{l_{t+1}} A' k_t^{\alpha} l_{t+1}^{1-\alpha} - w_{t+1} l_{t+1}$$
$$\text{s.t.} \quad w_{t+1} l_{t+1} \leq (1+r_t) d_t^F$$

Bank run

- The threshold value $\bar{A}_{t+1}$ is given as the solution to

$$\Theta\Big\{\bar{A}_{t+1}k_t^{\alpha}\big[l_{t+1}^*(\bar{A}_{t+1})\big]^{1-\alpha} - w_{t+1}l_{t+1}^*(\bar{A}_{t+1}) + (1+r_t)d_t^F + (1-\delta)k_t\Big\}$$
$$-(1+r_t)b_t + T_{t+1} = 0.$$

- If $A_{t+1} < \bar{A}_{t+1}$ then $\tilde{\pi}_{t+1}^B < 0$ even without a bank run.
    - Thus, all banks born in period t become insolvent if $A_{t+1} < \bar{A}_{t+1}$. That is,

$$s_{t+1} = 1 \quad \Longleftrightarrow \quad A_{t+1} < \bar{A}_{t+1}$$

- When a bank run occurs, the ex-post rate of return on the bank account is determined by

$$\xi_{t+1}(1+r_t)b_t = \theta\Pi_{t+1} + T_{t+1}.$$

Household's problem

- Preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t).$$

- The only financial asset that each household can hold is the bank account in banks owned by other households.
- Its flow budget constraint is

$$c_t + d_t^H = \tilde{\xi}_t (1 + r_{t-1}) d_{t-1}^H + w_t l_t + \pi_t^F + \pi_t^B - T_t$$

where T_t is lump-sum taxes.

Government policy

- Compare two simple policy regimes.
  1. Without policy intervention (laissez-faire):
  $$T_t = 0, \quad \text{for all } t.$$
  2. With intervention:
  $$T_t = \max\Big\{(1+r_{t-1})b_{t-1} - \Theta\big[A_t k_{t-1}^{\alpha}(l_t^*(A_t))^{1-\alpha} - w_t l_t^*(A_t) + (1+r_{t-1})d_{t-1}^F + (1-\delta)k_{t-1}\big], 0\Big\}$$
- With the second regime, $A_t \geq \bar{A}_t$ for all t so that a systemic bank run never occurs.

Summary: Flow of funds in normal times

- Loans to firms:

$$\text{depositors} \xrightarrow{d_t^H + d_t^F} \underset{\text{(born in } t)}{\text{banks}} \xrightarrow{b_t} \text{firms} \begin{cases} k_t \\ d_t^F \end{cases}$$

- Creation of liquidity (without govt subsidies):

$$\text{firms} \xrightarrow{\Theta\Pi_t} \underset{\text{(born in } t-1)}{\text{banks}} \xrightarrow{(1+r_{t-1})b_{t-1}} \begin{cases} \text{households: } (1+r_{t-1})d_{t-1}^H \\ \text{firms: } (1+r_{t-1})d_{t-1}^F \end{cases}$$

- The demand for liquidity is predetermined. As long as the supply of liquidity exceeds the demand, a bank run does not occur.

$$\underbrace{(1+r_{t-1})(d_{t-1}^H + d_{t-1}^F)}_{\text{demand for liquidity}} \leq \underbrace{\Theta\Pi_t}_{\text{supply of liquidity}}$$

Summary: Systemic bank run

- A negative productivity shock reduces Π_t, and hence the supply of liquidity $\Theta\Pi_t$.
- Under the laissez-faire policy regime, a systemic bank run occurs if the shock is large enough that

$$\underbrace{(1+r_{t-1})(d^H_{t-1}+d^F_{t-1})}_{\text{demand for liquidity}} > \underbrace{\Theta\Pi_t}_{\text{supply of liquidity}}$$

- As a result, the supply liquidity further reduces to $\theta\Pi_t$:

$$\text{firms} \xrightarrow{\theta\Pi_t} \cancel{\text{banks}} \xrightarrow{\theta\Pi_t} \begin{cases} \text{households: } \xi_t(1+r_{t-1})d^H_{t-1} \\ \text{firms: } \xi_t(1+r_{t-1})d^F_{t-1} \end{cases}$$

- Rationing of liquidity: only the fraction ξ_t of the liquidity demand is satisfied.

$$\xi_t(1+r_{t-1})(d^H_{t-1}+d^F_{t-1}) = \theta\Pi_t$$

Summary: Propagation and amplification

- A systemic bank run reduces the amount of working capital available to firms by a factor of ξ_t.
  - The working capital is used to pay the wage bill:

$$\underbrace{w_t l_t}_{\text{wage bill}} \leq \underbrace{\xi_t (1 + r_{t-1}) d_{t-1}^F}_{\text{working capital}}$$

  - Thus the run reduces employment and output further, amplifying the effect of the productivity shock.
- Define the labor wedge as the gap between MPL and MRS:

$$\text{labor wedge} = \frac{\text{MPL}}{\text{MRS}}$$

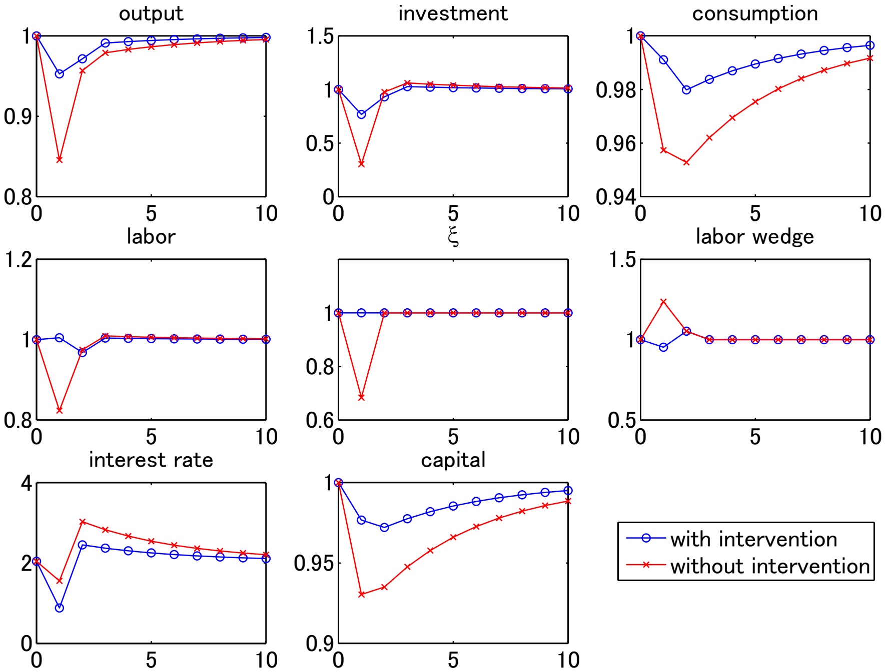
A systemic bank run distorts the economy by increasing this gap.

Numerical example

- Functional forms:

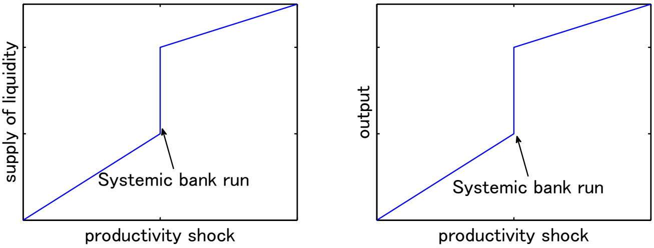
$$u(c, l) = \ln(c) + \psi \ln(1 - l).$$

- Parameter values: $\alpha = 0.4$, $\beta = 0.98$, $\delta = 0.1$, $\psi = 0.75$, $\Theta = 0.9$, $\theta = 0.65$.
- Period 0:
  - at the non-stochastic steady state associated with $A_t = 1$ for all t.
- Period 1:
  - there is an unexpected temporary decline in productivity: $A_1 = 0.95$.
- Periods $t \geq 2$:
  - A_t returns to the original level: $A_t = 1$ for all $t \geq 2$.


output
investment
consumption
labor
ξ
labor wedge
interest rate
capital
with intervention
without intervention
1
0.9
0.8
0
5
10
1.5
1
0.5
0
0.98
0.96
0.94
1.2
0.6
4
2
0.95

Conclusion

- constructs a DSGE model with systemic bank runs.
    - bank run $\Rightarrow \downarrow$ liquidity $\Rightarrow \downarrow$ working capital $\Rightarrow \uparrow$ labor wedge $\Rightarrow \downarrow$ output.
- The systemic bank run amplifies the effect of a negative productivity shock in an nonlinear way:



Conclusion

- Some directions for future research:
  - In the current model, the policy intervention to prevent a systemic bank run has no costs at all.
    - Distortionary effects of such policy should be taken into account.
  - consider more rich and realistic ways of policy intervention.
  - consider public liquidity such as money and government bonds.

Related literature

- bank runs:
  - Angeloni and Faia (2010): DSGE model with idiosyncratic bank runs;
  - Uhlig (2010): two-period model of systemic bank runs;
  - Kato and Tsuruga (2011): two-period OLG model with systemic bank runs.
- agency problems between banks and depositors:
  - Gertler and Karadi (2011), Gertler and Kiyotaki (2011), and Gertler, Kiyotaki and Queralto (2010).