Liquidity Management in Banking: the Role of Leverage?

Fabiana Gomez [1]   Quynh-Anh Vo [2]

[1]University of Bristol   [2]Bank of England

ESCB Research Cluster Workshop, November 2 - 3, 2017

The views expressed are not necessarily those of the Bank of England

Motivation

- In response to the global financial crisis of 2007-2009, the Basel Committee has proposed to:
  - Introduce a new global set of liquidity requirements: Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSTR):
    - Aimed at promoting better *liquidity risk* management.
  - Strengthen the capital requirement:
    - Address the banks' *solvency*.
- Questions:
  - Should one append a liquidity measure to the solvency one?

  or put differently
  - Can the capital requirement be used to induce a better liquidity risk management by banks?

Motivation

- What are rationales for the capital regulation?
  - A bank's capital forms a kind of cushion against losses.
  - The capital regulation is seen as an incentive device to curb the excessive risk-taking by banks.

    $\Longrightarrow$ So far, the banking literature focuses on the effects of banks' leverage on their choice of *credit risk*.
- How about the banks' choice of *liquidity risk*?

  $\Longrightarrow$ *In this paper, I construct a model to examine whether the banks' incentives to manage their liquidity risk is affected by their leverage.*

Related literature

- Rationales for the capital regulation: e.g. Rochet (1992), Besanko and Kanatas (1996), Blum (1999), Repullo (2004).
- Hölmstrom and Tirole (1998).
- Cash-in-the-market-pricing and financial fragility: E.g. Bolton et al. (2011), Acharya et Viswanathan (2011).
- Banks' liquidity holdings: E.g. Acharya et al. (2010), Malherbe (2014), Heider et al. (2015), Acharya et al. (2015).
- Optimal design of bank liquidity requirement: Calomiris et al. (2015), Walther (2015).

Outline

- Basic Model: a model with a single bank:
  - Description
  - Optimal Cash Holding Policy
- Multiple Banks Setting
  - Description
  - Asset Sales
  - Rational Expectation Equilibria
- Conclusion

Basic Model

- Time: 3 dates $t = 0, 1, 2$
- A bank with internal capital E.
- Bank's liabilities
  - The size of the bank's balance sheet is normalized to 1.
  - The bank is funded at date 0 with:
    - Equity of amount E.
    - Short-term debt of amount $1 - E$, payable at date $t = 1$. Face value of short-term debt is denoted by D.

- Two investment opportunities:
  - Storage technology (liquid assets or cash): Return equal to 1.
  - Investment project (long-term asset): constant return to scale:

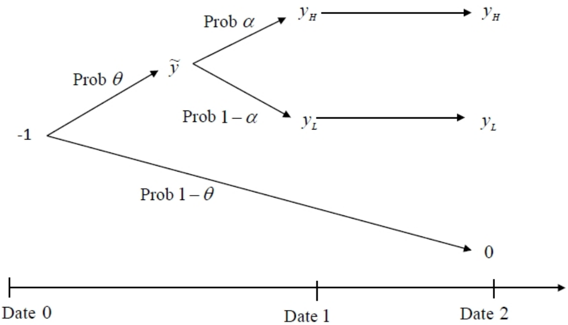


Figure: Risky Investment Opportunity

- **Assumption 1:** Positive NPV: $E(\theta\tilde{y}) = \alpha\theta y_H + (1-\alpha)\theta y_L > 1$

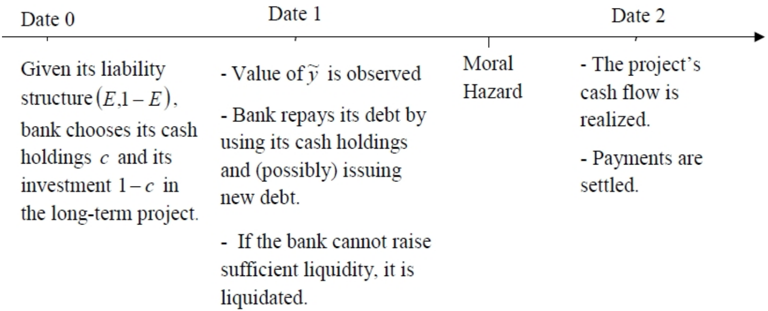
Basic Model

- Rollover Problem: Bank repays its short-term debt at date 1:
  - Two sources of liquidity:
    - Cash held from date 0.
    - Issuing new debt by pledging the date 2 cash flow.
  - The bank's funding capacity at date 1 may be limited by the moral hazard problem.
- Moral hazard
  - Between date 1 and date 2, the bank can switch investment to a (possibly) riskier asset:
    - This asset has the probability of success equal to θ_1 and the success cash flow equals to y_1.
- **Assumption 2:** Moral hazard problem matters only in the low state:

$$\theta > \theta_1; \; y_H > y_1 > y_L \text{ and } \frac{1}{2}\theta y_L > \theta_1 y_1$$

Basic Model: Timing

- Timing



- Liquidation value of long-term assets: it is assumed to be equal to ℓ
- **Assumption 3**: Asset specificity: $\ell < \theta y_L$
- **Assumption 4**:

$$\alpha \theta y_H + (1-\alpha)\,\ell - 1 > 0$$

Basic Model: Remarks

- Short-term debt:
  - Why banks use short-term debt: There exists two explanations:
    - Beneficial incentive effects of short-term debt.
    - Providing liquidity flexibility to creditors who may be hit by liquidity shocks.
  - In this model, we don't model the reason for which the bank uses short-term debt. We justify the use of short-term debt as a bank's response to the investors' demand of liquid investment.

Basic Model: Remarks

- Liquidity shock
  - No uncertainty about the debt repayment but uncertainty about the bank's funding capacity at date 1:
    - Good news at date 1, borrowing is not constrained $\Rightarrow$ no problem in rolling over short-term debt.
    - Bad news at date 1, funding capacity is restricted $\Rightarrow$ rolling-over debt is problematic.
  - The scenario is analogous to what happened in the 2007-2009 crisis.

Analysis

Date 0

Given its liability structure $(E, 1-E)$, bank chooses its cash holdings c and its investment $1-c$ in the long-term project.

Date 1

- Value of $\tilde{y}$ is observed
- Bank repays its debt by using its cash holdings and (possibly) issuing new debt.
- If the bank cannot raise sufficient liquidity, it is liquidated.

Moral Hazard

Date 2

- The project's cash flow is realized.
- Payments are settled.

Borrowing Capacity

- Liquidity needs are $D - c$
- If high state is realized $\Rightarrow$ no problem in rolling over short-term debt.
- If low state is realized, the ICC is as follows:

$$\theta \left(y_L - f \right) \geq \theta_1 \left(y_1 - f \right)$$

  where f is the face value of the new debt issued against one unit of long-term asset. This is equivalent to:

$$f \leq \frac{\theta y_L - \theta_1 y_1}{\theta - \theta_1} = f^* < y_L$$

  - f^*: maximum pledgeable income $\Rightarrow$ the bank's maximum borrowing capacity (per unit of long-term asset) is $\theta f^* < \theta y_L$.
- **Assumption 5**:

$$\ell < \theta f^*$$

Borrowing Capacity

- The bank's situation at date 1:
  - If $D - c \leq (1 - c)\,\theta f^*$: the bank can always roll over its debt $\Rightarrow$ *The bank is liquid.*
  - If $D - c > (1 - c)\,\theta f^*$: the bank is liquidated when being hit by a liquidity shock $\Rightarrow$ *The bank is illiquid.*

Optimal Cash Holding Policy

- If the bank chooses to be liquid, the bank's problem can be written as follows:

$$\underset{c}{Max}\ \alpha\theta\left[(1-c)\,y_H-\frac{D-c}{\theta}\right]+(1-\alpha)\,\theta\left[(1-c)\,y_L-\frac{D-c}{\theta}\right]$$

subject to

$$\begin{aligned}\alpha D+(1-\alpha)\,D &= 1-E &(1)\\ \frac{D-c}{1-c} &\leq \theta f^{*} &(2)\end{aligned}$$

Optimal Cash Holding Policy

- After simplification:

$$\underset{c}{Max}\ \left\{\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1 + E - c\left(\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1\right)\right\}$$

subject to

$$(1 - E - \theta f^*) \leq c\,(1 - \theta f^*)$$

- Trade-off involved in the cash holding decision:
  - Cost: long-term asset has higher return than cash.
  - Benefit: providing insurance against liquidity shock at date 1.

Optimal Cash Holding Policy

- Constraint
$$(1 - E - \theta f^*) \leq c\,(1 - \theta f^*)$$
matters if and only if
  - $\theta f^* < 1$: holding some cash makes sense if and only if the maximum liquidity raised from one unit of long-term asset is less than 1.
- **Assumption 6:**
$$\theta f^* < 1$$
- At the optimum
$$c = \max(\frac{1 - E - \theta f^*}{1 - \theta f^*}, 0)$$
The bank's expected profit **when choosing to be liquid** is:
$$\begin{aligned}\Pi^{li} \quad &= \quad \alpha\theta y_H + (1-\alpha)\,\theta y_L - 1 + E \\ &\quad - \max(\frac{1 - E - \theta f^*}{1 - \theta f^*}, 0)\,(\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1)\end{aligned}$$

Optimal Cash Holding Policy

- If the bank chooses to be illiquid:

$$\underset{c}{Max}\ \alpha\theta y_H + (1-\alpha)\,\ell\ -1 + E - c\,(\alpha\theta y_H + (1-\alpha)\,\ell - 1)$$

subject to

$$(1 - E - \theta f^*) > c\,(1 - \theta f^*)$$

  - At the optimum

$$c = 0$$

  - The bank's expected profit **when choosing to be illiquid** is:

$$\Pi^{illi} = \alpha\theta y_H + (1-\alpha)\,\ell - 1 + E$$

Optimal Cash Holding Policy

- The bank chooses to be liquid if and only if

$$\Pi^{li} \geq \Pi^{illi}$$

which is equivalent to

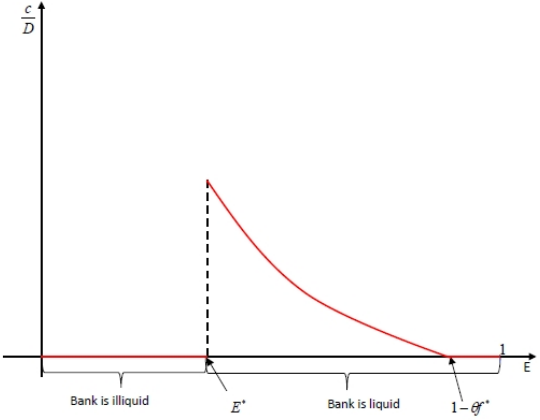
$$\underbrace{(1-\alpha)\,\theta y_L - (1-\alpha)\,\ell}_{\text{the value loss due to early liquidation}}$$

$$\geq \quad \underbrace{\max\Big(\frac{1-E-\theta f^*}{1-\theta f^*}, 0\Big)\,(\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1)}_{\text{the cost of buying insurance (i.e. holding cash)}}$$

or

$$E \geq (1-\theta f^*)\,\frac{\alpha\theta y_H + (1-\alpha)\,\ell - 1}{\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1} = E^*$$

Optimal Cash Holding Policy



- *Policy implication*: A properly designed capital requirement is sufficient to induce a better liquidity management.

Optimal Cash Holding Policy

$$E^* = \left(1 - \theta f^*\right) \frac{\alpha\theta y_H + (1-\alpha)\,\ell - 1}{\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1}$$

Corollary

The capital ratio threshold E^* is decreasing with the probability $(1-\alpha)$ that the liquidity shock happens.

Multiple Banks Setting

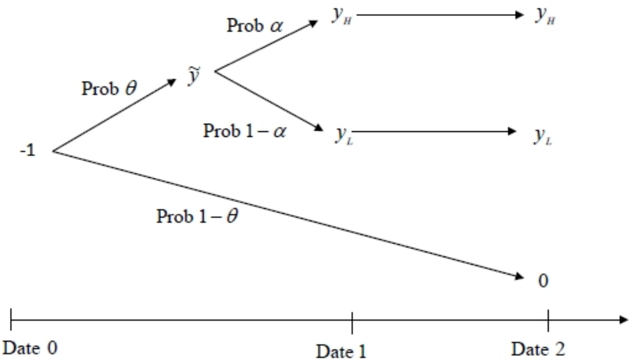
- In the basic model: no secondary market for long-term assets at date 1.
- In practice, when in need of liquidity, beside cash holdings and issuance of new debts, banks can also sell their long-term assets.

  $\Rightarrow$ Examine the consequences of permitting the sales of long-term assets.

Multiple Banks Setting

- Two potential implications:
  - The price of the assets depends on the aggregate liquidity of the banking system $\Rightarrow$ The distribution of leverage in the banking system should matter for banks' liquidity profile.
  - Beside the precautionary motive, banks can hold cash for speculative motive: buying the assets that are sold below their true value.

- Time: 3 dates $t = 0, 1, 2$.
- 3 banks A, B and C: E_i is internal capital of bank i ($i = A, B, C$).
    - Banks have access to the same investment technologies and are subject to the same moral hazard problem as described in the basic model.
    - Liquidity shock represents a common exposure of three banks:



Multiple Banks Setting

- Three sources of liquidity:
  - Cash holdings.
  - New debt issuance.
  - Sale of long-term assets.
- Secondary market for long-term assets
  - Asset specificity: potential purchasers of a bank's long-term assets are the other bank.
  - Asset sale vs. asset liquidation:
    - Asset sale: Transfer of the asset from one specialist to the other with the same ability to redeploy it.
    - Asset liquidation: Transfer of the asset to a non-specialist who can extract a much lower surplus from the asset.

Borrowing Capacity

- As in the basic model:
  - If the high state is realized, all banks can roll over their debt.
  - If the low state is realized, the maximum borrowing capacity (per unit of long-term asset) for each bank is θf^*.

Market for asset sales: Demand and Supply

- ρ_i: bank i's liquidity demand (per unit of long-term asset) at date 1:

$$\rho_i = \frac{D_i - c_i}{1 - c_i}$$

- p: per unit price of long-term asset.
- **Sellers**: banks with $\rho > \theta f^*$
  - β_i: fraction of long-term assets sold by bank i.
- **Buyers:** banks with $\rho \leq \theta f^*$
  - γ_i : volume of long-term assets bought by bank i.

Market for asset sales: Demand and Supply

- **Individual Supply**: β_i is determined as follows:

$$\beta_i (1 - c_i) p + (1 - c_i) (1 - \beta_i)\theta f^* \geq D_i - c_i$$

which is equivalent to

$$\beta_i = \min \left(1, \frac{\rho_i - \theta f^*}{p - \theta f^*} \right)$$

  - Funding liquidity expands with asset sales if $p > \theta f^*$.
  - Bank i will be closed if $\rho_i \geq p$.

- **Invidual Demand**:
  - If $p > \theta y_L$: $\gamma_i = 0$.
  - If $\theta f^* < p < \theta y_L$, γ_i is determined as follows:

$$(1 - c_i + \gamma_i)\,\theta f^* - (D_i - c_i) = \gamma_i p$$

which implies

$$\gamma_i = (1 - c_i)\,\frac{\theta f^* - \rho_i}{p - \theta f^*}$$

  - Hence:

$$\gamma_i = \begin{cases} 0 & \text{if} \quad p > \theta y_L \\ (1 - c_i)\,\frac{\theta f^* - \rho_i}{p - \theta f^*} & \text{if} \quad \theta f^* < p < \theta y_L \\ \text{any value btw 0 and } (1 - c_i)\,\frac{\theta f^* - \rho_i}{p - \theta f^*} & \text{if} \quad p = \theta y_L \\ \infty & \text{if} \quad p = \theta f^* \end{cases}$$

Market for asset sales: Unit price

Lemma

The equilibrium price of long-term assets has the following properties:

1. *It is increasing in the funding liquidity of the long-term asset.*
2. *It is lower than the asset's value when the spare liquidity in the banking system is low.*

Speculative Motive of Cash Holdings

- Compare bank i's expected profit if choosing to be liquid between two situations:
  - **No possibility of buying assets**: two other banks also choose to be liquid:

$$\Pi_i^{li\_ntr} = Max \left\{ \begin{array}{c} \alpha\theta y_H + (1-\alpha)\,\theta y_L - 1 + E_i \\ -c_i\,(\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1) \end{array} \right\}$$

subject to

$$c_i \geq \frac{1 - E_i - \theta f^*}{1 - \theta f^*}$$

  - **With opportunity to purchase assets**: At least one of the two other banks chooses to be illiquid:

$$\Pi_i^{li\_tr} = Max \left\{ \begin{array}{c} \alpha\theta y_H + (1-\alpha)\,\theta y_L - 1 + E_i \\ -c_i\,(\alpha\theta y_H + (1-\alpha)\,\theta y_L - 1) \\ +(1-\alpha)\,\gamma_i\,(\theta y_L - p) \end{array} \right\}$$

subject to

$$c_i \geq \frac{1 - E_i - \theta f^*}{1 - \theta f^*}$$

Speculative Motive of Cash Holdings

- Trading Profit: $TP_i = \gamma_i (\theta y_L - p)$:

$$\frac{dTP_i}{dc_i} = (\theta y_L - p) \frac{1 - \theta f^*}{p - \theta f^*} - \left[(\theta y_L - p) \frac{\gamma_i}{p - \theta f^*} + \gamma_i \right] \frac{dp}{dc_i}$$

Speculative Motive of Cash Holdings

Proposition

In a model with three banks, if a bank i chooses to be liquid, its cash holdings are as follows:

1. Given that two other banks choose to be liquid: $c_i^{li\_ntr} = \frac{1-E_i-\theta f^*}{1-\theta f^*}$

2. Given that at least one of two other banks chooses to be illiquid:

a) *If both banks j and k choose to be illiquid or as long as* $p = \theta y_L$: $c_i^{li\_ntr} = \frac{1-E_i-\theta f^*}{1-\theta f^*}$

b) *In the other case, i.e. among two other banks, one bank chooses to be liquid, say bank j, one bank chooses to be illiquid and is closed, say bank k:*

$$c_i^{li\_tr} = \max\left[\frac{1-E_i-\theta f^*}{1-\theta f^*}, \frac{1-E_i-\theta f^*}{1-\theta f^*} + \frac{\sqrt{\delta(1-c_k)\varepsilon_j}-\varepsilon_j}{1-\theta f^*}\right]$$

where ε_j is the excess liquidity held by bank j, i.e.

$$\varepsilon_j = (1-c_j)\left(\theta f^* - \rho_j\right)$$

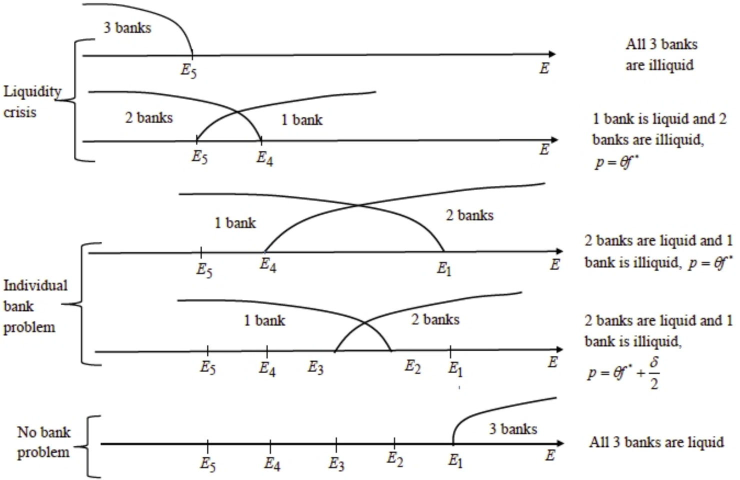
Equilibria

- *Equilibrium definition*: a quadruple $\left(c_A^*, c_B^*, c_C^*, p^*\right)$ is a rational expectation equilibrium if and only if:
  - (1) c_i^* is the optimal cash holding of bank i ($i = A, B, C$) given p^*
  - (2) p^* is the equilibrium price induced by the choices $\left(c_A^*, c_B^*, c_C^*\right)$
- Focus on pure strategy equilibria:
  - 3 banks are liquid
  - 2 banks are liquid and one bank is illiquid
  - 1 bank is liquid and two banks are illiquid
  - 3 banks are illiquid

Lemma

No equilibrium where $p = \theta y_L$ exists.

Equilibria


3 banks
E_5
E
All 3 banks are illiquid
Liquidity crisis
2 banks
1 bank
E_5
E_4
E
1 bank is liquid and 2 banks are illiquid, $p = \theta f^*$
1 bank
2 banks
E_5
E_4
E_1
E
2 banks are liquid and 1 bank is illiquid, $p = \theta f^*$
Individual bank problem
1 bank
2 banks
E_5
E_4
E_3
E_2
E_1
E
2 banks are liquid and 1 bank is illiquid, $p = \theta f^* + \frac{\delta}{2}$
No bank problem
3 banks
E_5
E_4
E_3
E_2
E_1
E
All 3 banks are liquid

Discussions: Leverage and Liquidity Crises

- A banking system where banks are highly leveraged can be prone to liquidity crises.
- The pattern of the crises

high leverage $\Rightarrow$ low ex-ante liquidity holdings $\Rightarrow$ serious fire-sale problem following a liquidity shock $\Rightarrow$ closure of illiquid banks

$\Longrightarrow$ consisten with what was observed during the 2007 - 2009 crisis

Discussions: Liquidity Support

- Lender of last resort:
  - Not helpful. The maximum borrowing capacity (per unit of long-term asset) is θf^*.
- Injecting liquidity in exchange of ownership or acquisition of long-term assets:
  - Avoid banks' failure but destroy ex-ante incentives of banks to hold cash.

Conclusion

- Analysing the impacts of banks' leverage on their incentives to manage their liquidity.
- Main findings:
  - Banks with higher capital ratio tend to better manage their liquidity risk.
  - A banking system composed of highly leveraged banks is prone to liquidity crises.
- Future research agenda:
  - Partial equilibrium analysis:
    - Banks choose their leverage: signaling device of their ex-ante monitoring effort .
    - Choice between short-term and long-term debts: Are holding liquid assets and funding by long-term debts perfect substitute from a liquidity risk perspective?
  - General equilibrium analysis:
    - Optimal amount of aggregate liquidity holdings.
  - Empirical studies: measures of banks' liquidity risk.