Bank liquidity mismatch in the reserve cycle[1]

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Abstract

We study how aggregate liquidity conditions driven by quantitative monetary policy affect banks' funding choices and their fragility. Our global game approach allows us to analyze banks' trade-off between reducing the chance of inefficient runs and the cost of stable funding (time deposits), targeted at agents with lower liquidity needs. Abundant reserves and low rates may induce banks to increase their liquidity promises. In contrast, a flat yield curve encourages stable funding. The net stability effect depends on both yield curve policy and aggregate reserves. The model rationalizes evidence that the rapid reserve expansion in 2020-21 led banks to increase their liquidity mismatch.

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1 Introduction

For more than a decade, large-scale quantitative easing (QE) and tightening (QT) have shaped financial market conditions. Following the extensive response to the 2008 financial crisis, central banks again acted on a massive scale in 2020 to address the global COVID-19 pandemic. The sharp increase in reserves pushed the yield curve toward its lower bound, and boosted liquidity across financial markets.

As inflation rose in late 2021 and more markedly in 2022, central banks shifted to a tightening phase, rapidly raising interest rates (Du et al., 2024). Higher rates improved bank profits but caused capital losses, leaving many banks vulnerable to runs (Jiang et al. 2023). Capital losses on security holdings contributed to significant bank runs in March 2023 and large defaults. Acharya and Rajan (2024) suggest that the rapid rise in reserves incentivized banks to issue more runnable claims (Figure 1), raising concerns that a quantitative cycle may create "liquidity dependence," increasing run risk when monetary policy tightens.

To shed light on these concerns, we examine banks' choices regarding liquidity mismatch in response to exogenous aggregate liquidity conditions shaped by quantitative monetary policy (QMP).[2] Our partial equilibrium framework allows us to study a context where aggregate liquidity conditions are exogenous to the banking sector. Such conditions arise when QMP is a response to large real shocks (such as the COVID-19 pandemic in 2020-2022), rather than from QE policy enacted in response to financial distress, as in 2009.

In a regime of reserve scarcity, interest rates are determined in equilibrium by reserve policy. In contrast, under QMP, the central bank is able to operate on the yield curve separately by large open market operations and by paying interest on

[2]We focus on banks' funding composition, while Acharya and Rajan (2024) model the scaling-up effects of QE within a simplified macroeconomic framework.

reserves. Accordingly, we treat both reserves and yields as exogenous and independent variables. Adopting a simple global-games framework allows us to derive unique run equilibria, and the underlying run frequency, in closed form. As in Goldstein and Pauzner (2005), some runs arise from poor fundamentals, while others result from strategic complementarities among depositors. We analyze when more stable funding (e.g., time deposits) can be optimal. Although the stable funding equilibrium is socially optimal, banks face a trade-off when choosing their liquidity mismatch –defined as asset liquidity minus runnable claims such as demandable debt– balancing lower funding costs against the risk of more frequent inefficient runs.

A bank's choice of liquidity mismatch depends on factors such as the volume of liquid reserves, market liquidity, and the slope of the yield curve. Taking QMP as given, we examine its impact on bank liquidity mismatch and run risk.[3] Banks choose their liquidity mismatch, fully aware of its impact on run frequency. We show that banks' decisions regarding stable funding involve a trade-off between its higher funding cost and the lower default probability. Stable funding can be secured by offering time deposits to agents with low liquidity needs. Its cost is influenced by term premia and market liquidity, both of which are shaped by the prevailing phase of Quantitative Easing (QE) or Quantitative Tightening (QT) policies. The benefits of stable funding include reduced strategic complementarities, fewer inefficient runs, and a more effective allocation of scarce liquidity during runs to those who need it most. Banks are more likely to prefer stable funding when their assets are illiquid, as runs under such circumstances are both costlier and more frequent. This preference becomes especially pronounced when reserves and market liquidity are low.

Both a run-prone and a stable funding equilibrium are possible during QE and QT phases. The incentives for stable funding in each phase depend on the balance between

[3]Through targeted asset purchases and yield curve guidance, central banks can influence reserves and term premia with some degree of independence.

term premia and market liquidity. The QE phase of the reserve cycle in 2020-2022 resulted in a yield curve flattened to its lower bound and elevated market liquidity. Figure 1 illustrates how U.S. banks responded to the vast expansion of reserves by increasing runnable liquidity promises. It is not surprising that as banks absorb more reserves, they may extend additional liquidity promises to the economy. However, when the aggregate liquidity effect begins to outweigh its pricing effect, banks may further amplify their liquidity mismatch.

While most bank defaults result from poor fundamentals, some may arise from self-fulfilling runs on illiquid banks (Diamond and Dybvig, 1983). Such "inessential runs" are most likely when a bank's liquidity mismatch is elevated.[4] As Kashyap et al. (2024) note, "most banking models ... neglect how bank fragility endogenously affects the structure of bank balance sheets and vice versa." They identify key trade-offs in capital and liquidity norms within a general framework that features unique run equilibria.

We contribute to this literature by examining endogenous bank exposure to runs in response to aggregate liquidity conditions. Earlier work on cyclical run risk has primarily focused on changing fundamentals over the business cycle (e.g., Jacklin and Bhattacharya (1988); Chari and Jagannathan (1988); Allen and Gale (1998)). In contrast, our approach emphasizes endogenous bank run risk under aggregate liquidity conditions, which are typically influenced by central bank reserve cycles and the phases of QE and QT.

1.1 The central bank reserve cycle

Since only banks can hold reserves, the rapid expansion of asset purchases during the COVID-19 pandemic led to a significant shift in bank sector liquidity. Purchases

[4] Allen and Gale (2003) show that large runs can sometimes be optimal for reallocating consumption across time.

rapidly reduced interest rates and term premia, resulting in a flat yield curve. Large purchases also enhanced trading conditions, considerably improving asset liquidity.

In a QT phase, these trends are reversed, with reduced market liquidity and higher interest rates.[5] However, the impact of the current QT phase appears far more muted than that of an outright QE reversal, primarily because the reduction in purchases has been more gradual and distributed over time. While interest rates could be raised rapidly by increasing the reward on reserves, the cross-country evidence by Du et al. (2024) suggests that the impact of QT on market liquidity so far has been very modest. Ultimately, liquidity risk incentives are influenced by the balance between rising term premia and changes in asset market liquidity. As term deposit rates rise, banks are less inclined to adopt stable funding. However, lower reserves decrease market liquidity, making runs more costly and frequent, thereby increasing the value of stable funding. Thus, the stability implications of central bank policy depend on both price (term premia) and quantity (reserves boosting market liquidity) dimensions. Time deposits reduce withdrawal incentives and direct liquidity toward those who value it most. On both counts, the stable funding equilibrium is socially optimal. Banks are more likely to choose stable funding when their assets are illiquid, as, for any given funding structure, runs become costlier and more probable. Moreover, banks are more likely to opt for stable funding when preference heterogeneity is substantial, allowing stable funding to be raised at a lower cost due to easier discrimination across depositor types.

An expansionary QE policy, characterized by a flat yield curve and high market liquidity, places banks in a stability trade-off. While low-term premia encourage a stable funding equilibrium, abundant market liquidity increases the liquidation value of bank assets. This reduces the likelihood of runs and incentivizes banks to scale up their liquidity promises. In contrast, the QT phase, marked by rising rates and

[5] Recent episodes of illiquidity also reflect the significantly larger public debt market (Copeland et al. 2022).

declining reserves, reverses these dynamics. The net effect on bank stability depends on the interplay between market liquidity and yield curve effects. In a context of "excess reserves," banks may increase their liquidity risk, as concerns about runs diminish. However, a shift to a QT phase brings higher term premia, making stable funding more costly. When market liquidity remains elevated, banks may prefer greater liquidity mismatch. A threshold effect can arise when reserves exceed the amount needed to flatten the yield curve, amplifying banks' liquidity risk-taking behavior. Introducing primary and secondary demands for liquidity allows for modeling the pricing of time deposits under competition with non-bank entities.[6]

The outline of the paper is as follows. Section 2 introduces the main model, where banks design optimal funding claims facing a heterogeneous liquidity demand. Section 3 solves for the run probability under any funding structure. Section 4 describes the possible funding equilibria. Section 5 derives the private bank choice, which may differ from the socially optimal stable funding. Section 6 examines the comparative statics on funding stability as aggregate liquidity conditions change, such as across the different phases of the reserve cycle. Section 7 offers some conclusions.

[6] During the QT phase, banks' reluctance to adjust deposit rates led to significant time deposit outflows to non-banks. Money market fund (MMF) assets rose from \$4 trillion in March 2020 to \$6.5 trillion over four years (OFR, 2024), adding to competitive pressure from online banks offering higher rates (Erel et al., 2023).

2 Model Setup

Environment. We consider an economy that lasts for three periods, $t \in \{0, 1, 2\}$, and it is populated by a unit mass of liquidity seekers (LS) with a unit endowment, and a bank (B) funded by risk-neutral shareholders. LS can invest in claims issued by the bank (derived below). Alternatively, LS can invest in an asset that returns y in period $t = 2$ (outside option). We assume that there is no safe storage from period $t = 0$ to period $t = 1$.

Liquidity Seekers. The utility function of LS is given by:

$$U_{LS} = u(c_1, \chi) + c_2,$$

where

$$u(c_1, \chi) = \begin{cases} c_1 & \text{if} \quad c_1 \geq 1 \\ c_1 - \chi\tau & \text{if} \quad c_1 < 1, \end{cases}$$

where c_t is the consumption at $t \in \{1, 2\}$ and $\chi \in \{0, 1\}$ indicates whether the investor is hit by a liquidity shock at $t = 1$. When hit by a shock, investors face an urgent consumption need of one unit. The parameter τ represents the cost incurred by investors when they are hit by a shock and unable to consume one unit. We allow for heterogeneity in liquidity needs, that is, $\tau \in \{\tau_L, \tau_H\}$ (where $\tau_L < \tau_H$) which is investors' private information at $t = 0$. We denote by HLS liquidity seekers with high $(\tau = \tau_H)$ needs, and by LLS liquidity seekers with low $(\tau = \tau_L)$ needs.

It is common knowledge that $\Pr(\tau = \tau_H) = m_H$ and $\Pr(\tau = \tau_L) = m_L = 1 - m_H$. The probability of a liquidity shock at $t = 1$ is common knowledge and equals $\Pr(\chi = 1) = \alpha$. The type of LS and the liquidity shock are independently distributed and there is no aggregate uncertainty. Finally, we assume that the bank cannot observe the liquidity preferences of its clients.

Bank assets. The bank can invest in assets comprising a liquid and an illiquid component. In particular, a fraction k is liquid and provides a gross return of 1 at all dates. A fraction $1-k$ is illiquid and yields a gross return of $y_t(\theta)$ if liquidated at $t \in \{1,2\}$. The state $\theta \sim U[0,1]$ at $t=1$ reflects asset fundamentals, specifically the chance of a high return. If allowed to mature, the illiquid asset component yields $y_2 = r > 1$ with probability θ and $y_2 = 0$ with probability $1-\theta$. If liquidated early, it generates $y_1 = \overline{\ell} \in (1,r)$ when $\theta > \overline{\theta}$ and $y_1 = \ell \in (0,1)$ when $\theta \leq \overline{\theta}$.

Bank funding. The bank chooses its funding composition (stable versus runnable) in period $t=0$ to maximize its profit subject to incentive compatibility and participation constraints of investors. A claim j is characterized by (p_j, s_j): p_j is the probability of being paid one unit at $t=1$ conditional on demanding withdrawal. The value of p_j depends on the priority of claim j; that is, if claim j has payment priority over claim z, either $p_j = 1$ and $p_z < 1$ or $p_j < 1$ and $p_z = 0$, whereas in the absence of priority $p_j = p_z$; $s_j > 0$ is the share of remaining assets if the holder waits until $t=2$ when $p_j > 0$.

The global game approach, which allows us to derive a unique equilibrium and explore its properties, requires that bank claims satisfy the lower and upper dominance region constraints. In our model, the lower dominance region constraint is satisfied if $p_j > 0$. As becomes clear below, the upper dominance region constraint is satisfied if $s_j > \frac{\ell}{r(1-k)(\ell-1)}$.

Interim information. The state θ is unknown at $t=0$. At $t=1$ each holder i of claim j receives a private noisy signal on the state, $x_i = \theta + \sigma\eta_i$, where $\sigma > 0$ is arbitrarily small, η_i are i.i.d. with continuous density $f_{j_i}(\cdot)$ with support on $\left[-\frac{1}{2}, \frac{1}{2}\right]$, and j_i is the claim held by agent i. This means that signals on asset fundamentals may differ depending on the claim type.

3 Probability of a Bank Run

This section derives the run probability under different funding and liquidity conditions. The next section characterizes the funding structure that maximizes expected bank profits. We focus on the case where the bank aims to attract both types of liquidity seekers, and focus on its chosen funding structure.

The bank finds it optimal to issue up to two types of deposits, $j \in \{1, 2\}$.[7] Let m_j be the mass of claim j, with $\sum_{j=1}^{2} m_j = 1$. When the bank issues deposits with different priorities ($m_1 > 0$, $m_2 > 0$, and $p_1 = 1 > p_2 > 0$), we refer to deposits $j = 1$ as demandable deposits, while $j = 2$ represents time deposits with a lower payment priority. We show later that in this equilibrium demandable deposits are safe while time deposits are risky with a higher expected return. If the bank chooses to issue only claims with the same priority ($m_1 = 0$, $m_2 > 0$, and $p_2 \in (0, 1)$), we refer to them as risky-liquidity demandable deposit. Table 1 summarizes the feasible claims and their equilibrium properties.

Claim	**Liquidity at** $t = 1$	**Return at** $t = 2$
(Risky-liquidity) DD	likely	low & risky
(Safe-liquidity) DD	certain	very low & risky
Time deposits	unlikely	high & risky

Table 1: Funding claims and their induced run frequency

If all depositors seek to withdraw at $t = 1$, the bank is liquidated when $\theta \leq \overline{\theta}$, that is, $\sum_{j=1}^{2} m_j p_j = \overline{m} \equiv k + (1 - k)\ell$.

Under our assumptions, LS hit by a liquidity shock will unconditionally seek to withdraw at $t = 1$. Let f_j be the fraction of investors not hit by liquidity shocks that choose to withdraw their claim j. The fraction of deposits withdrawn is $f \equiv \frac{m_1 p_1 f_1 + m_2 p_2 f_2}{\overline{m}} \in$

[7] We can show that secured debt is never optimal in this setting.

$[0, 1]$. Thus, the overall measure of withdrawals is $w(f) \equiv \alpha\overline{m} + (1-\alpha)\overline{m}f = \overline{m}[\alpha + (1-\alpha)f]$.

The net rollover payoff at $t = 1$ of LS holding deposits $j \in \{1, 2\}$ when they are not hit by a liquidity shock is

$$\Pi_j(f, \theta) = \begin{cases} s_j\left[(1-k)\theta r + k - w(f)\right] - p_j, & \text{if } w(f) \leq k \\ s_j\left\{\theta r\left[(1-k) - \frac{w(f)-k}{y_1(\theta)}\right]\right\} - p_j, & \text{if } k < w(f) \leq \overline{m} \end{cases}. \tag{1}$$

Π_j is increasing in θ (*state monotonicity*), decreasing in f (*action monotonicity*), and negative for all f if θ is in the *lower dominance region.* As we explained above, we are interested in claims that satisfy the upper dominance region restriction, since a depositor strictly prefers to roll over when the state is good enough; and strictly prefers to withdraw when the state is sufficiently low. However, depositors who receive an intermediate signal are subject to strategic complementarities. Their decision to withdraw depends on both their beliefs about the state θ (fundamental uncertainty) and the fraction of other depositors who withdraw (strategic uncertainty).

As shown by Steiner and Sakovics (2012) in a global-games approach with heterogeneous payoffs, there is a unique equilibrium in which holder i of claim j rolls over if the signal x_i is not lower than the threshold x_j^* and withdraws if otherwise. Moreover, as signals become nearly precise (i.e., $\sigma \to 0$), the cutoffs x_j^* of all claims converge to a state threshold θ^* such that $\int_0^1 \Pi_j(f, \theta^*) dA_j(f) = 0$ for all j, where $A_j(f)$ is the probability that a holder of claim j with the threshold signal x_j^* assigns that the fraction of withdrawals is less than f. Furthermore, the average of strategic beliefs is uniform on $[0, 1]$, that is, $\sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} A_j(f) = f$. This allows us to obtain a closed-form solution for θ^*. Let us define $v(f, \theta)$ as that value of remaining assets at $t = 2$. It follows that

θ^* is the unique solution to

$$\sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} \frac{p_j}{s_j} = \sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} \int_0^1 v(f, \theta^*) dA_j(f) \quad = \int_0^1 v(f, \theta^*) \sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} dA_j(f) = \int_0^1 v(f, \theta^*) df. \tag{2}$$

We formalize this in the following proposition.

Proposition 1. *In the limit as $\sigma \to 0$, there is a unique equilibrium where depositors with no liquidity needs withdraw at $t = 1$ if $\theta < \theta^*$, else wait till $t = 2$ where*

$$\theta^* = \frac{1}{r} \frac{\sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} \frac{p_j}{s_j} - \frac{(k - \overline{m}\alpha)^2}{2(1-\alpha)\overline{m}}}{(1-k)\left[\frac{1}{2} + \frac{k - \overline{m}\alpha}{2(1-\alpha)\overline{m}}\right]}. \tag{3}$$

Corollary 1. *The run cutoff has the following implications:*

1. *The impact of a higher mass of deposits j on θ^* is increasing in its withdrawal priority, $\frac{\partial \theta^*}{\partial m_j \partial p_j} > 0$, and decreasing in its share of remaining assets, $\frac{\partial \theta^*}{\partial m_j \partial s_j} < 0$.*
2. *The influence of the term s_j on θ^* is increasing in its mass, $\frac{\partial \theta^*}{\partial (p_j^2/s_j) \partial m_j} > 0$.*

According to Corollary 1, deposits with larger mass (m_j) are more influential in bank runs. In addition, deposits with higher withdrawal priority (captured by a higher value of p_j) and lower share of remaining assets (captured by a lower value of s_j) contribute to more frequent runs. Intuitively, the bank can reduce the risk of a bank run by increasing the share of lower priority funding (i.e., time deposits), at the cost of lower profits in the absence of a run (as time deposits promise a higher expected return in the absence of a run).

4 Run-prone vs stable funding equilibrium

4.1 Pooling Equilibrium

We start by characterizing in Proposition 2 the optimal funding structure when the bank does not seek to separate low and high liquidity needs (recall that τ is investors' private information). In this case, the bank issues a single claim targeting both HLS and LLS (i.e., pooling equilibrium). The optimality of pooling is explored in Section 5.

Proposition 2 builds on two observations. First, note that demandability allows investors to withdraw in period $t = 1$ and consume with probability p. Therefore, the bank finds it optimal to offer demandable deposits up to an amount p^* that does not exceed the liquidation proceeds in period $t = 1$, which equals $k + (1 - k)\ell$. Second, note that all else equal, HLS have a stronger incentive to invest in demandable deposits because they value consumption in period $t = 1$ more (as $\tau_H > \tau_L$), while they value consumption in period $t = 2$ as much as LLS. Hence, it is more costly for the bank to attract LLS; thus, their participation constraint binds in equilibrium, while the participation constraint of HLS is slack, implying that the latter extract a positive surplus in equilibrium. As a result, the optimal value s^* is determined by their binding participation constraint of LLS, conditional that this satisfies the upper dominate region constraint, i.e., $s^* > \frac{\ell}{r(1-k)(\ell-1)}$.

Proposition 2. *In a pooling equilibrium, the bank offers only demandable deposits, held by both types of liquidity seekers. In equilibrium $p^* = k + (1 - k)\ell$, and s^* is the minimum value of s solving the participation constraint of low liquidity seekers* (A.7). *The implied run probability is given by equation* (3)*, for $p_1 = p_2 = p^*$ and $s_1 = s_2 = s^*$.*

Proof. See Appendix. □

4.2 Separating Equilibrium

We now characterize the optimal funding structure in a separating equilibrium, that is, when the bank screens the two types of LS by offering a menu of claims; the optimality of screening LS is explored in Section 5.

As becomes clear below, the bank offers safe-liquidity demandable deposits ($p_1^* = 1$) targeting HLS, which dominate in terms of period $t = 1$ consumption, and risky time deposits ($p_2^* < 1$) targeting LLS, which dominate in terms of period $t = 2$ consumption. In what follows, we explain the main steps of the proof and the underlying intuition.

The bank offers a menu of two claims $\langle p_1, s_1 \rangle$ and $\langle p_2, s_2 \rangle$ to screen the two types of LS. As τ is investors' private information, the optimal funding structure should satisfy their period $t = 0$ participation and incentive compatibility constraints:

$$
\begin{aligned}
U_{LS}(p_1, s_1|\tau_H) &\geq \bar{U}_{\tau_H} \\
U_{LS}(p_2, s_2|\tau_L) &\geq \bar{U}_{\tau_L} \\
U_{LS}(p_1, s_1|\tau_H) &\geq U(p_2, s_2|\tau_H) \\
U_{LS}(p_2, s_2|\tau_L) &\geq U(p_1, s_1|\tau_L)
\end{aligned}
$$

where LS' outside option of not accepting any claim offered by the bank is given by:

$$\bar{U}_\tau \equiv -\alpha\tau + y. \tag{4}$$

As in the pooling equilibrium, the banks' optimal funding is such that the promised liquidity (i.e., $m_H p_1 + m_L p_2$) takes its maximum feasible value. Note that HLS have an incentive to mimic LLS since time deposits earn (in expectation) more. Thus, to achieve separation at the lowest cost, the bank chooses to offer claims for which the difference between p_1 and p_2 is maximized. By combining these two insights, we derive optimal values of p_1^* and p_2^*, that is, $p_1^* = 1$ and p_2^* solves $m_H + m_L p_2 = k + (1-k)\ell$.

Furthermore, as LLS suffers less from failing to satisfy her liquidity needs, under the optimal capital structure, their period $t = 0$ participation constraint binds, and together with the binding incentive compatibility constraint of HLS, determine the optimal values s_1^* and s_2^*, conditional that these values satisfy the upper dominate region constraint, i.e., $s_1^* > \frac{\ell}{r(1-k)(\ell-1)}$ (as $s_2^* > s_1^*$). Proposition 3 summarizes.

Proposition 3. *In a separating equilibrium, the bank offers safe-liquidity demandable deposits and time deposits, which are held by investors with high and low liquidity needs respectively. In equilibrium, $p_1^* = 1$, $p_2^* = \frac{(k+(1-k)\ell)-m_H}{m_L}$, and s_1^* and s_2^* are the minimum values of s_1 and s_2 solving the incentive compatibility constraint of high liquidity seekers* (A.8) *and the participation constraint of low liquidity seekers* (A.9) *and it holds that $s_1^* < s_2^*$. The run probability is given by* (3)*, for $p_1 = p_1^*$, $p_2 = p_2^*$, $s_1 = s_1^*$, $s_2 = s_2^*$.*

Proof. See Appendix. □

5 Bank's choice of liquidity mismatch

Before we study the bank's choice between a pooling and a separating funding equilibrium, we explore the implications of each equilibrium for the run incentives. The latter helps us highlight the underlying trade-off in the bank's funding choice.

Proposition 4 shows that a separating equilibrium with time deposits leads to a lower run probability, limiting deadweight losses of inefficient runs. The underlying intuition is that LLS, who hold time deposits, have a weaker incentive to run, because they have a lower priority in period $t = 1$, and they are promised a larger share of the realized return of remaining assets in period $t = 2$. Interestingly, HLS also exhibit a lower incentive to run, for two reasons related to strategic complementarities. First, HLS have higher priority compared to LLS, which reduces the likelihood that the bank's liquidation proceeds will be insufficient to repay them if they choose to run. Second, as noted earlier, LLS have a weaker incentive to run.

Proposition 4. *When the bank offers both safe-liquidity demandable deposits and time deposits (as in Proposition 3), the probability of an inefficient run is lower than in the pooling funding equilibrium, where the bank offers only risky demandable deposits (as in Proposition 2).*

Proof. See Appendix. □

Following Proposition 4, we can interpret the pooling equilibrium as the "run-prone" funding structure, while the separating equilibrium as the "stable" funding structure.

Next, we shed light on when the separating equilibrium is more or less likely to arise under the optimal funding structure. Lemma 1 summarizes.

Lemma 1. *Under the optimal funding structure, a separating (stable funding) equilibrium is more likely to arise when the liquidation proceeds in period $t = 1$ are limited, and the heterogeneity in liquidity needs is substantial.*

First, recall that the banks' funding choice involves a trade-off between its higher funding cost and the lower default probability. Note that if the liquidation proceeds in period $t = 1$, $m = k + (1 - k)\ell$, are limited, the default probability if the bank offers only risky demandable deposits (i.e., pooling equilibrium), all else equal, will be large, and the bank has to promise a significant share of the realized value at $t = 2$ to satisfy LS' participation constraint. In that case, the bank finds optimal sway from risky demandable deposits to a mix of safe-liquidity demandable deposits and time deposits associated with a smaller default probability.

Next, an essential determinant of whether a pooling or separating equilibrium is more likely to arise under the optimal funding structure is the heterogeneity among LS, which is captured by the difference $\tau_H - \tau_L$. Recall that in a separating equilibrium, the binding incentive compatibility constraint is IC_{τ_H}, i.e., HLS should be indifferent between safe-liquidity demandable deposits, which they are expected to hold in equilibrium, and time deposits, which target LLS. Note that if $\tau_H - \tau_L$ is relatively small, i.e., low heterogeneity, HLS has a strong incentive to mimic LLS, and the bank, to eliminate these mimicking incentives should offer to HLS a higher share s_2 of the realized value at $t = 2$. The latter increases the overall cost of implementing a separating equilibrium, which can result in the bank opting for a pooling equilibrium, which can have a higher default probability but allows the bank to maintain a higher share of the realized value in period $t = 2$.

5.1 Planner's preferred funding structure

In our setting, social welfare is defined as the sum of the expected utility of depositors and the bank's profit, given that the bank's equity is held by risk-neutral investors. Proposition 5 shows that a separating (stable funding) equilibrium is socially more efficient than the pooling equilibrium. There are two reasons. First, a separating equilibrium offers a more efficient allocation of proceeds in period $t = 1$, as more liquidity is provided to investors who value it more (since HLS hold safer demandable deposits and LLS hold time deposits). Second, as Proposition 4 shows, a separating equilibrium corresponds to a lower run probability, fewer inessential runs and more efficient continuation of long term project.

Proposition 5. *The welfare-maximizing bank funding structure consists of demandable deposits held by high liquidity need investors, and enough time deposits (held by low liquidity need investors) to ensure safety of demandable deposits.*

Proof. See Appendix. □

6 The impact of central bank policy

Building on the insights from Lemma 1, this section analyzes how the central bank's quantitative policy affects the funding structure of banks. Central bank reserves directly influence banks' reserves k and indirectly affect asset liquidation values ℓ (market liquidity), increasing the liquidity of bank balance sheets. Quantitative policy also targets interest rates and the slope of the yield curve. Accordingly, we treat these variables as exogenous variables for the bank funding choice, reflecting external conditions driven by the central bank's Quantitative Easing (QE) or Quantitative Tightening (QT) policy stance.

Consider, first, the effect of high market liquidity under QE. In that case, the bank's liquidation proceeds at $t = 1$ (equal to $k+(1-k)\ell$) are high, reducing the chance of a run under a pooling funding equilibrium. Thus the bank is less inclined to bear the higher cost of stable funding and is tempted to adopt a more runnable funding structure.

Consider next the effect of the term premium y on bank incentives. Quantitative policy influence the term structure of interest rates through large-scale security purchases, thereby affecting the slope of the term structure.[8] A lower term premium encourages a stable funding choice. The reason is that a high term premium increases the cost of implementing a separating (stable funding) equilibrium more than the cost of implementing a pooling (run-prone) equilibrium.

A QE phase may be associated with stable funding due to its flattening effect on the yield curve. Conversely, during a QT phase, when rates and term premia rise, the bank may respond to rising stable funding costs and shift to run-prone demandable debt funding. Thus, a QT policy may increase equilibrium liquidity mismatch by both reducing reserves k and increasing the scale of runnable claims. Indeed, when interest rates rise, banks often do not fully adjust term deposit rates (Drechsel et al. 2024).

[8] In contrast, ordinary monetary policy primarily impacts the short-term policy rate.

QMP Stand	**Reserves k**	**Yield y**	**Bank funding**
Large scale QE	Excess reserves	$y = 0$	Pooling (DD)
Moderate QE	High reserves	low y	Stable Funding (SF)
Moderate QT	Falling reserves	medium y	Pooling (DD)
Tight QT	Low reserves	high y	Stable Funding (SF)

Table 2: QE/QT stand and choice of funding equilibrium.

As a result, some investors with low liquidity need to switch to marginally less liquid non-bank claims. Proposition 6 summarizes this effect.

Proposition 6. *A higher term premium y favors a shift toward more liquidity mismatch under demandable debt funding.*

In a QT phase, a potentially stabilizing effect comes from reduced market liquidity. A lower liquidation value increases the cost and likelihood of runs, favoring more stable funding. Of course, this effect is weakened by expectations on a liquidity bailout in case of distress.

In the end, the net stability effect of QE and QT depends on the relative impact of a lower k (and thus l) versus a higher term premium y. Thus, the impact of aggregate liquidity involves both a price effect (term premium) and a quantity effect (reserves and market liquidity). When reserves are very abundant, banks choose to increase their liquidity promises, raising the chance of runs.

For illustration purposes, Table 2 summarizes how quantitative monetary policy may affect the bank's incentive to opt for stable instead of run-prone funding. It distinguishes between a QE policy with just enough reserves to flatten the yield curve (denoted by $k < \hat{k}$) and a more expansionary QE stance with "excess" reserves (denoted by $k > \hat{k}$). Similarly, it distinguishes between a moderate QT phase, where reserves are not scarce and the slope of the yield curve is moderate, and a very tight QT phase that leads to much higher rates and reduced market liquidity.

7 Conclusion

We study the bank's choice of liquidity mismatch in a context of heterogeneous liquidity demand, in a context where both fundamental and inefficient runs may occur. The private bank choice of liquidity mismatch depends on financial conditions, which are affected by exogenous central bank quantitative monetary policy (QMP) choices on reserves and the yield curve. Our analysis applies to reserve policy choices due to nonfinancial causes, such as in response to 2020 COVID epidemic, rather than after the 2008 financial crisis. The net effect of QMP on bank stability depends on a balance of price and quantity factors. In particular, while a flatter yield curve encourages stable funding, "excess" reserves –well beyond the scale required to achieve the target rate– may be destabilizing, both in a QE and a QT phase.

Our framework allows us to study the trade-off between funding cost and benefits of stable funding, in a context where aggregate liquidity conditions are exogenous to the banking sector. Such conditions arise when QMP is implemented in response to large real shocks, such as the COVID-19 pandemic in 2020–2022, rather than as a result of QE policies enacted in response to financial distress, as seen in 2009.

In a regime of reserve scarcity, interest rates are determined in equilibrium by reserve policy. In contrast, under QMP, the central bank can influence the yield curve independently through large open market operations and the payment of interest on reserves. The net effect of QMP on bank liquidity mismatch depends on both a price (term premium) and a quantity (aggregate liquidity) effect. A flat yield curve encourages more stable funding, reducing liquidity mismatch by adding time deposits. Banks may shift to run-prone funding when reserves become very abundant, boosting their asset liquidity. In a sense, when more reserves (outside money) are injected, banks adjust by increasing their liquidity promises to the economy (e.g., uninsured deposits or credit lines). The key questions are: how easy is it to reverse this process during tightening? How does the financial system respond to less liquidity and higher rates? We show that stable funding incentives may switch discreetly at some trigger point. A shift to higher liquidity mismatch is more likely under "excess" reserves, tempered by lower rates and term premia.

More work is needed to understand liquidity risk incentives across aggregate circumstances. Our approach takes credit risk as given to focus on endogenous liquidity risk. A full treatment should include the role of bank capital in promoting risk control, as discussed in Kashyap et al. (2024).

This work aims to contribute to the debate at a time of heightened awareness of run risk, even in viable banks. Recent work has highlighted how self-reinforcing outflows can be contained by settlement rules such as gating and swing pricing (Schilling 2023; Matta and Perotti 2024; Matta, Perotti, and Oostdam 2024). Containing outflows is essential to grant authorities a chance to pursue credible recovery steps in a timely manner (Martino et al. 2024; Martinova et al. 2022).

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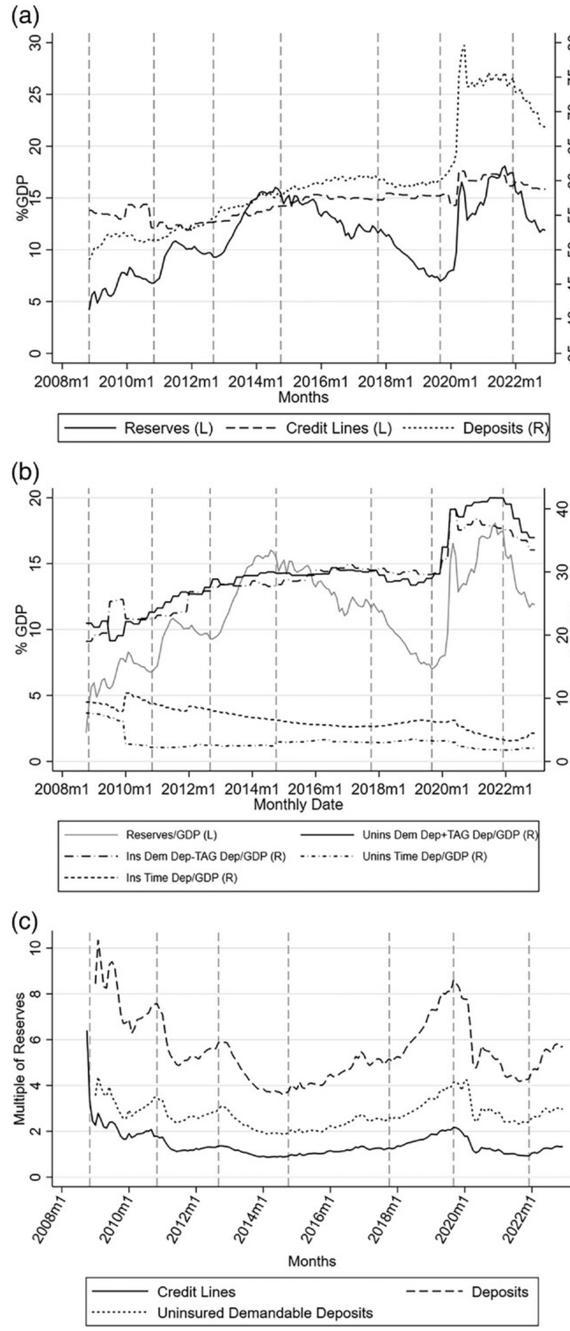

Figure 1: The reserve cycle (source Acharya and Rajan (2024)).

Appendix

A.1 Proof of Proposition 1

Proof. Steiner and Sakovics (2012) provide this result in their proof for Proposition 1 within a more general class of global games with heterogeneous payoffs that satisfy the following conditions: (a) $\Pi_j(f, \theta)$ is nondecreasing in θ and nonincreasing in f; (b) there exist $\overline{\theta}$ and $\underline{\theta}$ with $\frac{\sigma}{2} < \min\left\{1 - \overline{\theta}, \underline{\theta}\right\}$ such that $\Pi_j(f, \theta) < 0$ for all $f \in [0, 1]$ and $\theta < \underline{\theta}$ and $\Pi_j(f, \theta) > 0$ for all $f \in [0, 1]$ and $\theta \geq \overline{\theta}$; (c) $\Pi_j(f, \theta)$ is bounded; (d) $\Pi_j(f, \theta)$ is Lipschitz continuous in $\theta \in [0, \underline{\theta}) \cup [\overline{\theta}, 1]$; (e) there exists a function $v(f, \theta)$ and positive functions $s_j(\theta)$ and $p_j(\theta)$ such that $\Pi_j(f, \theta) = s_j(\theta)v(f, \theta) - p_j(\theta)$ for all j. Our model clearly satisfies all these conditions. The proof is derived from the following four results provided by Steiner and Sakovics (2012) — including the Online Appendix — using our notation.

Lemma 6 (Unique Equilibrium)**.** *There is a unique Bayes-Nash equilibrium in which the holder of depositsj not hit by a liquidity shock rolls over if $x_i > x_j^*$ and withdraws if $x < x_j^*$.*

Lemma 7 (Convergence of Equilibrium as $\sigma \to 0$)**.** *As $\sigma \to 0$, the cutoffs x_j^* converge to θ^*, which is the unique solution to $\int_0^1 \Pi_j(f, \theta^*) dA_j(f) = 0$ for all j, where $A_j(f)$ is the probability that a holder of claim j assigns that the fraction of withdrawals is less than f.*

Lemma 8 (The Belief Constraint)**.** *The weighted average strategic beliefs is the uniform belief on $[0, 1]$: $\sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} A_j(f) = f$.*

Proposition 3 (Unique Solution)**.** *As $\sigma \to 0$, the threshold θ^* is the unique solution to $\sum_{j=1}^{2} \frac{m_j p_j}{\overline{m}} \frac{p_j}{s_j} = \int_0^1 v(f, \theta^*) df$.*

This concludes the proof. □

A.2 Proof of Proposition 2

Proof. First, note that the outside option of LS of type $\tau = \{\tau_H, \tau_L\}$ is given by

$$\bar{U}_\tau \equiv -\alpha\tau + y. \tag{A.1}$$

Given the run cutoff θ^*, the expected utility of LS of type $\tau = \{\tau_H, \tau_L\}$ with claim $\langle p, s\rangle$ is

$$\begin{aligned} U_{LS}(p, s|\tau) \equiv & \int_{\theta^*}^{1} \{\alpha[p-(1-p)\tau] + (1-\alpha)s\left[(1-k)\theta r + k - m\alpha\right]\} \, d\theta \\ & + \int_{0}^{\theta^*} [p - \alpha(1-p)\tau] d\theta. \end{aligned} \tag{A.2}$$

Finally, the expected profit of the bank is

$$\overline{U}_B \equiv \int_{\theta^*}^{1} \left\{ \left[1-(1-\alpha)\sum_{j=1}^{2} m_j s_j\right] [(1-k)\theta r + k - m\alpha] \right\} d\theta. \tag{A.3}$$

In a pooling equilibrium, the participation constraint of both types should be satisfied, i.e., for $\tau = \{\tau_H, \tau_L\}$, it should hold

$$U_{LS}(p, s|\tau) \geq \bar{U}_\tau. \tag{A.4}$$

With the optimal claim, LS fail to satisfy their liquidity needs with probability $(1-p)$, whereas if they follow their outside option, the related probability is 1. The latter implies that for a given claim $\langle p, s\rangle$, HLS has more to gain (compared to LLS) from accepting this claim compared to her outside option, that is,

$$U_{LS}(p, s|\tau_H) - \bar{U}_{\tau_H} > U_{LS}(p, s|\tau_L) - \bar{U}_{\tau_L}. \tag{A.5}$$

The previous relationship implies that, under the optimal funding structure, the participation constraint of HLS, PC_{τ_H}, cannot be binding (that is, the left-hand-side of relationship (A.5) is equal to zero), because then the participation constraint of LLS, PC_{τ_L}, would be violated (that is, the right-hand-side of relationship (A.5) is negative). Hence, PC_{τ_H} is slack under the optimal funding structure. Finally, under the optimal funding structure $\langle p, s\rangle$, PC_{τ_L} should be binding, i.e.,

$$U_{LS}(p, s|\tau_L) = \bar{U}_{\tau_L}. \tag{A.6}$$

Furthermore, among the combination p and s for which PC_{τ_L} binds, the bank will always find it optimal to offer the one that corresponds to the highest credible p, as, in contrast to equity holders, LS derive additional utility from consumption at $t = 1$ if they are hit by a shock. Hence, focusing on pooling equilibria, the optimal value of p is $p^* = k + (1-k)\ell$. Note that p^* cannot be larger than the maximum liquidation proceeds at $t = 1$, $k + (1-k)\ell$, as this would not be consistent in equilibrium. Finally, given that $p^* = k + (1-k)\ell$, the optimal value of s, s^*, is the minimum value of s for which PC_{τ_L} binds. Thus, s^* is the minimum value of s solving:

$$\begin{aligned}
&(1-\theta^*)((1-\alpha)s(k-\alpha m) + \alpha(p^* - (1-p^*)\tau_L)) + \frac{1}{2}(1-\alpha)(1-k)rs\left(1-\theta^{*2}\right)\\
&+ \theta^*(p^* - \alpha(1-p^*)\tau_L) =\\
&- \alpha\tau_L + y,
\end{aligned} \tag{A.7}$$

where θ^* is given in equation (3). □

A.3 Proof of Proposition 3

Proof. In what follows, we derive the optimal values p_1^*, p_2^*, s_1^*, and s_2^*. To this end, we need to determine which incentive and participation constraints will be binding under the optimal funding structure. We start by explaining why IC_{τ_H} and PC_{τ_L} bind, whereas IC_{τ_L} and PC_{τ_H} are slack. First, note that in a separating equilibrium, it is always optimal that $p_1 > p_2$, as HLS derives a higher utility from consuming in period $t = 1$ when a liquidity shock hits her. Second, note that for $p_1 = 1$, if PC_{τ_H} binds, then LLS never have an incentive to mimic HLS because mimicking implies an expected utility that is smaller than their outside option $\bar{U}_{\tau_L}$ as

$$U_{LS}(p_1, s_1|\tau_L) = U_{LS}(p_1, s_1|\tau_H) = \bar{U}_{\tau_H},$$

and $\bar{U}_{\tau_L} > \bar{U}_{\tau_H}$. Note that the incentive of HLS to mimic LLS is minimized when p_2 is the lowest feasible and p_1 is the highest feasible, conditional that $m_H p_1 + m_L p_2 = k + (1-k)\ell$, which implies that $p_1^* = 1$ and $p_2^* = \frac{(k+(1-k)\ell)-m_H}{m_L} < 1$. Also, s_1^* and s_2^* are the minimum s_1 and s_2 solving the binding IC_{τ_H} and PC_{τ_L} constraints, given by

$$\begin{aligned}
&(1-\theta^*)((1-\alpha)s_1(k-\alpha m) + \alpha(p_1^* - (1-p_1^*)\tau_H)) \\
&+ \frac{1}{2}(1-\alpha)(1-k)rs_1\left(1-\theta^{*2}\right) + \theta^*(p_1^* - \alpha(1-p_1^*)\tau_H) = \\
&(1-\theta^*)((1-\alpha)s_2(k-\alpha m) + \alpha(p_2^* - (1-p_2^*)\tau_H)) \\
&+ \frac{1}{2}(1-\alpha)(1-k)rs_2\left(1-\theta^{*2}\right) + \theta^*(p_2^* - \alpha(1-p_2^*)\tau_H)
\end{aligned} \qquad \text{(A.8)}$$

$$
\begin{aligned}
&(1-\theta^*)((1-\alpha)s_2(k-\alpha m)+\alpha(p_2^*-(1-p_2^*)\tau_L)) \\
&+\frac{1}{2}(1-\alpha)(1-k)rs_2\left(1-\theta^{*2}\right)+\theta^*(p_2^*-\alpha(1-p_2^*)\tau_L)= \\
&-\alpha\tau_L+y
\end{aligned} \tag{A.9}
$$

where θ^* is given in equation (3). Finally, as HLS should be indifferent between the two claims, and given that $p_1^* > p_2^*$, then $s_1^* < s_2^*$. □

A.4 Proof of Proposition 4

Proof. To see why a separating equilibrium corresponds to a lower run probability than a pooling equilibrium, consider the following example. Suppose that the bank wishes to switch from a pooling equilibrium, where the optimal claim is $\langle p^*, s^*\rangle$ (characterized in Proposition 2) to a separating equilibrium where the two claims offered are $\langle p_1 = p^*, s^*\rangle$, targeting HLS, and $\langle p_2 = p^* - \epsilon, s_L\rangle$, targeting LLS, where ϵ is arbitrarily small. Note that to continue to attract LLS, the bank should compensate LLS for the lower expected consumption at $t = 1$ by offering a larger share of the remaining assets if there is no default, i.e., $s_L > s^*$. Following Proposition 1, the probabilities of default for the aforementioned pooling and separating equilibrium are given by

$$
\theta^*_{pool} = \frac{1}{r}\frac{\frac{p^{*2}}{s^*} - \frac{(k-\overline{m}\alpha)^2}{2(1-\alpha)\overline{m}}}{(1-k)\left[\frac{1}{2}+\frac{k-\overline{m}\alpha}{2(1-\alpha)\overline{m}}\right]}. \tag{A.10}
$$

$$
\theta^*_{sepa} = \frac{1}{r}\frac{\frac{m_H}{\overline{m}}\frac{p^{*2}}{s^*} + \frac{(1-m_H)}{\overline{m}}\frac{p^*-\epsilon^*}{s_L} - \frac{(k-\overline{m}\alpha)^2}{2(1-\alpha)\overline{m}}}{(1-k)\left[\frac{1}{2}+\frac{k-\overline{m}\alpha}{2(1-\alpha)\overline{m}}\right]}. \tag{A.11}
$$

Comparing (A.10) with (A.11), we obtain that for $s_L > s^*$ and $\epsilon > 0$, $\theta^*_{sepa} < \theta^*_{pool}$, which is consistent with the discussion following Proposition 1 that highlights that deposits with lower withdrawal priority (captured by lower p) and higher share (captured by higher s) of realized return of the remaining assets at $t = 2$ contribute to less frequent runs.

$\square$

A.5 Proof of Proposition 5

Proof. Given that the separating equilibrium, by definition, leads to a more efficient allocation of (the same) liquidity proceeds, and, thus, higher overall utility, it is sufficient to focus on the second channel. In what follows, we show that welfare is decreasing in the run probability, which, combined with Proposition 4, proves that a mix of safe-liquidity demandable deposits and time deposits is welfare-maximizing. Note that by adding up the utility of investors and the bank's profit, we obtain that welfare is given by

$$W = \int_{\theta^*}^{1} \{(1-k)\theta r + k - \alpha\overline{m} + \underbrace{\Sigma_{j=1}^{2} m_j \alpha[p_j + (1-p_j)\tau_j]}_{\equiv A_1}\} d\theta + \int_{0}^{\theta^*} \underbrace{\Sigma_{j=1}^{2} m_j [p_j + \alpha(1-p_j)\tau_j]}_{\equiv A_2} d\theta \tag{A.12}$$

where $m_1 = m_H$ and $m_2 = m_L = 1 - m_H$. Note that A_1 and A_2 are simplified to:

$$A_1 = \alpha(\overline{m} - \Sigma_{j=1}^{2} m_j \tau_j + \Sigma_{j=1}^{2} m_j p_j \tau_j), \tag{A.13}$$

$$A_2 = \overline{m} - \alpha\Sigma_{j=1}^{2} m_j \tau_j + \alpha\Sigma_{j=1}^{2} m_j p_j \tau_j. \tag{A.14}$$

By adding and subtracting $(1-k)\ell$ in the first term of eq. (A.12), we can re-write it as follows:

$$W = \int_{\theta^*}^{1} \{(1-k)(\theta r - \ell) + k - \alpha\overline{m} + (1-k)\ell + A_1\} d\theta + \int_{0}^{\theta^*} A_2 d\theta. \tag{A.15}$$

Also, given that $\overline{w} = k + (1-k)\ell$, we re-write the previous equation as:

$$W = \int_{\theta^*}^{1} \{(1-k)(\theta r - \ell) + \underbrace{\overline{m}(1-\alpha) + A_1}_{A_3}\} d\theta + \int_0^{\theta^*} A_2 d\theta, \tag{A.16}$$

which can be simplified further to

$$W = \underbrace{\int_{\theta^*}^{1} \{(1-k)(\theta r - \ell) d\theta}_{A_4} + \int_{\theta^*}^{1} A_3 d\theta + \int_0^{\theta^*} A_2 d\theta, \tag{A.17}$$

which is equivalent to

$$W = A_4 + A_3(1-\theta^*) + \theta^* A_2 \tag{A.18}$$

that simplifies further to

$$W = A_4 + A_3 + (A_2 - A_3)\theta^*. \tag{A.19}$$

Note that

$$A_2 - A_3 = \overline{w} - \alpha\Sigma_{j=1}^2 m_j\tau_j + \alpha\Sigma_{j=1}^2 m_j p_j \tau_j - \alpha\overline{w} + \alpha\Sigma_{j=1}^2 m_j\tau_j - \alpha\Sigma_{j=1}^2 m_j p_j\tau_j - \overline{w} + \alpha\overline{w} = 0, \tag{A.20}$$

which implies that

$$W = A_4 + A_3, \tag{A.21}$$

where A_4 is decreasing in θ^*, whereas A_3 is independent of θ^*; thus, welfare W is decreasing in θ^*, which completes the proof.

□

A.6 Proof of Proposition 6

Proof. Effectively, a higher term premium (captured by a higher y) increases the outside option of investors. Recall that the outside option $\overline{U}_\tau$ of LS is given by (A.1). The higher term premium implies that the outside option of LLS and HLS is given by $\overline{\overline{U}}_{\tau_L}$ and $\overline{\overline{U}}_{\tau_H}$, where $\overline{\overline{U}}_{\tau_L} > \overline{\overline{U}}_{\tau_H}$, as $\tau_H > \tau_L$.

In what follows, we explain that both pooling and separating equilibrium are affected by a higher term premium, but the separating equilibrium is affected more, which can lead banks to favor the pooling equilibrium, which is more fragile than the separating equilibrium.

We first consider the case in which the bank issues demandable debt targeting both types of LS (pooling equilibrium). As shown in the proof of Proposition 2, in a pooling equilibrium, PC_{τ_L} is binding, and PC_{τ_H} is slack. Hence, a higher term premium implies that the bank has to increase the share s to continue attracting investors, which decreases bank profitability. Furthermore, suppose that $\overline{\overline{U}}_{\tau_L}$ is sufficiently large. In that case, the bank will find it suboptimal to attract LLS, which decreases the amount of liquidity proceeds in period $t = 1$, and increases the run incentives, and, therefore, the run probability.

We now consider the case in which the bank issues safe-liquidity demandable deposits and time deposits (separating equilibrium). As shown in the proof of Proposition 3, in a separating equilibrium, PC_{τ_L} is binding, and PC_{τ_H} is slack. If the bank wishes to continue attracting LLS, it has to increase s_2. However, the latter will strengthen the incentive of HLS to mimic LLS – to prevent that, the bank will have to increase s_1. The previous discussion highlights that a higher term premium significantly increases the cost of implementing a separating equilibrium, which can result in the bank switching to a pooling equilibrium by issuing risky demandable deposits only, which are associated with higher run probability. □