# Preventing Bank Panics: The Role of the Regulator's Preferences*

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**Abstract**

How do the preferences of a banking authority (BA) affect its decision-making in periods of distress and thus financial stability? We study this question in a version of Diamond and Dybvig (1983) with a monopolistic bank and a time-consistent policy response by a BA. We show that limited commitment on the part of the BA may induce fragility but the BA's incentives are also an important determining factor in the degree of financial stability. In particular, under a simple suspension scheme, delegating a BA who places sufficient weight on a banker's welfare acts as a commitment device and prevents runs, in analogy with how a Rogoff (1985) "conservative" central banker helps reduce inflation bias. In contrast, once interventions take the form of payment rescheduling, the scope for the bank's susceptibility to a panic increases should the BA put more weight on monopoly rents. Identifying such an aspect of vulnerability suggests that appointing a BA whose objective function deviates from that of depositors may have unintended consequences.

**JEL Classification**: G21, G28
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# 1 Introduction

In recent years, the increasing concentration of assets among a small number of large banks in many advanced economies has drawn a significant amount of attention.[1] In parallel, available evidence suggests that concentration appears to be associated with less competitive outcomes in banking systems as large intermediaries could be able to exercise their market power over time.[2] Given the trend towards increased concentration due to bank consolidation and concerns about institutions that have been viewed as "Too Big To Fail" (TBTF), it is important to develop a framework to investigate the stability of large-scale financial intermediaries. Notably, though a growing literature examines the sources of instability among perfectly competitive banks, relatively less attention has been paid to concentrated banking systems such as monopolistic banks.[3] In this respect, failing to account for the impact of banking concentration may leave a huge void in policy debates regarding the stability of the financial system.

In addition to the changes in concentration across countries, modern banking systems in most nations rely heavily on public insurance, i.e., deposit insurance, to deter bank panics. Though government-sponsored deposit insurance programs may manage to prevent runs, they are plagued by credibility issues and do not cover many deposit-like liabilities. To examine other credible policy tools that are also capable of eliminating panics, we study time-consistent policy responses such as suspensions of convertibility (deposit freezes), among others, which have also been utilized widely in the past. While suspensions have been previously examined, existing research primarily focuses on settings with perfectly competitive banks where the incentives of the banking authority (BA) during a crisis are perfectly aligned with those of depositors.

Yet, past experiences with government-declared bank suspensions indicate that the implementation of deposit freezes can be subject to the political influence of banks with market power, e.g., see Friedman and Schwartz (1963) and Kennedy (1973). That is, the incentives of the BA may deviate from those of depositors in the sense that the regulator may place some weight on a banker's utility.[4] This aspect of policy-making is similar in spirit to that faced by monetary authorities in

[1] Based on U.S. call report data, for example, total consolidated assets of the largest three U.S. commercial banks increased from $1.19 trillion, $1.18 trillion, and $1.02 trillion on December 31, 2006 to $3.31 trillion, $2.52 trillion, and $1.78 trillion on December 31, 2021. See also Janicki and Prescott (2006), Ghossoub and Reed (2021), and Fernholz and Koch (2021) for the discussion of the increase in bank asset concentration in the U.S.; see Laeven et al. (2014) and Ghossoub and Reed (2019), among others, for banking consolidation in other countries.

[2] See Cetorelli and Gambera (2001), Beck et al. (2004), and Demirguc-Kunt et al. (2004), among others.

[3] Recent exceptions include Andolfatto and Nosal (2008), Carletti and Leonello (2019), and Gao and Reed (2021), among others.

[4] In particular, essential factors such as political pressure have received much attention in a number of recent cross-country studies. Brown and Dinc (2005), for example, identify the significant role of political concern in regulating the banking system. Notably, they find closures of failing banks are less likely to occur prior to elections as governments face pressure from various interest groups that would be adversely affected. Rosas (2006) also suggests that governments vary widely in their propensity to rescue institutions and that politics at various levels plays a role. Fur-

the literature on the political economy of central banking. As highlighted in the seminal papers by Kydland and Prescott (1977) and Barro and Gordon (1983), discretionary policy has an inflationary bias if the monetary authority is incentivized to expand output above its equilibrium level. Nevertheless, by appointing a "conservative" central banker who is more averse to inflation than society, Rogoff (1985) shows that the inflationary bias can be reduced under discretion. Following Rogoff's contribution, a large body of literature examines how a central banker's incentives should be structured to induce the socially optimal monetary policy, i.e., Walsh (1995). Yet, little previous research, if any, studies similar issues in theoretical frameworks regarding financial fragility, which seems quite important in light of events during the recent global financial crisis. In particular, many argued that the actions of governments were arbitrary which clouded decision-making by participants in the financial system.

The objective of this paper is to study how the preferences of a BA impact policy responses in times of crises and thus the stability of a monopolistic banking system. To this end, we build on a version of the Diamond and Dybvig (1983) model with a monopolistic bank and a time-consistent suspension scheme by a BA as in Ennis and Keister (2009a). We show that limited commitment on the part of the BA may induce bank run equilibria but there also exist substitutes for commitment, e.g., the bank's utility enters through the social welfare function significantly, that eliminate runs. That is, in contrast to the existing literature, explicitly modeling a monopolistic bank helps shed light on other essential factors such as the preferences of the BA in determining financial stability.

Prior to outlining the details of our results, we first discuss the adopted modeling strategy and highlight some important features of the current setup. As a starting point, in order to show the role of the BA's incentives for preventing panics under a regime where the regulator chooses when to suspend redemptions, we impose that runs are zero-probability events as in Ennis and Keister (2009a). In this setting, to attract funds, the rent-seeking monopolist announces a schedule of rates of return on deposits and with the funds received, the bank implements its portfolio decision. While the bank derives utility by consuming its capital gains only, it must first honor its payment scheme that stipulates consumption for depositors even in the event of a run. That is, it continues to make a fixed payment amount, which is the same as that prior to the revelation of a crisis, before withdrawals are frozen by the BA. Subsequently, the bank offers its pre-specified returns to deposits for all withdrawing individuals' post-suspension consumption if it still has sufficient funds. Otherwise, the late payoff to each requesting agent will be determined by the standard pro rata division of the matured assets. As a result, the bank will only access its profits, if any, after

thermore, Faccio et al. (2006) argue that political connections are closely related to corporate bailouts. To be specific, they investigate the likelihood of government bailouts of 450 politically connected firms from 35 countries over the period 1997-2002. They conclude that politically connected firms are significantly more likely to be bailed out than similar non-connected counterparts. In this vein, political connections impact the allocation of capital when connected companies experience economic distress.

payments are made to all depositors who contact the bank.

As a benchmark, we begin by considering a standard case where the BA focuses on maximizing depositors' welfare only. Under this scenario, the monopolist is susceptible to crises if consumers are less risk-averse but their degree of exposure to liquidity risk is high. Intuitively, the BA tends to intervene later in a run as she welcomes a transfer from an agent she does not care about, i.e., the monopolist, to agents she cares about, i.e., depositors, even if this transfer requires some costly liquidation. This optimal response, however, ends up playing against depositors because it makes the run equilibrium possible. In contrast, banking fragility will not occur should depositors' risk aversion be high enough, regardless of the total fundamental demand for liquidity in the short-term. The reason why panics are off the equilibrium path is that the BA will freeze funds at the first sign of a crisis due to a decline in aggregate welfare if one more depositor is served.

We next move to study fragility when the BA places some weight on the utility of the monopolistic bank. Returning to settings where consumers are relatively less risk averse, it follows that the bank may be susceptible to a crisis when the monopolist's utility only accounts for a small part of aggregate welfare. Nevertheless, if the social welfare function highly favors bank profits, then the BA would credibly suspend payments immediately once a run is identified in order to protect the bank's capital gains, irrespective of the degree of liquidity risk. Anticipating that funds will be frozen quickly before the crisis deepens so that the banking system is not liquidated, consumers have no incentive to run. Therefore, appointing a BA who places sufficient weight on the bank's profits acts as a commitment device in suspending withdrawals quickly. As a result, the truth-telling equilibrium is uniquely implemented, in analogy with how a Rogoff (1985) "conservative" central banker helps reduce inflation bias.

Consequently, our analysis demonstrates that the preferences of the BA may play an important role for determining financial stability in the presence of limited commitment. This juxtaposition cannot arise under perfect competition where the incentives of depositors and the BA are exactly the same. In this regard, we unveil a simple yet novel approach as to how to prevent bank panics. In turn, this may help lower the reliance on public insurance which has been plagued by credibility issues and would therefore reduce the risk of bank runs. More importantly, given that deposit insurance programs may not cover many deposit-like liabilities, our advocated approach to ruling out panics can be applied to intermediaries beyond depository institutions.

In practice, depositors may not fully understand how much they contribute to the BA's goals or the "type" of the policymaker they are facing and may still be inclined to panic. In this vein, we identify an important banking policy problem of uncertainty about the BA's "type." This kind of uncertainty about a policymaker's "type" was formally discussed in Barro (1986) for the reputation of monetary authorities to tackle inflation. In the spirit of Barro's example, we argue that when depositors do not have complete information about the BA's preferences, runs may not be

eliminated even if the suspension is triggered right after a panic is identified. Thus, this theory may help explain various historical episodes of bank runs and banking holidays, i.e., the first total statewide bank suspension in Nevada, U.S., on October 31, 1932.

To deepen our understanding of the role of the regulator's preferences for financial fragility under other types of intervention, we conclude by extending the benchmark framework to incorporate payment rescheduling à la Ennis and Keister (2009a). In this vein, the current structure departs from the existing literature such as Gao and Reed (2021) by introducing monopoly rents into the BA's objective function. Notably, the modeling strategy for this newly introduced resolution process differs from that in the baseline model in several critical dimensions. To be specific, under payment rescheduling, the BA dictates returns on deposits for the remaining consumers and the bank's capital gains immediately once a run is identified. Furthermore, as we will show, crises may not be eliminated under this type of intervention if the BA's objective function is sufficiently different from that of depositors. Thus, runs are not modelled as zero-probability events.

In this setup, we demonstrate that the monopolist is more vulnerable to a crisis if the BA places larger weight on a banker's welfare. In particular, there are two competing effects at work. First, when bank profits enter through the social welfare function significantly, the BA sets aside more income for the banker to be paid once long-term assets mature in the crisis state. Second, the reduced level of payments to consumers upon the identification of the panic state tightens the depositors' participation constraint. To ensure that consumers' expected utility will not be lower than the value of their outside options, the monopolist must respond by offering higher returns on early demandable deposits. Overall, higher degrees of illiquidity and lower payoffs in resolution leave the intermediary more susceptible to a crisis. Thus, identifying such a novel aspect of vulnerability suggests that delegating a BA whose objective function deviates from that of depositors may have unintended consequences by destabilizing the banking system. That is, unlike a simple suspension of convertibility, payment rescheduling no longer aligns the interest of the monopolist and depositors who do not have a pressing need to exercise their redemption option.

The remainder of the paper is organized as follows. In the next section, we turn to the literature review. Section 3 provides some historical background on bank suspensions. In particular, we offer a detailed discussion about the determinants of suspensions in practice, especially in the U.S. We then describe the baseline model and discuss its key assumptions and the definition of financial fragility in Section 4. In Section 5, we study a version of the Diamond-Dybvig model with a monopolistic bank and simple suspension scheme to highlight how the BA's incentives are an important determinant for the degree of financial stability in the presence of limited commitment. Section 6 extends the model to examine the role of the regulator's preferences for banking fragility where the resolution process takes the form of payment rescheduling. Section 7 concludes. Details of formal arguments are presented in the appendix.

# 2 Related literature

The model presented in this paper relates to a strand of literature that studies banking fragility in the Diamond and Dybvig (1983) tradition. In particular, as suggested by Diamond and Dybvig (1983) themselves, if aggregate risk over liquidity demand is absent, bank runs can be prevented based on suspensions of convertibility, which are off-equilibrium threats. Nevertheless, Ennis and Keister (2009a) demonstrate that such policy interventions to suspend withdrawals quickly may not be credible, implying that limited commitment is an essential ingredient to generate a bank run equilibrium. While this insight into how multiplicity can be recovered is a significant breakthrough, past experiences indicate that suspensions can also be subject to tension between banks and regulators. However, one cannot directly embed misaligned incentives among different groups of agents in the Ennis and Keister (2009a) model of perfectly competitive banks that earn zero profits with an uncommitted BA. In this vein, there remains an open question if the bank run equilibrium can be prevented once the assumption of perfect competition is relaxed. In this paper, we attempt to address this question and discuss any possibilities as substitutes for commitment that uniquely implement the truth-telling equilibrium. In this vein, our work also adds to the existing research studying Diamond-Dybvig monopolistic banks such as Chang and Velasco (2001) and Matsuoka (2013) that does not include any public intervention.

Our analysis also relates to studies that examine the effect of suspensions of convertibility on depositors' propensity to panic in the Diamond-Dybvig model. Yet, rather than focusing on ex-post policy responses, most contributions such as Gorton (1985), Chari and Jagannathan (1988), and Engineer (1989) investigate ex-ante policy interventions. Recent exceptions, among others, include Cipriani et al. (2014) and Voellmy (2021). In particular, in an Engineer version of the four-period Diamond and Dybvig model with fundamental risk on investment, Cipriani et al. (2014) show that the possibility of suspending convertibility can induce runs. In a similar setting absent fundamental risk, Voellmy (2021) studies how depositors' incentives to panic are affected by staggered revelation of liquidity needs over time under redemption fees and suspensions.

Regarding proposing means to prevent multiple equilibria, our work contributes to the existing literature such as Martin (2006) built on Cooper and Ross (1998) and Ennis and Keister (2006). Specifically, the author focuses on studying whether a central bank policy such as deposit insurance and liquidity provision in a period of a crisis can prevent bank runs. Martin shows that while deposit insurance can eliminate run equilibria, this occurs at the expense of the banks' incentive distortion. By comparison, a well-designed liquidity provision policy can achieve financial stability without causing moral hazard. In other work reconciling Bagehot's and the Fed's policy, Martin (2009) demonstrates when liquidity is scarce, a central bank should lend at a high interest rate to prevent bank panics.

Other related papers analyze whether the bank run equilibrium can be ruled out in a version of Diamond and Dybvig (1983) with aggregate uncertainty about the total fundamental demand for early consumption. Green and Lin (2003), for example, are among the first to use a direct mechanism to characterize the constrained efficient allocation in a modified Diamond and Dybvig (1983) environment. In particular, they show that the constrained efficient allocation can be implemented uniquely without admitting a bank run. On the other hand, Peck and Shell (2003) and Ennis and Keister (2009b) respectively relax some assumptions of the Green and Lin (2003) model to demonstrate that the run equilibrium still exists under an optimal direct mechanism. More recently, assuming that commitment is possible, Cavalcanti and Monteiro (2016) and Andolfatto et al. (2017) propose indirect mechanisms that prevent bank runs.

In addition to suspensions of convertibility, our extended model of payment rescheduling under monopolistic banks enriches the existing research such as Keister and Mitkov (2021) that largely focuses on perfectly competitive intermediaries. While the recent work by Gao and Reed (2021) studies the impacts of a similar resolution process on the stability of banks with market power, our environment differs from theirs. In particular, Gao and Reed (2021) concentrate on the BA's response to a panic where the monopolist does not retain any profits in the event of a run. In contrast, by introducing monopoly rents into the BA's objective function, the current paper provides a unique contribution towards the role of the bank's political influence and the regulator's preferences for financial fragility.

Last but not least, the current paper also relates to the extant literature on financial fragility in the context of imperfect competition where there are generally two opposing views about the effects of market power on banking stability. On the one hand, market power may promote stability for a combination of two reasons. Specifically, the prospect of the banks' franchise value in the future gives intermediaries an incentive to further protect against negative shocks and current monopoly rents serve as an extra cushion to guard against insolvency. See Marcus (1984) and Keeley (1990) for the first reason and Martinez-Miera and Repullo (2010), among others, for the latter. By comparison, Boyd and De Nicolo (2005) highlight the impact of risk shifting where market power leads to higher interest rates on loans and due to higher funding costs, borrowers tend to behave aggressively, increasing the bank's exposure to credit risk and thus financial fragility. In this regard, our paper contributes to both the concentration-stability and concentration-instability hypotheses by highlighting the role of the bank's political influence, which is novel to the existing literature.

# 3 Some historical background on bank suspensions

To develop deeper insights into how the preferences of the BA affect bank suspensions, we proceed by discussing some deposit freezes in U.S. banking history in greater detail. As pointed out by Friedman and Schwartz (1963, p.324-332), for example, authorities might be reluctant to suspend withdrawals even though they had identified that a crisis was underway. Specifically, the directors of the Federal Reserve Bank of New York, the New York Clearing House banks, and the state Superintendent of Banks failed to lobby for a nationwide banking holiday from President Herbert Hoover on March 3, 1933. Nevertheless, the same group successfully asked for a banking holiday in the state of New York from Governor Herbert Lehman on March 4, 1933. From this perspective, one might argue that the New York bankers could exert greater political pressure in the state of New York than across the United States. Eventually, a nationwide banking holiday was proclaimed by President Franklin D. Roosevelt on March 6, 1933 after his inauguration but this occurred after crises had resulted in a large number of bank failures.

In contrast, the regulator might make much effort to rescue its financial intermediaries if their interests are largely overlapped, leading to quick and strict deposit freezes. Notably, Kennedy (1973, p.61-67) described that the banking sector in Nevada was highly concentrated where virtually all of the state's banks were controlled by a single banker, George Wingfield. When Wingfield banks' situation was perilous, Governor Fred B. Balzar flew to Washington on October 30, 1932 to lay the banks' case before Hoover and the director of Reconstruction Finance Corporation. Then, a twelve-day bank and business holiday was approved quickly upon request on October 31, 1932. Notably, this was the first time in the U.S. that a state implemented total suspension of financial operations since a large proportion of its banking facilities was in trouble. As pointed out by Kennedy herself, the Wingfield episode held important lessons for handling banking crises: "A state's governmental administration became closely tied with its financial institutions. And when those banks were imperiled, the state did all in its power to save them."

In light of these experiences and from the perspective of history of thought, it is important to study how banking regulators' incentives affect their decision-making and should be structured when financial intermediaries possess market power. In particular, there has been a great amount of concern about the power of large institutions that impacted the regulatory landscape and development of the banking sector across the United States in the years prior to the Great Depression. In this regard, Allen and Gale (2000, p.234) write: "Distrust of power in the hands of very large institutions very early led to restrictions on the ability of banks to expand geographically or to diversify into other activities." Gorton (2012, p.181) also appears to share this view as he argues that: "The ability to act without political interference is rare, because crisis responses are inevitably political, as saving the banking system means saving bankers." Moreover, as discussed in

the introduction, the degree of banking concentration in many advanced economies has increased drastically in recent years, which may have created conditions in which a small number of large banks could exploit their market power over time. In this respect, this paper offers an interesting direction for understanding regulatory guidance of the modern banking sector where the existing research cannot speak to these issues in a rigorous manner.

# 4 The model

We analyze a version of the Diamond and Dybvig (1983) model with a monopolistic bank and a time-consistent simple suspension scheme by the BA as in Ennis and Keister (2009a). We begin by describing the physical environment and defining banking fragility in this setup.

## 4.1 The environment

There are three time periods indexed by $t = 0, 1, 2$ and the economy is populated by a $[0, 1]$ continuum of ex-ante identical consumers indexed by $i$. In particular, each individual is endowed with one unit of the all-purpose good at the start of period 0 and the utility function of an agent is of the constant relative risk aversion form:

$$u\left(c_1, c_2; \omega_i\right) = \frac{\left(c_1 + \omega_i c_2\right)^{1-\gamma}}{1-\gamma}, \tag{1}$$

where $c_t$ denotes the consumption level in period $t = 1, 2$, $\omega_i$ represents consumer $i$'s preference type and is a privately observed binomial random variable with support $\Omega \equiv \{0, 1\}$, and $\gamma > 0$ is the coefficient of relative risk aversion. With probability $\pi$, an individual $i$ is impatient, i.e., $\omega_i = 0$, and only values consumption in period 1; with probability $1 - \pi$, an individual $i$ is patient, i.e., $\omega_i = 1$, and values consumption equally in both periods. Further, individuals' preference types are independent and identically distributed (i.i.d). Due to the law of large numbers, the fraction of impatient or patient agents in the population is also $\pi$ or $1 - \pi$.

There are two types of constant-returns-to-scale technologies in the economy. For example, one unit of the good placed in a simple storage technology yields one unit of the consumption good in the following period. There is also an investment technology in which one unit of the good invested in period 0 yields $R > 1$ units of goods in period 2 but only $1 - \tau$ units if liquidated early. That is, the parameter $\tau \in (0, 1)$ represents the liquidation cost per unit of goods invested, as in Cooper and Ross (1998).

In comparison to perfectly competitive intermediaries which are studied in Ennis and Keister (2009a), we model a monopolistic bank that has the exclusive right to offer banking services.

While the objective of the risk-neutral monopolist is to maximize its own profits, the bank needs to offer services such that depositors derive expected utility that is not lower than the value of their outside options. In this manner, consumers must have an incentive to deposit their funds and thus the depositors' participation constraint is an important consideration in the rent-seeking behavior of the monopolist. To determine individuals' reservation utility, note that consumers also have access to both technologies. Then, under financial autarky, they hold a portfolio consisting of $1-x$ and $x$ units of liquid and illiquid assets to maximize:

$$W = \max_{\{x\}} \pi u\left(1 - x + (1-\tau)\, x\right) + (1-\pi)\, u\left(1 - x + Rx\right).$$

Let $x^A$ and $W^A$ denote the optimal level of illiquid assets and autarky welfare respectively. In particular, when the probability of receiving a liquidity shock is low enough, i.e., $\pi \in (0, \pi_L]$ where $\pi_L = \frac{R-1}{\left(\frac{R}{1-\tau}\right)^{\gamma}\tau + R - 1}$, the portfolio choice under autarky would be such that all resources are invested in the illiquid technology, i.e., $x^A = 1$. Yet, over intermediate levels of liquidity risk, i.e., $\pi \in (\pi_L, \pi_H)$ where $\pi_H = \frac{R-1}{R-(1-\tau)}$, agents hold a more liquid portfolio where $x^A = \frac{\left(\frac{R-1}{1-(1-\tau)}\frac{1-\pi}{\pi}\right)^{\frac{1}{\gamma}} - 1}{\left(\frac{R-1}{1-(1-\tau)}\frac{1-\pi}{\pi}\right)^{\frac{1}{\gamma}}\tau + (R-1)}$. On the other extreme, if consumers are highly susceptible to liquidity risk, i.e., $\pi \in [\pi_H, 1)$, $x^A = 0$, implying that all funds are kept in the storage technology to avoid costly liquidation. Therefore, autarkic utility is summarized as follows:

$$W^A = \begin{cases} \frac{\pi(1-\tau)^{1-\gamma} + (1-\pi)R^{1-\gamma}}{1-\gamma} & \text{if } \pi \in (0, \pi_L] \\ \frac{(R-(1-\tau))^{1-\gamma}\left[\pi + (1-\pi)\left(\frac{R-1}{1-(1-\tau)}\frac{1-\pi}{\pi}\right)^{\frac{1-\gamma}{\gamma}}\right]}{(1-\gamma)\left[\left(\frac{R-1}{1-(1-\tau)}\frac{1-\pi}{\pi}\right)^{\frac{1}{\gamma}}\tau + (R-1)\right]^{1-\gamma}} & \text{if } \pi \in (\pi_L, \pi_H) \\ \frac{1}{1-\gamma} & \text{if } \pi \in [\pi_H, 1) \end{cases}. \tag{2}$$

In addition, the bank forms deposit contracts where it guarantees to pay to each withdrawing agent fixed amounts in periods 1 and 2 respectively, if feasible. At the beginning of period 1, consumers can choose to contact the bank in this period or to wait until period 2 after learning their consumption types. If they decide to withdraw in period 1, requesting depositors will do so in a randomly assigned order and must consume immediately upon arrival. As in Wallace (1988, 1990), the bank is assumed to be subject to this sequential service constraint where it only observes that a depositor has come and thus the payment to each withdrawing individual can only depend on the number of total withdrawals that have been made.

## 4.2 Bank panics and deposit freezes

As is common in the literature such as Diamond and Dybvig (1983) and Ennis and Keister (2009a), the ex-ante crisis probability is assumed to be arbitrarily close to zero. Yet, runs may still appear unexpectedly where both the monopolistic bank and the BA identify run behavior through the flow of withdrawals. To be specific, since a fraction $\pi$ of depositors in a bank are impatient and have an urgent need to consume in period 1, they will choose to withdraw early with certainty. Thus, if only $\pi$ depositors show up in period 1, the monopolist and the BA infer that a panic has not occurred and, under such circumstances, the bank would resume its operations free of any public intervention. That is, as the bank is still able to raise depositors' welfare above what they would have achieved under financial autarky should no crises emerge, the BA has no incentive to intervene.

Nevertheless, the BA identifies that the bank experiences runs if more than a fraction $\pi$ of depositors request withdrawals before long-term assets mature. Among these scenarios: $(i)$ the bank will follow its pre-specified deposit contracts to pay a fixed amount, which is the same as that to the first fraction $\pi$ of consumers, until it depletes all resources in period 1; $(ii)$ the BA decides when to freeze deposits in period 1 if she believes doing so would improve social welfare.

For the post-suspension payment scheme, the monopolist will continue to offer the pre-specified period-2 contract, if feasible, to all depositors who contact the bank after long-term assets mature. Once the bank has made all payments to withdrawing depositors in period 2, any resources left would be retained by the monopolist as capital gains. However, if the bank does not have enough resources to honor all of its promised payments in period 2, the late payoff to each withdrawing depositor will be determined by the standard pro rata division of the matured assets.

## 4.3 Withdrawal strategies and financial fragility

Based upon the above discussion, the function for a depositor's withdrawal strategy, which depends on her type, can be written as:

$$y_i : \Omega \mapsto \{0, 1\}.$$

Specifically, $y_i(\omega_i) = 0$ and $y_i(\omega_i) = 1$ correspond to withdrawing in periods 1 and 2 respectively.

To proceed, we turn to formally define bank runs. In particular, we focus on actions taken by patient depositors as impatient agents only value consumption in period 1 and will choose to withdraw early with certainty. In this vein, we define that a bank run takes place if there is a positive measure of patient depositors who withdraw in period 1, i.e., $y_i(1) = 1$, and therefore the bank is fragile.

**Definition 1.** *If there exists a strategy profile $y_i(1) = 0$ for a positive measure of patient depositors, the bank is defined to be fragile.*

Note also that if the parameter space in which run equilibria exist is larger, then the bank is said to be more unstable.

# 5 Equilibrium under suspensions of convertibility

In this section, we conduct analysis in a version of the Diamond-Dybvig model with a monopolistic bank and simple suspensions of convertibility to highlight how the BA's preferences play a non-trivial role in determining the degree of financial stability. To this end, we begin by characterizing how the portfolio choice and deposit contracts that stipulate consumption in the different periods are determined by the monopolist. We then show that in such a setting free of regulation, though there exists a truth-telling equilibrium, there may also exist an equilibrium that resembles bank runs under a technical condition. Subsequently, we study ex-post policy responses should a run occur unexpectedly to stress the role of the BA's incentives for impacting stability.

Before setting up the bank's problem, we summarize the timing of events as follows. In period 0, after receiving their endowments, consumers deposit all their resources at the monopolist and the bank implements the portfolio choice regarding how much of its attracted deposits are placed in investment. Upon learning their liquidity needs at the start of period 1, depositors choose to withdraw early or to wait until long-term assets mature. In period 2, the remaining patient depositors contact their bank and the monopolist will access its profits, if any, after making payments to all requesting depositors.

## 5.1 The bank's problem

We now examine how the bank makes its portfolio choice and the payment scheme $c_t$ for $t = 1, 2$, which denotes the amount paid to depositors who withdraw in period $t$. As discussed previously, the bank derives utility by consuming monopoly rents. Risk neutrality of the bank and the productive asset return further imply that the monopolist will only access its profits after all payments are made in period 2. Given that the best-response allocation also requires that the bank neither holds excess liquidity nor resorts to costly liquidation, the value of $x$ and $c_t$ will be chosen to solve:

$$\Pi \equiv \max_{\{x, c_1, c_2\}} Rx - (1 - \pi) c_2$$

subject to:

$$1 - x - \pi c_1 = 0, \tag{3}$$

$$\pi u(c_1) + (1 - \pi) u(c_2) \geq W^A, \tag{4}$$

where $W^A$ is given by $(2)$. As the monopolist can extract all of the gains from consumers, the depositors' participation constraint $(4)$ holds with equality. In this manner, the solution regarding the optimal choice of the bank payment $c_t$ requires:

$$u'(c_1) = Ru'(c_2). \tag{5}$$

The above analysis demonstrates the best responses of a monopolistic bank. We can express the best-response allocation as a vector as follows:

$$c^* \equiv \{x^*, c_1^*, c_2^*\}.^5$$

These components are jointly determined by the optimal risk-sharing condition $(5)$ and the participation constraint $(4)$.

Note that we study equilibria of a simultaneous-move game where depositors choose when to withdraw at the start of period 1. As demonstrated above, by keeping depositors indifferent to financial autarky, the bank forms a deposit contract in period 0 to maximize its expected monopoly rents. Given these actions in the withdrawal game, each depositor determines $y_i$ to maximize her expected utility $\sigma_i(y_i, y_{-i})$. The definition of an equilibrium is thus as follows:

**Definition 2**. *The equilibrium of the withdrawal game at the bank is the profile of strategies $y_i^*$ such that $\sigma_i\left(y_i^*, y_{-i}^*\right) \geq \sigma_i\left(y_i, y_{-i}^*\right)$ for all $y_i$ and all $i \in [0,1]$.*

In a similar spirit to Diamond and Dybvig (1983), there may exist multiple equilibria if depositors play the withdrawal game when the bank offers the deposit contract $(c_1^*, c_2^*)$. To see these possibilities, first suppose that a patient depositor anticipates that all other consumers will withdraw at $t = 2$ when patient. Given that the period-2 return on deposits $c_2^*$ is greater than the period-1 payoff $c_1^*$, her best response would be to withdraw in period 2. In this vein, there is a Nash equilibrium where all agents withdraw according to their true liquidity needs and therefore allocation $c^*$ is obtained. Yet, suppose instead that the patient depositor anticipates that everyone else will run on the bank. Among these circumstances, she may find it optimal to join the run and hence there may exist another Nash equilibrium in which all consumers request to withdraw early. Notably, this occurs if and only if:

$$c_1^* > 1 - \tau\left(1 - \pi c_1^*\right), \tag{6}$$

implying that if the patient agent waits until period 2 to withdraw, she would end up receiving zero consumption as the bank has failed in period 1. Equivalently, if the liquidation cost is high enough,

[5] See the Appendix for the calculated consumption levels.

i.e., $\tau > \tau_F = \frac{1-c_1^*}{1-\pi c_1^*}$, bank runs may be on the equilibrium path of play. It is also worth noting that the inequality $(6)$ is necessarily satisfied for any $(R, \pi, \tau)$ when depositors are sufficiently risk-averse, i.e., $\gamma > 1$. In general, in order to examine whether panics can be prevented when the BA plays an active role, we limit our attention to cases satisfying the condition specified in $(6)$ throughout the remainder of the analysis.

## 5.2 The impact of the regulator's preferences on stability

We now turn to study equilibria of the withdrawal game under simple suspension schemes where the BA reacts optimally knowing that depositors' strategies will correspond to equilibria generated by such optimal policy. Yet, it is also worth noting that if the bank can choose when to freeze deposits independently, panics can be eliminated costlessly. It is straightforward that as the monopolist only values its own profits, it would credibly cut off access to funds immediately if a run is identified. That is, the monopolistic bank does not face the same credibility issue as the competitive bank or the BA under perfect competition as in Ennis and Keister (2009a). From this perspective, run equilibria and suspensions of convertibility would not take place under banks with market power.[6] We then summarize our arguments in the lemma below.

**Lemma 1**. *If the ex-post deposit freeze is determined by the monopolist, the bank is not fragile.*

In practice, no individual banks in the U.S., for example, have had the legal option to freeze deposits, which would be viewed as transgressions by legislatures and courts.[7] Moreover, to avoid the onus of closing banks, bankers might request the BA to react during crises, e.g., the government upholds deposit freezes and declares banking holidays. Thus, if the authority to allow suspensions is determined by the BA, is a monopolist susceptible to a run? Specifically, how does the BA carry out time-consistent deposit freeze policy? Are there any possibilities that can act as commitment devices that uniquely implement the truth-telling equilibrium?

In what follows, we examine suspensions of convertibility by the BA with limited commitment and discuss potential substitutes for commitment that prevent bank runs. In order to focus on the role of one particular source of financial fragility, we further assume that depositors have complete

[6]This in part mirrors and rationalizes the latest effort by the U.S. Securities and Exchange Commission (SEC) to strengthen the stability of money market funds recently. Specifically, as of October 14, 2016, the SEC has granted money market fund boards of directors the discretion to impose redemption gates, which are temporary suspensions of redemptions, on prime and tax-exempt money market funds.

[7]See also Gorton (2012).

information about the BA's preferences:

$$V\left(c_1, c_2, \eta; \omega_i, \delta\right) = \underbrace{\int_0^{1-\pi} E\left[u\left(c_1\left(i\right), c_2\left(i\right); \omega_i\right)\right] di}_{\textit{the remaining depositors' welfare}} + \underbrace{\delta\eta}_{\textit{weighted bank's welfare}}, \tag{7}$$

where $\eta$ denotes the bank's rents and $\delta \geq 0$, which can be viewed as a proxy for the political or bargaining power of the monopolist, measures the relative importance of the bank's expected utility in overall welfare. As we will demonstrate later, uncertainty about the BA's preferences may create another channel that endangers the stability of the banking system. Further, to extend to the case of $\gamma > 1$, one may modify the utility function to:

$$u\left(c\right) = \frac{\left(c+b\right)^{1-\gamma} - b^{1-\gamma}}{1-\gamma}, \tag{8}$$

where $b$ is a positive constant but approximately zero. The main reason for this modification is that should a run and a deposit freeze occur, some impatient depositors receive zero consumption. Thus, employing the utility functional form specified in $(1)$ does not satisfy $u\left(0\right) = 0$, leading to negative infinite utility.

### 5.2.1 Suspensions when incentives of the BA and depositors are aligned

We begin by considering a case where the incentives of the BA and depositors are perfectly aligned, i.e., $\delta = 0$. To examine whether runs are on the equilibrium path under an anticipated suspension policy, first suppose that panics occur unexpectedly. That is, after the first $\pi$ withdrawals, both the monopolistic bank and the BA observe that there are more depositors who are waiting to withdraw in period 1. In seeking to study optimal deposit freezes, let $\pi_s$ represent the "freeze point" imposed by the BA and according to the post-suspension sharing rule discussed previously, the period-2 consumption level is either $c_2^*$ or

$$c_2\left(\pi_s\right) = \frac{\left[1 - \tau\left(1 - \pi c_1^*\right) - \pi_s c_1^*\right] \frac{R}{1-\tau}}{\left(1-\pi\right)\left(1-\pi_s\right)}. \tag{9}$$

To be specific, the bank is still able to offer $c_2^*$ if $\pi_s \in \left[\pi, \pi_P\right]$, where $\pi_P = \frac{\frac{R}{1-\tau}\left[1-\tau\left(1-\pi c_1^*\right)\right]-(1-\pi)c_2^*}{\frac{R}{1-\tau}c_1^*-(1-\pi)c_2^*}$ is defined such that $c_2\left(\pi_s\right) \leq c_2^*$ if $\pi \geq \pi_P$ and represents the maximum freeze point with which the bank earns positive profits. Nevertheless, each withdrawing consumer receives the even share of the bank's remaining resources if $\pi_s \in \left(\pi_P, \pi_s^U\right]$, where $\pi_s^U = \frac{1-\tau\left(1-\pi c_1^*\right)}{c_1^*}$ is the maximum

proportion of agents who can be paid $c_1^*$ in period 1. In this manner, $\pi_s$ is chosen to solve:

$$V(\pi_s) = \max_{\{\pi_s\}} \pi_s u(c_1^*) + (1-\pi_s)(1-\pi) u(\min\{c_2^*, c_2(\pi_s)\}) \tag{10}$$

subject to:

$$\pi \leq \pi_s \leq \pi_s^U. \tag{11}$$

In particular, the equation $(10)$ states that for the remaining fraction $1-\pi_s$ of depositors who have not withdrawn in period 1, only a fraction $1-\pi$ will be patient and return to withdraw in period 2.

In solving this optimization problem, we divide the above constraint into two distinct cases according to the period-2 payoffs on deposits described above. To begin, suppose that $\pi_s \in [\pi, \pi_P]$ such that $\min\{c_2^*, c_2(\pi_s)\} = c_2^*$. Then, the optimality condition regarding the freeze point must satisfy:

$$\frac{dV(\pi_s)}{d\pi_s} = u(c_1^*) - (1-\pi) u(c_2^*) \leq 0, \tag{12}$$

where it can be shown that for $\gamma > 1$, the above inequality holds unambiguously. Suppose instead that $\pi_s \in (\pi_P, \pi_s^U]$ such that $\min\{c_2^*, c_2(\pi_s)\} = c_2(\pi_s)$. Under these scenarios, the first-order condition regarding the choice of the suspension is as follows:

$$\frac{dV(\pi_s)}{d\pi_s} = u(c_1^*) - (1-\pi) u(c_2(\pi_s)) + (1-\pi_s)(1-\pi) u'(c_2(\pi_s)) \frac{dc_2(\pi_s)}{d\pi_s} = 0. \tag{13}$$

Letting $\pi_s^M$ denote the solution to the BA's optimization problem $(10)$, we proceed to examine under what conditions runs are on the equilibrium path of play. First, it is trivial to argue that panics will not emerge if the deposit freeze is anticipated to occur relatively early where the bank is still able to offer the payoff $c_2^*$. We then focus on situations in which $\pi_s^M \in (\pi_P, \pi_s^U]$. In particular, whether runs can be prevented critically depends on whether the optimal suspension $\pi_s^M$ occurs before the cutoff $\pi^T$, which is defined by $c_2(\pi^T) = c_1^*$. Alternatively, if $\pi_s^M \geq \pi^T$, then $c_2(\pi_s^M) \leq c_1^*$, indicating that whenever a patient depositor expects that everyone else will withdraw at first opportunity, she would be better off by choosing to withdraw early as well. We then offer the following proposition regarding the stability of a monopolistic bank.

**Proposition 1.** *Suppose that $\gamma \in (\gamma_F, 1)$, $\tau \in (\tau_F, 1)$, and $\pi \in [\pi_F, 1)$, where $\gamma_F = \frac{R-(1-\tau)}{R}$ and $\pi_F = \frac{1-\gamma}{\gamma}\left(\frac{R-(1-\tau)}{1-\tau}\right)$. Under these conditions and the ex-post efficient suspension by the BA, the bank is fragile. Suppose instead that $\gamma \in (1, \infty)$. Under this condition and the ex-post efficient suspension by the BA, the bank is not fragile.*

Notably, when depositors' risk aversion is relatively high over initially lower values of $\gamma$ and asset liquidation is somewhat costly, i.e., $\gamma \in (\gamma_F, 1)$ and $\tau \in (\tau_F, 1)$, monopolistic banks are

fragile if liquidity risk exceeds a threshold level, $\pi_F$. Intuitively, the BA would intervene later because it only values depositors' welfare, especially when there is a large fundamental demand for early consumption. This happens as the BA welcomes a transfer from an agent she does not care about, i.e., the monopolist, to agents she cares about, i.e., depositors, even if this transfer requires some costly liquidation. Nevertheless, this optimal response ends up playing against consumers as it makes the run equilibrium possible.

Furthermore, since some impatient depositors consume nothing should a suspension be implemented, one must resort to the utility function $(8)$ for cases of $\gamma > 1$ so that the welfare loss of consuming nothing is negligible. Yet, as is explained below the inequality $(12)$, funds are necessarily frozen at $\pi$ and hence run behavior will never emerge in equilibrium. The reason why panics are off the equilibrium path is that the BA finds it optimal to freeze funds at the first sign of a crisis due to a decrease in aggregate welfare if one more depositor is allowed to withdraw in period 1. This necessarily happens as the utility derived from consuming the early payment is strictly lower than that from the late payoff if the individual is patient while the welfare loss of late, impatient consumers who receive nothing is negligible as before.

**Discussion** In what follows, we discuss our results in relation to the literature. In particular, our findings demonstrated in Proposition 1 suggest that the set of conditions under which the monopolist is fragile is the same as that under perfect competition as in Ennis and Keister (2009a). Such outcomes indicate that instability across banking structures does not depend on different levels of liquidity transformation endogenously implemented by banks due to market power. In this vein, TBTF does not seem to be a practical problem. However, this insight is based upon competitive equilibria where the incentives of the BA are perfectly aligned with those of banks and depositors. By comparison, we relax this assumption in the following analysis so as to understand how the political influence of the monopolist on the BA's suspension policy affects the degree of financial stability.

### 5.2.2 Suspensions when the BA values the bank's welfare

As demonstrated in the previous analysis where the BA only values depositors' welfare, a delay of suspension will emerge if consumers are less risk-averse but their degree of exposure to liquidity risk is high, i.e., $\gamma \in (\gamma_F, 1)$ and $\pi \in [\pi_F, 1)$. Though liquidating the banking system lowers the possibility that a large population of impatient depositors receives nothing, it is clear that such policies are not in the best interests of the banker. Notably, past experiences indicate that public intervention might be subject to tension between banks with market power and the BA. To formalize the point where the BA faces a trade-off of balancing the welfare of different groups of agents, we next consider a case where $\delta > 0$ in the social welfare function specified in $(7)$.

To study whether panics will be observed in equilibrium, we now turn to examine optimal deposit freeze policy by the BA should a run be identified after the first $\pi$ withdrawals. Recall that the period-2 consumption level to depositors is either $c_2^*$ if $\pi_s \in [\pi, \pi_P]$ or $c_2(\pi_s)$, which is given by $(9)$, if $\pi_s \in \left(\pi_P, \pi_s^U\right]$. Further, after serving all withdrawing depositors in period 2, the bank consumes capital gains $\eta(\pi_s)$ which are defined to be the amount of resources left, if any. Then, in determining when to freeze, the BA seeks to maximize aggregate welfare by solving:

$$\begin{aligned} V(\pi_s) &= \max_{\{\pi_s\}} \pi_s u(c_1^*) + (1-\pi_s)(1-\pi) u(\min\{c_2^*, c_2(\pi_s)\}) \\ &\quad + \delta \max\{\underbrace{[1-\tau(1-\pi c_1^*) - \pi_s c_1^*] \frac{R}{1-\tau} - (1-\pi)(1-\pi_s) c_2^*}_{=\eta(\pi_s)}, 0\} \end{aligned} \tag{14}$$

subject to the constraint $(11)$. In particular, the first two parts on the first line of the above optimization problem represent depositors' expected utility should a deposit freeze occur at $\pi_s$ whereas the last part on the second line denotes the weighted bank's welfare. Note that $\eta(\pi_s)$ is a strictly decreasing function of $\pi_s$ and $\eta(\pi_P) = 0$, implying that $\eta(\pi_s) > 0 \; \forall \pi_s \in [\pi, \pi_P)$. Note also that $\min\{c_2^*, c_2(\pi_s)\} = c_2^*$ must imply that $\max\{\eta(\pi_s), 0\} = \eta(\pi_s)$ or $\min\{c_2^*, c_2(\pi_s)\} = c_2(\pi_s)$ suggests $\max\{\eta(\pi_P), 0\} = 0$. That is, the bank earns zero rents if it does not have enough funds to honor its pre-specified payments in period 2 and vice versa.

In solving the above optimization problem, we again divide the constraint $(11)$ into two distinct cases as before. Suppose, for example, that $\pi_s \in [\pi, \pi_P]$ such that $\min\{c_2^*, c_2(\pi_s)\} = c_2^*$ and $\max\{\eta(\pi_s), 0\} = \eta(\pi_s)$. Under these scenarios, the first-order condition regarding the choice of the deposit freeze is given by:

$$\frac{dV(\pi_s)}{d\pi_s} = u(c_1^*) - (1-\pi) u(c_2^*) + \delta \left[ -c_1^* \frac{R}{1-\tau} + (1-\pi) c_2^* \right] \leq 0. \tag{15}$$

Recall from the discussion below equation $(12)$ that if $\gamma > 1$, then $u(c_1^*) - (1-\pi) u(c_2^*) < 0$. Combining such a result with the fact that $\left[-c_1^* \frac{R}{1-\tau} + (1-\pi) c_2^*\right] < 0$, inequality $(15)$ is necessarily satisfied, suggesting that funds will be frozen immediately at $\pi$ and hence panics will not occur when depositors are highly risk averse. Given the non-existence of run equilibria over higher values of risk aversion, we confine to the case of $\gamma < 1$ in the following analysis of deposit freezes. Yet, suppose instead that $\pi_s \in \left(\pi_P, \pi_s^U\right]$ such that $\min\{c_2^*, c_2(\pi_s)\} = c_2(\pi_s)$ and $\max\{\eta(\pi_s), 0\} = 0$. Then, the optimality condition regarding the suspension is again given by $(13)$.

Similarly, let $\pi_s^M$ represent the solution to the BA's optimization problem $(14)$. We now turn to discuss whether runs can be prevented if the BA values the bank's welfare. First, it follows that for any $\pi_s^M \in \left[\pi_P, \pi_s^U\right]$, the bank does not retain any profits in period 2 and thus the BA's objective

function $V(\pi_s)$ given by $(14)$ would be exactly the same as that given by $(10)$ though the bank's welfare is valued. As a result, the determinants of optimal suspension would be the same as those demonstrated in Proposition 1. In this regard, as the intuition for financial (in)stability closely follows that presented in the last subsection, it is omitted here. Next, we restrict our attention to situations where ex-post monopoly rents are non-negative.

Among these scenarios, it is worth emphasizing that the assumption of risk neutrality of the monopolistic bank is crucial for the optimal deposit freeze policy by the BA. To understand why, note that bank profits would be the highest at $\pi_s = \pi$ since the monopolist must use its potential capital gains to mitigate the effects of runs on depositors' payoffs in period 2. Conversely, suppose that it is desirable for the BA to suspend deposits at $\pi_P$. Then, at this critical level of the deposit freeze, the monopolist earns zero profits after meeting its period-2 obligations. In turn, for any $\pi_s \in [\pi, \pi_P)$, the welfare-improving suspension by the BA depends on whether the welfare gain from allowing one more depositor to withdraw $c_1^*$ or the welfare loss from the monopolist whose profits are decreasing when one more agent is served dominates. In particular, the welfare gain and loss that are denoted by $w_G$ and $w_L$ respectively are as follows:

$$w_G = u(c_1^*) - (1-\pi)\, u(c_2^*) \quad \text{and} \tag{16}$$

$$w_L = -\delta \left[ -c_1^* \frac{R}{1-\tau} + (1-\pi)\, c_2^* \right]. \tag{17}$$

Notably, neither $w_G$ nor $w_L$ depends on $\pi_s$ due to linear preferences of the bank. In this manner, the optimal choice of the BA to suspend withdrawals is reduced to freezing payments either at $\pi$ immediately or at a point where monopoly rents are exhausted while depositors' welfare is maximized. Specifically, the optimal deposit freeze is such that:

$$\begin{cases} \pi_s^M = \pi & \text{if } w_G \leq w_L \\ \pi_s^M \in \left[\pi_P, \pi_s^U\right] & \text{if } w_G > w_L \end{cases}.$$

As before, our interest is to study whether such time-consistent deposit freeze policy can rule out bank run equilibria. Interestingly, we show that when the bargaining power of the monopolist is relatively weak, the fragility condition is the same as the case if the BA only focuses on maximizing the expected utility of depositors. If, instead, the BA highly values the bank's welfare, deposits will be frozen immediately after a run is identified and thus the banking system is not fragile. For notational convenience, we define:

$$\underline{\delta} \equiv \frac{(1-\pi)\, u(c_2^*) - u(c_1^*)}{(1-\pi)\, c_2^* - \frac{R}{1-\tau} c_1^*}, \tag{18}$$

where $\underline{\delta} > 0 \ \forall \gamma < 1$. Recall that $\gamma_F$ and $\pi_F$ are defined in Proposition 1. We then offer the following result:

**Proposition 2.** *Suppose that $\gamma \in (\gamma_F, 1)$, $\tau \in (\tau_F, 1)$, and $\pi \in [\pi_F, 1)$. Under these conditions and the ex-post efficient suspension by the BA, runs are prevented if $\delta > \underline{\delta}$.*

Intuitively, if liquidity risk is substantial and the BA's primary preference is to augment depositors' welfare, suspensions will occur relatively late, leaving the bank unstable. However, if the bank's utility is an important part of social welfare, then the BA would credibly suspend payments immediately should a run emerge in order to protect bank profits. Anticipating that deposits will be frozen quickly before the crisis deepens, patient depositors have no ex-ante incentive to run on the bank and thus the results about banking fragility demonstrated in Proposition 1 are overturned.

In this manner, delegating a BA who places sufficient weight on the bank's welfare acts as a commitment device in suspending payments quickly and the good equilibrium is uniquely implemented. This implication is similar in spirit to the literature on optimal monetary policy such as Rogoff (1985). That is, it is plausible that society should appoint a BA with different objectives from depositors so that the banking system is less susceptible to fragility.

Lastly, it is shown that a sufficiently high liquidation cost makes the run equilibrium possible in the absence of public intervention while significant liquidity risk may induce fragility under optimal deposit freeze policy. In this vein, we next examine the effects of these parameter changes on the critical level of the relative importance of the bank's welfare $\underline{\delta}$. Notably, when characterizing the impact of liquidity risk, we only focus on settings with a somewhat lower range of risk aversion for a higher degree of tractability:

**Lemma 2**. *Suppose that $\tau \in (\tau_F, 1)$ and $\pi \in [\pi_F, 1)$. Further suppose that $\gamma \in (\gamma_F, 1)$. Under these conditions and the ex-post efficient suspension by the BA, the parameter space where runs are prevented is larger if the liquidation cost is higher, i.e., $\frac{d\underline{\delta}}{d\tau} < 0$. Suppose instead that $\gamma \in (\gamma_F, \gamma_1)$, where $\gamma_1 = \frac{(R-(1-\tau))^2}{(R-1)(1-\tau)+(R-(1-\tau))^2}$, such that $\pi_F > \pi_H$ and thus autarkic welfare is $W^A = \frac{1}{1-\gamma}$. Under these conditions, the parameter space where runs are prevented is smaller if consumers' degree of exposure to liquidity risk is higher, i.e., $\frac{d\underline{\delta}}{d\pi} > 0$.*

If the liquidation cost is higher, the BA has more incentive to avoid liquidating productive investment prematurely when choosing a freeze point. As a result, the minimum relative importance of the bank's welfare does not need to be too high so that a credible suspension of payments occurs right after the BA identifies a run. Consequently, the parameter space in which a run is ruled out is larger. However, when the depositors' degree of exposure to liquidity risk is higher, the BA is more inclined to delay a deposit freeze. By allowing more withdrawals in period 1, the authority

augments aggregate welfare where only a small proportion of impatient consumers receives nothing. Therefore, when individuals are highly exposed to liquidity risk, the BA must place larger weight on the bank's welfare in order to justify quick suspensions that prevent panics.

In addition, to relax the assumption of lower degrees of risk aversion so that the impact of the intermediate values of liquidity risk can be captured, we illustrate in Figure 1 how $\underline{\delta}$ varies when depositors are more risk averse, i.e., $\gamma \in (\gamma_1, 1)$. Specifically, we construct examples with parameters $(R, \gamma, \tau) = (1.05, 0.5, 0.1)$ under which $\gamma_F = 0.1429$, $\gamma_1 = 0.3333$, $\pi_F = 0.1667$, $\pi_L = 0.3164$, and $\pi_H = 0.3333$. Under the parameters considered, $\underline{\delta}$ is monotonically increasing in consumers' degree of exposure to liquidity risk, which is the same as that in Lemma 2.

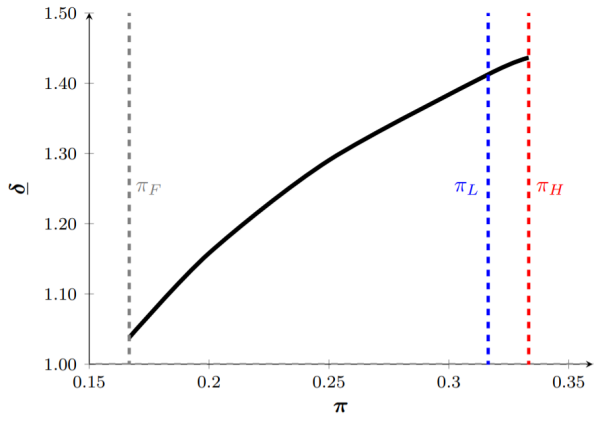


Figure 1: The impact of $\pi$ on $\underline{\delta}$ over a relatively higher level of risk aversion

### 5.2.3 The "type" of the BA, weight uncertainty, and financial fragility

We have previously explained that it may be difficult to pin down how a BA will respond to distress in the banking system. If, for example, the BA imposes large weight on the bank's welfare, depositors should have a less incentive to run: an early suspension announcement would be expected and the banking system would not be fragile. However, in practice, this may not be the case – for example, depositors may not know how much they contribute to the BA's goals or the "type" of the regulatory authority they are facing. In this manner, we identify an important banking policy problem of uncertainty about the BA's "type." This kind of uncertainty about a policymaker's "type" was formally discussed in Barro (1986) for the reputation of monetary authorities to tackle inflation. In the spirit of Barro's example, we explain why run equilibria may not be completely eliminated even if the BA may have strong incentives to freeze deposits once a panic is identified. That is, the BA may not be able to communicate its preferences effectively.

To begin, suppose that consumers are relatively risk averse, i.e., $\gamma \in (\gamma_F, 1)$ and the degree of liquidity risk in the economy is relatively high, i.e., $\pi \in [\pi_F, 1)$. Further suppose that the BA may

place weight $\delta_\theta$ on the bank's welfare when choosing optimal suspensions once a run is identified. In particular, uncertainty about the BA's type is represented by $\theta \in \{H, L\}$ and the respective probabilities are as follows:

$$\begin{cases} \delta_H \in [\underline{\delta}, \infty) & \text{with probability } \lambda \\ \delta_L \in [0, \underline{\delta}) & \text{with probability } 1-\lambda \end{cases},$$

where $\underline{\delta}$ is given by $(18)$. That is, with probability $\lambda$, the BA is of a "tough" type in which deposits are frozen immediately at $\pi$, as established in Proposition 2. In contrast, with probability $1-\lambda$, the BA behaves in a "weak" manner, leading to a late suspension $\pi_s^M \in \left[\pi^T, \pi_s^U\right]$.

Under weight uncertainty about the BA's type, the period-2 payoff on deposits is now type-dependent. Specifically, patient depositors are still guaranteed to receive $c_2^*$ if the BA is of the "tough" type. The problem faced by a "weak" type BA whose main objective is to maximize depositors' welfare is analogous. That is, the period-2 consumption level to depositors under a "weak" BA will be determined such that

$$c_2\left(\pi_s^M\right) = \frac{\left[1-\tau\left(1-\pi c_1^*\right)-\pi_s^M c_1^*\right]\frac{R}{1-\tau}}{\left(1-\pi\right)\left(1-\pi_s^M\right)},$$

where $\pi_s^M$ is the solution to the problem $(14)$ for any $\gamma \in (\gamma_F, 1)$, $\tau \in (\tau_F, 1)$, $\pi \in [\pi_F, 1)$, and $\delta \in (0, \underline{\delta})$. As a result, the expected utility to a patient depositor from waiting to withdraw is $\lambda u\left(c_2^*\right) + (1-\lambda)\, u\left(c_2\left(\pi_s^M\right)\right)$. We then summarize the condition under which bank runs occur.

**Proposition 3.** *Suppose that $\gamma \in (\gamma_F, 1)$, $\tau \in (\tau_F, 1)$, and $\pi \in [\pi_F, 1)$. Under these conditions, the ex-post efficient suspension, and weight uncertainty of the different "types" of the BA, there exists a maximum probability $\lambda^T \in \left[0, R^{\frac{\gamma-1}{\gamma}}\right]$ with which bank runs are not prevented.*

If depositors anticipate that the probability that the BA is of a "tough" type is sufficiently low, they have an incentive to panic. This happens because they have a strong belief that they will receive a lower payment from waiting to withdraw than the payoff from joining the run. Thus, in the presence of incomplete information over the BA's type, depositors' expectations truly determine whether the banking system is fragile (not the actual preferences of the BA) – by definition, the bank is fragile if all patient depositors choose to run on the system and behave in a way that is inconsistent with their privately observed preferences over the timing of consumption. By comparison, the preferences of the BA matter for the actual suspension point. If the BA is truly tough in freezing deposits but cannot communicate that it would impose a suspension early, one problem is that some truly impatient consumers will be shut off from access to their funds. That is, in the presence of incomplete information regarding the BA's type, run behavior may be observed even though the suspension is triggered upon the revelation of a crisis.

# 6 Equilibrium under payment rescheduling

In this section, we proceed to extend our framework by allowing the BA to have the instrument of payment rescheduling as in Ennis and Keister (2009a) and Gao and Reed (2021). In particular, in our previous analysis, we focused on suspensions of convertibility as the only policy intervention available to the BA. While this type of policy has been utilized widely in the past, other resolution processes for financial intermediaries may be considered as well. Thus, the primary purpose of this section is to examine whether our previous insights are robust to the introduction of payment rescheduling.

Note that as indicated by Gao and Reed (2021), payoffs in the event of a panic must be dictated by the BA as returns on deposits would be indeterminate should the BA not be involved in payment rescheduling. Note also that, as we will demonstrate later, runs may exist under this type of intervention if the BA's objective function is sufficiently different from that of depositors. In this vein, following Cooper and Ross (1998) and Peck and Shell (2003), among others, we introduce an exogenous sunspot signal on which depositors can condition their actions. Specifically, there are two aggregate states, $s \in S \equiv \{\alpha, \beta\}$, with respective probabilities $\{1-q, q\}$. The value of $q$ is assigned strictly between 0 and 1 and thus the potential for run behavior occurs with a non-trivial probability. Notably, the realization of the sunspot state is revealed to depositors immediately at the beginning of period 1 whereas the bank and the BA need to infer the state from the flow of withdrawals.

To proceed, without loss of generality, depositors withdraw funds according to their preference types in state $\alpha$, which is labeled the good state. Nevertheless, runs may occur in state $\beta$, which is called the panic or crisis state. We focus on actions taken by patient depositors, since impatient agents only value consumption in period 1 and will choose to withdraw early with certainty. In this manner, we consider a specific partial-run strategy profile for depositors at the bank as follows:

$$\begin{aligned} &y_i(\omega_i, \alpha) = \omega_i \qquad \text{for } i \in [0,1] \text{ and} \\ &y_i(\omega_i, \beta) = \left\{ \begin{array}{c} 0 \\ \omega_i \end{array} \right\} \quad \text{for } \left\{ \begin{array}{l} i \in [0, \pi] \\ i \in (\pi, 1] \end{array} \right\}. \end{aligned} \tag{19}$$

In this profile, the patient consumer with $i \leq \pi$ at the bank chooses to run in period 1 in the crisis state. As we will show below in our analysis, once the remaining consumption levels are rescheduled after the first $\pi$ withdrawals, the remaining patient depositors do not have an incentive to run.[8] In this vein, we next state the formal definition of financial fragility.

[8] As in Keister (2016), among others, we restrict our attention to a single wave run to simplify notation and concentrate on the role of the BA's preferences for financial stability. One could generalize the model by introducing multiple

**Definition 3.** *If the strategy profile* $(19)$ *is part of equilibria, the bank is defined to be fragile.*

Note also that this form of fragility is different from that in the benchmark framework where depositors run en masse and there is no payment rescheduling. However, the interpretation of relative fragility under which runs are partial would be the same as that in a model where full runs are possible. That is, if the parameter space in which a run equilibrium exists is larger, then the bank is said to be more fragile.

As before, we summarize the timing of events in Figure 2 below prior to setting up the BA's and the bank's problems. In period 0, after receiving their endowments, consumers decide whether to use the banking service. If the expected utility of the risk-sharing arrangement offered by the bank is not strictly worse than autarky, consumers then deposit their funds. Furthermore, they choose state-contingent withdrawal strategies after which the monopolist implements the portfolio decision about how much of its attracted deposits are placed into productive investment.

At the beginning of period 1, depositors follow their withdrawal plan once they learn their liquidity needs and the realized aggregate state. For tractability, if individuals decide to withdraw in period 1, they know their position in the queue and will arrive one at a time in the order given by their index and must consume immediately upon arrival. As before, the bank is subject to the sequential service constraint and a flexible payout scheme to consumers will be offered. That is, once the monopolist and the BA infers the aggregate state after a fraction $\pi$ of depositors have withdrawn, payments to the remaining agents in states $\alpha$ and $\beta$ will be rescheduled based on the updated information.

In period 2, depositors who have not withdrawn contact their bank and the banker will access its profits after making payments to all depositors.

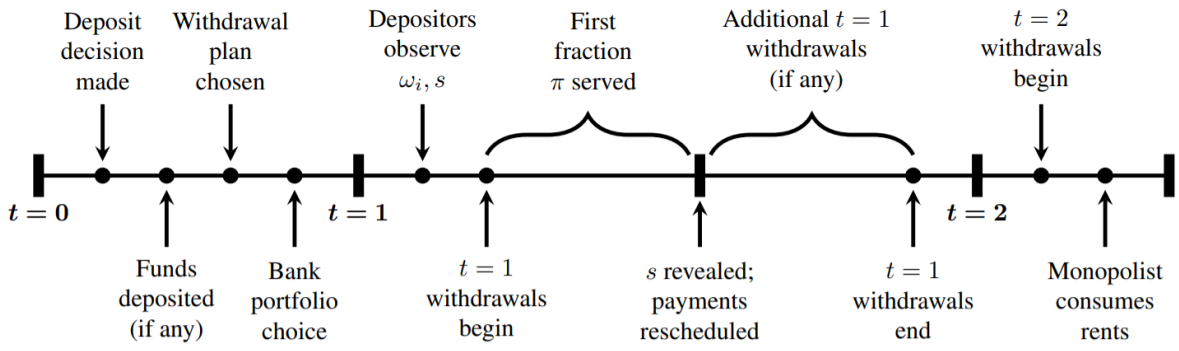


Figure 2: Timeline

waves of runs in an environment of a richer sunspot variable as in Ennis and Keister (2010). However, employing such an approach does not alter the main mechanisms and results in the model qualitatively.

## 6.1 The best responses of the BA and the monopolist

### 6.1.1 Resolution in the panic state

After making the early payment $c_1$ to each of the first fraction $\pi$ of depositors, the banker and the BA infer the sunspot signal. If the panic state is revealed, the bank is taken over by the BA. Notably, similar to that under the regime of suspensions of convertibility, the regulator has an objective to maximize aggregate utility, which may deviate from depositors' welfare. In seeking to dictate the consumption levels of consumers, the BA can calculate the fraction of the remaining impatient individuals based on the strategy profile $(19)$ and will choose payments conditional on this information. That is, the authority will offer common amounts $c_{1\beta}$ and $c_{2\beta}$ to each remaining impatient depositor and patient depositor in periods 1 and 2 respectively and $\eta_\beta$ as monopoly rents to the banker in order to maximize ex-post welfare $V_\beta$. In this regard, the introduction of bank profits into the BA's objective function departs from Gao and Reed (2021) where the BA dictates payouts to maximize welfare of the remaining depositors only. Recall that $x$ represents units of deposits invested in the illiquid technology and the BA's preferences are publicly known. Then, $c_{t\beta}$ and $\eta_\beta$ will be chosen to solve:

$$V_\beta \equiv \max_{\{c_{1\beta}, c_{2\beta}, \eta_\beta\}} (1-\pi)\left[\pi u\left(c_{1\beta}\right) + (1-\pi)\, u\left(c_{2\beta}\right)\right] + \delta\eta_\beta \tag{20}$$

subject to the resource constraints:

$$1 - x - \pi c_1 \leq (1-\pi)\,\pi c_{1\beta} \tag{21}$$

$$(1-\pi)^2 c_{2\beta} + \eta_\beta = R\left(x - \frac{(1-\pi)\,\pi c_{1\beta} - (1 - x - \pi c_1)}{1-\tau}\right) \tag{22}$$

In particular, the constraint $(21)$ means that all resources held in storage must be consumed and the BA liquidates investment to fulfill additional withdrawal requests in period 1 if this constraint does not bind. Further, the period-2 consumption level to consumers in the panic state is an even share of the bank's remaining resources offset by bank profits, as implied by the constraint $(22)$.

In solving this problem, we divide the above two constraints along with possible outcomes in normal times into three distinct scenarios summarized in Table 1 below. Under Scenario $I$, the bank only holds liquid assets for the first fraction $\pi$ of agents in state $\alpha$ and liquidates long-term investment for any additional period-1 withdrawals beyond the first $\pi$ depositors in state $\beta$. Under Scenario $II$, some of the returns from holdings of short-term assets are paid to patient consumers in period 2 in normal times but costly liquidation still occurs should a run emerge. Under Scenario $III$, the bank holds a sufficiently liquid portfolio so that any withdrawal demand is met without liquidation of productive assets.

| | State $\alpha$ | State $\beta$ |
|---|---|---|
| Scenario $I$ | No-excess liquidity | Liquidation |
| Scenario $II$ | Excess liquidity | Liquidation |
| Scenario $III$ | Excess liquidity | No liquidation |

Table 1: Three possible scenarios

Letting $\mu_{1\beta}$ and $\mu_{2\beta}$ denote the multipliers on the resource constraints $(21)$ and $(22)$, the first-order conditions characterizing $c_{1\beta}$, $c_{2\beta}$, and $\eta_\beta$ are given by:

$$u'(c_{1\beta}) = \frac{R}{1-\tau}\mu_{2\beta} - \mu_{1\beta}, \quad u'(c_{2\beta}) = \mu_{2\beta}, \quad \text{and} \quad \delta = \mu_{2\beta}. \tag{23}$$

The above conditions imply that the ex-post optimal payout scheme to depositors entails: $\frac{c_{2\beta}}{c_{1\beta}} \leq \left(\frac{R}{1-\tau}\right)^{\frac{1}{\gamma}}$, depending on whether long-term assets are liquidated should the crisis state be revealed. Moreover, bank profits in state $\beta$ would be higher if the BA places larger weight $\delta$ on monopoly rents, which is inversely related to the levels of consumers' consumption ex-post. Note, however, that allowing the monopolist to realize higher capital gains in the event of a run than in normal times may be highly undesirable. Hence, we only focus on equilibria in which bank profits are lower should run behavior emerge.

In seeking to summarize the sum of depositors' expected utilities in state $\beta$, first suppose that the monopolist finds it optimal to make its portfolio choice such that no excess liquid assets are held, i.e., $1 - x = \pi c_1$, as described by Scenario $I$. In these situations, the authority must resort to liquidation to meet the extra demand for period-1 consumption should the panic state be inferred, implying that the constraint $(21)$ does not bind and thus $\mu_{1\beta} = 0$. In this vein, the relationship between $c_{1\beta}$ and $c_{2\beta}$ is characterized by:

$$u'(c_{1\beta}) = \frac{R}{1-\tau}u'(c_{2\beta}). \tag{24}$$

Combining the resource constraint $(22)$ and the above optimality condition, we can write depositors' ex-post welfare as follows:

$$v_\beta = \frac{\left((1-\pi)\left[\pi + (1-\pi)\left(\frac{R}{1-\tau}\right)^{\frac{1-\gamma}{\gamma}}\right]\right)\left(\frac{\delta R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}}{1-\gamma}, \tag{25}$$

which implies that should the BA place more weight on a banker's utility, consumers' welfare derived from banking services will be lower. Moreover, straightforward algebra yields the expression

for the amount of monopoly rents:

$$\eta_\beta = R\left(1-\pi c_1\right) - \left(1-\pi\right)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}} + \left(1-\pi\right)\right]\delta^{-\frac{1}{\gamma}}. \tag{26}$$

Yet, it is also possible that the monopolistic bank holds excess liquidity against runs, i.e., $1 - x > \pi c_1$, and the BA liquidates long-term assets, as in Scenario $II$. Under this case, the constraint $(21)$ again does not bind and thus the relationship between $c_{1\beta}$ and $c_{2\beta}$ is still delineated by $(24)$. Similarly, using the resource constraint $(22)$ and the ex-post optimal risk-sharing condition in equation $(24)$, we can express the expected utility of depositors in state $\beta$ by condition $(25)$ again but the level of bank profits contingent on state $\beta$ under this scenario is:

$$\eta_\beta = Rx + \frac{R}{1-\tau}\left(1-x-\pi c_1\right) - \left(1-\pi\right)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}} + \left(1-\pi\right)\right]\delta^{-\frac{1}{\gamma}}. \tag{27}$$

It is clear that the only difference between the profit functions $(26)$ and $(27)$ is whether liquid assets are used for additional period-1 consumption beyond the first $\pi$ withdrawals.

Lastly, as suggested by Scenario $III$, the banker holds a sufficient amount of precautionary liquid assets so that costly liquidation never occurs even though a positive measure of patient consumers run on the bank. That is, the constraint $(21)$ binds and therefore $\mu_{1\beta} > 0$. Then, the consumers' welfare level in the panic state can be summarized as:

$$v_\beta = \frac{\left[\left(1-\pi\right)\pi\right]^\gamma\left(1-x-\pi c_1\right)^{1-\gamma} + \left(1-\pi\right)^2\delta^{\frac{\gamma-1}{\gamma}}}{1-\gamma}, \tag{28}$$

reflecting that excess liquidity and matured investment offset by monopoly rents are paid to the remaining impatient and patient agents respectively. Furthermore, the amount of monopoly rents is as follows:

$$\eta_\beta = Rx - \left(1-\pi\right)^2\delta^{-\frac{1}{\gamma}}. \tag{29}$$

Importantly, conditions $(25)$ and $(28)$ also state that once the portfolio choice $x$ and the early payment $c_1$ are made to the first $\pi$ consumers, there would be no uncertainty related to the expected utility of consumers in resolution. In other words, the value function $v_\beta$ would be deterministic as the monopolistic bank anticipates that the BA will reallocate the remaining resources to depositors according to $(23)$. Similarly, bank profits $\eta_\beta$ would be "fixed" upon the identification of a run.

### 6.1.2 Bank payments in normal times

We now turn to study how much the monopolist will pay to each withdrawing depositor if the good aggregate state is revealed. First, from the strategy profile $(19)$, the monopolistic bank knows that no one will further request the period-1 payment after the first fraction $\pi$ of depositors has been served. Next, let $\mathbb{I}$ denote the indicator function in which $\mathbb{I}_{(1-x=\pi c_1)} = 1$ and $\mathbb{I}_{(1-x>\pi c_1)} = 0$ if no excess liquidity is held whereas $\mathbb{I}_{(1-x=\pi c_1)} = 0$ and $\mathbb{I}_{(1-x>\pi c_1)} = 1$ if the opposite occurs. Note also that the banker derives utility by consuming profits denoted by $\eta_\alpha$, which is the difference between the bank's remaining resources and total payments to patient agents in period 2. As a result, the common amount contingent on state $\alpha$, $c_{2\alpha}$, is chosen to maximize:

$$\eta_\alpha \equiv \max_{\{c_{2\alpha}\}} R\left(1-\pi c_1\right)\mathbb{I}_{(1-x=\pi c_1)} + \left(1-x-\pi c_1+Rx\right)\mathbb{I}_{(1-x>\pi c_1)} - \left(1-\pi\right)c_{2\alpha} \tag{30}$$

subject to the depositors' participation constraint:

$$\pi u\left(c_1\right) + \left(1-q\right)\left(1-\pi\right)u\left(c_{2\alpha}\right) + qv_\beta \geq W^A, \tag{31}$$

where the expression for $v_\beta$ is given by $(25)$ or $(28)$. In other words, the participation constraint states that depositors would derive expected utility over both aggregate states not lower than financial autarky. Moreover, since the monopolistic bank can extract all of the gains from consumers, the constraint $(31)$ holds with equality.

Notably, this constraint is relevant when the bank chooses $c_{2\alpha}$ ex-post even though the crisis state did not occur. To understand why, note that the expected utility of consumers contingent on state $\beta$ has been resolved once the portfolio choice and the consumption level to the first fraction $\pi$ of depositors are determined. Alternatively, the monopolist has already taken into account what the BA would have done should a crisis occur when issuing short-term obligations before inferring the sunspot state. To be precise, as implied by the equation $(25)$ or $(28)$, the last term on the left-hand-side of the participation constraint, $qv_\beta$, is deterministic from the monopolist's perspective. Yet, unlike payments in resolution that are not offered by the monopolist, the payoff in normal times $c_{2\alpha}$ is chosen to maximize bank profits, which in turn affects the early return on deposits $c_1$.

Letting $\mu_d$ denote the multiplier on the participation constraint of depositors, the solution regarding the optimal choice of the bank payment in period 2 requires:

$$\left(1-q\right)u'\left(c_{2\alpha}\right) = \frac{1}{\mu_d}. \tag{32}$$

The above risk-sharing condition implies that when the shadow value $\mu_d$ is lower where the participation constraint is relaxed, the remaining depositors' expected consumption in normal times

would be relatively lower.

### 6.1.3 Early payments

Moving backwards, the monopolist must choose its early payment for the first fraction $\pi$ of consumers, recognizing that ex-post payoffs on deposits in resolution will be offered according to $(23)$ and it will adopt the appropriate state-contingent consumption level in normal times according to $(32)$. As the bank has no information as to the realization of the aggregate state, it chooses the same amount $c_1$ to each withdrawing, risk-averse depositor. Recall that $\eta_\alpha$ and $\eta_\beta$ are given by $(30)$ and $(26)$, $(27)$, or $(29)$. In this manner, the value of $c_1$ is chosen to solve:

$$\Pi \equiv \max_{\{c_1\}} (1-q)\,\eta_\alpha + q\eta_\beta \tag{33}$$

subject to $(31)$ due to the uncertainty about the realized aggregate state at this point in time.

To demonstrate the solution characterizing the optimal choice of $c_1$, note that under Scenario $I$, no precautionary liquid assets are held and thus the early payment is determined by:

$$u'(c_1) = \frac{R}{\mu_d}. \tag{34}$$

Under Scenario $II$ where the bank holds excess liquidity and costly liquidation occurs in state $\beta$, $c_1$ is chosen such that:

$$u'(c_1) = \frac{(1-q) + q\frac{R}{1-\tau}}{\mu_d}. \tag{35}$$

Further, under Scenario $III$, no long-term investment is liquidated in the event of a panic and hence the early return on deposits satisfies:

$$u'(c_1) = \frac{1-q}{\mu_d} + q\left[(1-\pi)\,\pi\right]^\gamma (1 - x - \pi c_1)^{-\gamma}. \tag{36}$$

Across all specifications, if the participation constraint is tightened, the monopolist must increase its early payment so that depositors' welfare does not drop below their reservation level.

### 6.1.4 Portfolio choice

We proceed to discuss how the intermediary makes its portfolio choice in period $0$. In particular, as suggested by Scenario $I$, portfolio choices are made such that the bank depletes all of its holdings of assets in the storage technology once the aggregate state is inferred:

$$x = 1 - \pi c_1. \tag{37}$$

Nevertheless, under Scenario $II$, a more liquid portfolio may be chosen by the bank but the BA still needs to liquidate productive investment upon the revelation of the crisis state. Notably, owing to the fact that all consumption levels and thus the depositors' participation constraint is independent of $x$, the monopolist seeks to alter the amount of investment so that expected profits $(33)$ are maximized. As we will discuss in greater detail later, however, such a portfolio choice critically hinges on the prospect of a run. In a less crisis-prone economy, for example, the monopolist tends not to hold any excess liquidity against runs. By comparison, if there is greater potential for consumer sentiment to deteriorate, the portfolio choice will be such that the demand for any additional period-1 withdrawals can be met by using all of holdings of the bank's liquid assets. Yet, neither banking behavior described above is consistent with Scenario $II$.

In contrast, under Scenario $III$, the bank may hoard a sufficient amount of liquidity so that the BA does not need to resort to costly liquidation for depositors' consumption contingent on the crisis state. In this case, the monopolist would choose $x$ to maximize expected profits $(33)$ subject to the only constraint $(31)$. Then, the optimality condition regarding the portfolio choice is:

$$q\left[(1-\pi)\,\pi\right]^{\gamma}\left(1-x-\pi c_1\right)^{-\gamma}=\frac{R-(1-q)}{\mu_d}. \tag{38}$$

Notably, the condition $(38)$ indicates that once the depositors' participation constraint is relaxed, the bank places more funds into the investment technology in order to realize higher expected rents.

## 6.2 Equilibrium fragility and allocations

The above analysis demonstrates the best responses of a BA and a monopolistic banker to the strategy profile $(19)$. In particular, there are three distinct scenarios in total. Letting the superscripts $I$, $II$, and $III$ designate the results under each scenario, we can express the best-response allocations as three different vectors as follows:

$$\hat{c}^{*}\equiv\left\{\hat{x}^{*},\hat{c}_1^{*},\hat{c}_{2\alpha}^{*},\hat{c}_{1\beta}^{*},\hat{c}_{2\beta}^{*}\right\}\quad\text{ for }*=I,II,III.^{9}$$

In each vector, information about the monopolist's portfolio choice and payment scheme to depositors is contained. The components are determined by conditions $(23)$, $(32)$, $(34)$, $(36)$ to $(38)$, the resource constraints $(21)$, $(22)$, and the participation constraint $(31)$. Moreover, let $\hat{W}^{*}$ and $\eta_s^{*}>0$ for $s=\alpha,\beta$ and $*=I,II,III$ represent the expected utility of depositors delivered by the monopolist and equilibrium bank profits in state $s$.

Recall that $y$ denotes a complete profile of strategies for all depositors at the bank and let $\chi$ represent the repayment strategy for the monopolist. Then, prior to discussing under what conditions

[9] See the Appendix for the calculated consumption levels.

the strategy profile $(19)$ is part of an equilibrium, note that we study equilibria of a withdrawal game where: $(i)$ each depositor determines $y_i$ to maximize her expected utility $\sigma_i(\chi,(y_i,y_{-i}))$; $(ii)$ the monopolist chooses $\chi$ to maximize its own profits $\Pi(\chi,y)$; $(iii)$ each agent's strategy is a best response to the strategies of others. Thus, the formal definition of an equilibrium is given by:

**Definition 4**. *The equilibrium of the withdrawal game at the bank is the profile of strategies* $(\chi^*,y^*)$ *such that:*

*i.* $\sigma_i\left(\chi^*,\left(y_i^*,y_{-i}^*\right)\right)\geq\sigma_i\left(\chi^*,\left(y_i,y_{-i}^*\right)\right)$ *for all* $y_i$ *and all* $i\in[0,1]$*;*

*ii.* $\Pi(\chi^*,y^*)\geq\Pi(\chi,y^*)$ *for all* $\chi$*.*

In what follows, we determine conditions under which the profile $(19)$ emerges as part of an equilibrium. To begin, we only focus on actions taken by patient depositors since impatient agents with a pressing need to consume will necessarily withdraw in period 1. In this vein, we begin by considering the behavior of patient individuals with $i>\pi$. To be specific, as all uncertainty has been resolved once the aggregate state is inferred, ex-post payments on deposits are set such that $\hat{c}_{2\beta}^*>\hat{c}_{1\beta}^*$. As a result, withdrawing in period 2 is a strictly dominant strategy for a patient depositor $i>\pi$.

To proceed, we consider separately two possible cases for patient agents who have the chance to withdraw before the aggregate state is revealed by the monopolist and the BA. In particular, a patient depositor $i\leq\pi$ receives $\hat{c}_{2\alpha}^*$ should the good state be realized and $\hat{c}_1^*$ if she contacts the bank in period 1. In this regard, as is common in the literature, we restrict our attention to circumstances where $\hat{c}_{2\alpha}^*>\hat{c}_1^*$ and thus no runs occur in normal times. By comparison, if the panic state is realized at the start of period 1, a patient agent $i\leq\pi$ anticipates to receive $\hat{c}_{2\beta}^*$ if she waits until period 2 but $\hat{c}_1^*$ if she joins the run. Consequently, the partial-run strategy profile specified in $(19)$ is part of an equilibrium if and only if $\hat{c}_1^*\geq\hat{c}_{2\beta}^*$.

Based upon the criteria discussed above, we next examine whether allocation $\hat{c}^*$ for $*=I,II,III$ will be on the equilibrium path. As a starting point, it is worth noting that under Scenario $I$, $\hat{c}_{2\alpha}^I>\hat{c}_1^I$ if and only if $q<\bar{q}^I=1-\frac{1}{R}$. Thus, to focus on pure strategy Nash equilibria where allocation $\hat{c}^I$ is on the equilibrium path of play, we limit our attention to lower crisis probabilities and hence patient agents never run on the bank in normal times. Moreover, for the results that the monopolist generates higher profits in truth-telling than in run equilibria, i.e., $\eta_\alpha^I>\eta_\beta^I$ and $\hat{c}_1^I\geq\hat{c}_{2\beta}^I$, the following two conditions need to be imposed simultaneously. To be specific, the coefficient of relative risk aversion is greater than unity and the probability of a panic exceeds the lower bound $\underline{q}^I=1-\frac{\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)\right]^\gamma}{R}$, where $\underline{q}^I<\bar{q}^I$.

To understand why, first note that depositors must exhibit a minimal amount of risk aversion for higher bank profits during normal times than in the event of a run, i.e., $\gamma\in(1,\infty)$. Among these

circumstances, however, the latter restriction on the crisis probability is not binding, i.e., $\underline{q}^I < 0$, as long as $\pi > \underline{\pi}^I = \frac{R^{\frac{1}{\gamma}}-1}{\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}-1}$. That is, run behavior may still be observed even though the prospect of a panic is negligible if the fraction of impatient depositors is large enough. Intuitively, the intermediary infers the sunspot state after the first $\pi$ redemptions have taken place and if there are more individuals with a pressing need for their consumption, runs, if any, will be identified relatively late. In this vein, the monopolist will be subject to fragility over higher values of $\pi$ as it only has fewer resources left for ex-post redistribution by the BA. Notably, if $\gamma \in (1, \infty)$ and $\tau \in \left(\max\left\{0, \underline{\tau}^I\right\}, 1\right)$, where $\underline{\tau}^I = 1 - R^{\frac{2-\gamma}{1-\gamma}}$, then $\underline{\pi}^I < 1$, implying that there is room for the condition $\pi > \underline{\pi}^I$ to hold. In this sense, runs on the monopolist with higher rents in normal times may occur over lower probabilities of crises when agents are more risk-averse and the liquidation cost is high enough.

It can also be verified that under Scenario $II$, the condition $\hat{c}^{II}_{2\alpha} > \hat{c}^{II}_1$ holds $\forall q < \bar{q}^{II} = \frac{R-2(1-\tau)}{R-(1-\tau)}$ and given that both $\hat{c}^{II}_1$ and $\hat{c}^{II}_{2\alpha}$ are independent of $\hat{x}^{II}$, $\frac{d\Pi^{II}}{d\hat{x}^{II}} \leq (>)\, 0$ if and only if $q \geq (<)\, \hat{q}^{II} = \frac{R-1}{\frac{R}{1-\tau}-1}$. In this vein, over initially lower run probabilities, i.e., $q \in \left(0, \min\left\{\bar{q}^{II}, \hat{q}^{II}\right\}\right)$, the portfolio choice will be such that the bank does not hold excess liquidity against crises. Nevertheless, this allocation of resources belongs to Scenario $I$. If instead crises are more likely to occur, i.e., $q \in \left[\hat{q}^{II}, \bar{q}^{II}\right)$, the monopolist seeks to hold as much precautionary liquid assets as possible so that costly liquidation during a panic is avoided. Yet, this suggests that the solution to the BA's and the bank's problem lies under Scenario $III$. Thus, we eliminate allocation $\hat{c}^{II}$.

Lastly, though the allocation of resources under Scenario $III$ can be run prone in the crisis state as there exists a parameter space in which both conditions $\hat{c}^{III}_{2\alpha} > \hat{c}^{III}_1$ and $\hat{c}^{III}_1 \geq \hat{c}^{III}_{2\beta}$ hold, the criterion on bank profits $\eta^{III}_\alpha > \eta^{III}_\beta$ is never satisfied. Specifically, when the monopolist holds a sufficiently liquid portfolio such that no costly liquidation is needed should a run be identified, $1-\hat{x}^{III}-\pi\hat{c}^{III}_1 = (1-\pi)\,\pi\hat{c}^{III}_{1\beta}$. By this fact and $\hat{c}^{III}_{1\beta} < \hat{c}^{III}_{2\beta}$, $\frac{\eta^{III}_\alpha}{\eta^{III}_\beta} = \frac{1-\hat{x}^{III}-\pi\hat{c}^{III}_1+R\hat{x}^{III}-(1-\pi)\hat{c}^{III}_{2\alpha}}{R\hat{x}^{III}-(1-\pi)^2\hat{c}^{III}_{2\beta}} > 1$ can be reduced to $\hat{c}^{III}_{2\alpha} < \pi\hat{c}^{III}_{1\beta} + (1-\pi)\,\hat{c}^{III}_{2\beta} < \hat{c}^{III}_{2\beta}$ where the strategy profile in $(19)$ is not consistent with equilibrium so that Scenario $III$ is not considered as well. We then summarize the results in the following lemma.

**Lemma 3.** *Suppose that $\eta^*_\alpha > \eta^*_\beta > 0$. Under this condition, if the monopolistic bank is fragile under the regime of payment rescheduling, the solution to the bank's problem belongs to Scenario $I$ only.*

It is worth emphasizing again that in economies where depositors' risk aversion is low enough, i.e., $\gamma \in (0, 1)$, the fragility condition $\hat{c}^I_1 \geq \hat{c}^I_{2\beta}$ may hold but the monopolist would generate more profits in times of crises.

### 6.2.1 Discussion

In what follows, we offer a more intuitive exposition of banking fragility under payment rescheduling. To better compare across the two policy interventions, suppose that the possibility of a run is close to zero as under the regime of suspensions of convertibility. In these situations, the monopolist finds it optimal to implement the allocation $c^*$ given under Section 5.1 where the depositors' participation constraint is not affected by any ex-post public intervention if runs occur unexpectedly. Further, suppose that the BA places an arbitrarily large weight on monopoly rents in the sense that, once a panic is identified, nearly all remaining resources are retained as bank profits. Then, after observing the adverse sunspot signal, depositors who have the opportunity to withdraw before payments are rescheduled will choose to do so with certainty, implying that the strategy profile in $(19)$ is part of equilibria.

Yet, in practice, such a resolution process may be highly undesirable as it implicitly allows the bank to take advantage of a financial crisis by realizing higher rents in the event of a run. Furthermore, as we analyzed above, should the fragility condition $\hat{c}_1^I \geq \hat{c}_{2\beta}^I$ hold and depositors' risk aversion be sufficiently low, the monopolist would always earn higher profits contingent on the poor realization of the sunspot state. This is in stark contrast to that under the simple suspension scheme where the bank consumes more rents in a truth-telling equilibrium. To circumvent the undesirability of higher capital gains during panics than in normal times under payment rescheduling, we limit our attention to cases in which consumers are highly risk-averse throughout the remainder of the analysis.

## 6.3 The impact of the regulator's preferences on stability

We now study our primary question of interest: What are the effects of the regulator's preferences on depositors' incentives to panic? The following proposition demonstrates that the bank is more vulnerable to a run if the BA places larger weight on a banker's welfare when rescheduling payments.

**Proposition 4**. *Suppose that run equilibria under Scenario $I$ exist. Under this condition, depositors' inclination to panic increases if the BA places larger weight on the banker's utility.*

In particular, there are two competing effects at work. First, when bank profits enter through the social welfare function significantly, the BA sets aside more income for the banker to be paid once long-term assets mature in the crisis state. That is, ex-post payments on deposits would be lowered, augmenting consumers' propensity to run on the bank. Second, the reduced level of payments upon the identification of the panic state also tightens the depositors' participation constraint. To ensure that consumers' expected utility will not be lower than financial autarky,

the monopolist must respond by increasing the return on early demandable deposits. Overall, higher degrees of illiquidity and lower payoffs in resolution leave the bank more susceptible to a crisis. Importantly, identifying such a novel aspect of vulnerability in the banking system suggests that delegating a BA whose objective function deviates from that of depositors may increase the potential for a banking system to be unstable.

In the following analysis, we turn to examine the existence of run equilibria under Scenario $I$ by providing a precise parameter region for the weight placed by the BA on the banker's welfare in which the results in Proposition 4 hold. To begin, we concentrate on situations in which $\gamma \in (1, \infty)$ and $q \in \left(\max\left\{0, \underline{q}^I\right\}, \bar{q}^I\right)$ and therefore it would be optimal for the bank to implement allocation $\hat{c}^I$. It follows from Proposition 4 that the monopolist is more prone to a crisis over higher values of $\delta$ and hence agents have an incentive to panic if the weight placed on monopoly rents is relatively high. Specifically, $\hat{c}_1^I \geq \hat{c}_{2\beta}^I$ if and only if:

$$\delta \geq \left( \frac{(1-\gamma) W^A}{\pi + (1-\pi) R^{\frac{1-\gamma}{\gamma}} (1-q)^{\frac{1}{\gamma}} + q(1-\pi)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}} + (1-\pi)\right]} \right)^{\frac{\gamma}{\gamma-1}} = \delta_F^I, \tag{39}$$

where $\delta_F^I > 0$. Further, for the results that the monopolist earns a lower amount of rents in the event of a crisis than in normal times, i.e., $\eta_\alpha^I > \eta_\beta^I$, an upper bound on the relative importance of bank profits needs to be placed:

$$\delta < \left( \frac{(1-\gamma) W^A}{\left[\pi + (1-\pi) R^{\frac{1-\gamma}{\gamma}} (1-q)^{\frac{1}{\gamma}}\right]\left(\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}} + (1-\pi)\right][R(1-q)]^{-\frac{1}{\gamma}}\right)^{1-\gamma} + q(1-\pi)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}} + (1-\pi)\right]} \right)^{\frac{\gamma}{\gamma-1}} = \delta^I. \tag{40}$$

More importantly, monopoly rents conditional on the poor realization of the sunspot state must be non-negative for run behavior under Scenario $I$ to emerge in equilibrium. Yet, due to the complexity of characterizing run equilibria under this scenario when there is greater potential for consumer sentiment to deteriorate, we begin by examining a case where $q$ goes to zero:

**Proposition 5.** *Suppose that $\gamma \in (1, \infty)$, $\tau \in \left(\max\left\{0, \underline{\tau}^I\right\}, 1\right)$, and $\pi \in \left(\underline{\pi}^I, 1\right)$. Further, suppose that the run probability $q$ is arbitrarily low. Under these conditions, there exists a threshold weight placed by the BA on monopoly rents $\underline{\delta}^I \in \left(0, \delta^I\right)$ such that if $\delta \in \left(\underline{\delta}^I, \delta^I\right)$, $\eta_\alpha^I > \eta_\beta^I > 0$ and thus run equilibria under Scenario $I$ exist $\forall \delta \in \left(\max\left\{\underline{\delta}^I, \delta_F^I\right\}, \delta^I\right)$.*

In economies where the probability of a panic is negligible, the monopolist is always able to earn positive profits should no runs occur. In turn, run equilibria under Scenario $I$ where $\eta_\alpha^I > \eta_\beta^I$ exist as long as the amount of bank capital gains during crises is positive but does not exceed that

in normal times.

In addition, to relax the parameter restriction on $q$ imposed in Proposition 5, Figure 3 illustrates run equilibria under Scenario $I$ when the prospect of a crisis is relatively high. Specifically, we construct examples with the following set of parameters $(\pi, R, \gamma, \tau, q) = (0.55, 1.25, 8, 0.2, 15\%)$ under which $\delta_F^I = 1.0023$, $\underline{\delta}^I = 1.0928$, and $\delta^I = 4.4047$. Notably, though depositors are less inclined to panic if their utility accounts for a larger part of social welfare, run behavior will still be on the equilibrium path as long as $\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I} \geq 1$. Nevertheless, $\delta_F^I < \underline{\delta}^I$ implies that run equilibria under Scenario $I$ where $\eta_\alpha^I > \eta_\beta^I$ only exist if $\underline{\delta}^I < \delta < \delta^I$.

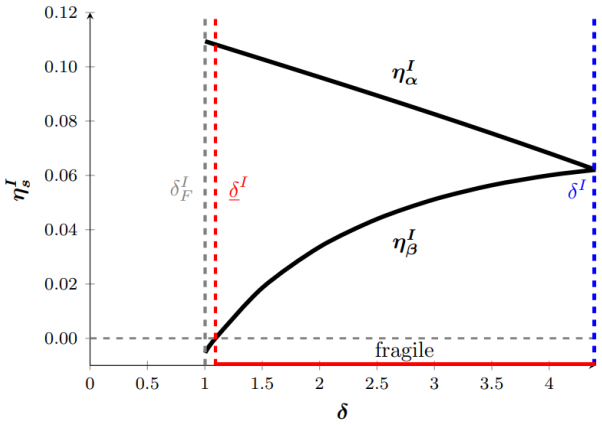


Figure 3: Run equilibria under Scenario $I$ when $\pi$ is intermediate

To draw further insights, we consider situations where depositors are more susceptible to liquidity risk by modifying parameters to $(\pi, R, \gamma, \tau, q) = (0.8, 1.25, 8, 0.2, 15\%)$ in Figure 4. Under the parameter values considered, $\delta_F^I = 0.9969$, $\underline{\delta}^I = 3.4216$, and $\delta^I = 8.9712$ below which $\eta_\alpha^I > \eta_\beta^I$. Importantly, there exists a maximum weight placed on bank profits denoted by $\bar{\delta}^I = 7.8207$ with which $\eta_\beta^I = 0$ and therefore run equilibria exist if and only if $\underline{\delta}^I < \delta < \bar{\delta}^I$. In comparison to that in Figure 3, the parameter space in which the monopolist under Scenario $I$ exists over lower values of $\delta$ is smaller. Intuitively, the bank has fewer remaining resources kept in investment after meeting higher demand for early consumption. In these situations, if the weight placed by the BA on monopoly rents is low, relatively high ex-post payoffs on deposits would lead to negative bank profits in state $\beta$. Consequently, in environments where the proportion of impatient consumers is large, the BA must place sufficient weight on the bank's profits in order for run equilibria to exist.

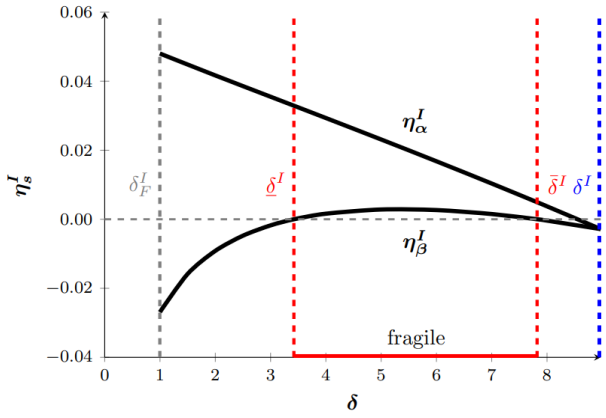


Figure 4: Run equilibria under Scenario $I$ when $\pi$ is relatively high

# 7 Conclusion

The emergence of large-scale financial institutions and concerns about TBTF banks in advanced economies has generated a recent policy debate about the effects of increasing concentration on financial stability. In addition, credibility issues and the limited scope of the government safety net such as deposit insurance call for research into other policy tools that are also capable of eliminating panics. In this vein, we build on a version of the Diamond and Dybvig (1983) model with a monopolistic bank and a time-consistent policy response by a BA.

We show that limited commitment on the part of the BA may induce instability but the BA's incentives are also an important determining factor in financial stability. In particular, under the regime of a simple suspension scheme, appointing a BA who places sufficient weight on a banker's welfare acts as a commitment device and prevents runs, in analogy with how a Rogoff (1985) "conservative" central banker helps reduce inflation bias. Further, we identify an important banking policy problem of uncertainty about the BA's "type" where such uncertainty can be another source of instability. That is, if depositors do not have complete information about the BA's objectives, runs may still occur even if a suspension is triggered right after a panic is identified.

In contrast, once interventions take the form of payment rescheduling, the scope for the bank's susceptibility to a panic increases should the BA put more weight on monopoly rents. Identifying such an aspect of vulnerability suggests that delegating a BA whose objective function deviates from that of depositors may have unintended consequences by exacerbating financial stability.

# 8 Technical appendix

**The best-response allocation of the monopolistic bank**

The best-response allocation under a monopolistic bank is determined by the condition $(5)$ and the participation constraint $(4)$. Then, the vector $c^* \equiv \{x^*, c_1^*, c_2^*\}$ is given by:

$$\begin{aligned} x^* &= 1 - \pi c_1^*, \\ c_1^* &= \left( \frac{(1-\gamma) W^A}{\pi + (1-\pi) R^{\frac{1-\gamma}{\gamma}}} \right)^{\frac{1}{1-\gamma}}, \\ c_2^* &= R^{\frac{1}{\gamma}} c_1^*, \end{aligned}$$

where $\frac{c_2^*}{c_1^*} = R^{\frac{1}{\gamma}} > 1$.

■

**Proof of Proposition 1**

Suppose that $\gamma \in (0,1)$ and $\tau \in (\tau_F, 1)$ or $\gamma \in (1, \infty)$ such that run equilibria may exist under a monopolistic bank. To see whether banks are fragile under a time-consistent simple suspension, differentiating the BA's objective function with respect to $\pi_s$ and evaluating at $\pi_s = \pi^T$ yield:

$$\left. \frac{dV(\pi_s)}{d\pi_s} \right|_{\pi_s = \pi^T} = u(c_1^*) \left( \pi - \frac{u'(c_1^*) c_1^*}{u(c_1^*)} \left[ \frac{R - (1-\tau)(1-\pi)}{1-\tau} \right] \right).$$

In particular, if $\left. \frac{dV(\pi_s)}{d\pi_s} \right|_{\pi_s = \pi^T} \geq 0$, $\pi_s^M \geq \pi^T$ and thus the bank is fragile.

In this vein, note that using the utility functional form $(1)$ if $\gamma \in (0,1)$, $u(c_1^*) > 0$ and $\pi - \frac{u'(c_1^*) c_1^*}{u(c_1^*)} \left[ \frac{R-(1-\tau)(1-\pi)}{1-\tau} \right] \geq 0$, implying that $\left. \frac{dV(\pi_s)}{d\pi_s} \right|_{\pi_s = \pi^T} \geq 0$, if and only if $\pi \geq \pi_F = \frac{1-\gamma}{\gamma} \left( \frac{R-(1-\tau)}{1-\tau} \right)$. Note also that $\pi_F < 1$ if $\gamma \in (\gamma_F, 1)$, where $\gamma_F = \frac{R-(1-\tau)}{R}$, and therefore for any $\gamma \in (\gamma_F, 1)$, runs are on the equilibrium path of play $\forall \pi \in [\pi_F, 1)$.

Yet, using the utility functional form $(8)$ if $\gamma \in (1, \infty)$, $u(c_1^*) < 0$ and $\pi - \frac{u'(c_1^*) c_1^*}{u(c_1^*)} \left[ \frac{R-(1-\tau)(1-\pi)}{1-\tau} \right] > 0$, indicating that $\left. \frac{dV(\pi_s)}{d\pi_s} \right|_{\pi_s = \pi^T} < 0$. In fact, it can further be shown that $u(c_1^*) - (1-\pi) u(c_2^*) < 0$, suggesting that deposits would be suspended upon the identification of a panic, reduces to $(c_1^*)^{1-\gamma} > (1-\pi)(c_2^*)^{1-\gamma}$ which necessarily holds as $c_1^* < c_2^*$. To summarize, given that funds are expected to be frozen immediately at $\pi$, run behavior will not emerge in equilibrium.

■

**Proof of Proposition 2**

As discussed in the text, both the welfare gain and loss $w_G$ and $w_L$ are independent of $\pi_s$. Thus, the choice of the BA to suspend withdrawals is reduced to freezing payments either at $\pi$ immediately or at a point where bank profits are exhausted. That is, any interior choice of $\pi_s$ is dominated by these two extremes. To examine the effects of the relative importance of the bank's welfare $\delta$ on instability, we confine to the situation where $\eta(\pi_s) > 0$. Thus, for funds to be suspended at $\pi$ so that the bank earns positive profits, we must have $w_G \leq w_L$, which reduces to $\delta \geq \underline{\delta} = \frac{(1-\pi)u\left(c_2^*\right)-u\left(c_1^*\right)}{(1-\pi)c_2^*-\frac{R}{1-\tau}c_1^*}$. Otherwise, if $\delta < \underline{\delta}$, $\pi_s^M > \pi^T$ and therefore the bank is fragile.

■

**Proof of Lemma 2**

Suppose that $\tau \in (\tau_F, 1)$ and $\pi \in [\pi_F, 1)$. Further suppose that $\gamma \in (\gamma_F, 1)$. Under these conditions, $(1-\pi)\,u(c_2^*) - u(c_1^*) < 0$ and $\underline{\delta} > 0$. Then, differentiating $\underline{\delta}$ with respect to $\tau$ yields:

$$\frac{d\underline{\delta}}{d\tau} = \frac{\left[(1-\pi)\,u(c_2^*) - u(c_1^*)\right]\frac{R}{(1-\tau)^2}c_1^*}{\left[(1-\pi)\,c_2^* - c_1^*\frac{R}{1-\tau}\right]^2} < 0.$$

In what follows, we examine the impact of liquidity risk on the critical level of the relative importance of the bank's welfare. To this end, suppose instead that $\gamma \in (\gamma_F, \gamma_1)$, where $\gamma_1 = \frac{(R-(1-\tau))^2}{(R-1)(1-\tau)+(R-(1-\tau))^2} < 1$, such that $\pi_F > \pi_H$ and thus $W^A = \frac{1}{1-\gamma}$, which is given by $(2)$. In this vein, it can be shown that:

$$\frac{dc_1^*}{d\pi} = \left(\frac{1}{\gamma-1}\right)\left[\pi + (1-\pi)\,R^{\frac{1-\gamma}{\gamma}}\right]^{\frac{1}{\gamma-1}-1}\left(1 - R^{\frac{1-\gamma}{\gamma}}\right) > 0.$$

To proceed, it can easily be shown that $(1-\pi)\,c_2^* - \frac{R}{1-\tau}c_1^* < 0$ reduces to: $\left[R^{\frac{1-\gamma}{\gamma}} - \frac{1}{(1-\pi)(1-\tau)}\right] < 0$. Then, differentiating $\underline{\delta}$ with respect to $\pi$ yields:

$$\frac{d\underline{\delta}}{d\pi} = -\left(\frac{R^{\frac{1-\gamma}{\gamma}}-1}{(1-\gamma)\,R}\right)(c_1^*)^{\gamma}\,\frac{\gamma\,(c_1^*)^{-1}\,\frac{dc_1^*}{d\pi}\left[R^{\frac{1-\gamma}{\gamma}} - \frac{1}{(1-\tau)(1-\pi)}\right] - \frac{1}{(1-\tau)(1-\pi)^2}}{\left((c_1^*)^{\gamma}\left[R^{\frac{1-\gamma}{\gamma}} - \frac{1}{(1-\tau)(1-\pi)}\right]\right)^2} > 0.$$

■

**Proof of Proposition 3**

Bank runs are prevented if and only if $\lambda u(c_2^*) + (1-\lambda)\,u\left(c_2\left(\pi_s^M\right)\right) > u(c_1^*)$, which reduces to $\lambda > \lambda^T = \frac{u\left(c_1^*\right)-u\left(c_2\left(\pi_s^M\right)\right)}{u\left(c_2^*\right)-u(c_2(\pi_s^M))}$. Further, the derivative $\frac{d\lambda^T}{d\pi_s^M}$ is as follows:

$$\frac{d\lambda^T}{d\pi_s^M} = \frac{u'\left(c_2\left(\pi_s^M\right)\right)\left[u\left(c_1^*\right) - u\left(c_2^*\right)\right]\frac{dc_2\left(\pi_s^M\right)}{d\pi_s^M}}{\left[u\left(c_2^*\right) - u\left(c_2\left(\pi_s^M\right)\right)\right]^2} > 0,$$

as $c_1^* < c_2^*$ and $\frac{dc_2\left(\pi_s^M\right)}{d\pi_s^M} < 0$. To proceed, consider a case in which $\pi_s^M = \pi^T$. In this manner, $c_2\left(\pi_s^M\right) = c_2\left(\pi^T\right) = c_1^*$, suggesting that $\lambda^T = 0$. To proceed, consider another extreme in which $\pi_s^M = \pi_s^U$ where $c_2\left(\pi_s^M\right) = c_2\left(\pi_s^U\right) = 0$. In this vein, the maximum probability $\lambda^T$ entails that $\lambda^T = \frac{u\left(c_1^*\right)}{u\left(c_2^*\right)} = R^{\frac{\gamma-1}{\gamma}} < 1$. To summarize, suppose that $\gamma \in (\gamma_F, 1)$, $\tau \in (\tau_F, 1)$, and $\pi \in [\pi_F, 1)$. Under these conditions, there exists a threshold $\lambda^T \in \left[0, R^{\frac{\gamma-1}{\gamma}}\right]$ below which run equilibria exist.

■

**The best-response allocation of the BA and the monopolistic bank**

The best-response allocation under a monopolistic bank is determined by conditions $(23)$, $(32)$, $(34)$, $(36)$ to $(38)$, the resource constraints $(21)$, $(22)$, and the participation constraint $(31)$.

**Scenario** $I$: $1 - x - \pi c_1 = 0$ and $1 - x - \pi c_1 < (1 - \pi)\pi c_{1\beta}$

If $\gamma > 1$ and $q \in \left(\max\left\{0, \underline{q}^I\right\}, \bar{q}^I\right)$, where $\underline{q}^I = 1 - \frac{\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}} + (1-\pi)\right]^{\gamma}}{R}$ and $\bar{q}^I = 1 - \frac{1}{R}$, no excess liquid assets are held while costly liquidation occurs should a run be identified. Then, the vector $\hat{c}^I = \left\{\hat{x}^I, \hat{c}_1^I, \hat{c}_{2\alpha}^I, \hat{c}_{1\beta}^I, \hat{c}_{2\beta}^I\right\}$ is given by:

$$\begin{aligned}
\hat{x}^I &= 1 - \pi\hat{c}_1^I, \\
\hat{c}_1^I &= \left(\frac{(1-\gamma)W^A - q(1-\pi)\left[\pi + (1-\pi)\left(\frac{R}{1-\tau}\right)^{\frac{1-\gamma}{\gamma}}\right]\left(\frac{\delta R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}}{\pi + (1-\pi)R^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}}\right)^{\frac{1}{1-\gamma}}, \\
\hat{c}_{2\alpha}^I &= \left[R(1-q)\right]^{\frac{1}{\gamma}}\hat{c}_1^I, \\
\hat{c}_{1\beta}^I &= \left(\frac{\delta R}{1-\tau}\right)^{-\frac{1}{\gamma}}, \\
\hat{c}_{2\beta}^I &= \delta^{-\frac{1}{\gamma}},
\end{aligned}$$

where $\frac{\hat{c}_{2\beta}^I}{\hat{c}_{1\beta}^I} = \left(\frac{R}{1-\tau}\right)^{\frac{1}{\gamma}} > 1$ and $\frac{\hat{c}_{2\alpha}^I}{\hat{c}_1^I} > 1$ holds $\forall q < \bar{q}^I$. Further, if $\gamma > 1$ and $q \in \left(\max\left\{0, \underline{q}^I\right\}, \bar{q}^I\right)$, there is room for conditions $\frac{\eta_\alpha^I}{\eta_\beta^I} \geq 1$, $\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I} \geq 1$, and $\eta_\alpha^I > 0$, and $\eta_\beta^I > 0$ to hold.

**Scenario** $II$: $1 - x - \pi c_1 > 0$ and $1 - x - \pi c_1 < (1 - \pi)\pi c_{1\beta}$

Under Scenario $II$, a more liquid portfolio may be chosen by the bank but the BA still needs to liquidate productive investment upon the revelation of the crisis state. Notably, it can be shown that all consumption levels $\hat{c}_1^{II}$, $\hat{c}_{2\alpha}^{II}$, $\hat{c}_{1\beta}^{II}$, and $\hat{c}_{2\beta}^{II}$ are independent of $x$ and are given by:

$$\begin{aligned}
\hat{c}_1^{II} &= \left( \frac{(1-\gamma) W^A - q(1-\pi)\left[\pi + (1-\pi)\left(\frac{R}{1-\tau}\right)^{\frac{1-\gamma}{\gamma}}\right]\left(\frac{\delta R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}}{\pi + (1-\pi)\left[(1-q) + q\frac{R}{1-\tau}\right]^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}} \right)^{\frac{1}{1-\gamma}}, \\
\hat{c}_{2\alpha}^{II} &= \left( \left[(1-q) + q\frac{R}{1-\tau}\right](1-q) \right)^{\frac{1}{\gamma}} \hat{c}_1^{II}, \\
\hat{c}_{1\beta}^{II} &= \left( \frac{\delta R}{1-\tau} \right)^{-\frac{1}{\gamma}}, \\
\hat{c}_{2\beta}^{II} &= \delta^{-\frac{1}{\gamma}},
\end{aligned}$$

where $\frac{\hat{c}_{2\beta}^{II}}{\hat{c}_{1\beta}^{II}} = \left(\frac{R}{1-\tau}\right)^{\frac{1}{\gamma}} > 1$. By this virtue, the monopolist seeks to alter the amount of investment so that expected profits $(33)$ are maximized. In particular, as we discussed in the main text, if $q \in \left(0, \min\left\{\hat{q}^{II}, \bar{q}^{II}\right\}\right)$, where $\hat{q}^{II} = \frac{R-1}{\frac{R}{1-\tau}-1}$ and $\bar{q}^{II} = \frac{R-2(1-\tau)}{R-(1-\tau)}$, the portfolio choice will be such that the bank does not to hold excess liquidity against crises. Nevertheless, this allocation of resources should belong to Scenario $I$. If $q \in \left[\hat{q}^{II}, \bar{q}^{II}\right)$, the monopolist seeks to hold as much precautionary liquid assets as possible so that costly liquidation in the event of a panic is avoided. Yet, this suggests that the solution to the BA's and the bank's problem lies under Scenario $III$.

**Scenario** $III$: $1 - x - \pi c_1 > 0$ and $1 - x - \pi c_1 = (1-\pi)\pi c_{1\beta}$

Under this scenario, excess liquid assets are held and no costly liquidation occurs should a run be identified. Then, the vector $\hat{c}^{III} = \left\{\hat{x}^{III}, \hat{c}_1^{III}, \hat{c}_{2\alpha}^{III}, \hat{c}_{1\beta}^{III}, \hat{c}_{2\beta}^{III}\right\}$ is given by:

$$\begin{aligned}
\hat{x}^{III} &= 1 - \pi\left[\left(\frac{R-(1-q)}{Rq}\right)^{\frac{1}{\gamma}} + (1-\pi)\right]\hat{c}_{1\beta}^{III}, \\
\hat{c}_1^{III} &= \left(\frac{R-(1-q)}{Rq}\right)^{\frac{1}{\gamma}} \hat{c}_{1\beta}^{III}, \\
\hat{c}_{2\alpha}^{III} &= \left(\frac{(1-q)\left[R-(1-q)\right]}{q}\right)^{\frac{1}{\gamma}} \hat{c}_{1\beta}^{III}, \\
\hat{c}_{1\beta}^{III} &= \left( \frac{(1-\gamma) W^A - q(1-\pi)^2 \delta^{\frac{\gamma-1}{\gamma}}}{\left[\pi + (1-\pi) R^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}\right]\left(\frac{R-(1-q)}{Rq}\right)^{\frac{1-\gamma}{\gamma}} + q(1-\pi)\pi} \right)^{\frac{1}{1-\gamma}}, \\
\hat{c}_{2\beta}^{III} &= \delta^{-\frac{1}{\gamma}}.
\end{aligned}$$

Yet, as discussed in the main text, this allocation of resources is eliminated since for any $\frac{\eta_{\alpha}^{III}}{\eta_{\beta}^{III}} \geq 1$, $\frac{\hat{c}_1^{III}}{\hat{c}_{2\beta}^{III}} < 1$ and hence the run strategy of agents is inconsistent with the equilibrium.

■

**Proof of Lemma 3**

Given that the allocation of resources belongs to Scenario $I$ if $q \in \left(0, \min\left\{\hat{q}^{II}, \bar{q}^{II}\right\}\right)$ and to Scenario $III$ if $q \in \left[\hat{q}^{II}, \bar{q}^{II}\right)$, Scenario $II$ is ruled out. Furthermore, Scenario $III$ is eliminated as well since $\frac{\eta_{\alpha}^{III}}{\eta_{\beta}^{III}} = \frac{1-\hat{x}^{III}-\pi\hat{c}_1^{III}+R\hat{x}^{III}-(1-\pi)\hat{c}_{2\alpha}^{III}}{R\hat{x}^{III}-(1-\pi)^2\hat{c}_{2\beta}^{III}} > 1$ if and only if $\hat{c}_1^{III} < \hat{c}_{2\alpha}^{III} < \hat{c}_{2\beta}^{III}$, implying that run equilibria do not exist.

In addition, we demonstrate that for any $\gamma \in (0,1)$, the satisfaction of the fragility condition $\hat{c}_1^I \geq \hat{c}_{2\beta}^I$ indicates that the condition $\eta_{\alpha}^I > \eta_{\beta}^I$ is necessarily violated. To this end, note that $\frac{\eta_{\alpha}^I}{\eta_{\beta}^I} > 1$ and $\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I} \geq 1$ if $1 \leq \delta^{\frac{1}{\gamma}}\hat{c}_1^I < \frac{\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)}{[R(1-q)]^{\frac{1}{\gamma}}}$. By this result and given that $\left[R\left(1-q\right)\right]^{\frac{1}{\gamma}} > 1$ $\forall q < \bar{q}^I$, there is room for conditions $\frac{\eta_{\alpha}^I}{\eta_{\beta}^I} > 1$ and $\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I} \geq 1$ to hold simultaneously if and only if $\gamma > 1$.

■

**Proof of Proposition 4**

Suppose that $\gamma \in (1,\infty)$ and $q \in \left(\max\left\{0, \underline{q}^I\right\}, \bar{q}^I\right)$ such that there exists a parameter space in which $\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I} \geq 1$ holds. Then, it can easily be shown that $\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I}$ is monotonically increasing in $\delta$:

$$\frac{d\frac{\hat{c}_1^I}{\hat{c}_{2\beta}^I}}{d\delta} = \left(\frac{\left(1-\gamma\right)W^A\delta^{\frac{1-\gamma}{\gamma}} - q\left(1-\pi\right)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+\left(1-\pi\right)\right]}{\pi+\left(1-\pi\right)R^{\frac{1-\gamma}{\gamma}}\left(1-q\right)^{\frac{1}{\gamma}}}\right)^{\frac{\gamma}{1-\gamma}} \frac{\frac{1-\gamma}{\gamma}W^A\delta^{\frac{1-2\gamma}{\gamma}}}{\pi+\left(1-\pi\right)R^{\frac{1-\gamma}{\gamma}}\left(1-q\right)^{\frac{1}{\gamma}}} > 0.$$

■

**Proof of Proposition 5**

To begin, suppose that $\gamma \in (1,\infty)$, $\tau \in \left(\max\left\{0, \underline{\tau}^I\right\}, 1\right)$, and $\pi \in \left(\underline{\pi}^I, 1\right)$ such that $\underline{q}^I < 0$. Further suppose that the run probability $q$ is arbitrarily low. Under these conditions, the monopolist must be able to deliver the expected utility to depositors amounting to financial autarky and to earn positive profits contingent on state $\alpha$, irrespective of the value of $\delta$.

Moreover, it is straightforward to show that:

$$\frac{d\eta_{\alpha}^I}{d\delta} = -R\pi\frac{d\hat{c}_1^I}{d\delta} - \left(1-\pi\right)\frac{d\hat{c}_{2\alpha}^I}{d\delta} < 0,$$

as $\frac{d\hat{c}_1^I}{d\delta} > 0$ and $\frac{d\hat{c}_{2\alpha}^I}{d\delta} > 0$, and $\eta_\alpha^I > \eta_\beta^I$ if and only if:

$$\delta < \left( \frac{(1-\gamma)W^A}{\left[\pi+(1-\pi)R^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}\right]\left(\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)\right][R(1-q)]^{-\frac{1}{\gamma}}\right)^{1-\gamma}+q(1-\pi)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)\right]} \right)^{\frac{\gamma}{\gamma-1}} = \delta^I.$$

In this vein, $\lim_{\delta\to\delta^I} \eta_\alpha^I = \lim_{\delta\to\delta^I} \eta_\beta^I > 0$ for any $(\pi, \gamma, R, \tau)$ should the run probability go to zero.

Lastly, it is helpful to note that the derivative $\frac{d\eta_\beta^I}{d\delta}$ is as follows:

$$\begin{aligned} \frac{d\eta_\beta^I}{d\delta} &= (1-\pi)\left[\pi\left(\tfrac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)\right]\tfrac{1}{\gamma}\delta^{-\frac{1}{\gamma}-1} \\ &\quad \times\left[1-\pi R\left(\frac{(1-\gamma)W^A-q(1-\pi)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)\right]\delta^{\frac{\gamma-1}{\gamma}}}{\pi+(1-\pi)R^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}}\right)^{\frac{1}{1-\gamma}-1}\frac{q\delta}{\pi+(1-\pi)R^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}}\right], \end{aligned}$$

where $\frac{d\eta_\beta^I}{d\delta} \geq (<)\, 0$ if and only if $\delta \leq (>)\left( \frac{(1-\gamma)W^A}{\left[\pi+(1-\pi)R^{\frac{1-\gamma}{\gamma}}(1-q)^{\frac{1}{\gamma}}\right]^{\frac{1}{\gamma}}(\pi Rq)^{\frac{\gamma-1}{\gamma}}+q(1-\pi)\left[\pi\left(\frac{R}{1-\tau}\right)^{\frac{\gamma-1}{\gamma}}+(1-\pi)\right]} \right)^{\frac{\gamma}{\gamma-1}}$.

By this virtue and the facts that $\lim_{\delta\to 0} \eta_\beta^I < 0$ and $\lim_{\delta\to\delta^I} \eta_\alpha^I = \lim_{\delta\to\delta^I} \eta_\beta^I > 0$, there must exist a unique cutoff weight placed by the BA on monopoly rents $\underline{\delta}^I \in \left(0, \delta^I\right)$ such that if $\delta \in \left(\underline{\delta}^I, \delta^I\right)$, $\eta_\alpha^I > \eta_\beta^I > 0$ and hence run equilibria under Scenario $I$ exist $\forall \delta \in \left(\max\left\{\underline{\delta}^I, \delta_F^I\right\}, \delta^I\right)$.

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# References


- Allen, F. and Gale, D. (2000) *Comparing Financial Systems* (Cambridge, MA: MIT Press).
- Andolfatto, D. and Nosal, E. (2008) "Bank Incentives, Contract Design and Bank Runs." *Journal of Economic Theory*, 142, 28-47.
- Andolfatto, D., Nosal, E., and Sultanum, B. (2017) "Preventing Bank Runs." *Theoretical Economics*, 12, 1003-1028.
- Barro, R.J. and Gordon, D.B. (1983) "A Positive Theory of Monetary Policy in a Natural Rate Model." *Journal of Political Economy*, 1983, 91, 589-610.
- Barro, R.J. (1986) "Reputation in a Model of Monetary Policy with Incomplete Information" *Journal of Monetary Economics*, 17, 3-20.
- Beck, T., Demirguc-Kunt, A., and Maksimovic, V. (2004) "Bank Competition and Access to Finance: International Evidence." *Journal of Money, Credit, and Banking*, 36, 627-648.
- Boyd, J.H. and De Nicolo, G. (2005) "The Theory of Bank Risk-taking and Competition Revised." *Journal of Finance*, 60, 1329-1343.
- Brown, C. and Dinc, S. (2005) "The Politics of Bank Failures: Evidence from Emerging Markets." *Quarterly Journal of Economics*, 120, 1413-1444.
- Carletti, E. and Leonello, A. (2019) "Credit Market Competition and Liquidity Crises." *Review of Finance*, 23, 855-892.
- Cavalcanti, R. de O. and Monteiro, P.K. (2016) "Enriching Information to Prevent Bank Runs." *Economic Theory*, 62, 477-494.
- Cetorelli, N., and Gambera, M. (2001) "Banking Market Structure, Financial Dependence and Growth: International Evidence from Industry Data." *Journal of Finance*, 56, 617-648.
- Chari, V.V. and Jagannathan, R. (1988) "Banking Panics, Information, and Rational Expectations Equilibrium" *Journal of Finance*, 43, 749-761.
- Chang, R. and Velasco, A. (2001) "A Model of Financial Crises in Emerging Markets." *Quarterly Journal of Economics*, 116, 489-517.
- Cipriani, M., Martin, A., McCabe, P., and Parigi, B.M. (2014) "Gates, Fees and Preemptive Runs." Federal Reserve Bank of New York Staff Reports No. 670.

- Cooper, R. and Ross, T.W. (1998) "Bank Runs: Liquidity Costs and Investment Distortions." *Journal of Monetary Economics*, 41, 27-38.
- Demirguc-Kunt, A., Laeven, L., and Levine, R. (2004) "Regulations, Market Structure, Institutions, and the Cost of Financial Intermediation." *Journal of Money, Credit, and Banking*, 36, 593-622.
- Diamond, D. and Dybvig, P. (1983) "Bank Runs, Deposit Insurance, and Liquidity." *Journal of Political Economy*, 91, 191-206.
- Engineer, M. (1989) "Bank Runs and the Suspension of Deposit Convertibility." *Journal of Monetary Economics*, 24, 443-454.
- Ennis, H.M. and Keister, T. (2006) "Bank Runs and Investment Decisions Revisited." *Journal of Monetary Economics*, 53, 217-232.
- Ennis, H.M. and Keister, T. (2009a) "Bank Runs and Institutions: The Perils of Intervention." *American Economic Review*, 99, 1588-1607.
- Ennis, H.M. and Keister, T. (2009b) "Run Equilibria in the Green-Lin Model of Financial Intermediation." *Journal of Economic Theory*, 144, 1996-2020.
- Ennis, H.M. and Keister, T. (2010) "Banking Panics and Policy Responses." *Journal of Monetary Economics*, 57, 404-419.
- Faccio, M., Masulis, R.W., and McConnell J.J. (2006) "Political Connections and Corporate Bailouts." *Journal of Finance*, 61, 2597-2635.
- Fernholz, R.T. and Koch, C. (2021) "The Rise of Big U.S. Banks and the Fall of Big European Banks: A Statistical Decomposition." *European Economic Review*, 135, 103723.
- Friedman, M. and Schwartz, A.J. (1963) *A Monetary History of the United States, 1867-1960* (Princeton, NJ: Princeton University Press).
- Gao, J. and Reed, R.R. (2021) "Sunspot Bank Runs and Fragility: The Role of Financial Sector Competition." *European Economic Review*, 139, 103877.
- Ghossoub, E.A. and Reed, R.R. (2019) "Banking Competition, Production Externalities, and the Effects of Monetary Policy." *Economic Theory*, 67, 91-154.
- Ghossoub, E.A. and Reed, R.R. (2021) "Banking Competition, Capital Accumulation, and Interest on Reserves." *Economic Inquiry*, 59, 671-695.

- Gorton, G. (1985) "Bank Suspension of Convertibility." *Journal of Monetary Economics*, 15, 177-193.
- Gorton, G. (2012) *Misunderstanding Financial Crises: Why We Don't See Them Coming* (Oxford: Oxford University Press).
- Green, E.J. and Lin, P. (2003) "Implementing Efficient Allocations in a Model of Financial Intermediation." *Journal of Economic Theory*, 109, 1-23.
- Janicki, H.P. and Prescott, E.S. (2006) "Changes in the Size Distribution of U.S. Banks: 1960-2005." *Federal Reserve Bank of Richmond Economic Quarterly* Fall, 291-316.
- Keeley, M.C. (1990) "Deposit Insurance, Risk, and Market Power in Banking." *American Economic Review*, 80, 1183-1200.
- Keister, T. (2016) "Bailouts and Financial Fragility." *Review of Economic Studies*, 83, 704-736.
- Keister, T. and Mitkov, Y. (2021) "Bailouts, Bail-ins and Banking Crises." mimeo, January.
- Kennedy, S.E. (1973) *The Banking Crisis of 1933* (Lexington, KY: University Press of Kentucky).
- Kydland, F.E. and Prescott, E.C. (1977) "Rules Rather Than Discretion: The Inconsistency of Optimal Plans." *Journal of Political Economy*, 85, 473-491.
- Laeven, L., Ratnovski, L., and Tong, H. (2014) "Bank Size and Systemic Risk." IMF Staff Discussion Note.
- Marcus, A.J. (1984) "Deregulation and Bank Financial Policy." *Journal of Banking and Finance*, 8, 557-565.
- Martin, A. (2006) "Liquidity Provision vs. Deposit Insurance: Preventing Bank Panics Without Moral Hazard." *Economic Theory*, 28, 197-211.
- Martin, A. (2009) "Reconciling Bagehot and the Fed's Response to September 11." *Journal of Money, Credit and Banking*, 41, 397-415.
- Martinez-Miera, D. and Repullo, R. (2010) "Does Competition Reduce the Risk of Bank Failure?" *Review of Financial Studies*, 23, 3638-3664.
- Matsuoka, T. (2013) "Sunspot Bank Runs in Competitive versus Monopolistic Banking Systems." *Economics Letters*, 118, 247-249.

- McCord, R. and Prescott, E.S., (2014) "The Financial Crisis, the Collapse of Bank Entry, and Changes in the Size Distribution of Banks." *Federal Reserve Bank of Richmond Economic Quarterly* 100, 23-50.
- Peck, J. and Shell, K. (2003) "Equilibrium Bank Runs." *Journal of Political Economy*, 111, 103-123.
- Rogoff, K. (1985) "The Optimal Degree of Commitment to an Intermediate Monetary Target." *Quarterly Journal of Economics*, 100, 1169-1189.
- Rosas, G. (2006) "Bagehot or Bailout? An Analysis of Government Responses to Banking Crises." *American Journal of Political Science*, 50, 175-191.
- Voellmy, L. (2021) "Preventing Runs with Fees and Gates." *Journal of Banking and Finance*, 125, 106065.
- Wallace, N. (1988) "Another Attempt to Explain an Illiquid Banking System: the Diamond and Dybvig Model with Sequential Service Taken Seriously." *Federal Reserve Bank of Minneapolis Quarterly Review*, 12, (Fall), 3-16.
- Wallace, N. (1990) "A Banking Model in Which Partial Suspension Is Best." *Federal Reserve Bank of Minneapolis Quarterly Review* Fall, 11-23.
- Walsh, C.E. (1995) "Optimal Contracts for Central Bankers." *American Economic Review*, 85, 150-167.