

Uncertainty as Commitment[☆]

Jaromir B. Nosal¹

Boston College

Guillermo Ordoñez²

University of Pennsylvania and NBER

Abstract

When governments cannot commit to *not* providing bailouts, banks may take excessive risks and generate crises. At the outbreak of a financial crisis, however, governments are usually uncertain about its systemic nature, and may delay intervention to learn more from endogenous market outcomes. We show such delay introduces *strategic restraint*: banks restrict their portfolio riskiness relative to their peers to avoid being the worst performers and bearing the costs of delay. Hence, uncertainty has the potential to self-discipline banks and mitigate crises in the absence of commitment. We study the effects of standard regulations on these novel forces.

Keywords: imperfect information, commitment, bailouts, moral hazard, time consistency

1. Introduction

Few would disagree that bailouts are socially costly. Yet, they are ubiquitous during crises in most countries, dating as far back as the 1800s. In the recent global financial crisis, for example, the U.S. government used a variety of

[☆]We especially thank Urban Jermann and an anonymous referee for excellent suggestions to improve the paper. We also thank Mark Aguiar, Marco Bassetto, Philip Bond, V.V. Chari, Hal Cole, Emmanuel Farhi, Francesco Girlanda, Mike Golosov, Gary Gorton, Oleg Itskhoki, Bob King, Nobu Kiyotaki, Svetlana Pevnitskaya, Richard Rogerson, Esteban Rossi-Hansberg, Alp Simsek, Jean Tirole, Jonathan Vogel, Warren Weber and seminar participants at Boston College, Boston University, Chicago Fed, Columbia, Florida State University, Harvard, National Bank of Poland, Minneapolis Fed, Notre Dame, Penn State, Princeton, St. Louis Fed, Toulouse School of Economics, University of Pennsylvania, Wharton, the Roma Macro Junior Conference at the EIEF, the SED 2012 Annual Meetings in Cyprus and the LAEF Conference at Santa Barbara for helpful comments. The usual waiver of responsibilities applies.

¹Email: nosalj@bc.edu, Address: 140 Commonwealth Avenue, 322 Maloney Hall, Chestnut Hill, MA 02467

²Email: ordonez@econ.upenn.edu, Address: 3718 Locust Walk, 428 McNeil Building, Philadelphia, PA 19104

instruments to bail out, on an unprecedented scale, many financial entities that were exposed to systemic risk.

Equally ubiquitous is the uncertainty that governments face at the onset of a financial crisis about its systemic nature. Anecdotal evidence suggests that policymakers are limited in their capacity to acquire and rapidly process information about the scope and severity of an unraveling crisis. This *government uncertainty* is usually considered a shortcoming of policymaking while dealing with crises. We argue, however, that government uncertainty has a positive effect self-disciplining the behavior of financial firms ex-ante, hence mitigating the likelihood and magnitude of financial crises.

At the onset of the recent U.S. crisis, for example, Kelly et al. (forthcoming) document that U.S. policymakers avoided the provision of bailouts ('funds at subsidized rates') until September 15, 2008, when it became evident that financial markets were experiencing a systemic event as Lehman Brothers filed for bankruptcy and no private party was willing to take over its operations. Half a year earlier, on March 14, 2008, the Federal Reserve Bank of New York refused to extend a collateralized loan to Bear Stearns, forcing the company to sign a merger agreement with JP Morgan Chase two days later at \$2 a share (less than 7% its market value just two days before). Similarly, on September 7, 2008, the Treasury announced plans to help Fannie Mae and Freddie Mac, but not with the provision of public funds but rather by placing them into conservatorship. Cochrane and Zingales (September 9, 2009) argue that the Lehman failure *did not cause* the subsequent unraveling of the financial market, but rather was the first convincing signal of a bigger problem.³

One of the leading explanations of why bailouts are relatively common despite being costly relies on the time inconsistency of no-bailout policies (e.g. Holmström and Tirole (1998) and Farhi and Tirole (2012)). If bank failures are costly for an economy ex-post, a government may be tempted to bail out banks in distress. Without commitment, banks internalize this ex-post reaction and hence have no incentive to avoid exposing themselves to risks ex-ante, effectively leading to endogenous crises. Due to this moral hazard problem, the equilibrium outcome obtaining under no commitment is typically inferior to the one in which governments can commit to not intervening and offering bailouts during periods of financial distress.

This paper demonstrates that *government uncertainty* has the potential for sustaining commitment outcomes even when the government lacks commitment. Intuitively, in the absence of systemic problems banks in trouble are usually taken-over by other banks, resolving the distress efficiently 'inside' the financial sector. If at the onset of financial problems governments are uncertain about the actual need for intervention, they may want to *delay bailout* and let the

³The bailout of Continental Illinois Bank and Trust Company in 1984 provides another example. The FDIC chairman at the time, William Isaac, stressed that the decision to bail out the bondholders was made given 'the best estimates of our staff, with the sparse numbers we had at hand', acknowledging the remaining uncertainty concerning the case at the time of intervention.

first bank(s) in distress fail in order to observe more signals and *learn* about the nature of the shock, possibly avoiding a potentially costly and unnecessary intervention if the shock is not systemic. Crucially, expected delays make the *relative performance* of banks' portfolios critical in their leverage decisions since no bank wants to be amongst the first in line for government help. We call this effect *strategic restraint*, as banks endogenously restrict the riskiness of their portfolio relative to their peers in order to avoid being amongst the worst performers, inducing a sort of competition that reduce excessive risk-taking.

The paper presents a theoretical model to formally study the role of *government uncertainty* in sustaining commitment outcomes in the absence of commitment. In the model, bankers borrow short-term from households to finance projects that are illiquid. Projects may suffer shocks over time, in which case they require extra funds to bring them to fruition. The shock hitting a project may be idiosyncratic, affecting only certain banks, or aggregate, affecting all banks. High levels of short-term debt allow banks to invest in large projects at the cost of restricting availability to future funds to refinance if a shock hits. A central authority, called the *government*, maximizes total welfare (bankers' plus households') by affecting the cost of borrowing. An intervention that reduces the cost of borrowing to bankers, called a *bailout*, is financed through taxes on households in a way that is socially costly (e.g. due to distortions). The benefits of bailouts, however, is bringing banks' projects to fruition, thus increasing output.

When the government observes a bank in distress, which is defined as the bank running out of cash and ability to obtain loans for refinancing, it does not observe the nature of the shock. If the shock is idiosyncratic, other banks have enough liquidity to take over the distressed bank, and no intervention is necessary. If the shock is aggregate, intervention is the only way to avoid a project failure. Hence, the government's decision to bail out the bank depends on its beliefs about the shock's nature.

If the government is initially optimistic that the shock is not aggregate, then it chooses to learn more by delaying intervention, not bailing out the first distressed bank(s). By delaying bailouts, the government observes further signals – whether the distressed bank(s) are taken-over or not, whether there are more banks showing distress, etc – maintaining the option of intervening at a later time under a more precise belief about the nature of the problem. For banks, however, this delay makes their relative performance relevant, introducing incentives to avoid being the worst performers. In the model, this happens through banks leveraging less, downsizing their projects, and carrying more cash reserves than their peers for the eventuality of being hit by the refinancing shock – that is, through *strategic restraint*.

Our benchmark considers a stark case in which banks can guarantee not being among the first banks showing distress when the shock is aggregate just by choosing slightly less leverage than other banks, giving rise to a Bertrand-type competition. In this stark setup, banks compete away all excessive leverage and the allocation coincides with the one under commitment. Our results, however, are more general, which is demonstrated in an extended environment which in-

roduces shocks to cash holdings of individual banks, such that small deviations in leverage do not guarantee not being among the first banks in distress. In this case, *government uncertainty* and *strategic restraint* forces still operate, moving the allocation closer to the one under commitment, but not completely. In this more general setting, bailouts and crises are observed on the equilibrium path, but smaller and less frequently than in the absence of government uncertainty.

Since *government uncertainty* has the potential to trigger *strategic restraint* and implement allocations that dominate non-commitment outcomes in terms of welfare, a natural question is how this insight shapes our evaluation of different regulatory proposals. Our mechanism reinforces the benefits of some regulations, such as limiting financial innovation that facilitates cross-insurance and correlation of investments, encouraging entry in the banking industry and restricting bank size. On the other hand, our mechanism discourages other regulatory efforts, such as broadening the government access to detailed balance sheet information of financial institutions or introducing steps toward speeding up intervention decisions in case of financial distress. Our analysis of regulatory proposals is split into three sets of results.

The first set of results characterizes the effects of financial innovation on the likelihood and size of crises. Specifically, we study financial instruments that allow banks to insure away part of their idiosyncratic risk, such as securitized products or over-the-counter derivatives. When banks hold large amounts of cross-insurance – like in the most recent crisis – our mechanism loses effectiveness. Intuitively, cross-insurance links banks’ portfolio performance and the liquidity of one bank depends on the liquidity of all others. Hence, the time at which a single bank shows distress reveals information about the nature of the shock, reducing government uncertainty and relaxing strategic restraint. As there are benefits to share risk across banks, and a cap on the level of cross-insurance exists above which the ability of *government uncertainty* to implement welfare-superior allocations is lost. Thus, our analysis points to an unexplored effect of financial innovation, and suggests a new rationale for restricting its magnitude.

The second set of results studies the effect of bank size heterogeneity – in particular, the existence of few banks that are asymmetrically large in the industry. When a bank’s balance sheets is overwhelmingly large relative to the industry it is less likely to be acquired by its peers in case of distress and hence less likely that the government avoids to bail it out, regardless of the nature of the shock. Hence, in the absence of commitment, sufficiently large banks do not have any concern for their relative performance, choosing excessive leverage. Given this behavior, smaller banks have a strategic incentive to expose themselves only slightly less than the large bank. In our setting, the ‘too big to fail’ problem shows up very differently than in the rest of the literature – large banks become ‘shields’ for smaller banks to take excessive risk, imposing a negative externality in terms of larger endogenous systemic crises. Our novel mechanism introduces a new rationale for capping bank size, over and above the size of potential bailouts.

Finally, the third set of results explores the role of industry concentration,

measured by the number of banks. We show that a larger number of banks strengthens the two forces that induce governments to delay intervention. First, more banks increase the chance that there is enough liquidity in the system for a takeover of a single distressed bank. Second, more banks increase the option value of learning the true nature of the shock, by making the potential loss of one bank's failure relatively smaller and the benefits of making better informed decisions larger. This force provides a new rationale to reduce industry concentration, which increases the likelihood and magnitude of crises.

On a general level, our work suggests that it may be optimal for governments to design political structures that delay bailout decisions, or regulatory standards that maintain an optimal level of uncertainty, facilitating self-regulation. Clearly, an alternative would be macro-prudential regulation and direct oversight of banking activity. However, historically regulators have been incapable to design macro-prudential regulation that prevents crises without choking off growth. Our results suggest that, from an ex-ante perspective, governments that lack commitment and good enforcement ability would rather not have the possibility to learn rapidly, making more mistakes when crises happen, but also reducing the magnitude and the likelihood of those crises happening. Even though it may be difficult for a government to commit not to modify bailout decisions ex-post, they could easily avoid ex-ante the implementation of technologies to learn rapidly or to take fast decisions when distress happens.

These conclusions stand in stark contrast to recent financial regulatory efforts that emphasize monitoring and financial transparency. The Dodd-Frank act and the recently proposed Financial Transparency Act argue for information to be collected and more efficiently shared among government agencies. European Banking Authority's new set of guidelines for disclosure under Basel III also argue for more availability and transparency of information. These efforts are in part designed to provide markets a better picture of institutions' risks, and in part to provide means of direct oversight of financial institutions' activities. While our mechanism is silent about the first motivation (indeed in our model markets have full information and price debt correctly) it highlights that making information more transparent to governments may improve their reaction when crises occur, but at the cost of making crises larger and more likely to occur.

Related Literature There is a large literature on the time inconsistency of no bailout policies and moral hazard behavior of banks, to which this paper contributes. A number of papers, starting with Holmström and Tirole (1998) and extensively reviewed in Stern and Feldman (2004), argue that the existence of 'too big to fail' banks is the source of time inconsistency and at the root of crises. Another strand of the literature, most recently represented by Acharya and Yorulmazer (2007), Pasten (2015) and especially Farhi and Tirole (2012) argue that 'too big to fail' banks are not a pre-requisite for time-inconsistency as coordinated actions by smaller banks can also give rise to endogenous crises. Our paper introduces government's uncertainty, which gives rise to a mechanism

that applies equally to both environments, with and without large banks.⁴

In relation to Farhi and Tirole (2012), our environment introduces idiosyncratic shocks and the possibility of government uncertainty about the nature of the shock. We additionally allow for efficient takeovers of distressed banks by healthy banks, making the true nature of the shock crucial for the government's decision to intervene. This introduces a 'rat race' effect on banks' choices as the relative performance vis-a-vis other banks determines the likelihood of receiving a bailout.

Acharya and Yorulmazer (2007) develop a model of 'too-many to fail' in an environment where bank takeovers are possible and technologically superior to bailouts, as in our setup.⁵ In our model, however, the 'wait and see' strategy of the government has the additional gain of providing information about the nature of shocks, which creates *strategic restraint* and hinders the possibility of herding that they highlight.

Freixas (1999) shows in a banking setup that the optimal policy for a lender of last resort is to randomize ex-post between bailing out banks in distress and not. This 'constructive ambiguity' strategy, however, requires commitment. In our setting, a similar policy emerges in equilibrium when there is no commitment but the government is uncertain about the nature of distress.

Recently, Green (2010) and Keister (2015) argue that bailouts may be optimal to avoid excessive hoarding of liquidity. In a similar vein, Cheng and Milbradt (2012) suggest bailouts can instill confidence on credit markets. In our setup, whatever the optimal level of liquidity is, it can be attained as long as government uncertainty and strategic restraint forces are at work, even in the absence of commitment.

Bianchi (2016) argues that moral-hazard effects of bailouts are mitigated by making them contingent on the occurrence of a systemic financial crisis. In our framework shocks are unobservable and hence the government cannot make bailouts contingent upon them. This gives rise to a positive option of delay and learning, which is exactly what mitigates the moral-hazard problem.

A recent strand of the literature highlights the effects of policy uncertainty in inducing crises and delaying recoveries. Cukierman and Izhakian (2015), for example, show that uncertainty about policymakers's actions can induce sudden financial collapses when investors follow a max-min behavior. Baker et al. (forthcoming) argue that uncertainty about future policies delays recoveries since individuals prefer to 'wait and see'. As in our extension to asymmetric bank sizes, Davila (2012) also argues that large banks induce small banks to take more risks, increasing economy-wide leverage when banks are uncertain about bailout policies. In our model, however, what reduces the likelihood of endogenous crises is the government's uncertainty about the nature of refinanc-

⁴In the main text we focus on a 'too big to fail' setting and in the Appendix we develop a model with collective moral hazard and map our setting with a model with 'too many to fail' banks.

⁵Perotti and Suarez (2002) model additional reasons why takeovers may be the superior outcome, based on takeover's effect on the market power of the banks.

ing shocks and not the banks' uncertainty about the government's choices.

Finally, there is a previous literature that explores the ability of imperfect information to improve equilibrium outcomes under time inconsistency. Cremer (1995) shows in a static decision problem that the inability of a principal to observe workers' types can serve as a commitment device to punishing low output realizations. Carrillo and Mariotti (2000) show that an agent with time-inconsistent preferences might optimally choose not to learn in order to restrict future selves. The effect of imperfect information in our model has a similar flavor, but in our banking setting, the competition that arises from the banks' concerns for their relative performance is critical for the results, and is absent in those settings. Furthermore, our analysis additionally explores how dynamics affect decisions and incentives, with the government not only delaying to intervene because of uncertainty but also because there are gains from learning and resolving the uncertainty.

2. The Model

The model environment builds on Holmström and Tirole (1998), with several important modifications. First, it introduces two types of shocks, aggregate and idiosyncratic, and allows for imperfect information about the nature of the shock. Second, it features a non-degenerate timing of events, in which banks with higher leverage endogenously show distress earlier. Third, the model admits the possibility that healthy banks take over distressed banks. With these modifications, we can shed light on the effect of what the government knows on what the banks do. All proofs are in Appendix A, which is part of the supplementary material.

2.1. Environment

Time is continuous and finite, $t \in [0, 2]$, and there is no discounting. There are three types of agents in the economy: a continuum of households, two banking entrepreneurs (*banks* hereafter), and a government. Each bank borrows short-term from households to finance a single illiquid project that either pays off at $t = 1$ or suffers a refinancing shock and needs extra funds to mature, paying off at $t = 2$. The refinancing shock can be an *aggregate shock* (the projects of both banks need refinancing) or an *idiosyncratic shock* (only the project of one of the two banks needs refinancing). These shocks hit only at date $t = 1$, and for the rest of time the economy is deterministic. The state space is partitioned so that the probability that (i) both projects need refinancing is denoted as P_2 , (ii) only one project needs refinancing as $2P_1$ and (iii) no project needs refinancing as P_0 .

Households: A continuum of risk-neutral households are born at dates $t = 0$ and $t = 1$. They are endowed with assets S_t when born, which they allocate between holding cash (or storing at a return 1) and lending to banks, consuming their savings in period $t + 1$. Assuming perfect competition across households,

the return for savings is always 1, and denoting potential government taxes as T , utility for each generation is given simply by $U_t = S_t - T_{t+1}$.

Banks: The two banks in the economy have the objective of maximizing their individual net worth. At $t = 0$, they choose the size i of their project, financed using own initial assets A and funds borrowed from the households, bi . Since the alternative use of cash for households is storage with return 1, their competitiveness and risk-neutrality imply that the market interest rate is $R = 1$ (i.e. households do not require a premium as debt is risk-free). Then

$$i - A = bi, \quad \text{and hence} \quad i = A/(1 - b). \quad (1)$$

The size i also determines the speed of expense outflows (to pay suppliers, workers, etc), which happens at a rate idt during the period, such that all projects run out of funds exactly at $t = 1$ and larger projects have a larger outflow rate than smaller projects. If at any moment expense outflows are interrupted (the firms stop paying workers, for example, or stop buying supplies), the project is discontinued and output is scaled-down to the point at which it was discontinued.⁶

The payoff from each bank's project consists of two parts. The first part is deterministic, πi at time $t = 1$. The second part is random. At time $t = 1$, if the project does not suffer any shock, it returns $(\rho_0 + \rho_1)i$ and if the project suffers a shock, it returns nothing, and then the bank has the choice to refinance the project to a new size $j \leq i$. Refinancing a project, however, does not change its intrinsic rate of expenses outflow, and hence a smaller refinancing scale means that the project is terminated early and the payoff is scaled down to $(\rho_0 + \rho_1)j$ at time $t = 2$. For example, if only half of a large project is refinanced ($j = i/2$) the bank would run out of cash to pay expenses at $t = 1.5$.

Since, in case of a shock, the cash available at $t = 1$ for reinvestment purposes is equal to $c = (\pi - b)$ per unit of investment, banks face a tradeoff between increasing the initial size of the project and holding some cash for potential refinancing needs. In particular, the reinvestment scale j depends on the cash carried at $t = 1$, $ci = (\pi - b)i$, that can be levered by taking a new loan. The new loan, however, is constrained by a pledgeability constraint, i.e. from the total output of the project, ρ_1 is a benefit that can only be captured by bankers, and hence not pledgeable.⁷ Then, if the required market rate of return on bank lending is R , the maximum the bank can raise at $t = 1$ is

$$R(j - ci) = \rho_0 j, \quad \text{and hence} \quad j = \min \left\{ \frac{c}{1 - \rho_0/R}, 1 \right\} i. \quad (2)$$

By refinancing a project below the potential scale (i.e., $j < i$) the bank shows distress (does not have access to any more funds) and discontinues the project

⁶Our results strengthen if the whole output is lost upon discontinuation.

⁷This can be derived from first principles as in Holmström and Tirole (1998), for example by moral hazard within the bank, in which the banker exerts hidden efforts that affect the outcome of the project.

before $t = 2$. Let $\bar{t}(c)$ be the calendar time of distress. When $R = 1$,

$$\bar{t}(c) = \min \left\{ 1 + \frac{c}{1 - \rho_0}, 2 \right\}. \quad (3)$$

Note that the decision of the bank of how much cash c to hold per unit of investment determines both the size of the project, $i(c)$, and the size of the project in case of refinancing, $j(c)$ (and hence also the time at which the bank would show distress in case of a refinancing shock, $\bar{t}(c)$). If banks hold $c = 0$, then they can invest in the largest feasible project, $i = A/(1 - \pi)$ at $t = 0$, but will not be able to refinance anything at the market rate in case of a shock at $t = 1$. In contrast, if banks hold $c = 1 - \rho_0$, then they can invest in a smaller project, $i = A/(2 - \pi - \rho_0)$ at $t = 0$, but will be able to refinance the project fully at a market rate $R = 1$ in case of a refinancing shock at $t = 1$.

Parametric assumptions that make the model economically interesting are:

Assumption 1. *Assumptions about projects's payoffs*

1. *Binding pledgeability:* $\pi < 1$ and $\rho_0 < 1$.
2. *Efficient projects:* $\pi + \rho_0 + \rho_1 > 1 + P_1 + P_2$.
3. *Efficient refinancing:* $\rho_0 + \rho_1 > 1$.

The first part of Assumption 1 guarantees that investment in period $t = 0$ is finite, and that refinancing depends on retained earnings.⁸ The second part guarantees that financing the project at $t = 0$ is socially efficient – the payoff of always taking the project to fruition is greater than the expected cost of doing so (this is, initial investment plus expected refinancing). The third part guarantees that refinancing the project at $t = 1$ is also socially efficient.⁹

Takeovers. In case of an idiosyncratic shock, the healthy bank has a chance to make a *take-it-or-leave-it offer* to buy the project that needs refinancing. As the project pays $\rho_0 + \rho_1 - 1 > 0$ per unit of investment, the value of a takeover is $V_{TO} = (\rho_0 + \rho_1 - 1)(i' - j')$, where i' is the original size and j' is the refinanced size of the distressed bank's project, both of which only depend on the distressed bank's choice of cash, c' . In a symmetric equilibrium the healthy bank will always have resources to take over the distressed bank project. In an asymmetric situation this is also the case as long as the smallest project's proceeds are enough to refinance the largest project, which holds if $\rho_1 > 1/(1 - \pi)$. To keep the exposition simple, this parametric restriction is maintained throughout, but relaxing it would just increase the incentives for banks to hold cash, reinforcing the results.

The possibility of takeovers in our setting is at the heart of the mechanism of the paper. A government would rather let projects to change hands privately than stepping in with bailouts, which we describe next.

⁸If $\pi > 1$, a project of infinite size can be financed just claiming the deterministic portion of the project. If $\rho_0 > 1$, no cash is necessary to borrow and refinance the project fully.

⁹The special case with $\pi = 0$ and $\rho_0 = 0$ satisfies all restrictions and represent a problem of self-financing. Still, all results regarding bailouts and uncertainty as commitment apply.

The Government. The government is benevolent and maximizes welfare $W = \beta V + U_0 + U_1$, the weighted sum of the banks' surplus, V , and each generation's of households surpluses, U_0 and U_1 . To maximize W the government may need to transfer resources from households to banks to refinance projects that suffer a shock. This is what is called a *bailout*.¹⁰ The weight $\beta < 1$ captures the idea that these transfers from households to banks are costly in terms of welfare.¹¹

There are many ways in which governments can introduce bailouts. Here, the government bails out banks by lending to them directly at below-market interest rates, denoted by $R(t)$ at $t \in [0, 2]$, financed by taxes on households. Any path of interest rates introduced by the government is a transfer from the households to the banks equal to $T = (1 - \rho_0)(i - j)$, which is the difference between what the bank cannot refinance itself ($i - j$) and the maximal return the government can recover from the pledgeable part of the project, $\rho_0(i - j)$. Without loss of generality, in what follows the policy interest rate is assumed to take only two values: (i) a no intervention *market rate* of $R = 1$ and (ii) a *bailout rate* of $R = \rho_0$, at which even banks with zero cash can fully refinance. Additionally, bailouts are *targeted*, which means that a government can reduce interest rates only for certain banks and not others.¹²

Even though banks know the state of the economy at $t = 1$ (which banks suffered a shock, if any), we introduce different assumptions on what the government knows at $t = 1$. In the *full information* case, the government observes the state at $t = 1$ (our benchmark) and, alternatively, in the *imperfect information* case, the government does not. In the latter case, let $t \in [1, 2]$ be the calendar time at which the government observes a *bank in distress*, that is the time $t \geq 1$ at which the bank eventually runs out of refinancing opportunities in the market, inferring then that the observed bank's project must have suffered a shock.

More formally, let the government's belief that, conditional on a bank showing distress, both banks need refinancing, be denoted by p . Under full information, p is either 0 (idiosyncratic shock) or 1 (aggregate shock), as the government learns at $t = 1$ the nature of the shock. Under imperfect information, $p = P'_2$

¹⁰As our analysis focuses solely on fully collateralized, risk-free, loans, bailouts help equity holders and not debt holders. In an extension that allows for default, interest rates would include a premium for default's expected probability. When lenders expect interventions in case of default, the premium would be subsidized and bailouts would help debt holders.

¹¹It is possible to formally include distortionary effects of transfers, or fixed costs of intervening, as in Farhi and Tirole (2012). These extensions, as discussed in the Appendix B, do not change our main results, and so they are omitted here for expositional purposes.

¹²In Appendix B, we show that non-targeted bailouts, under which all banks can borrow at a lower rate, regardless of whether they are in distress or not, strengthen the results.

according to Bayes' rule¹³

$$P_2' = \frac{P_2}{P_1 + P_2} > P_2. \quad (4)$$

The decision of the government at the time t of observing a bank in distress is a binary one: whether or not to bailout, given its belief that both banks are in need of refinancing, p . This decision is summarized by a function $\Pi(t, p) \in \{0, 1\}$, where 1 is a bailout, and 0 lack thereof. Based on this function, define

$$t_p^* = \min\{t | \Pi(t, p) = 1\}, \quad (5)$$

the minimum time at which the government is willing to provide a bailout when the probability that both banks need refinancing is p and the government observes a bank in distress. The set of government policies Π is restricted to ones that guarantee that t_p^* is well defined. When it does not generate confusion, the policy when the government knows the shock is aggregate (i.e., $p = 1$) is simply denoted as t^* .

At $t = 0$, the government announces a bailout policy as a function of the time the first and second banks show distress. If the government has commitment, it then just executes the announcement. In contrast, if the government lacks commitment, it can deviate from the announced policy ex-post.

In relation to takeovers, the government is assumed to move first after observing the first bank in distress, and decide whether to bail out or not. If the government does not bail out and the shock is idiosyncratic, the second bank decides whether to take over the distressed project or not. In case the shock is aggregate, the government decides whether to provide a bailout to the second bank when and if it shows distress.¹⁴

The above timing of events applies to both the full information and the imperfect information cases, with the difference between those being the belief p that the government assigns to an aggregate shock when a bank shows distress.

In what follows, it is assumed that bailouts are socially costly (raising public funds introduces distortions and then governments prefer takeovers to bailouts) but beneficial (bailouts save socially useful projects). Define $x \equiv \beta\rho_1 - (1 - \rho_0)$ to be the social gain per unit of investment of refinancing with social funds (bailout) and $y \equiv \beta\rho_1 - \beta(1 - \rho_0)$ to be the social gain per unit of investment of refinancing with private funds (takeover). Then

Assumption 2. *Bailouts are socially costly, but beneficial: $y > x > 0$.*

¹³The update in equation (4) assumes that banks are not anonymous, i.e. the conditioning event is that a *given bank* needs liquidity, not just *any* bank. Under the alternative assumption of bank anonymity, the denominator would be $2P_1 + P_2$, and the rest of analysis would go unchanged.

¹⁴We assume the government is not able to change its decision upon observing the takeover action of the second bank. Our results are robust to introducing alternatives to that assumption, which are explored in detail in Appendix B.

Assumption 2 implies that the possibility of a private takeover of a distressed bank is crucial for the incentives of the government to provide a bailout. Specifically, as long as $\beta < 1$, the government strictly prefers takeovers to bailouts. The government, however, still prefers to bail out a project than to let it fail. The possibility of a takeover will be the force inducing the government to delay its bailout decision.

2.2. Full Information

This section provides the full information benchmark, in which the government observes at $t = 1$ how many projects suffer a shock, if any. In this case, given Assumption 2, the government would never bailout a bank when the shock is idiosyncratic, as it prefers the healthy bank to take over. Below, the choice of the government in case of an aggregate shock is studied, with and without government commitment to its announced policies.

2.2.1. Commitment

Assume the government is able to commit to a policy announced at $t = 0$ about whether to bail out a bank in distress in case of an aggregate shock. We first solve the optimal reaction of banks given a policy announcement and then compute the optimal policy announcement.

At $t = 0$, each bank chooses how much cash c to retain (which implies the size of the project $i(c)$ and the time of distress in case of a shock $\bar{t}(c)$), conditional on the government's policy. The value of the bank as a function of the cash choice c depends on whether $\bar{t}(c)$ is larger or smaller than the government's policy t^* :

$$V(c) = \begin{cases} V_s(c) + P_2[c + (\rho_0 + \rho_1 - 1)(\bar{t}(c) - 1)]i(c) & \text{if } \bar{t}(c) < t^* \\ V_s(c) + P_2[c + \rho_0 + \rho_1 - (t^* - 1) - \rho_0(2 - t^*)]i(c) & \text{if } \bar{t}(c) \geq t^* \end{cases} \quad (6)$$

where $V_s(c) = (P_0 + P_1)(c + \rho_0 + \rho_1)i(c) + P_1\rho_1j(c) + P_1V_{TO}$, is the expected value when there are no shocks or when the shock is idiosyncratic and hence it is independent of government policy, and V_{TO} is the value of takeover, defined earlier and independent of c .

Equation (6) implies a jump in the value function, generated by the government policy. Since there are no bailouts before t^* , a bank not holding cash to refinance until t^* (that is, $\bar{t}(c) < t^*$) should scale down the project to $j(c) = (\bar{t}(c) - 1)i(c) < i(c)$. In that case, the payoff for the bank is ci plus the returns $(\rho_0 + \rho_1)j$ minus the cost of refinancing j at a market-rate $R = 1$ per unit of reinvestment. As $j - ci = \rho_0j$, the value function when $\bar{t}(c) < t^*$ could be rewritten simply as $V_s(c) + P_2\rho_1j(c)$.

In contrast, a bank holding cash to refinance until t^* (that is, $\bar{t}(c) \geq t^*$) enjoys a bailout at time t^* , borrowing at rate ρ_0 . This implies banks refinance as little as possible at interest rate $R = 1$, and then refinance up to full scale at rate $R = \rho_0$. Then, a fraction $(t^* - 1)i$ of the project is refinanced at cost of 1 per unit of refinancing and the rest (a fraction $(2 - t^*)i$ of the project) is refinanced at cost ρ_0 per unit of refinancing.

We now impose two assumptions that make the model economically interesting. First, Assumption 3 guarantees that banks care about refinancing scale – when faced with a tradeoff between increasing investment i or increasing reinvestment j , they choose to increase reinvestment. Under this assumption, banks will always choose c such that $\bar{t} \geq t^*$.

Assumption 3. *Banks care about reinvestment scale ($\bar{t}(c) \geq t^*$):*

$$(P_0 + P_1)(\rho_0 + \rho_1 + \pi - 1) - (P_1 + P_2) \frac{1 - \pi}{1 - \rho_0} \rho_1 < 0.$$

The first term is the cost of holding c in terms of financing a smaller project, which is borne when there is no shock (P_0) or when only the other bank needs refinancing (P_1). The second term is the benefit of holding c in terms of upscaling j , as the bank can leverage extra cash $(1 - \pi)$ by $(1 - \rho_0)$ to gain ρ_1 per unit of refinancing, which accrues when the bank needs refinancing (P_2 and P_1).

Assumption 4 guarantees that, if the government provides a bailout at $t^* < 2$, banks will always choose c such that $\bar{t}(c) \leq t^*$, that is banks choose to exploit bailouts as much as possible.

Assumption 4. *The promise of a bailout increases leverage ($\bar{t}(c) \leq t^*$):*

$$(P_0 + P_1 + P_2)(\rho_0 + \rho_1 + \pi - 1) - P_1 \frac{1 - \pi}{1 - \rho_0} \rho_1 - P_2 > 0$$

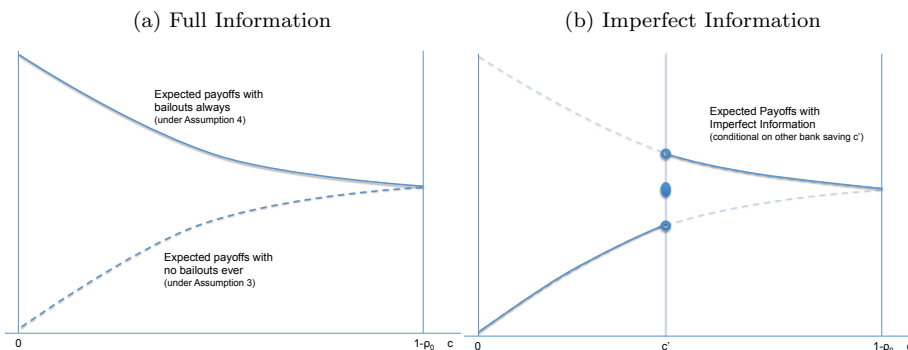
The first term on the left shows again the cost of holding c in terms of financing a smaller project. Compared with Assumption 3, this cost is additionally borne in case both banks fail as there is no change in reinvestment scale j if $\bar{t} > t^*$. The second term shows the benefit of holding c in terms of upscaling j , which only happens when an idiosyncratic shock pushes the bank to be taken over. The third term captures the benefit of consuming c in case of a bailout when an aggregate shock occurs. As the government takes care of refinancing through bailouts in case of an aggregate shock, the assumption guarantees that the costs of holding cash are larger than the benefits of holding cash.¹⁵

Figure 1, panel (a), shows the banks' expected payoffs when the government commits to never bailout (dashed line under Assumption 3) and when the government commits to bailout if the shock is aggregate (solid line under Assumption 4). Under our stated assumptions, the expected payoff of the bank is decreasing in cash if bailouts always happen after an aggregate shock hits, and increasing in cash if bailouts never happen. This implies that under commitment the government is able to select either $c = 0$ or $c = 1 - \rho_0$ just by announcing the appropriate bailout policy.

The Lemma below establishes that, with commitment and under the stated assumptions, banks optimally choose to hold cash to refinance fully in case of an aggregate shock, given a government policy t^* .

¹⁵For details of the derivation Assumptions 3 and 4, see the Appendix.

Figure 1: Expected Payoffs of Banks



Lemma 1. *Under Assumptions 1-4, given government policy t^* , the optimal choice of cash is characterized by $c^*(t^*) = (1 - \rho_0)(t^* - 1)$, where $t^* \in [1, 2]$.*

Given Lemma 1, the earliest bailout time t^* is enough to characterize the policy rule $\Pi(t, p)$, which under commitment is equivalent to choosing c^* directly from the set $[0, 1 - \rho_0]$. Ex-ante social welfare can therefore be expressed in terms of the cash choice of banks. Ignoring constant terms,

$$W^{ea}(c) = \beta[\pi + \rho_0 + \rho_1 - 1 - P_1 - P_2]2i(c) - (1 - \beta)P_2((1 - \rho_0) - c)2i(c). \quad (7)$$

where $i(c) = \frac{A}{1 - \pi + c}$ and $ci(c) = (\pi - 1)i(c) + A$.

The first term shows the ex-ante payoffs from projects that are always refinanced fully, weighted by the bankers' β . The second term shows the size of the bailout weighted by the difference between households' and bankers' weights $1 - \beta$, this is, the distortion cost in terms of welfare.

Clearly, the optimal policy depends on the welfare weight on bankers. When $\beta = 1$ (equal weights for bankers and households in the welfare function) bailouts do not affect welfare, as utility is transferrable one to one between households and banks. In that case, the government only cares about output, and ex-ante wants to transfer resources from households to bankers but only when refinancing is needed. This implies an optimal policy of $t^* = 1$ and $c^* = 0$. In contrast, when β is low, the weight governments put on producing output is low, since households gain nothing from it. As β is a shortcut for potential distortions from the transfers, one could interpret low β as destroying output from households when transferring resources to bankers.

Next we define and, in Proposition 1, characterize the equilibrium under commitment

Definition 1 (Commitment Equilibrium). *A symmetric equilibrium with commitment is banks' cash level c^* and a government's policy $\Pi(t, p = 1)$, such that c^* maximizes (6) given policy $\Pi(t, p = 1)$, and policy $\Pi(t, p = 1)$ is such that c^* maximizes welfare (7).*

Proposition 1 (Optimal Policy with Commitment). *Define*

$$\beta^* = \frac{P_2(2 - \rho_0 - \pi)}{(\pi + \rho_0 + \rho_1 - 1 - P_1 - P_2) + P_2(2 - \rho_0 - \pi)} < 1.$$

Then,

- (i) *If $\beta < \beta^*$, there are no bailouts, $t^* = 2$, and cash holdings are $c^* = 1 - \rho_0$.*
- (ii) *If $\beta > \beta^*$, bailouts are immediate, $t^* = 1$, and cash holdings are $c^* = 0$.*
- (iii) *If $\beta = \beta^*$, policy is indeterminate, $t^* \in [1, 2]$ and cash holdings $c^*(t^*)$ are determined as in Lemma 1.*

The proof is evident from inspection of equation (7). If $\beta > (<) \beta^*$, $\frac{dW^{ea}(c)}{dc} < (>) 0$ for all $c \in [0, 1 - \rho_0]$. Intuitively, the benefits of committing to no bailouts when the shock is aggregate are given by the social gains from private refinancing (using other banks resources) relative to the social gains from public refinancing (using households resources), $P_2(y - x) = P_2(1 - \beta)(1 - \rho_0)$. The costs of committing to no bailouts when the shock is aggregate are given by the unnecessary reduction in the projects' scale, $\beta \left[\frac{1 - \rho_0}{2 - \rho_0 - \pi} \right] [\pi + \rho_0 + \rho_1 - 1 - P_1 - P_2]$. The cost is adjusted by the weight β that governments assign to bankers. The equation for β^* in the proposition comes from equalizing these costs and benefits.

2.2.2. No Commitment

In this section, the government is assumed unable to commit to its policy announcements. Banks internalize the government's optimal ex-post actions in their optimization problem, effectively making them first-movers and giving them the ability to choose the time of the bailout t^* to maximize (6).

Given Assumption 2, the government never bails out when the shock is idiosyncratic and always bails out when the shock is aggregate. How much do banks save at $t = 0$ knowing these government reactions? Under Assumption 4, banks would rather hold no cash and force a bailout in case the shock is aggregate. Formally,

Definition 2 (Non-Commitment Equilibrium). *A symmetric equilibrium without commitment is banks' cash level c^* and a government's policy $\Pi(t, p = 1)$, such that the policy $\Pi(t, p = 1)$ is the ex-post best response to c^* and c^* maximize (6) given the policy.*

Proposition 2 (Optimal Policy without Commitment). *Under Assumptions 2 and 4, the unique equilibrium without commitment is characterized by banks choosing $c^* = 0$, and the government immediately intervening when the shock is aggregate, $t^* = 1$.*

Notice that the outcome of the non-commitment equilibrium coincides with the outcome of the commitment equilibrium when $\beta > \beta^*$ (bailout distortions are small), as there is no time inconsistency because the government prefers to bailout both ex-ante and ex-post. In what follows, we focus on the opposite case in which governments would ex-ante commit to no bailouts when the shock

is aggregate, but would find ex-post optimal to bail out banks in such state. Formally, this time inconsistency is introduced as follows

Assumption 5. *Time inconsistency:* $\beta < \beta^*$.

Under this assumption (which is more likely to hold when P_2 is low, ρ_1 is low and π is high relative to ρ_0) there are inefficient bailouts on the equilibrium path in absence of commitment.¹⁶

2.3. Imperfect Information

This section characterizes the case in which the government does not observe the nature of the shock at $t = 1$. At some time $1 \leq t < 2$, however, the government may observe a bank in distress and decide whether to bail out the bank or not. The government that decides not to bail out the first bank in distress always faces the concern that the shock is aggregate and part of the project is lost. The posterior probability that the shock is aggregate conditional on one bank showing distress is given by $p = P'_2$ in equation (4). The probability that the shock is aggregate conditional on a second bank showing distress is naturally $p = 1$.

Next, we define and, in Proposition 3, characterize the equilibrium with imperfect information and non-commitment

Definition 3 (Equilibrium with Government Uncertainty). *A symmetric equilibrium without commitment under imperfect information is banks' cash level c^* and government's policies $\Pi(t, p)$ and $\Pi(t, 1)$, such that the policy $\Pi(t, P'_2) \forall t$ is the ex-post best response to c^* after observing the first bank in distress, the policy $\Pi(t, 1) = 1 \forall t$ after observing the second bank in distress and c^* maximizes (9) for each bank given the policies and the other bank's choice.*

In case of bailing out the first bank in distress, interim welfare is $[P'_2(2x) + (1 - P'_2)x](2 - \bar{t})i$, this is with probability P'_2 the shock is aggregate and the government bails out the two banks, but with probability $1 - P'_2$ the shock is idiosyncratic and the government bails out a project that could have been taken over. In case of *not* bailing out the first bank in distress, interim welfare is $[P'_2x + (1 - P'_2)y](2 - \bar{t})i$, this is with probability P'_2 the project of the bank in distress fails and the government bails out just the second bank in distress, and with probability $1 - P'_2$ the bank in distress is taken over by the healthy bank. In both cases, the payoffs are proportional to the size of refinancing, $2 - \bar{t}$. Comparing these two payoffs the government decides to delay the bailout of the first bank in distress if

$$P'_2 < \bar{P} \equiv 1 - \frac{x}{y}. \quad (8)$$

¹⁶If $x < 0$, it is ex-ante optimal for governments to commit to bailout banks when the shock is aggregate, but it is ex-post optimal not bailing out banks in such state. In this case there is inefficient insufficient liquidity in the absence of commitment and the mechanism we highlight in the next section is not effective to eliminate such inefficiency.

Condition (8) is more likely to hold when the difference between the social benefits of takeover versus bailout is large. If this condition does not hold, the first bank in distress is bailed out regardless of the nature of the shock. In such case, banks have even less incentives to reduce the scale of the project than under full information and no commitment, since the bank expects to be bailed out regardless of whether the shock is aggregate or idiosyncratic. Then, in absence of commitment the equilibrium is as in Proposition 2, with no cash holdings and immediate bailouts on the equilibrium path.

If condition (8) is satisfied, the first bank in distress is not bailed out, but the second bank in distress is. This implies that the banks' value functions are

$$V(c) = \begin{cases} V_s(c) + P_2[c + (\rho_0 + \rho_1 - 1)(\bar{t}(c) - 1)]i & \text{if } \bar{t}(c) < \bar{t}(c') \\ V_s(c) + P_2[c + (\rho_0 + \rho_1 - 1)(\bar{t}(c) - 1)]i + \frac{1}{2}P_2\rho_1(2 - \bar{t}(c))i & \text{if } \bar{t}(c) = \bar{t}(c') \\ V_s(c) + P_2[c + (\rho_0 + \rho_1 - 1)(\bar{t}(c) - 1)]i + P_2\rho_1(2 - \bar{t}(c))i & \text{if } \bar{t}(c) > \bar{t}(c') \end{cases} \quad (9)$$

where $V_s(c)$ is the same as before in equation (6).

Now, as in the full information case, there is a jump in the value function – in fact there are two (panel (b) of Figure 1). The additional one is the midpoint between being bailed out or not when the two banks hold the same level of cash (this is, $\bar{t}(c) = \bar{t}(c')$). The difference between equations (9) and (6) is that now what matters is whether the bank runs out of cash before or after its competitor (summarized by the relation between $\bar{t}(c)$ and $\bar{t}(c')$).

The next part solves for the ex-ante cash choice of a bank, c , taking as given the cash choice of the other bank, c' . In particular, it studies incentives of a bank to deviate from a symmetric strategy $c = c'$ (which implies $\bar{t}(c) = \bar{t}(c')$), as any deviation $c \neq c'$ affects the probability that the bank is the first one showing distress, and hence the one failing when the condition (8) holds.

Note that a marginal deviation upwards from $c = c'$ (i.e. carrying slightly *more* liquidity than the other bank), has the benefit of increasing discontinuously the probability of a bailout (Section 2.4 discusses a version of the model in which the bailout probability changes continuously), at the cost of downsizing the project just slightly from $i(c')$ to $i(c) < i(c')$. For any marginal change, the first effect dominates, and there are always incentives to deviate as long as

$$\frac{1}{2}P_2\rho_1[2 - \bar{t}(c')]i(c') > 0, \quad (10)$$

which holds for all $\bar{t}(c') < 2$. We refer to this equation as the *strategic restraint condition*. This condition is computed in the following way: when the other bank holds cash c' , the fraction of the project that cannot be refinanced is $(2 - \bar{t}(c'))$, and the benefit from being bailed out is ρ_1 per unit of refinancing (the non-pledgeable part of the payoff). By holding slightly more cash, the bank changes discretely the probability of being bailed out when the shock is aggregate (with probability P_2) from 1/2 to 1. How this condition affects incentives is presented graphically in Figure 1, panel (b), which plots the value function of a bank with cash c under imperfect information, when the other bank's cash holdings are c' . For any $c \leq c' < 1 - \rho_0$, the bank would like to

deviate upwards, and in particular, this is true for any tie-break ($c = c'$). The only point in which incentives for deviation vanish is at $c = 1 - \rho_0$, which is the point of full refinancing. The next Proposition characterizes the equilibrium.

Proposition 3 (Equilibrium with Government Uncertainty). *If $P'_2 > \bar{P}$, there is a unique symmetric equilibrium in which $\Pi(t, P'_2) = 1 \forall t$ after observing the first bank in distress, $\Pi(t, 1) = 1 \forall t$ after observing the second bank in distress, and banks do not hold any cash for refinancing, $c^* = 0$.*

If $P'_2 < \bar{P}$, there is a unique symmetric equilibrium in which $\Pi(t, P'_2) = 0 \forall t$ after observing the first bank in distress, $\Pi(t, 1) = 1 \forall t$ after observing the second bank in distress, and banks hold enough cash to refinance fully, $c^ = 1 - \rho_0$.*

This Proposition presents the main result of the paper. When the government is uncertain enough to delay bailouts after the first signs of distress, the banks hold enough cash flows to refinance fully without any need for bailouts in case of shocks, which is the ex-ante efficient outcome under the stated assumptions.

The statement of the proposition follows from applying the *strategic restraint condition* to all cases in which the *delayed bailout condition* holds. In all such cases, the value of being the second bank in distress is discontinuously higher than the value of being the first bank in distress. Following a Bertrand-style undercutting argument, banks want to deviate from a symmetric strategy in order to avoid being the first in distress. At $\bar{t} = 2$, there is a corner solution and no more incentives to deviate, since banks can self-finance completely.

This result is purposefully made very stark to highlight the main forces in the model – it relies on a discrete change in probabilities of default driven by a continuous change in cash holdings and then on the Bertrand competition logic. Section 2.4 below provides a setup in which both change continuously. In that setup, the main forces of the model remain intact: strategic restraint bring leverage closer to the social optimum, but not completely.

Remark on the timing of moves. In the benchmark model, the government decides whether to bail out a distressed bank or not *before* knowing if a potential non-distressed bank is willing to take over. Appendix B provides a version of the model with the alternative assumption of giving the first move opportunity to a potentially existing healthy bank. The equilibrium in this case is determined by how the outside investment opportunities of healthy banks depend on government interventions and the stability of the financial sector. When a bank gets liquidated and taken over, there may be negative external effects on the investment opportunities of the healthy banks, for example due to contagion, runs, loss of confidence, higher collateral requirements, tightening on regulation or government oversight, etc. In this case, even though a healthy bank would choose to take over a distressed bank in the absence of a bailout, the presence of a bailout may increase their other investment opportunities. In this case the bank would rather not to make a take over offer to force the bailout, and the analysis goes through unchanged.

Remark on non-targeted bailouts. In the benchmark model, bailouts are targeted, i.e. only the distressed bank has access to the low interest rate offered by the government. Appendix B provides a discussion the effects of an increased scope of the bailout so that the transfer is available to healthy banks as well. This extension makes our results stronger in two respects. First, it makes the delayed bailout condition easier to satisfy, because it increases the social benefit of a private takeover. Second, this possibility may discourage healthy banks from making take over bids, as discussed in the previous paragraph, to force bailouts and take advantage of subsidized interest rates.

Remark on gradual bailouts. In the benchmark model, bailouts are discrete events – if the government does not provide the total amount of funds needed for reinvestment, the project is prematurely terminated. Appendix B presents a version of the model which allows the government to introduce *gradual bailouts*, i.e. bailouts that keep the project running until some endogenously chosen time t' , where $t' = 2$ corresponds to the benchmark model. In this version of the model, if there are no incentives for healthy banks to make takeover bids (in cases explained previously), our benchmark analysis goes through without change – if the shock is idiosyncratic, the government would not learn about it by doing a gradual bailout and, foreseeing this time inconsistency, it would rather bail out the whole project at once. We also characterize government delay in a general case of choosing a gradual bailout duration optimally. In the general setup developed in the next section, such possibility affects the cutoff for delayed bailout, but it is always bounded away from zero when cash holdings are risky.

Remark on the time of distress and running out of cash. In the benchmark model the time of distress is defined as the moment banks run out of cash, and then of refinancing options at market interest rates. This is indeed banks' optimal strategy under our set of assumptions. On the one hand, since an interruption of the project's flow of expenses implies a premature termination, no bank would want to ask for a bailout strictly *after* it runs out of cash. On the other hand, under government uncertainty and the delayed condition holding, no bank would want to ask for a bailout *before* it runs out of cash – as there is a chance that the other bank will run out of funds first.

Remark on strategic coordination. The setup of benchmark model abstracts from forces that make banks' leverage choices strategic complements (which are present, for example, in Farhi and Tirole (2012)). Appendix B, however, provides a derivation of the delayed bailout condition in a case when there is an additional fixed cost of intervention, independent of the total volume of bailouts, which introduces strategic complementarity in banks' actions. Intuitively, banks would rather show distress together as this situation minimizes the average cost of the intervention relative to the benefits of saving more projects. In such extended setup, under full information banks have incentives to coordinate. However, under imperfect information, the delayed bailout condition is

more easily satisfied, and strategic restraint forces make banks' actions strong strategic substitutes, counteracting the incentives to coordinate.

Remark on informational assumptions. In the benchmark model, even though banks and investors know the refinancing actions of banks, the government does not. Otherwise government would perfectly infer the state of the economy just observing how many banks raise funds at $t = 1$. Our results do not depend on whether the market participants know the state of each bank or not, as all refinancing is fully collateralized, but governments would like ex-post (at $t = 1$) to conduct a potentially costly (and noisy) monitoring activity in order to track aggregate cash levels. Our results, however, imply that ex-ante (at $t = 0$) the government would actually not want to spend resources on such monitoring, in order to improve outcomes under no commitment.

Remark on the possibility of contagion. An extension we do not formally consider is the possibility of contagion, where a failure of one bank may *trigger* the need for refinancing other banks, then making the probability of an aggregate shock endogenous to the decision of delay. Still, our benchmark model can be easily extended to include this possibility, interpreted as an increase in the belief about the probability of an aggregate shock, say from P_2 to $P_2 + \chi$, conditional on allowing a project fail. If contagion is independent of refinancing needs the delayed bailout condition becomes $\hat{P}'_2 = \frac{P_2 + \chi}{P_1 + P_2 + \chi} > P'_2$, implying that it is more difficult to satisfy in the presence of contagion. Even though this is clearly an ad-hoc way to introduce contagion, any micro-founded model would map into a distribution over χ and hence could be analyzed from this perspective. Giving a full evaluation of the effects of contagion would require modeling such micro-foundations explicitly as the details of the mechanism could potentially affect the welfare costs and benefits of delay. These interesting considerations are outside of the scope of this paper.

Remark on crises and bailouts on the equilibrium path. In the benchmark model, when the delayed bailout condition holds, the equilibrium features banks holding enough cash reserves so that on the equilibrium path there are no bank failures and bailouts – just like in the equilibrium under commitment. This prediction, however, is just the result of the purposefully stark assumption about Bertrand type of competition in the benchmark model. Section 2.4 presents an extension of our model that includes ex-post shocks to cash holdings. In that model, both crises and bailouts can happen on the equilibrium path. Banks still choose to hold more liquidity than in a full-information, no commitment equilibrium, but they choose levels that do not fully exclude bank failures. Hence, in the extended setup with government uncertainty, crises happen with lower probability and they are smaller in magnitude.

2.4. Ex-post Shocks to Cash Holdings

So far in our analysis, once, at $t = 0$, banks chose their cash holdings c for potential refinancing at $t = 1$, they did not face any uncertainty about

those cash holdings. This section extends the benchmark model by assuming that banks suffer idiosyncratic and independent shocks to their cash position at $t = 1$, after the refinancing shock has been realized. A positive shock to cash holdings implies that a bank holds more cash than planned (the return from savings is higher than expected, for example) while a negative shock implies the bank holds less cash than planned (there is an unexpected expense to cover, for example). Formally, the cash available for refinancing at $t = 1$ is

$$\widehat{c}(h)i = (c + h)i, \quad \text{where } h \sim \mathcal{N}(0, \sigma_h^2) \text{ and i.i.d. across banks.} \quad (11)$$

For analytical tractability and simplicity of exposition, shocks to cash holdings (the potential extra cash h) are allowed to be used to refinance own projects in distress, but not other banks' projects in distress. Were this assumption relaxed, one would need to consider the possibility that a distressed bank with good enough cash holdings can refinance both projects when the shock is aggregate, not adding to the conclusions and just making the equations cumbersome.

Given refinancing needs, cash maps into time of distress analogously to (3):

$$t(h|c) = \bar{t}(c) + \frac{h}{1 - \rho_0} \quad \text{if} \quad -(\bar{t} - 1) < \frac{h}{1 - \rho_0} < (2 - \bar{t}), \quad (12)$$

where $\bar{t}(c) = 1 + \frac{c}{1 - \rho_0}$ is the expected time of distress when the bank chooses to hold cash c at $t = 0$, and $t(h|c) = 1$ and $t(h|c) = 2$ at the corners.

Given the h distribution, $t(h|c)$ is distributed according to

$$f(t|c) = \begin{cases} \Phi\left(-\frac{1 - \rho_0}{\sigma_h}(\bar{t}(c) - 1)\right) & \text{for } t = 1 \\ \phi\left(\frac{1 - \rho_0}{\sigma_h}(t - \bar{t}(c))\right) & \text{for } 1 < t < 2 \\ 1 - \Phi\left(\frac{1 - \rho_0}{\sigma_h}(2 - \bar{t}(c))\right) & \text{for } t = 2 \end{cases} \quad (13)$$

where Φ denotes the standard cumulative normal distribution and ϕ denotes the density of the standard normal distribution.

Assuming the delayed bailout condition (8) holds, the equivalent of the strategic restraint condition (10) can be derived. The value of a bank (net of the expected value of takeovers, V_{TO}) of choosing c conditional on c' is

$$V(c|c') = \left[(P_0 + P_1)(c + \rho_0 + \rho_1) + P_1 \rho_1 \frac{c}{1 - \rho_0} + P_2 \rho_1 \left(\eta(c|c') + (1 - \eta(c|c')) \frac{c}{1 - \rho_0} \right) \right] i(c),$$

where $\eta(c|c')$ is the probability of being bailed out conditional on saving c while the other bank saves c'

$$\eta(c|c') \equiv \Pr(t > \bar{t}) = \Pr(h' - h < c - c') = \Phi\left(\frac{c - c'}{\sqrt{2}\sigma_h}\right),$$

and h' denotes the other bank's cash holding shock, such that $h' - h \sim \mathcal{N}(0, 2\sigma_h^2)$.

Taking the derivative of the value function with respect to c ,

$$\frac{dV(c|c')}{dc} = -C \frac{i^2(c)}{A} - \eta(c|c') \frac{P_2 \rho_1}{1 - \rho_0} [2 - \rho_0 - \pi] \frac{i^2(c)}{A} + \eta'(c|c') \frac{P_2 \rho_1}{1 - \rho_0} [1 - \rho_0 - c] i(c), \quad (14)$$

where C is given by the left hand side of Assumption 3 (hence negative), and $\eta'(c|c')$ is the marginal increase in the probability of bailout from saving more cash, conditional on the other bank still saving c' :

$$\eta'(c|c') = \frac{\partial \eta(c|c')}{\partial c} = \left(\frac{1}{\sqrt{2}\sigma_h} \right) \phi \left(\frac{c - c'}{\sqrt{2}\sigma_h} \right).$$

In a symmetric equilibrium, $c = c'$, and the probability of showing distress second is 50% when the shock is aggregate (this is, $\eta(c'|c') = 0.5$) and the marginal change in this probability due to holding more cash is $\eta'(c'|c') = \frac{\phi(0)}{\sqrt{2}\sigma_h}$, where $\phi(0)$ is the density of the standard normal distribution evaluated at 0.

To put the derivative (14) in perspective, assume full information and commitment to no bailouts (then $\eta(c|c') = 0$ and $\eta'(c|c') = 0$). This implies

$$\frac{dV(c)}{dc} = -C \frac{i^2(c)}{A} > 0,$$

and that, absent bailouts, banks always want to increase cash holdings to refinance fully. In contrast, under full information and no commitment (and ex-post bailouts), $\eta(c|\bar{c}) = 1$ and $\eta'(c|\bar{c}) = 0$. This implies

$$\frac{dV(c)}{dc} = -[D + P_2(2 - \rho_0 - \pi)] \frac{i^2(c)}{A} < 0$$

where D is given by the left hand side of Assumption 4 (and hence positive). In this case, banks always want to reduce cash reserves to maximize the size of the project, as bailouts are guaranteed.

Hence, if holding more cash does not change the probability of bailouts, i.e. $\eta' = 0$, there is a cutoff $\bar{\eta}$, such that for all probabilities of bailout low enough (this is, $\eta < \bar{\eta}$), banks would like to increase cash holdings to refinance fully. Focusing on symmetric strategies (deviations evaluated at $c = c'$) and substituting $\eta(c'|c') = 0.5$ and $\eta'(c'|c')$ into expression (14),

$$\frac{dV(c)}{dc} = -Z \frac{i^2(c)}{A} + \frac{\phi(0)}{\sqrt{2}\sigma_h} \frac{P_2\rho_1}{1 - \rho_0} [1 - \rho_0 - c] i(c),$$

where Z is defined by $Z \equiv C + \frac{P_2\rho_1}{1 - \rho_0} [1 - \frac{\rho_0 + \pi}{2}]$.

Using these expressions, one can characterize the equilibrium with shocks to cash holdings and relate it to the variance of those shocks, σ_h .

Proposition 4 (Equilibrium with Shocks to Cash Holdings).

(i) If $Z \leq 0$, there is a unique equilibrium with cash holdings to refinance fully in expectation, $c^*(\sigma_h) = 1 - \rho_0$ for all σ_h .

(ii) If $Z > 0$, define

$$\underline{\sigma}_h = \frac{P_2\rho_1\phi(0)}{\sqrt{2}(1 - \rho_0)Z} (1 - \rho_0)(1 - \pi).$$

For all $\sigma_h > \underline{\sigma}_h$ equilibrium cash holdings are $c^*(\sigma_h) = 0$.

For all $\sigma_h \leq \underline{\sigma}_h$ equilibrium cash holdings $c^*(\sigma_h) \in [0, 1 - \rho_0]$ are unique, decreasing in σ_h and solve

$$\frac{dV(c^*)}{dc} = -\frac{Z}{1 - \pi + c^*} + \frac{\phi(0)}{\sqrt{2}\sigma_h} \frac{P_2\rho_1}{(1 - \rho_0)} [1 - \rho_0 - c^*] = 0. \quad (15)$$

Intuitively, a bank wants to deviate from a symmetric strategy, holding more cash than the other bank, to increase the chances of being second in distress and obtaining a bailout when the shock is aggregate. The gains from this deviation, however, are decreasing in σ_h , as the larger the variance of shocks to cash holding the more uncertain is the relative position as a function of c . In contrast, the cost from the deviation is independent of shocks to cash holdings. This implies that the larger is σ_h , the lower the benefit from deviating and in equilibrium banks hold less cash to face refinancing needs in case of an aggregate shock.

If $\sigma_h = \infty$ the randomness of cash holdings is so large that banks cannot change their relative position by reducing leverage. Then, strategic restraint depends purely on the sign of (14) evaluated at $\eta = \frac{1}{2}$ and $\eta' = 0$ (that is, the sign of Z). For $\sigma_h < \infty$, holding more cash reduces the probability of being the first bank in distress when the shock is aggregate, which is captured by $\eta' > 0$. The smaller the σ_h , the larger the marginal increase in such probability and the more likely that expression (14) is positive, inducing more deviations and more cash holdings in equilibrium. In the limit, when $\sigma_h = 0$, $\eta' = \infty$, and the bank can guarantee being the second in distress just by deviating and holding slightly more cash, recovering the benchmark model and the commitment outcome with full refinancing.

3. Policy Implications

The results of the previous section show that *government uncertainty* together with *strategic restraint* has the potential to implement allocations closer to efficient commitment outcomes, even in the absence of commitment. The sections below discuss which market structures and features of the industry support the discipline on leverage implied by our informational friction. This analysis illustrates the applicability of the insights from the theoretical model to regulation and design of the banking industry, as well as provides an overview of the limitations of the mechanism.

More specifically, we study the impact of financial innovation, excessively large banks and industry concentration on the potential of government uncertainty to induce more efficient outcomes in the absence of commitment. Our analysis points to three concrete policy prescriptions. First, it suggests a cap on the amount of cross insurance banks can hold, such as restrictions on the level of securitization across financial institutions. Second, it provides a new rationale for preventing ‘too big to fail’ banks, not only to avoid their bailouts in case of distress but also to prevent externalities that induce excessive leverage among smaller banks. Finally, it suggests encouraging competition in the banking industry through promoting entry.

3.1. Financial Innovation

How *government uncertainty* and bank behavior change with financial innovation that allows banks to insure away part of their idiosyncratic risk? The results of this section show that when banks are allowed to share risk with other banks, for example by holding a large amount of correlated assets, using swaps, over-the-counter derivatives, and other instruments to cross-insure each other's cash flows—as in the most recent period before the great recession—the industry as a whole is more susceptible to excessive leverage, crises and bailouts. Intuitively, when banks' balance sheets are connected, a single bank's distress is a more precise signal that the whole system received a shock and the government is more likely to bail out banks as soon they observe distress. As the delayed bailout condition is less likely to be satisfied, banks tend to take excessive leverage ex-ante. Below, we derive an optimal cap on the amount of cross insurance, denoted \bar{s} , that keeps moral hazard in check and still implements superior outcomes.

Consider the general setting of Section 2.4, with i.i.d. shocks to banks' cash holdings, $h \sim \mathcal{N}(0, \sigma_h^2)$, which hit at $t = 1$, after the refinancing shock has been realized (either aggregate or idiosyncratic). As a new element, let s be the fraction of the project of the other bank that each bank is holding. The remainder of this section derives comparative statics results on s , to analyze its effects on cash holdings and bailouts. Note that the well-known benefits of diversification are not modeled here, which allows us to focus on an unexplored cost of diversification – making the timing of distress of the first bank informative about the nature of the refinancing shock, hence hindering the strength of uncertainty as commitment.

The cash available to refinance when the shock is aggregate is as equation (11), while the cash available to refinance when the shock is idiosyncratic is

$$\widehat{c}(h, s)i = (c + s(\rho_0 + \rho_1) + h(1 - s))i.$$

In words, the bank has to pay for a smaller fraction of the project that needs refinancing and gets extra resources from the healthy project of the other bank.

Denote the time of distress when the shock is aggregate as $t^a(h|c)$ such that $(t^a(h|c) - 1)i$ is the scale of the project that can be refinanced at market rate. When the shock is aggregate, this is equivalent to Section 2.4, and hence $t^a(h|c) = t(h|c)$ is given by equation (12), with density given by $f^a(t|c) = f(t|c)$ in equation (13).

Denote the time of distress when the shock is idiosyncratic as $t^i(h|c)$, such that $(t^i(h|c) - 1)i$ is the scale of the project that can be refinanced at market rate. $t^i(h|c)$ can be written as a function of the expected time of distress $\bar{t}(c) = 1 + \frac{c}{1 - \rho_0}$ as follows

$$t^i(h|c) = \frac{\bar{t}(c) - s}{(1 - s)} + \frac{s(\rho_0 + \rho_1)}{(1 - \rho_0)(1 - s)} + \frac{h}{1 - \rho_0} \quad \text{if} \quad 1 - \bar{t}(c) < \frac{h(1 - s) + s(\rho_0 + \rho_1)}{1 - \rho_0} < 2 - \bar{t}(c) - s$$

with $t^i(h|c) = 1$ and $t^i(h|c) = 2$ in the corners of the interval.

Given the distribution of h , $t^i(h|c)$ is distributed according to density

$$f^i(t|c) = \begin{cases} \Phi\left(-\frac{1-\rho_0}{\sigma_h} \frac{(\bar{t}(c)-1)}{(1-s)} - \frac{s(\rho_0+\rho_1)}{\sigma_h(1-s)}\right) & \text{for } t = 1 \\ \phi\left(\frac{1-\rho_0}{\sigma_h} \left(t - \frac{\bar{t}(c)-s}{(1-s)} - \frac{s(\rho_0+\rho_1)}{(1-\rho_0)(1-s)}\right)\right) & \text{for } 1 < t < 2 \\ 1 - \Phi\left(\frac{1-\rho_0}{\sigma_h} \frac{(2-\bar{t}(c)-s)}{(1-s)} - \frac{s(\rho_0+\rho_1)}{\sigma_h(1-s)}\right) & \text{for } t = 2 \end{cases} \quad (16)$$

where ϕ and Φ are the pdf and cdf of the standard normal distribution, and the mean of $t^i(h|c)$ (i.e. setting $h = 0$) is equal to $\frac{\bar{t}(c)-s}{(1-s)} + \frac{s(\rho_0+\rho_1)}{(1-\rho_0)(1-s)}$.

When $s > 0$, $f^i(1|c) < f^a(1|c)$ and $f^i(2|c) > f^a(2|c)$, which implies that the government is more likely to see aggregate shocks earlier than idiosyncratic shocks. The updated probability of an aggregate shock, conditional on observing a first bank in distress is then

$$P'_2 = \frac{P(t^a(h) = t|Agg)P_2}{P(t^a(h) = t|Agg)P_2 + P(t^i(h) = t|Id)P_1},$$

and the government does not bailout the first bank in distress when this probability is smaller than the cutoff \bar{P} from the delayed bailout condition (8)

$$P'_2 = \frac{\frac{f^a(t|c) P_2}{f^i(t|c) P_1}}{1 + \frac{f^a(t|c) P_2}{f^i(t|c) P_1}} \leq \bar{P}. \quad (17)$$

Note that, when $s = 0$, $f^a(t|c) = f^i(t|c)$, and P'_2 is the one obtained in the benchmark model in equation (4). For $s > 0$, the likelihood ratio under normality is declining in t , and therefore a sufficient condition for (17) to hold at any moment t is that it holds at $t = 1$, which gives

$$\left(\frac{\bar{t}(c)-s}{(1-s)} + \frac{s(\rho_0+\rho_1)}{(1-\rho_0)(1-s)} - 1\right)^2 - (\bar{t}(c)-1)^2 \leq 2\sigma_h^2 \ln\left(\frac{\bar{P}}{(1-\bar{P})} \frac{P_1}{P_2}\right). \quad (18)$$

Since the left hand side of (18) is strictly increasing in s and the right hand side is a constant, there is a strictly positive cross-insurance level \bar{s} that is the minimum between 1/2 (the maximum possible level of cross-insurance) and the value of s that satisfies (18) with equality.

Any level of cross-insurance lower than or equal to \bar{s} guarantees an outcome more efficient than the non-commitment outcome with full information. Banks always want to engage in maximum allowable cross-insurance if it induces bailouts, and are indifferent otherwise. This implies that a government should set a restriction of not allowing securitization above \bar{s} .

Finally, it is straightforward to see that \bar{s} is weakly increasing in σ_h^2 . There is a σ_h^2 large enough such that $\bar{s} = 1/2$ and full insurance does not prevent uncertainty to implement the commitment outcome. In contrast, if $\sigma_h^2 = 0$, we are back to the benchmark case, in which $\bar{s} = 0$ and then any level of cross-insurance eliminates government uncertainty. In other words, the lower the volatility of cash flows the less cross-insurance (or securitization) a government should allow.

Remark on systemic risk. Cross-insurance here does not operate through affecting the systemic risk in the market, but instead by allowing governments to learn better about a systemic event. Alternatively, financial innovations could also allow banks to coordinate on a particular risk factor, making systemic events more likely. This is a straightforward extension of our model in which banks can directly affect the value of P_2 . If banks could coordinate to induce a relatively high probability of an aggregate shock (i.e., $P'_2 > \bar{P}$) then the government would not delay bailouts and, in the absence of strategic restraint, the outcome would be the full information no-commitment solution of our model. The policy prescription in such situation is to limit the use of cross insurance, inducing enough uncertainty about facing a systemic event to delay government intervention and induce banks to save more.

3.2. Too Big To Fail

This section studies the effects of asymmetric bank sizes on government incentives to delay bailouts. Our goal is to analyze the impact of *too big to fail banks* – banks whose balance sheets are very large relative to the whole industry. We show that our novel mechanism introduces a new rationale for the policy of capping bank size, beyond contagion and beyond moral-hazard of large banks, as highlighted by the literature. Banks that are ‘too big to fail’, i.e. so large that the rest of the industry cannot take them over privately, do not care about their relative position in showing distress, and hence have no incentive to reduce leverage. Then, in equilibrium, smaller banks just want to be slightly less leveraged than the big bank, and the ‘too big to fail’ problem generates more leverage in the whole industry.

Formally, in the benchmark model let us assume additionally that Bank 1 has higher initial assets than Bank 2, i.e. $A_1 > A_2$. This ex-ante asymmetry implies ex-post asymmetry in investment size and consequently a healthy Bank 2 may not have enough funds to take over a distressed Bank 1. Specifically, Bank 2’s available cash when its project is healthy is equal to $(\rho_0 + \rho_1 + c_2)i_2$. Hence, the scale of Bank 1’s project Bank 2 could refinance is

$$I = \min \left\{ \frac{(\rho_0 + \rho_1 + c_2)i_2}{1 - \rho_0}, (2 - \bar{t}_1)i_1 \right\},$$

Clearly, for large enough asymmetry, the maximal amount of money that Bank 2 can raise by leveraging up its own cash is not enough to refinance the portion of the project that Bank 1 cannot refinance with own funds.

Taking this restriction into account, the government delays the bailout of a large bank in distress when $(1 - P'_2)yI \geq x(2 - \bar{t}_1)i_1$, or

$$P'_2 \leq 1 - \frac{x}{y \left(\frac{I}{(2 - \bar{t}_1)i_1} \right)}. \quad (19)$$

When A_2/A_1 goes to zero, i_2/i_1 also goes to zero, as does the right hand side of the inequality. This implies there is a level of asymmetry large enough

such that the government always bails out the large bank in distress, regardless of the updated belief about the probability of an aggregate shock. In contrast, as A_2/A_1 goes to one, the inequality converges to the original equation (8).

If condition (19) does not hold, Bank 1 has no incentive to restrain leverage, as it is bailed out anyways, then choosing $c_1 = 0$. This implies that it is optimal for Bank 2, conditional on Bank 1 holding no cash, to hold a slightly positive amount of cash to guarantee showing distress in second place when the shock is aggregate. The large bank becomes a ‘shield’ for the small bank to engage in inefficient levels of leverage. This points to an unexplored source of negative externality of ‘too big to fail’ banks for households, who may not only need to bailout large banks but also excessively exposed small banks.

3.3. Number of banks

This section studies the government incentives to bail out the first bank in distress when $N > 2$. Having more banks in the economy reduces the incentives to bail out the first bank in distress due to two forces. First, having more banks implies a higher chance that there is enough liquidity in the system for a takeover of a single distressed bank. Second, it increases the option value of delaying and learning. Both having a smaller ‘test case’ and larger ‘rest of industry’ at stake makes it more valuable for governments to wait and see in order to make more informed decisions later on. This implies a beneficial role of policies that encourage a large number of banks operating in the industry.

An important insight is that not bailing out the *first* bank in distress is enough to trigger strategic restraint and obtain outcomes closer to the commitment allocation. Hence, the analysis below focuses on the government’s incentives to bail out the first bank in distress. Denote by $p_{(N,d)|\hat{d}}$ the probability of having d banks in distress conditional on having N banks in total and observing \hat{d} banks already in distress. In our benchmark with $N = 2$, $p_{(2,2)|1} \equiv P'_2$ was the probability of an aggregate shock conditional on observing one bank in distress.

We initially impose two restrictions, which will be relaxed later. First, the second bank in distress is always bailed out. Second, the probability of an aggregate shock is independent on the number of banks. The next Lemma, proved in the Appendix, is an important benchmark to understand the effects of N on delay decisions. Under the above two restrictions, the number of banks N does not affect the conditions for delaying the bailout of the first bank.

Lemma 2. *Let $p_{(N,N)|1} = p$ for all N . If the government always bails out a second bank in distress, the delayed bailout condition is $p < 1 - \frac{x}{y}$ for all N .*

In the next two lemmas, each of the two restrictions is separately relaxed to isolate the two reasons for which the government is more likely to delay intervention as the number of banks increases.

First, let us relax the assumption that governments have to intervene if a second bank is in distress. This introduces the option value of not bailing out the first bank and having the chance to make the optimal decision of not bailing out other banks in distress. Lemma 3 shows that having more banks introduce an option value of learning and making better decisions ex-post.

Lemma 3. *For all N , let $p_{(N,N)|1} = p$, $p_{(N,N-1)|2,to} = p'$ conditional on the first bank being taken over (to) and $p_{(N,N-1)|2,nto} = 1$ conditional on the first bank not being taken over (nto). The probability to bailout the first bank in distress weakly decreases with N .*

Second, Lemma 4 relaxes the assumption that the probability of an aggregate shock is independent of N . Intuitively, if the idiosyncratic shocks are i.i.d., and independent of the aggregate shock,¹⁷ then it is more likely that at least one bank is in distress (for idiosyncratic reasons) when there are many banks, and then less likely that the first bank in distress is not taken over by another bank.

Lemma 4. *If governments always bailout second banks in distress, the probability of a bailout of the first bank in distress weakly decreases with N .*

Together, the previous three lemmas are summarized as follows.

Proposition 5. *The larger the number of banks in the economy, the more likely it is for the government to delay the bailout of the first bank in distress.*

This proposition implies that a large number of banks in the economy results in a more likely delayed intervention. In such case, the strategic restraint kicks in as banks compete for their relative position and reduce their excessive leverage.

4. Conclusions

At the onset of financial crises banks usually show distress sequentially. Then, at least initially, governments are *uncertain* about the nature of the problem at hand, and may decide to delay intervention to learn more about the underlying situation from market outcomes. Crucially, these intervention delays trigger a ‘rat-race’ competition among banks for not being among the first in distress, which *strategically restrain* their risk taking and their exposure to refinancing shocks, reducing the likelihood and size of crises.

These novel forces have dramatic effects on equilibrium outcomes. While seminal models of banking and liquidity, such as Holmström and Tirole (1998) and Farhi and Tirole (2012), show that non-commitment tends to lead to endogenous crises and inefficient bailouts, our analysis shows that this is not necessarily the case in the presence of *government uncertainty* about the nature of crises.

Based on these insights, we provide a novel discussion of how financial innovations, banking concentration and the existence of excessively large banks increases the likelihood and size of crises and the needs for inefficient bailouts. In our mechanism, these characteristics of the banking industry work through

¹⁷As long as the idiosyncratic shocks are not perfectly correlated, one can split them into purely i.i.d. component and the aggregate component, which would directly map into our setup and all the analysis goes through.

improving learning about the nature of shocks or by reducing the incentives to delay intervention.

The literature has identified the time-inconsistency of governments' policies as an important justification for macro-prudential regulation and direct oversight of banking activity. However, historically regulators have been incapable to design macro-prudential regulation that prevents crises without choking off growth. Our work suggests that it may be optimal for governments to also design political structures that delay intervention, or regulatory standards that maintain an optimal level of uncertainty, imposing lower burdens on preventive regulation and giving more room to facilitate optimal self-regulation. Contrary to the common view that more information and faster action are desirable characteristics of policymaking, we make the case that banks' perception about governments reacting fast to systemic events give them incentives to coordinate on those events, endogenously generating crises.

In our analysis, governments cannot learn the nature of a bank's distress, but clearly in the model, ex-post they would prefer to have such knowledge and react optimally. From an ex-ante perspective, however, governments that lack commitment would rather not have the possibility to learn rapidly, making more mistakes when crises happen, but also reducing the probability of those crises. Even though it may be difficult for a government to commit not to modify bailout decisions ex-post, they could easily avoid ex-ante the implementation of technologies to learn rapidly or to take fast decisions when distress happens. Examples of these ex-ante institutional designs include cumbersome bureaucratic steps for decision-making, parliamentary systems with lengthy discussions and supermajority rules to pass interventions, the fragmentation of supervisory bodies with separate functions and access to incomplete pieces of information, insufficient information sharing across government bodies, etc.

References

- Acharya, V., Yorulmazer, T., 2007. Too many to fail - an analysis of time-inconsistency in bank closure policies. *Journal of Financial Intermediation* 16, 1–31.
- Baker, S., Bloom, N., Davis, S., forthcoming. Measuring economic policy uncertainty. *Quarterly Journal of Economics* .
- Bianchi, J., 2016. Efficient bailouts? NBER Working Paper 18587.
- Carrillo, J., Mariotti, T., 2000. Strategic ignorance as a self-disciplining device. *Review of Economic Studies* 67, 529–544.
- Cheng, I.H., Milbradt, K., 2012. The hazards of debt: Rollover freezes, incentives and bailouts. *Review of Financial Studies* 25, 1070–1110.
- Cochrane, J.H., Zingales, L., September 9, 2009. Lehman and the financial crisis. *The Wall Street Journal* .

- Cremer, J., 1995. Arm's length relationships. *Quarterly Journal of Economics* 110, 275–296.
- Cukierman, A., Izhakian, Y., 2015. Bailout uncertainty in a microfounded general equilibrium model of the financial system. *Journal of Banking & Finance* 52, 160–179.
- Davila, E., 2012. Does size matter? bailouts with large and small banks. Working Paper, Harvard University.
- Farhi, E., Tirole, J., 2012. Collective moral hazard, maturity mismatch and systemic bailouts. *American Economic Review* 102, 60–93.
- Freixas, X., 1999. Optimal bail out policy, conditionality and constructive ambiguity. Working Paper 400, Universitat Pompeu Fabra.
- Green, E., 2010. Bailouts. *Economic Quarterly*, Richmond Fed .
- Holmström, B., Tirole, J., 1998. Private and public supply of liquidity. *Journal of Political Economy* 106, 1–40.
- Keister, T., 2015. Bailouts and financial fragility. *The Review of Economic Studies* , rdv044.
- Kelly, B., Lustig, H., Van Nieuwerburgh, S., forthcoming. Too-systemic-to-fail: What option markets imply about sector-wide government guarantees. *American Economic Review* .
- Pasten, E., 2015. Bailouts and prudential policies - a delicate interaction. Working Paper, Central Bank of Chile.
- Perotti, E., Suarez, J., 2002. Last bank standing: What do i gain if you fail? *European Economic Review* 46, 1599–1622.
- Stern, G., Feldman, R., 2004. Too Big to Fail: The Hazards of Bank Bailouts. The Brooking Institution.