Rules versus Discretion in Bank Resolution*

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Recent reforms give regulators broad powers to "bail-in" bank creditors during financial crises. We analyze efficient bail-ins and their implementation. To preserve liquidity, regulators must avoid signaling negative private information to creditors. Therefore, optimal bail-ins in bad times depend only on public information. As a result, the optimal policy cannot be implemented if regulators have wide discretion, due to an informational time-inconsistency problem. Rules mandating tough bail-ins after bad public signals, or contingent convertible (co-co) bonds, improve welfare. We further show that bail-in and bailout policies are complementary: if bailouts are possible, then discretionary bail-ins are more effective.

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In many modern financial crises, governments have bailed out failing banks at the expense of taxpayers.[1] Since the crisis of 2008, governments have focused on ending this "too big to fail" problem. One element of this policy has been the plan to replace bailouts with *bail-ins*. During bail-ins, bank regulators write down the debt liabilities of large failing banks rather than letting them go into a standard bankruptcy process. An attractive feature of this approach is that the reduction in bank leverage comes at the expense of private creditors, not taxpayers, which mitigates the concerns about moral hazard and fairness that are associated with bailouts. However, the credibility of the new regime is hotly debated. On one hand, policy-makers have expressed great confidence, and the availability of bail-in has even been cited as an argument *against* tougher capital regulation.[2] On the other hand, bail-in is mostly untested, and its first applications in 2017 did not work exactly as envisioned: The Italian government wrote down debt to avert the failure of Monte dei Paschi di Siena, but then used public funds to provide support to its creditors. In Banco Popular of Spain, debt was bailed-in, but its resolution was achieved mainly through "purchase and assumption" by its much larger competitor Santander, which made a substantial capital injection. It is therefore still unclear whether bail-ins alone can credibly avoid bailouts in banks that are too large and complex to be resolved by purchase and assumption, or in future systemic crises where willing and able buyers are not available.[3]

Despite this active policy debate, few papers have formally studied the effectiveness of bail-in regimes, or asked how bail-in policy ought to be designed to ensure credibility. In this paper, we introduce the regulatory option to bail-in to a standard model of banking. A simple example illustrates the key friction: Suppose that a regulator has bail-in powers, and finds out that an important bank is exposed to large potential losses. The regulator will be keen to conduct an aggressive bail-in policy to recapitalize the bank, but if the bank's exposure is not yet public

[1] Laeven and Valencia (2013), for example, provide an account of the fiscal costs of financial crises.

[2] For example, Treasury Secretary Jack Lew (2013) states that *"the reforms we are putting in place raise the cost for a bank to be large, requiring firms to internalize their risks, and together, with resolution authority and living wills, make clear that shareholders, creditors, and executives—not taxpayers—will be responsible if a large financial institution fails"*. Bank of England Governor Mark Carney (2016) argues that bail-in *"will reduce both the likelihood and probable impact of systemic bank failures, leaving the system less reliant on going concern capital to do the heavy lifting"*.

[3] See Financial Times (2017a) and Financial Times (2017b) for an account of the bail-ins at Monte dei Paschi di Siena and Banco Popular, respectively.

information, then she needs to tread carefully avoid signaling bad news which would create a bank run. This dual concern about bank runs and bank capital became apparent, for example, during the Cypriot financial crisis of 2013, when regulators were obliged to close banks temporarily in order to avoid bank runs while bail-ins were finalized. We show that this simple problem has rich implications for institutional design; in particular, it implies that the existing policy framework – which gives regulators wide discretion over their bail-in policies – is generally inefficient.[4]

Our formal model features a bank which invests in long-term projects, financed by a combination of long-term debt, short-term debt and its own equity capital. Debt investors are willing to pay a premium for safe, liquid securities, and equity capital is a scarce resource and is therefore costly. These two deviations from the Modigliani-Miller assumptions generate a meaningful choice of capital structure. At an interim date, there is a public signal about the bank's asset value. The bank and a benevolent regulator have additional private information about the value of the bank's assets. The regulator has the power to conduct a bail-in policy, that is, to write down long-term debt obligations.[5] The motivation for bail-ins is a classic debt overhang problem: If asset values have deteriorated and the bank owes a lot of debt, then its shareholders do not take value-maximizing actions, because the benefits from doing so would mainly accrue to debtholders. At the same time, the bank's short-term debt becomes due and it must issue new debt to creditors, who draw inferences about its health from the public information s and from the regulator's bail-in choice. If the bank cannot roll over its debt, then there is in effect a bank run and the bank fails prematurely.

In this setting, we first solve for the socially optimal combination of bank capital structure and bail-in policy. Formally, we consider a constrained social planner who can determine the

[4]The current legal "triggers" for new bank resolution regimes and bail-ins are largely based on judgment calls by governments and regulators. For example, the FDIC's Orderly Liquidation Authority (Chapter II of the Dodd-Frank Act) is triggered whenever the Treasury Secretary determines that "a financial company is in default or in danger of default", and "its resolution under otherwise applicable Federal or State law would have serious adverse effects on financial stability", among other criteria (see Title 12 U.S. Code, §5383). Similarly, the European Single Resolution Mechanism takes action when its Board finds that a bank "is failing or is likely to fail" and that a resolution action is necessary to avoid "significant adverse effects on financial stability", among other objectives (see EU Regulation 806/2014, Articles 14-18). Since these criteria involve subjective predictions about financial stability, they effectively allow for wide regulatory discretion.

[5]In practice, creditors often receive newly issued shares in the bank when their debt claims are written down, in order to satisfy the legal requirement that bail-in must not leave them worse off than bankruptcy. We discuss these additional design choices in depth in Section 3.

bank's funding choices and commit to a state-contingent bail-in policy, but who cannot circumvent financing constraints. We show that welfare is maximized by making bail-ins insensitive to private information in states of the world where bad public news has already arrived. Doing so prevents further negative swings in market beliefs about the bank's health and, therefore, enhances the bank's capacity to issue safe, liquid assets at a premium without facing bank runs. This benefit is traded off against the cost of failing to fine-tune bail-ins to the assets of the bank: using an information-sensitive policy reduces the overall extent of write-downs, decreasing the cost of long-term debt to the bank. Specifically, with a more information sensitive policy, the yield on the bank's long-term debt falls, and less costly equity is needed; however, less safe debt can be issued at a premium, increasing the need for equity finance. The optimal policy ex ante strikes a balance between these two, minimizing the cost of financing the bank's investment.

Next, we analyze how the planner's choices can be implemented in a decentralized economy. In practice, bail-ins choices are delegated to regulatory institutions. We consider a class of games where the government imposes restrictions on the permitted set of bail-in policies as a function of publicly available information (since the regulator's private information is difficult to verify). The regulator observes the public information and her private signal about the bank, and then chooses the bail-in policy within the permitted set which maximizes welfare.

Given that the regulator is benevolent and well-informed, it might seem natural to give her full discretion to act upon her superior information, that is, to impose no restrictions her choice on the bail-in policy, and in fact existing bail-in legislation does give regulators wide discretion as to when and how much debt to write down. However, we show that full discretion never implements the optimal policy in a stable equilibrium. The difficulty arises after bad public news, when the optimal policy is information-insensitive. In that case, if the regulator receives good private news, she has a strict incentive to signal it to the market, and can credibly do so by weakening her bail-in policy relative to the ex ante optimum. Since this is a profitable deviation, an information-sensitive policy cannot survive in the decentralized equilibrium with discretion.

The regulator thus faces a time-inconsistency problem:[6] For bad public signals, she would like

[6] Although the regulator's time-inconsistency problem is distinct from that of Kydland and Prescott (1977), because it is driven by an informational externality: From an ex ante perspective, it is sometimes optimal for regulators with

to commit to an information insensitive policy ex ante, but when good news arrives ex post, she has every incentive to reveal it. This destroys the liquidity insurance that she hoped to benefit from if bad private news arrived, but at this point, the value of insurance is a bygone since good private news has arrived.

We show that the optimal regime can instead be implemented by allowing the regulator discretion after good public news (to allow her to choose the optimal separating policy) and imposing binding rules on bail-ins after bad public news (to eliminate her ability to deviate from the optimal pooling policy). One can think of this implementation as a prescription for explicit legislation which forces regulators to be tough in bad times, but allows them discretion in good times. We further show that the optimal regime can be implemented, equivalently, with contingent convertible (co-co) bonds, which write down the value of debt contingently on publicly observable signals.

As an extension, we analyze the interaction between bail-ins and bailouts. We introduce a bailout fund that the government can use to make transfers to struggling banks. Our model uncovers a complementarity between bail-ins and bailouts. We show that one benefit of bailouts is that they allow for a more accurate, information-sensitive bail-in policy, because they alleviate creditors' immediate concerns about bank runs. Conversely, if the government removes the possibility of bailouts, the time-inconsistency problem of bail-ins becomes more acute, and it is necessary to impose tighter rules on bail-in policy. Interestingly, this result stands in some contrast to current practice: Since 2008, governments have been striving to put in place institutional commitments that will make it harder for them to grant bailouts in future crises, but these commitments have coincided with the introduction of bail-in regimes which still allow for a significant amount of discretion (see footnote 4). Our analysis suggests that, instead, a partially rule-based regime would be more desirable.

good private news to provide insurance to ones with bad news by conducting an information-insensitive policy. In Kydland and Prescott (1977) and subsequent literature, the government moves last, and is tempted to create ex post inflation surprises to boost output. In our model, markets move last, and the problem of discretion is rather that the regulator has private information and that her action choice results in undesirable information leakage.

Related literature

Our results contribute to a recent literature on bail-ins and bank resolution. Bolton and Oehmke (2018) study the problem of coordinating bail-ins in multinational banking corporations and characterize the incentive problems that arise between national regulators. Keister and Mitkov (2017) analyze a model where banks themselves choose the timing of bail-in, and show that banks will not pull the trigger to initiate a bailout at the right time if they expect to be bailed out by the state. Colliard and Gromb (2017) show that a moderate commitment to bail-ins can prevent inefficient delays in debt restructuring negotiations. We focus instead on the optimal design of bail-in policy and its interaction with bailouts, when policies are chosen by benevolent regulators without conflicts of interest. Mendicino et al. (2017) numerically solve for a bank's optimal capital structure when bail-ins are frictionless. We complement their work by analyzing how the capital structure and bail-in policy should be jointly designed in a second-best world.

The starting point of our analysis relates to Angeletos et al. (2006) and Bouvard et al. (2015), who point out policy frictions related to signaling. Unlike these papers, we solve for the optimal institutional structure. We highlight a trade-off between liquidity creation and accurate policy, and associated institutional considerations, which provide specific insights for the problem of bail-ins in banking.

Bail-in policies are an example of ex post interventions in times of financial crisis. Previous work focuses on the most efficient ways to design government support and bailouts (Farhi and Tirole, 2012; Keister, 2016; Bianchi, 2016), stress test disclosures (Bouvard et al., 2015; Goldstein and Leitner, 2018; Faria-e-Castro et al., 2016; Orlov et al., 2017; Quigley and Walther, 2017) and liquidity support in frozen credit markets (Aghion et al., 1999; Tirole, 2012; Philippon and Skreta, 2012). A consensus in this literature is that it is neither desirable nor feasible to provide full, unconditional support to failing banks. We show that under such conditions, bail-in improves welfare by increasing bank capital without public funds, but is still limited by the need to prevent bank runs. Moreover, various authors have studied the trade-off regulators face between taking inefficient private actions (forbearance) and efficient public actions (foreclosure) in struggling banks, in the presence of reputational concerns (Boot and Thakor, 1993; Shapiro and Skeie, 2015; Morrison

and White, 2013). In our paper, the regulator does not have the option of taking a secret action, so her choice is instead between public action or public hesitation. This modeling choice can be interpreted as reflecting the level of transparency required of the Federal Reserve, for example.

Our work also relates to the literature on contingent convertible (co-co) bonds and related securities.[7] Pennacchi (2011) and Albul et al. (2013) analyze the impact of co-cos on insiders' incentives. Sundaresan and Wang (2014) and Pennacchi and Tchistyi (2019; 2017) assess whether market-based triggers in contingent contracts can lead to multiple equilibria. Pennacchi et al. (2013), Hart and Zingales (2011) and Bulow and Klemperer (2015) propose security designs to overcome this problem. Our results present an entirely new rationale for encouraging banks to issue such securities, namely to provide commitment for regulatory policy. Our analysis of contingent capital also helps to motivate the question of co-co design: Our implementation works best if co-cos avoid multiple equilibria and their conversion is credibly beyond the regulator's control.

1 Model

We analyze bail-in policies in an economy where a bank faces potential illiquidity, and where the bank and its regulator privately observe information about the value of the bank's assets. When the regulator obtains this information, she has the power to conduct an early bail-in; in particular she can choose to write down the face value of bank's existing long-term debt to a fraction of its initial value. Early bail-ins serve to alleviate a debt overhang problem that arises when the bank's assets have lost value. In Sections 2 and 3, we discuss the wider institutional details of bail-in policy, the role of debt overhang, and the extent to which our insights go through under alternative assumptions.

Timing and agents: There are three dates $t \in \{0, 1, 2\}$ and three sets of agents: A single bank, a government agency called the regulator, and a population of creditors with unit measure. The

[7] Co-co bonds were first proposed by Flannery (2005) as "reverse convertible debentures". Flannery (2013) provides an excellent survey of the existing literature. As an alternative, Bolton and Samama (2012) propose "capital access bonds" that allow equity issuance at a pre-specified price. Duffie (2015) discusses the related issue of resolving central counterparties in financial markets.

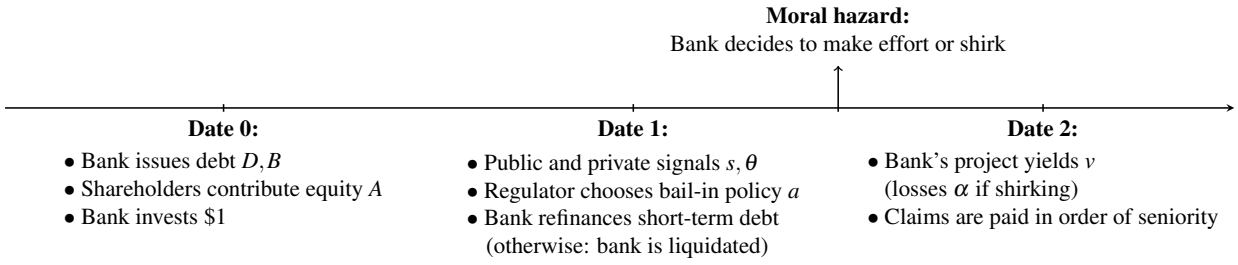


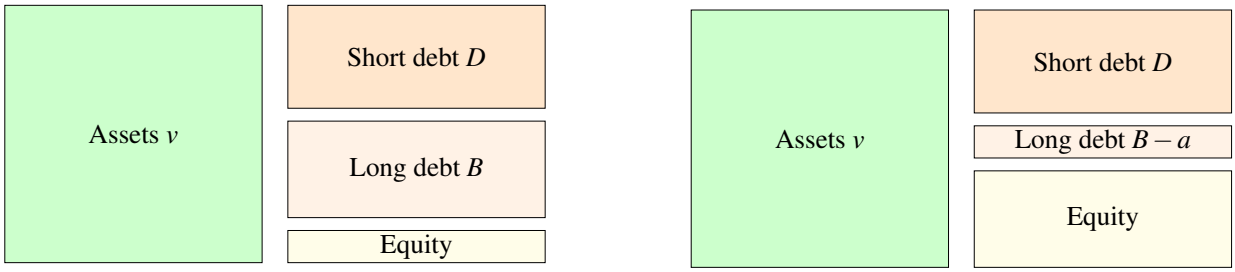
Figure 1: Timeline

regulator is benevolent and maximizes expected total welfare. The bank acts in the interest of its shareholders, who have limited liability. All agents are risk-neutral. Figure 1 illustrates the timing of events, and Figure 2 shows the bank's balance sheet, which we now describe in detail.

Bank assets: At date 0, the bank makes a long-term risky investment, which requires one dollar of investment at date 0. The investment pays a random cash flow of $v \in [\underline{v}, \overline{v}]$ dollars, with density $f(v)$, if held to maturity at date 2, and nothing if it is liquidated at date 1. In making this latter assumption, we intend our model to analyze large, systemically important banks. When small banks fail, they are typically resolved by finding an expert buyer such as another bank (a model known as "purchase and assumption"), which may allow the deadweight losses of early liquidation to be avoided. By contrast, bail-in policies were introduced specifically to allow regulators to resolve "too-big-to-fail" banks, whose assets and operations cannot be easily absorbed by other banks, without having to resort to costly taxpayer subsidies.

If assets are not liquidated at date 1, the bank's shareholders choose whether to make further effort to manage the bank's project, or to shirk. If they choose to shirk, then the bank's asset values fall by a fraction α, but shareholders enjoy a private benefit equal to β.[8] We define $x \in \{0, 1\}$ as a (possibly state-contingent) indicator denoting whether the bank shirks at date 1.

[8]For simplicity, we do not model the agency problem between the bank's shareholders and its managers. One can think of our reduced form in two ways. First, one can consider that outside shareholders decide on the bonus level for the inside managers. If the shareholders decide to provide a sufficiently large bonus for the managers, then the managers will not shirk, and the bank's asset values will be maintained between date 1 and date 2; whereas if shareholders decide to offer reduced bonuses, managers will not exert effort to maintain asset values, but shareholders will save on compensation. Second, one can consider that a large fraction of the equity in some systemic financial institutions is actually held by insiders, so that the decision of shareholders to exert effort to maintain asset value if equity has sufficient stake in the outcome can actually be taken literally.



(a) Before bail-in (b) After bail-in

Figure 2: Bank balance sheets before refinancing at date 1

At date 1, there is asymmetric information about the value v of the bank's assets. Everybody observes a noisy public signal $s \in [\underline{s}, \bar{s}]$ about v, drawn from the conditional density $g(s|v)$. The regulator and the bank further observe a private signal θ of v, drawn from the conditional density $h(\theta|v)$. The private signal is binary (either good news or bad news): $\theta \in \{\theta_B, \theta_G\}$, with $\theta_G > \theta_B$. We assume that s and θ are independent conditional on v, and that they are ordered in the sense of the strict monotone likelihood ratio property: $g(s|v')/g(s|v)$ and $h(\theta|v')/h(\theta|v)$ are strictly increasing in s and θ respectively, for all $v' > v$.

We further assume that $0 < \beta < \alpha E[v|s, \theta]$ for all s and θ, so that effort is costly, but has positive social value conditional on the information available at date 1.

Bank liabilities and bail-in policies: At date 0, the bank issues short-term debt with face value D and long-term bonds with face value B.[9] The rest of its investment is funded with an equity contribution A from the shareholders. At date 1, the bank needs to raise D in order to refinance its short-term debt. Otherwise, it faces insolvency and liquidation. To raise D, the bank issues new short-term debt at date 1 with face value $D(1 + r)$, where r is an endogenous, possibly state-contingent, interest rate.

The regulator can intervene at date 1 by writing down the face value of long-term debt to $B - a$, where $a \in [0, B]$. The amount of the *bail-in,* a, which is the focus of our analysis, is

[9]In our model, the bank's debt is not explicitly insured by the government. In modern banking systems with deposit insurance, runs generally take place in uninsured wholesale credit markets, such as repo and commercial paper, rather than on retail deposits. Wholesale runs are discussed in detail by Shin (2009), Gorton and Metrick (2012) and Krishnamurthy et al. (2014).

publicly observed. A bail-in generates a social deadweight loss of κa, where $\kappa > 0$. The cost parameter κ can represent the administrative cost of intervention. It can also capture the political cost of transferring resources away from debtholders. Since such costs may be second-order for the regulator, compared to the economic benefits of resolving an important bank, we present our main analysis for the limiting case where they are infinitesimal, $\kappa \downarrow 0$, but still positive. This treatment implies that the impact of bail-in costs on welfare is negligible, but *ceteris paribus*, the government prefers a smaller intervention. We discuss the nature of these costs in more detail in Section 3.1, where they become more salient.

For the simplest exposition, we have defined bail-ins as a simple "haircut" on long-term debt. In practice, instead of writing down long-term debt, the regulator could convert each bond into a certain number of equity shares. In our model, it is not essential whether the bank's shareholders after a bail-in are the original shareholders, or newly converted bondholders. The only important feature is that effort choices at date 1 are made to maximize the expected value of the residual equity claim, regardless of who owns this claim. The distinction between haircuts and conversion would be more economically important if there were additional moral hazard at date 0, so that the incentives of initial shareholders would depend on whether they expect to be diluted during future bail-ins. In that context, it would also be important to consider the coordination between initial shareholders ("insiders") and newly converted bondholders ("outsiders"). We defer a detailed discussion of these effects to Section 3.[10]

At date 2, all outstanding debt claims on the bank are settled. If the value of the bank's assets is less than the debt claims upon them, $v < D(1 + r) + B - a$, then the bank is insolvent and its creditors seize its assets. In line with current practice, we assume that short-term debt enjoys absolute priority over long-term bonds in case of insolvency.[11]

[10] In addition to choosing between haircuts and conversions, regulators could further decide whether to relax the seniority of short-term creditors or even impose losses on them as part of a bail-in. However, we show in Section 3 that the case we consider – where short-term creditors remain senior in a bail-in – is an optimal arrangement.

[11] Short-term debt in bank holding companies is *structurally* senior to most long-term debt, because short-term debt is issued at the subsidiary level, while long-term debt tends to be a claim on the holding company. For an accessible guide to how this structural subordination is achieved, and other recent policy changes, see Tucker (2014).

Preferences: Creditors and bankers are risk-neutral and do not discount the future. We introduce two departures from the Modigliani-Miller conditions which imply that the bank faces a genuine trade-off between long-term debt, short-term debt and equity finance. First, creditors derive utility from holding safe and liquid claims between dates 0 and 1. Specifically, if the bank's short-term debt D is completely safe (i.e. certain to be repaid in full at date 1), then creditors are willing to pay $(1+\lambda)D$ for this claim, where $\lambda > 0$ is a measure of liquidity preference. This specification generates a social role for risk and maturity transformation in banks (see, for example, Stein (2012), Dang et al. (2017), Bolton and Oehmke (2018)).

Second, equity contributions are costly and reduce bank shareholders' utility by ϕA, where $\phi > 0$ measures the cost of equity and A is the amount of equity. This parameter can capture direct costs of equity issuance, a time preference for early consumption among shareholders, or the shadow cost of committing scarce equity capital that could have been used to increase the scale of investment instead of reducing per-unit leverage (e.g., Holmstrom and Tirole (1997)).

2 Optimal design of bail-in policy

We set up and solve the problem of a constrained social planner in order to understand which bail-in policies are, in principle, most efficient. In this section, the planner can dictate the bank's capital structure choices at date 0, and commit to a bail-in policy at date 1. Moreover, the bail-in choice can be made contingent on both public and private information. However, the planner must respect the fundamental financial frictions in the model, namely, the bank's refinancing constraint and the debt overhang problem at date 1. Our main insight is that after good realizations of public news s, the optimal bail-in policy a is fine-tuned to the private signal θ, while after bad realizations of s, the planner commits to an information-insensitive policy so as to avoid revealing bad news to creditors in states when these creditors are already pessimistic.

The focus in this section is on the mechanism design problem, which clarifies the underlying economics without going into the institutional detail. In the next section, we show that the optimal policy can be implemented in a decentralized setting using a mixture of rules and discretionary

powers for regulatory institutions.

2.1 The planner's problem

Formally, we define the social planner's choices as follows: At date 0, she chooses the bank's capital structure: D (short-term debt) and B (long-term debt), and equity A to finance its investment. She also commits to a deterministic state-contingent bail-in policy $a(s, \theta)$ which she will employ at date 1, as well as an interest rate $r(s, \theta)$ that will be offered to new short-term creditors, and a recommended shirking decision $x(s, \theta)$ for the bank. These policies are designed before the realization of the public signal s and the private signal θ are known. Importantly, at date 1, the bail-in choice and the interest rate are publicly observed by creditors and may reveal information about θ if these policies were made contingent on θ. For any realization of s, we say that the policy is *pooling in state* s if $a(s, \theta_G) = a(s, \theta_B)$ and $r(s, \theta_G) = r(s, \theta_B)$, so that the regulator's actions after good and bad private news θ are indistinguishable. Otherwise, creditors can infer θ and we will say that the policy is *separating in state* s.

The planner's objective is to maximize aggregate welfare. Under our assumptions, it is never optimal to allow the bank to fail at date 1.[12] Expected welfare at date 0 is then proportional to

$$(E[v(1 - \alpha x(s, \theta)) + \beta x(s, \theta)] - 1) + \lambda D - \phi A \tag{1}$$

The first term in this objective function is the NPV of the bank's project, taking into account the bank's shirking behavior. The last two terms measure the social value of liquidity creation, and the cost of equity finance respectively. In our formulation, the scale of the project is fixed, so the project's NPV is constant. Alternatively, one could interpret the above as welfare *per unit* of a scaleable project, as in Holmstrom and Tirole (1997). Then, ϕ would represent the shadow cost of allocating more scarce equity capital to each unit of investment, which would reduce the overall scale of the project which can be undertaken with scarce equity.

[12]The bank fails at date 1 if it cannot roll over its short-term debt D. In that case, the liquidity benefit λD is lost because short-term debt is not safe, so that issuing short-term debt provides no social benefit. Thus, any choice where the bank fails is dominated by setting $D = 0$ and avoiding inefficient liquidation.

The planner's problem is to maximize welfare subject to three constraints. To specify them, it is useful to define the bank's total state-contingent debt burden at date 2, which is:

$$\delta(s,\theta) = (1 + r(s,\theta))D + B - a(s,\theta) \tag{2}$$

The first constraint is the incentive compatibility condition for the bank's unobserved shirking decision:

$$x(s,\theta) \in \arg\max_{x\in\{0,1\}} E[\max\{v(1-\alpha x) - \delta(s,\theta), 0\}|s,\theta] + \beta x \tag{3}$$

For example, when $x(s,\theta) = 0$, then this constraint states that the expected value of the bank's equity must be larger when it makes effort than if it shirks and collects the associated private benefit.

The second constraint is that creditors must be willing to refinance the bank's debt at date 1, given the information they have inferred from the public signal and from the regulator's bail-in choice a. Hence, for all s and θ, the planner must satisfy:

$$D = \begin{cases} E[\min\{v, (1 + r(s,\theta))D\}|s], & \text{if pooling in state } s \\ E[\min\{v, (1 + r(s,\theta))D\}|s,\theta], & \text{if separating in state } s \end{cases} \tag{4}$$

Finally, creditors' willingness to pay for bank debt at date 0 must be sufficient to finance the bank's project ex ante. We can express this participation constraint as follows:

$$E[\min\{v, \delta(s,\theta)\}] + \lambda D = 1 - A \tag{5}$$

The first term on the left-hand side is the expected date 2 repayment to (junior and senior) debtholders. Since the bank's short-term debt is refinanced on actuarially fair terms at date 1, this quantity also equals the expected repayment to creditors who purchase debt at date 0. The second term is the additional willingness to pay of short-term creditors at date 0 due to their preference for liquidity. The total willingness to pay must be equal to the bank's net funding requirement $1 - A$.

This participation constraint is aggregated, in the sense that it combines the total willingness to pay of short-term and long-term creditors. In Appendix C, we show that, in addition, any solution to the planner's problem can be implemented in a way that satisfies the participation constraints of short-term and long-term creditors *separately* at date 0. In other words, no cross-subsidy between different types of debt is required to satisfy the aggregated constraint (5).

We will focus on the case where it is optimal to for the bank not to shirk. This amounts to assuming that the loss α from shirking is large enough:

Lemma 1. *There is a value* $\bar{\alpha} \in (0,1)$ *such that any optimal contract prevents shirking, setting* $x(s,\theta) = 0$ *with probability* 1*, if*

$$\alpha \geq \bar{\alpha} \tag{6}$$

We will assume for the remainder of the paper that (6) is satisfied. Hence, we may assume that the regulator's choices satisfy the incentive compatibility constraint (3) with $x(s,\theta) = 0$ in every state of the world. It is easy to show (see Appendix B) that an increase in the debt burden δ tightens this constraint, while an improvement in either the public signal s or the private signal θ relaxes it. As a result, we can re-write the incentive compatibility constraint (3) as a state-contingent debt limit:

$$\delta(s,\theta) \leq \bar{\delta}(s,\theta), \tag{7}$$

where $\bar{\delta}(s,\theta)$ denotes the largest debt value satisfying (3), and is increasing in s and in θ. This highlights the role of *debt overhang* in our model. If the bank's debt burden is too large, relative to the quality of its assets, then it does not take value-maximizing actions, to the detriment of overall welfare. The representation in (7) shows that our results do not depend on the specifics of the debt overhang problem. Indeed, in any model where debt beyond a certain limit implies inefficient behavior, an equivalent constraint would arise and our qualitative results would go through.

2.2 The trade-off between pledgeable income and liquidity

Using the participation constraint (5) and the fact that the bank does not shirk under an optimal contract, the planner's objective function in Equation (1) can be re-written as a constant plus

$$\phi E[\min\{v, \delta(s,\theta)\}] + (1+\phi)\lambda D \tag{8}$$

Intuitively, pledging income to outsiders as debt has a marginal social value of ϕ because it reduces the need for equity finance. Hence, the first term in the social objective is ϕ times the expected value of the bank's debt. The second term is the additional value generated by issuing safe debt D, which is the sum of two terms: On one hand, the direct welfare benefit is λD, and on the other hand, safety further boosts the market value of short-term debt and reduces the need for equity finance, yielding an indirect welfare benefit of $\phi\lambda D$.

The refinancing constraint, along with the asymmetry of information, introduces a trade-off between the two terms in the planner's objective. In terms of maximizing pledgeable income, the best policy would be to achieve the binding debt limit (7): $\delta(s,\theta) = \bar{\delta}(s,\theta)$ for all s and θ, pledging as much as possible to outsiders without harming the bank's incentives.

However, this policy is not optimal in terms of maximizing the social benefit of liquidity creation, because it generates a threat of bank runs. To see this, note that the maximal debt level $\bar{\delta}(s,\theta)$ can only be achieved with a *separating* bail-in policy, which always reveals the regulator's private signal to the public at date 1, including at times when this signal is bad with $\theta = \theta_B$. Then, even if the regulator were to write down all of the bank's long-term debt ($a(s,\theta) = B$), the new short-term creditors would agree to refinance the bank's debt only if the public signal s is good enough to guarantee that

$$D \leq E[\min\{v, \bar{\delta}(s,\theta)\}|s, \theta_B]. \tag{9}$$

If this does not hold, then the separating policy $\bar{\delta}(s,\theta)$ would trigger a form of bank run, where short-term creditors refuse to roll over the bank's debt. To avoid the threat of a run, the planner now has to reduce the amount D of short-term debt issued ex ante. Therefore there is a trade-off between generating pledgeable income (the first term in (8)), which is best achieved by a fully revealing bail-in policy, and maximizing the liquidity benefit (the second term), which is best achieved by a pooling policy that shields creditors from bad news, allowing easier refinancing for

short-term debt.

2.3 Characterization of optimal policies

To understand how the second-best policy resolves this trade-off, it is useful to start with a given safe debt level D, solve for the best policy which guarantees that D can be sustained, and then find the optimal D in a second step.

For a given D, let $s^\star(D)$ be the lowest public signal s that satisfies the no-bank-run condition (9). If the bank has issued D, and the public signal turns out to be better than $s^\star(D)$, then there is no fear of a bank run and it is best to implement the separating policy and set the debt level to $\bar{\delta}(s,\theta)$ for each realization of θ (we will show below that there always exists a θ-contingent bail-in policy $a^\star(s,\theta)$ which achieves this). In other words, in terms of bail-in policy, if the public news is not too bad, it is best to commit to writing down the long-term debt as little as possible in order to maximize the value of the long-term debt when it is used at date 0. If public news is worse than $s^\star(D)$, by contrast, the regulator is forced to choose a *pooling* policy, where write downs do not depend on her private information at date 1, in order that the short-term debt can always be refinanced.

However, the regulator still needs to ensure that the bank does not shirk in case of bad private news θ_B, so the highest debt level that is possible if bail-ins are pooled across states is $\bar{\delta}(s,\theta_B)$. Formalizing this line of reasoning yields:

Proposition 1. *For a given short-term debt level D, there exists a policy satisfying constraints (4), (5), (7) if and only if D satisfies*

$$0 \leq D \leq E[\min\{v, \bar{\delta}(\underline{s},\theta_B)\}|\underline{s}] \equiv D_{max} \tag{10}$$

For any optimal policy, the total state-contingent debt burden is

$$\delta^\star(s,\theta) = \begin{cases} \bar{\delta}(s,\theta), & s \geq s^\star(D), \\ \bar{\delta}(s,\theta_B), & s < s^\star(D) \end{cases} \tag{11}$$

where $s^\star(D)$ is the lowest $s \in [\underline{s}, \bar{s}]$ that satisfies the no-bank-run condition (9).

Equation (10) describes the feasible range for short-term debt. Even if the regulator chooses a pooling policy, bad public signals limit the amount of debt that creditors are willing to roll over. The upper bound D_{max} is the largest amount of safe short-term debt which can be refinanced even in the face of the worst public news, without resulting in shirking by the equity holders.[13]

Equation (11) describes the optimal policy, which we illustrate in Figure 3. The thick dashed line is the optimal debt burden $\delta^\star(s, \theta_B)$ implemented for a regulator with bad private news; the solid line above it is the equivalent for good private news. For low public signals $s < s^\star(D)$, the two are identical because the policy is pooling, and achieve the binding debt limit $\bar{\delta}(s, \theta_B)$ for the bad type. Ideally, the planner would want to exhaust the debt limit $\bar{\delta}(s, \theta_G)$ (the thin dashed line) when she has good news, but refrains from doing so in order to avoid signaling her information to creditors. This generates a deadweight loss proportional to the shaded area. For high public signals $s \geq s^\star(D)$, the range of policies expands and the regulator fine-tunes debt levels to her private information.

The optimal policy always involves a positive amount of bail-inable debt $B > 0$. To see this, note that whenever short-term debt D lies in the feasible range defined by (10), the bank has enough pledgeable income to repay its short-term creditors in the worst state $s = \underline{s}$. This implies that, in better states $s > \underline{s}$, the bank has spare pledgeable income. Moreover, since equity finance is more expensive than debt finance, it is optimal to promise some of this income to outside creditors by issuing long-term bonds.

To complete our characterization of the planner's choices, we now turn to the optimal value of safe debt D. In our characterization of welfare in (8), a higher D increases the second term (value of liquidity creation), with marginal value $(1 + \phi)\lambda$. However, a higher D also decreases the first term (pledgeable income) because it raises the critical signal $s^\star(D)$ below which pooling,

[13]The definition of D_{max} depends on our assumption that the support of s is bounded below. If there is no lower bound (e.g., with Gaussian signals), then beliefs given public information can become arbitrarily pessimistic. In this setting, it is not possible for the bank to create *perfectly* safe debt, because there are always states of the world in which arbitrarily bad public information prevents the bank from refinancing and repaying its debt at date 1. However, one would recover a similar condition to (10) if short-term creditors were willing to accept a small probability of default while still enjoying the liquidity benefit λ.

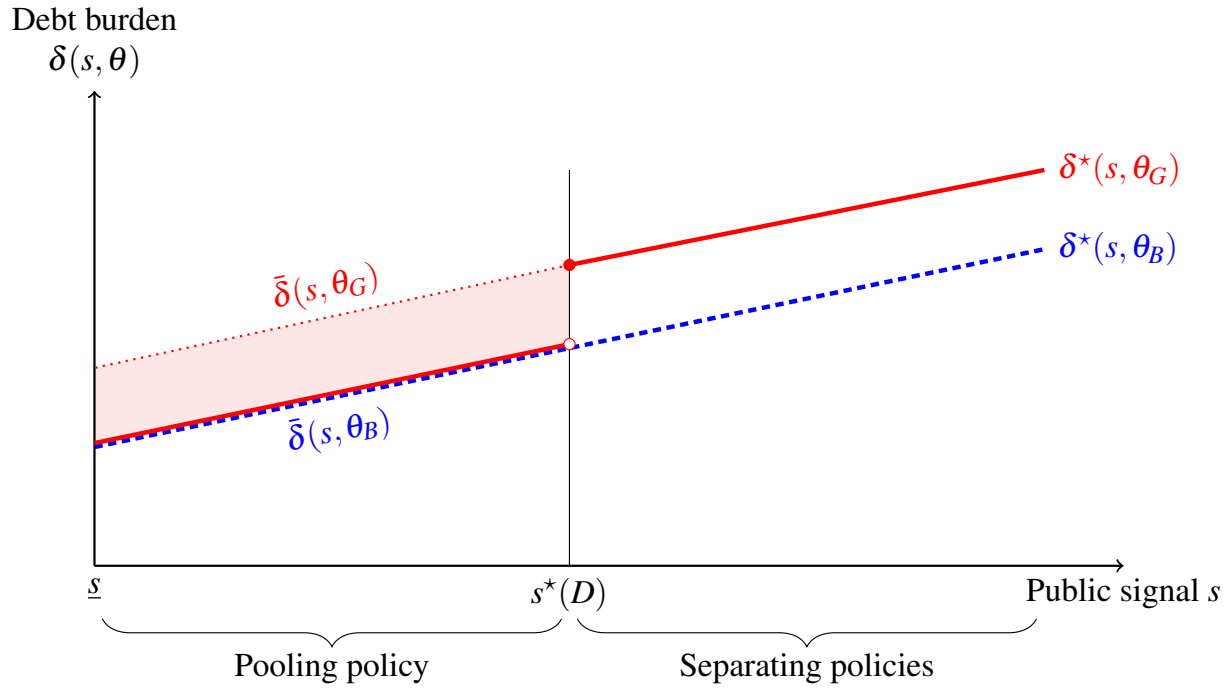


Figure 3: Optimal policy

which is inefficient from the perspective of pledgeable income, is required. The marginal value of a unit reduction in pledgeable income is ϕ. Hence, the overall marginal benefit of increasing D is increasing in the *relative* social value of safe versus risky debt, which we can define as:

$$\xi \equiv \frac{(1+\phi)\lambda}{\phi} = \left(1+\frac{1}{\phi}\right)\lambda \tag{12}$$

A standard monotone comparative statics argument now allows us to characterize the optimal policy:

Proposition 2. *The optimal choices of $D^\star$, and hence of the signal $s^\star(D^\star)$ below which the optimal policy is pooling, are monotone increasing functions of ξ.*[14] *Moreover:*

[14]The optimal choice of $D^\star$ need not be unique, although the case where multiple $D \in [D_{min}, D_{max}]$ (as defined in the proposition) achieve the same maximized welfare is a knife-edge case. In this scenario, Proposition 2 applies in the sense the the optimal policy correspondence increases in ξ in the strong set order (see Milgrom and Shannon, 1994).

- *If ξ is sufficiently small , then $D^\star = D_{min}$, where*

$$D_{min} = E[\min\{v, \bar{\delta}(s, \theta_B)\}|\underline{s}, \theta_B], \tag{13}$$

  and the bail-in policy is separating in all states s.

- *If ξ is sufficiently large, then $D^\star = D_{max}$, where D_{max} is the largest feasible value defined in (10), and the optimal bail-in policy is pooling for a positive measure of states $s \leq s^\star(D^\star)$.*

Proposition 2 formalizes the trade-off described above. It is always efficient to issue at least D_{min} in safe debt: the amount of debt that can be refinanced when the worst public news s arrives, and the worst private news θ_B is revealed, in order to benefit from the liquidity premium associated with safe short term debt. The maximum of safe short term debt issuance that can be issued is D_{max}, the amount that can surely be refinanced when the worst public news arrives, but private news is not revealed.

The choice for short-term debt issuance between these upper and lower bounds depends on the relative importance of banks' role as creators of safe, liquid claims. On one hand, if liquid claims are socially highly valuable (ξ is large), then high short term debt issuance is optimal, which means that information-insensitive resolution policies (i.e., pooling) must be employed because they allow the bank to remain liquid after bad news. The downside of this policy is that the issue price of the banks' long-term bonds falls, because pooling means that bail-in will, in expectation, be excessive (that is, debt-write downs will sometimes be beyond what is strictly necessary to overcome the debt-overhang problem in order to avoid revealing bad news). This means that, if instead liquidity preference is weaker or equity is very costly (ξ is small), then it is better to use the regulator's private information to fine-tune resolution policies, using them only when they are strictly necessary, to allow the bank to raise more funds through long term bonds, even this case means restricting short term debt issuance. In between these two extremes, smaller short term debt issuance at date 0 means that the regulator can use a separating policy for a larger number of states, which increases the income pledgeable to long term bond holders, but reduces the liquidity benefits to short term creditors. The regulator trades off these two considerations according to the relative size of the

cost of equity versus the liquidity premium, as represented by ξ.

With these characterizations in hand, we can derive the remaining components of the optimal policy: For each state of the world (s, θ) at date 1, Proposition 1 states whether the optimal policy is pooling or separating. Then, the interest rate offered to new investors $r^\star(s, \theta)$ is the solution to the appropriate refinancing constraint in (4). Taking this interest rate and the optimal total debt level $\delta^\star(s, \theta)$ from Equation (11), we can rearrange (2) for the optimal bail-in action:

Corollary 1. *Let $D^\star$ be the optimal choice of short-term debt in Proposition 2, let $\delta^\star(s, \theta)$ the optimal debt burden in Proposition 1, and let $r^\star(s, \theta)$ be the solution to the refinancing constraint (4) when evaluated at the optimal policy. Then, the bail-in action which implements the optimal mechanism is:*

$$a^\star(s, \theta) = B + (1 + r^\star(s, \theta))D^\star - \delta^\star(s, \theta). \tag{14}$$

In this analysis, we have restricted attention to deterministic policies. There is also a potential role for randomized bail-ins, which generate "constructive ambiguity". For example, consider a public signal $s < s^\star(D^\star)$ for which the optimal deterministic policy is pooling, with $\delta^\star(s, \theta) = \bar{\delta}(s, \theta_B)$. If the good type θ_G of regulator took the first-best action $\bar{\delta}(s, \theta_G)$ with a small probability, this would marginally worsen creditors' beliefs when they observe the pooling action $\bar{\delta}(s, \theta_B)$, but not by enough to violate the refinancing constraint. This deviation therefore strictly increases pledgeable income and welfare. However, as we discuss in the next section, it would not be possible to implement this randomized policy in a setting where the regulator lacks commitment and θ is not verifiable.

2.4 Loss-absorption and the role of debt overhang

Our results in this section clarify the benefit of bail-ins in our model: Bail-ins ensure the efficient operation of the bank, even if it has incurred losses, by resolving its debt overhang problem. To further appreciate the role of debt overhang, one can view our model through the lens of the literature on debt relief, which advocates the idea of a debt "Laffer curve" (Krugman, 1988):

Under certain circumstances, all stakeholders are better off if some distressed (sovereign) debt is written off. Interestingly, Krugman shows that write-downs are valuable if *and only if* there is debt overhang, in the sense that debtors need to take an efficient action after the debt is resolved. If there is no debt overhang, then it is optimal to issue high-yielding senior bonds to refinance short-term debt.

A similar intuition applies in our model. Consider a situation where the bank does not have to choose an action (work or shirk) after date 1, so that the only relevant constraint is the need to avoid immediate failure by refinancing the bank's short-term debt. Note that this constraint (4) does not depend on write-downs. Intuitively, the short-term creditors at date 1 do not care about the face value of long-term debt, because they are strictly senior to it. In this case, an optimal policy is to simply to allow the bank to refinance its short-term debt as it sees fit at date 1, without bail-ins, diluting junior creditors in the process. Bail-in policy becomes valuable when refinancing coincides with debt overhang, because allowing dilution without bail-in would exacerbate the debt overhang problem. In addition, our analysis highlights an issue that is more specific to financial markets: Debt overhang generates a case for fine-tuning debt-relief based on private information, and therefore a trade-off between liquidity creation and pledgeable income.

Bail-ins are often motivated by the idea that it is necessary to help banks to absorb losses. Our model is consistent with this narrative, since the reason for bail-ins is exactly to prevent inefficiencies within the bank after losses are discovered. The need to restore loss absorption capacity at banks in order to avoid the problems of debt-overhang is supported by growing empirical evidence that under-capitalized banks tend to engage in detrimental activities such as zombie lending (see, for example, Caballero et al. (2008), Jiménez et al. (2014) and Acharya et al. (2018)). Another potential rationale for loss-absorption capacity is that early bail-ins (e.g., at date 1) create a buffer against future losses and costly bankruptcy (e.g., at date 2). However, without debt overhang at date 1, our analysis implies that it is better to wait until date 2 to execute the bail-in in these circumstances, because waiting to do so avoids revealing information before refinancing and hence preserves liquidity in the event of bad news. The case for stepping in and writing down debt early (at date 1) in our setting arises precisely because debt overhang will otherwise generate a downward drift in asset

values between dates 1 and 2 if the bank's debt burden is too large.

Similar results are likely to obtain in any model in which the regulator values bank equity between dates 1 and 2. For example, suppose high leverage between dates 1 and 2 risks a disorderly bank failure during that time which imposes negative externalities on other agents in the economy (through the loss of relationship lending, where customers are dependent on a particular bank for access to credit, or through fire sales in asset markets). In this alternative environment, there is also a case for early bail-ins, and as in our model, bail-in policy needs to trade off the gains from the earlier reduction in debt burden against the loss from the reduction in liquidity.

3 Implications for institutional design

So far, we have characterized the solution to the social planner's problem. We have allowed the planner to commit to a bail-in policy ex ante, including the choice as to whether to act on private information θ at date 1 or not. In practice, such a commitment is hard to make directly, because a regulator's *private* signals about the health of a bank can be difficult to verify ex post (and, by assumption, they are private information, so impossible to verify ex interim).[15] To complement the previous section, we therefore study the optimal design of *decentralized* institutions where it is possible to make commitments to actions based on the public signal s, but not on the private signal θ. This means that the regulator chooses the bail-in policy at date 1 after observing θ. We show that the commitment issue is non-trivial: If the regulator is given full discretion to act at date 1, there is a time-inconsistency problem because (under natural conditions) she wishes to signal her good private signal to creditors; ex ante, however, it would may be better if she refrained from doing so in order to avoid signaling bad news when she does not take the action associated with good news. We show that, despite this problem, the optimal policy can be implemented by adopting a bail-in regime which involves a mixture of rules and discretion.

We consider a class of institutional settings where, before the start of the game, the government

[15] Even if it is possible to verify θ ex post, it might be politically difficult to enforce regulatory rules ex post, especially because the deviation from the optimal mechanism that the regulator would wish to make is ex post efficient. In particular, in order to enforce pooling after bad public news, it would be necessary to punish the regulator for failing to write down debt in a bank which did not require a write-down.

writes a binding bail-in regime into law (e.g., the EU's Bank Recovery and Resolution Directive, or Chapter II of the Dodd Frank Act). The law specifies, for each possible realization s of public information, the set $\mathcal{P}(s) \subset [0, B]$ of permitted bail-in policies a. For example, if this set is a singleton $\mathcal{P}(s) = \{\bar{a}\}$, the regime imposes a rule which mandates that the bail-in must be $\bar{a}$ whenever s is observed; or if $\mathcal{P}(s) = [0, B]$, then the regulator has full discretion in state s. Given this regime, agents play the following game: At date 0, the bank chooses its capital structure $\langle A, B, D \rangle$. At date 1, the regulator observes s and θ and chooses her write-down action $a \in \mathcal{P}(s)$, which is observed by creditors. The bank makes an interest rate offer r to short-term creditors in order to refinance its debt; creditors accept or reject this offer; and if the bank is refinanced it chooses whether to make effort or shirk. At date 2, claims are settled as before. Note that this is a *signaling* game because, as before, the regulator's choice a at date 1 is publicly observed and may reveal information about θ to uninformed agents.[16]

A Perfect Bayesian Equilibrium in regime $\mathcal{P}(.)$ is a profile of (state-contingent) strategies such that the bank acts optimally to maximize shareholders' expected utility, the regulator acts optimally to maximize expected total welfare, and creditors break even given their beliefs about θ, which are derived from Bayes' rule along the equilibrium path. Off the equilibrium path, we will employ the *Intuitive Criterion* restriction on creditors' beliefs: If the regulator takes an unexpected action at date 1, then creditors must place probability zero on any type θ of regulator for whom the observed deviation is strictly dominated by the level of welfare achieved in equilibrium.

3.1 Discretion and time-inconsistency

Since the regulator is benevolent and better informed than other market participants, a natural proposal is to give the regulator full discretion when choosing the bail-in policy, that is, to set $\mathcal{P}(s) = [0, B^\star]$ for all s. We begin by showing that this is problematic:

Lemma 2. *Suppose that the social planner's policy is pooling for a set of public signals $s \in$*

[16] In principle, the bank's interest rate offer r can also reveal information about θ. However, if the regulator's choice does not reveal θ, then there cannot be a separating equilibrium in the bank's choices: The bad type of bank would always deviate by copying the good type's (lower) interest rate offer. Hence, the bank effectively takes creditors' information set as given.

$[\underline{s}, s^\star(D^\star))$ *with positive measure, and that the bail-in regime is full discretion with* $\mathcal{P}(s) = [0, B^*]$ *for all* s*. Then there is no Perfect Bayesian Equilibrium in which (i) the regulator's bail-in policy replicates the social planner's choices on the equilibrium path, and (ii) creditors' beliefs satisfy the Intuitive Criterion.*

Lemma 2 is a negative result, which exposes an important time-inconsistency problem: Under reasonable conditions on creditors' beliefs, the regulator's optimal action *ex post* differs from the action she would promise *ex ante* if she had commitment. This arises because, in bad states of the world $s < s^\star$, the optimal policy involves pooling. (Recall that this is optimal because it allows the bank to issue more safe short-term debt, which is socially valuable.) Proposition 1 shows that in these states, the bank's debt level is set at $\bar{\delta}(s, \theta_B)$ regardless of the true realization of θ, i.e., debt is bailed-in aggressively to avoid bad behavior even if the bank has bad private news $\theta = \theta_B$. This policy is excessive from the perspective of a regulator who has good news $\theta = \theta_G$. The time inconsistency arises from her desire to cut back on the expected bail-in once good news has been realized. Indeed, the proof of Lemma 2 shows that the regulator with $\theta = \theta_G$ prefers to deviate to a smaller bail-in and raise the debt level to $\bar{\delta}(s, \theta_G)$ ex post. Creditors reasonably (in the Cho-Kreps sense) attribute this deviation to the good type, because the bad type's equilibrium action is first-best from her perspective. Therefore, the good type's deviation remains profitable, and pooling on the large bail-in cannot be an equilibrium.[17]

Note that our deviation-based argument relies on the assumption that bail-ins are costly. Although we have focused on the limiting case where the cost κ of bail-in is negligible relative to other welfare considerations, we do require this cost to be strictly positive. If κ is exactly zero, then the deviation we have described leaves the regulator indifferent *ex post*, because she is indifferent between an excessive bail-in and an accurate one. However, it is questionable whether the administrative costs of large interventions could ever be exactly zero in reality.

More importantly, even if costs were exactly zero, discretion would still be an unstable policy.

[17] It may also be useful to recall that Cho and Kreps (1987) show that the Intuitive Criterion is a necessary condition for *stability* of equilibrium. Lemma 2 therefore states that there is no stable equilibrium that implements the optimal policy when the regulator has full discretion. In other words, even small changes in the model environment could lead to large deviations from optimal behavior. This is an unattractive feature for financial policy, which ought to be robust to small model mis-specifications.

For example, even a small extension to our model makes positive costs strictly necessary: If we consider a probability, no matter how small, that the bank has suffered severe losses at date 1 which the regulator cannot observe, then with a zero cost, the regulator would always choose the largest possible bail-in ex post "just in case", which would lower the value of the bank's debt at date 0, leading to a socially excessive equity contribution. For these reasons, we now propose a more robust solution to the time-consistency problem, which does not hinge on these details.

3.2 Implementation with rules and discretion

We now show that, despite the issues with discretion, there is a bail-in regime which allows the social planner's choices to be implemented in equilibrium:

Proposition 3. *Let $D^\star$ be the social planner's optimal choice of short-term debt, as defined in Proposition 2. Define the bail-in regime $\mathcal{P}^\star(s)$ as follows:*

- *For public signals $s \geq s^\star(D)$, the regulator has full discretion with $\mathcal{P}^\star(s) = [0, B^\star]$*
- *For public signals $s < s^\star(D^\star)$, the regulator is bound by a rule with $\mathcal{P}^\star(s) = \{a^\star(s, \theta_B)\}$.*

Then there is a Perfect Bayesian Equilibrium in which all agents' strategies replicate the planner's choices and creditors' beliefs satisfy the Intuitive Criterion.

Proposition 3 advocates a simple fix to the time-inconsistency problem: In states $s < s^\star(D^\star)$ where a pooling policy is socially optimal, the regulator should be bound by rules, so that she cannot succumb to the temptation to weaken the bail-in policy ex post. This underlines the key idea of this paper: The optimal mixture of separating and information-insensitive policies requires careful design of the relevant institutions, with a mixture of rules and discretion. Interestingly, rules strictly improve welfare because of the *interaction* between liquidity creation and asymmetric information in our model. If the bank does not issue safe, liquid debt D, then there is no need for information-insensitive policy, and regulatory discretion is optimal because the regulator is benevolent and has superior information. On the other hand, in the absence of private information, there would be no loss to using appropriately designed rules based on s.

Our discussion of implementation has focused on the regulator's incentives. The proof of Proposition 3 also sets out the bank's incentives to choose the optimal capital structure $\langle A^\star, B^\star, D^\star \rangle$ and the optimal state-contingent interest rate offer $r^\star(s, \theta)$. The bank's choices align with what the regulator would wish, so that in this model, capital structure and refinancing choices can be delegated to the bank. In a more general setting with externalities, one would also have to constrain banks at date 0 in order to ensure that the planner's choice $\langle A^\star, B^\star, D^\star \rangle$ is implemented. The ways in which this can be done with capital and liquidity requirements are well-known, and so we do not focus on these issues here.[18] As for the interest rate offer at date 1, both the bank and the planner wish to offer the lowest rate consistent with refinancing, so again, there is no conflict of interest.

The absence of externalities therefore facilitates an implementation in which the regulator does not need to intervene at date 0. However, it is important to note that even without externalities, one cannot implement the planner's choices in an entirely *laissez faire* regime where the bank makes all the decisions. To appreciate this, consider a state $s \geq s^\star(D^\star)$ where the optimal bail-in policy is separating. If one gave the bank discretion to choose a bail-in in this state, shareholders would always choose the policy that leads to the lowest debt burden, regardless of their true private information. By contrast, a regulator is willing to truthfully reveal θ because she sees no benefit to write-downs unless they resolve a debt-overhang problem, and this debt-overhang problem is absent if news are sufficiently good.

3.3 Implementing rules using contingent capital contracts

Proposition 3 implies that one can implement the optimal mixture of rules and discretion by requiring the bank to issue an appropriately chosen set of contingent convertible (co-co) debt securities. Co-cos specify that the face value of long-term bonds will be written down in a given way, contingent on the realization of public news s falling below some predesignated "trigger" value. To see how co-cos can substitute for an explicit bail-in regime, consider an alternative game: The bank issues co-co contracts instead of long-term debt at date 0. Each contract entitles creditors to

[18] For instance, a capital requirement in our model would be $(1 - B - D) \geq K_{min}$, while a stable funding or liquidity requirement in the spirit of Basel 3 would be $(1 - D) \leq L_{min}$. Setting $L_{min} = 1 - D^\star$ and $K_{min} = 1 - B^\star - D^\star$ would implement the planner's choice.

a junior debt claim with face value B. After bad public signals $s < s^\star(D^\star)$, the contract further specifies that the face value is reduced to $B - c(s)$, where $c(s)$ denotes a contractually mandated write-down.[19] At date 1, the regulator then has full discretion to write down additional debt, but cannot undo the contractually mandated write-down. Around half of all co-cos that have been issued in practice operate in this fashion, by explicitly writing down debt based on a publicly observable trigger (Avdjiev et al., 2013).[20] In addition, almost all co-cos have a so-called regulatory trigger, which allows the regulator to write down or convert the co-co as specified by the contract even if the public trigger has not been breached.

This is a reduced-form treatment of co-cos, where the distribution of the trigger signal s remains exogenous. In practice, the value of public signals such as prices and book values could be affected by the extent of write-downs,[21] or by the regulator's actions.[22] Contractual design features that circumvent the associated problems are proposed by Hart and Zingales (2011), Pennacchi et al. (2013) and Bulow and Klemperer (2015) among others. Complementing this literature, we show that in principle, co-cos can substitute for explicit rule-writing:

Corollary 2. *Consider the alternative game in which the bank issues co-co contracts and the regulator has full discretion. This game has a Perfect Bayesian Equilibrium in which all agents' strategies replicate the planner's choices, and creditors' beliefs satisfy the Intuitive Criterion. In particular, the write-down mandated by co-co contracts in this equilibrium is $c(s) = a^\star(s, \theta)$ for all $s < s^\star(D^\star)$, where $a^\star(s, \theta)$ is the social planner's optimal (pooling) policy in state s. For all $s \geq s^\star(D^\star)$, the mandated write-down is $c(s) = 0$ and the regulator uses her discretion to choose the social planner's optimal (separating) policy $a^\star(s, \theta)$.*

The corollary is almost immediate from Proposition 3. Indeed, the regulator's choice ex post

[19] One can think of this as *every* debt contract losing $c(s)$ of face value, or as the bank issuing co-co bonds with a continuum of triggers, where the joint face value of bonds with trigger above s is $c(s)$.

[20] The alternative is to convert debt into equity upon conversion. We discuss the trade-offs between write-downs and conversions in detail at the end of this section.

[21] There are concerns that, if co-co triggers were based on market equity prices, the event of conversion itself could influence the value of equity, so that market prices would not reflect exogenous fundamentals. However, it is possible to design co-co contracts that do not suffer from this problem (see, for example, Hillion and Vermaelen, 2004). In practice, all existing contract triggers have so far been specified as a function of book values, not market values.

[22] This is not guaranteed, for example, if the trigger is based on regulatory capital ratios and regulators have discretion in deciding when to require banks to write down non-performing assets (Bulow and Klemperer, 2015).

choice with the co-co contract specified in the Corollary is essentially the same as in the optimal regime from Proposition 3: For good signals $s \geq s^\star$, she has full discretion, while for bad signals, the co-cos mandate a write-down that is *at least* as large as in the optimal regime. Thus, to verify that the regulator behaves as before, it is sufficient to check that she would not want to write down additional debt after bad news. However, since the optimal write-down $a^\star(s, \theta)$ is already sufficient for bank incentives (and is, in fact, excessive from the perspective of type θ_G), she has no incentive to do so. Moreover, as before, in the absence of externalities, the bank's incentives *ex ante* are aligned with the planner's, and so it has no incentive to deviate from the optimal co-co structure. Again, in a world with externalities, additional regulation of co-co issuance may be needed to ensure optimality.

3.4 Discussion of further policy dimensions

We have presented a stylized treatment of bail-in policies in order to highlight the trade-offs between rules and discretion. Before extending our model to include bailouts in the next section, we discuss two additional dimensions of policy design.

3.4.1 The case for protecting short-term debt

In our model, short-term creditors are doubly protected. We have assumed that they cannot be written down as part of a bail-in, and that they enjoy seniority in case of default. More generally, one could extend the institutional design problem to include bail-ins that can extend to short-term debt. However, this would never be optimal in our model, because the sole motivation for issuing short-term debt is the fact that creditors value safe, liquid securities. If there were a positive probability of short-term debt experiencing a write-down, this value would be lost. For any policy that involves write-downs of short-term debt, we can therefore find a superior policy that simply issues less short-term debt in the first place.

Beyond our environment, it is possible to imagine a "smoother" specification of creditor preferences, where a write-down with small probability does not wipe out the entire liquidity benefit. However, our qualitative results are likely to go through, in the sense that optimal bail-ins concen-

trate on long-term debt, as long as the costs of extending bail-in to D are sufficiently large. For example, in the Cypriot financial crisis, the final bail-in also included short-term liabilities, but the associated level of public outrage suggests large marginal costs for the government in conducting such a policy. Current bail-in policy specifically excludes all short-term liabilities from bail-in, also suggesting a high political cost from bailing in short-term liabilities.

It would also be possible to include the relative seniority of long-term and short-term creditors as a policy choice. However, giving seniority to short-term debt is already an optimal arrangement. To see this, suppose instead that short-term and long-term debt were given *pari passu* status. In that case, there is a stricter refinancing constraint at date 1, because new short-term creditors do not expect to be paid first if the bank defaults at date 2. However, this does not affect the characterization of optimal policy in Propositions 1 and 2, because these results and their proofs are in terms of the bank's *total* debt burden $\delta(s,\theta)$. The only change is how this total debt burden is achieved: The bank needs to offer a weakly higher interest rate $r^\star_{pp}(s,\theta) \geq r^\star(s,\theta)$ in each state and, hence, a more aggressive bail-in policy $a^\star_{pp}(s,\theta) \geq a^\star(s,\theta)$ becomes necessary.[23] Therefore, giving seniority to short-term debt achieves optimal total debt burdens with a less invasive bail-in policy than alternative arrangements, and is socially optimal.[24]

3.4.2 Bail-in design and *ex ante* moral hazard

We have modeled bail-ins as simple "haircuts" on long-term debt: The face value is written down in bad times, and creditors receive nothing in return. In practice, regulators can alternatively convert long-term bonds into equity shares as part of a bail-in. The number of shares that each bondholder receives is then another choice variable for the policy maker. For example, if this number is zero,

[23] Formally, under *pari passu* rules, the repayment inside the expectations operator on the right-hand side of (4) becomes

$$1_{v\geq\delta(s,\theta)}(1+r(s,\theta))D + 1_{v<\delta(s,\theta)}\frac{(1+r(s,\theta))D}{\delta(s,\theta)}v < \min\{v,(1+r(s,\theta))D\}$$

so that for every $r(s,\theta)$, the right-hand side is smaller than when short-term debt has priority. Hence, the lowest interest rate that allows refinancing must increase. The fact that the bail-in must also increase follows from (14). The argument for other alternatives, where short-term creditors get an arbitrary share of asset values in bankruptcy, is identical.

[24] Another reason for giving seniority to short-term debt, which we have not modeled, would arise if there is an additional liquidity benefit (akin to the benefit λ at date 0 in our model) associated with issuing a safe tranche of short-term debt at date 1. In that case, it also seems clear that it is better to give short-term debt priority in bankruptcy.

then we have simple haircuts, while if the number is very large, the bail-in dilutes all existing shareholders and transfers ownership of the bank's equity to former bondholders.

In our model, debt overhang becomes important *ex post*, i.e. after the bail-in, because the bank decides whether to work or shirk between dates 1 and 2. In these circumstances, our assumption that bail-ins are simple haircuts is without loss of generality: The incentives of existing shareholders are best preserved by not diluting them, so it is always an optimal policy to impose simple haircuts on bondholders. However, the design of bail-ins would be more complicated if there were also concerns about shareholders' incentives between dates 0 and 1. For example, consider a situation where shareholders make an additional unobserved effort choice between dates 0 and 1. Then simple haircuts introduce a new problem: They increase the value of equity in bad states of the world, rewarding shareholders for low returns, and encouraging them to shirk ex ante.

How the problem of providing both date 0 and date 1 incentives for shareholders should be addressed depends on the efficiency of corporate governance, namely, on whether or not bondholders become "insiders" and participate in the bank's decision-making once their bonds are converted into equity. At one extreme, consider the case where converted bondholders participate fully, so that they decide the bank's effort jointly with original shareholders and also receive their share of the private benefits if the bank shirks. In this scenario, the bank's effort choice between dates 1 and 2 depends only on the bank's total debt burden, not on whether original shareholders have been diluted. In this case, it would always be optimal to make bail-ins as dilutive as possible in order to sharpen incentives for original shareholders *ex ante.* At the other extreme, consider the case where converted bondholders do not participate in decision-making at all. A dilutive bail-in now sharpens incentives *ex ante* but, because only the stake of original "inside" shareholders matters for decision-making *ex post*, it will induce the bank to shirk *ex post.* In fact, this trade-off is familiar from the literature on dynamic principal-agent problems (e.g., DeMarzo and Sannikov, 2006; Biais et al., 2007): Upholding incentives after bad interim returns is expensive, and can often only be achieved by giving the agent a large amount of skin in the game – in the case of banking, this would mean a larger equity contribution.

A full analysis of a dynamic moral hazard problem for the bank, and the associated optimal

choice of the co-co dilution ratio, is beyond the scope of this paper. This problem would be complicated by possible feedback effects: Any change in the bank's decisions at date 0 will have an impact on its asset values and, therefore, on the distribution of public and private signals at date 1. We conjecture that adding ex ante moral hazard and corporate governance frictions to the model would require the regulator to complement bail-in regimes with stricter equity requirements ex ante. Mendicino et al. (2017), among others, provide a detailed analysis of the additional trade-offs that ex ante incentives introduce to the design of bail-in bonds and contingent convertibles. The contribution of this paper is instead to highlight a key constraint on the regulatory problem ex post: Optimal bail-ins, dilutive or otherwise, must allow the regulator to avoid signaling information in bad times. This constraint would still be present in a model with these additional complications. Therefore, we believe that fundamental insight that bail-ins are optimally implemented using a mixture of rules in bad times and discretion in good times is robust to such additions, even though the precise choices for capital structure and co-co design will change.

4 The interaction between bail-ins and bailouts

Our baseline model assumes that the government cannot make transfers to distressed banks at date 1. Effectively, therefore, we have discussed institutional design in a world where the government has made strong, credible commitments not to resolve banks by injecting public money. Although policy-makers would like bail-ins to replace bailouts, it is interesting to analyze how our results change when small amounts of government assistance are available. Understanding this scenario also furthers our understanding of the effect of making commitments against bailouts, and how they interact with the other trade-offs we have explored.

Consider a version of our model where the government has a bailout fund containing F dollars. At date 1, in addition to the bail-in policy $a(s, \theta)$, the regulator can choose a state-contingent bailout policy $t(s, \theta) \in [0, F]$ at date 1. Bailing out incurs a social cost of $\chi t(s, \theta)$, where $\chi > 0$. Because our model is not rich enough to do justice to the literature on optimal bailout funds,[25] we take F as exogenously given. Bailouts relax the bank's refinancing constraint at date 1: The

[25] See, for example, Freixas (1999), Bianchi (2016), and Chari and Kehoe (2016).

net amount of bank debt to be refinanced at date 1 with private money (the left-hand side of (4)) falls from D to $D - t(s, \theta)$. The social planner's problem stays the same otherwise, and a rigorous solution (following the same steps as in Section 2) is in Appendix D.

Figure 4 summarizes the result in terms of the optimal bail-in and bailout policies, for a given level D of short-term debt. With bailouts available, the optimal policy is separating for a wider range of public signals $s \geq s^{\star\star}(D)$ (the threshold $s^{\star}(D)$ without bailouts is shown for comparison).

To see why it is optimal to extend the separating region, recall that $s^{\star}(D)$ is the threshold where creditors are just willing to refinance when there is no bailout and θ_B is revealed. For public signals just below $s^{\star}(D)$, an infinitesimal bailout with the bad private signal would be enough to allow these banks to refinance their short-term debt. Bailing out in these marginal public states, however, generates a first-order welfare gain for the banks with a good private signal, proportional to g in the Figure, because they no longer need to be subjected to excessive bail-ins to pool with banks with a bad private signal. In these additional states, therefore, the cost to the regulator of supporting marginal banks with a bad private signal is second order, whereas the gain to avoiding a pooling policy with excessive bail-ins is of first order. As a result, it always pays to have a small bailout and decrease the threshold for pooling. The Figure shows the case where F is small, so that the new threshold is determined by the point where the bailout fund is exhausted.[26] As in Section 3, the new optimal policy can be implemented by giving the regulator discretion for $s \geq s^{\star\star}(D)$, and binding her with rules otherwise.

This characterization also highlights the interaction between bail-ins and bailouts. An increase in the size F of the bailout fund implies that $s^{\star\star}(D)$ shifts down for any given D.[27] It then becomes possible to conduct discretionary, separating bail-in policies for a wider range of public signals. This

[26] If the constraint $t(s, \theta) \leq F$ is not binding, then the new threshold is determined by the point where the marginal increase in pledgeable income for $\theta = \theta_G$ (which scales with ϕ) equals the marginal bailout cost for $\theta = \theta_B$ (which scales with χ). When F is large, there are further possibilities for the optimal policy, such as another separating region for very bad public signals, in which the regulator reveals θ and conducts a large bailout. Appendix D discusses this in more detail.

[27] Generally, we cannot say whether the optimal $D^{\star}$ becomes smaller or larger when bailouts are available, because the marginal social benefits of short-term debt are sensitive to the underlying distributions. However, notice that when bailouts are available, the maximal amount of safe short-term debt that the bank can issue increases from D_{max} to $D_{max} + F$. If this issuance limit is binding with $D^{\star} = F$, which occurs (by Proposition 2) when the social benefit of liquidity creation is large, then it is always optimal to increase short-term debt to $D^{\star} > F$ when bailouts become available.

change brings bail-in policies closer to the policy which maximizes pledgeable income, and which would be optimal in the absence of a refinancing constraint at date 1. Of course, there are costs associated with more generous bailouts, which we have not modeled here. However, our argument in this section highlights that one marginal *benefit* of bailouts is that they allow wider discretion in bail-in policy. In this sense, there is a complementarity between bailouts and bail-ins: If bailouts are available, bail-ins can be more targeted, will be smaller on average and also used less frequently.[28]

Conversely, if the government makes strong commitments against bailouts, i.e., if F falls, then the optimal range of separating policies shrinks. In terms of institutional design, this means that the time-inconsistency problems become more acute, and the case for regulatory rules becomes stronger as bailouts are less available.[29] This insight, which is specific to the interaction of bail-in institutions and bailouts, complements an existing literature which shows that the expectation of bailouts can have (sometimes beneficial) announcement effects on bank and market behavior (e.g., Cordella and Yeyati, 2003).

5 Conclusion

The design of bank resolution schemes is of central importance in the plan to end "too big to fail" for large banks. Policy-makers' idea is that if regulators are willing and able to restructure banks' debts by "bailing in" creditors before a crisis hits, then there will be less need for taxpayers to "bail out" bank creditors later. In this paper, we have highlighted a problem which limits bank regulators' ability to act effectively in this regard, even when equipped with the best of intentions, information, powers and tools. In order to stave off problems, the regulator must act before creditors are fully aware of the seriousness of the bank's problems. But then, the fact that the regulator acts becomes a signal to creditors that problems at the bank are worse than they had expected, and

[28] The complementarity we highlight is derived in a model without moral hazard *ex ante*. It is possible that a combination of bailouts and bail-ins would worsen banks' incentives at date 0, for example, if bail-ins did not dilute initial shareholders and effectively rewarded them for bad performance.

[29] Another thought experiment underlines this point: Suppose that the government then promises to reduce the bailout fund to $F' < F$ *without* changing the bail-in regime. Then, the separating threshold $s^{\star\star}(D)$ increases, but the regulator retains discretion for an interval of states $s < s^{\star\star}(D)$. From Section 3.1, we know that the (optimal) pooling policy cannot be implemented in these states. In the absence of a bailout, the regulator would end up either with a bank run, or with shirking by the bank (or both, because when the bank is expected to shirk, it may become impossible to refinance the short-term debt), which is clearly inefficient.

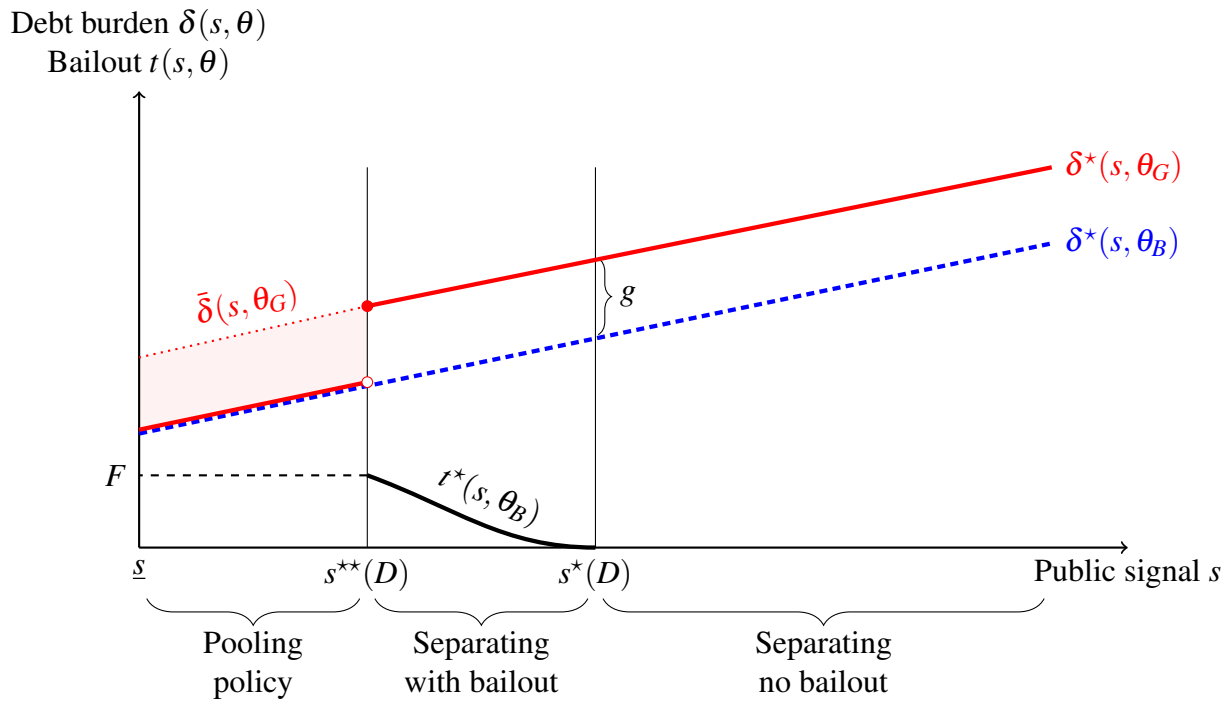


Figure 4: Optimal bail-in policy with bailouts

could precipitate a bank run, or create difficulties for the bank in refinancing short-term debt that would not otherwise have arisen.

We have outlined a mechanism that could be used to ameliorate this problem. In particular, we showed that in bad times, bail-in policies need to be insensitive to regulators' private information. In practice, we argue that this is best achieved by committing the regulator to acting on a rule which mandates action based on publicly available information. This can be preferable to giving the regulator full discretion to act on the basis of her private information, even though this is of superior quality. The key here is that because the regulator's action is now tied to public information, it provides no further information to the market than what is already available, because there is no scope for regulators with good news to distinguish themselves by conducting a weaker bail-in policy. There is a cost to tying the regulator's hands in this way, because it means that in some states, bail-ins will be excessive. Therefore, in states of the world when public information is sufficiently good that refinancing of short-term debt is unlikely to cause difficulties, the regulator should be allowed to act as she sees fit, writing down debt only as necessary. As a result, the

optimal regulatory arrangement is a combination of rules and discretion: Discretion when public information is relatively benign, and rules when public information is more negative. We explained how a mechanism of this kind could be implemented by encouraging banks to issue appropriate denominations of contingent-convertible (co-co) bonds with carefully chosen triggers at which the bonds convert to equity or are written down.

Finally, we considered the interaction between bail-ins and bailouts. Governments, knowing that bail-in is available as a tool to deal with failing banks, may be tempted to make strong commitments not to engage in future bailouts, in order to assure voters that they have ended the "too big to fail" problem. However, we have shown that such commitments should not be made without carefully considering the design of institutions for bank resolution, for example, of regulatory agencies with bail-in powers. If a commitment to avoid bailouts is not accompanied by appropriate *rules* governing bail-ins and curtailing regulatory discretion, then it can do considerable damage by resulting in undesirable behavior such as "zombie lending" by under-capitalized banks (e.g., Caballero et al., 2008; Jiménez et al., 2014; Acharya et al., 2018) or even precipitating bank runs.[30]

We close with an observation about the wider policy implications of our results. A direct corollary of our argument is that resolution schemes, on the one hand, and bank capital and liquidity regulation, on the other hand, should not be designed in isolation from one another. Indeed, the frictions inhibiting bail-in in our model are generated by the fact that the bank transforms liquidity and risk, earning a premium on its safe, liquid security issuance. When there are externalities associated with bank leverage, such as implicit government subsidies, banks have an incentive to engage in excessive liquidity transformation. In a typical credit boom, banks become more levered, reduce long-term lending standards, and finance a larger proportion of their illiquid investments with short-term debt. In such a scenario, the threat of runs becomes more salient once bad news arrives, and regulators have to tread even more carefully when implementing bail-in policies. As a result, recent regulations increasing bank capital and liquidity, by counteracting such trends and

[30]This concern is also expressed by Geithner (2016): *"A strategy designed to reduce the exposure of the taxpayer to losses and to reduce the risk of moral hazard can end up exacerbating both risks. Since few governments will ultimately choose to let the system collapse, a strategy of haircuts in conditions vulnerable to panic can end up costing more money in terms of losses to the taxpayer and require the government to socialize more risk."*

reducing the threat of bank runs, will have the additional benefit of allowing the bail-in regime to run more smoothly, reducing the need for future bailouts. That is, when the credibility of bail-in policies is at issue, tightening capital and liquidity requirements are policies which are complementary to bail-in, and not substitutes as has been suggested by some commentators (Carney, 2016). Liquidity and capital regulation are more beneficial at the margin when bail-in is possible, since they have not only the anticipated direct effect on the probability of bank failure, but also the indirect effect of increasing the regulator's willingness to conduct bail-ins when problems do arise.

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A Proofs

Proposition 1

Take any D in the range feasible defined by (10). Suppose that, taking D as given, the planner's remaining policy choices $\langle A, B, a(.), r(.)\rangle$ maximize welfare in (1) subject to the incentive compatibility constraint (7), the refinancing constraint (4) and the participation constraint (5). Recall that the critical public signal $s^\star(D)$ is the lowest s satisfying (9). We show by contradiction that the optimal policy must satisfy (11) in all public states s.

Suppose that there is a set Σ_0 of public signals $s \geq s^\star(D)$, with positive measure, for which the optimal policy implies a total debt level $\delta(s,\theta) \neq \bar{\delta}(s,\theta)$ for some θ. Then, using incentive compatibility, we have $\delta(s,\theta) \leq \bar{\delta}(s,\theta)$, with strict inequality for some θ. Suppose that the planner decreases $a(s,\theta)$ by $\Delta(\theta) = \bar{\delta}(s,\theta) - \delta(s,\theta)$ for all θ and $s \in \Sigma_0$, so that the total debt level becomes $\bar{\delta}(s,\theta)$. This policy satisfies incentive compatibility and, by the definition of $s^\star(D)$, it also satisfies the refinancing constraint, but now, the participation constraint is slack. Therefore, it is possible to decrease equity A by a small amount, which strictly increases welfare, contradicting optimality. Similarly, suppose that there is a set Σ_1 of signals $s < s^\star(D)$, with positive measure, for which the optimal policy implies $\delta(s,\theta) \neq \bar{\delta}(s,\theta_B)$ for some θ. The optimal policy must be pooling in state each $s \in \Sigma_1$ (otherwise, either incentive compatibility or refinancing are violated, contradicting feasibility), with $\delta(s,\theta) < \bar{\delta}(s,\theta_B)$. Suppose that the planner decreases $a(s,\theta)$ by $\Delta(\theta) = \bar{\delta}(s,\theta) - \delta(s,\theta)$ for all θ and $s \in \Sigma_1$. After this change, the refinancing and incentive compatibility constraints are still satisfied, and the participation constraint is slack, again contradicting optimality.

To complete the proof, we show that (10) is necessary and sufficient for feasibility. For sufficiency, note that the policy in (11) is feasible for any D satisfying (10). For necessity, suppose that $D > D_{max}$. Then by definition of D_{max} and the refinancing constraint, for the worst public signal $\underline{s}$, we have $\delta(\underline{s},\theta) > \bar{\delta}(\underline{s},\theta)$ for some θ, contradicting incentive compatibility.

Proposition 2

Using (8) and (12), we can re-write the regulator's objective function as

$$E[\min\{v, \delta(s,\theta)\}] + \xi D \tag{15}$$

Substituting the optimal debt burden for a given D from Proposition 1, we get maximized welfare for a given D:

$$\begin{aligned} W(D,\xi) = \xi D &+ \int_{\underline{s}}^{s^\star(D)} E[\min\{v, \bar{\delta}(s,\theta_B)\}|s] g(s) ds \\ &+ \int_{s^\star(D)}^{\bar{s}} \Big(Pr[\theta_G|s] E[\min\{v, \bar{\delta}(s,\theta_G)\}|s,\theta_G] + Pr[\theta_B|s] E[\min\{v, \bar{\delta}(s,\theta_B)\}|s,\theta_B] \Big) g(s) ds \end{aligned} \tag{16}$$

where $g(s) = \int f(v) g(s|v) dv$ is the marginal density of the public signal s. The optimal choice of D maximizes this expression over the feasible range defined in (10). Differentiating with respect to D, we have

$$\frac{\partial W(D,\xi)}{\partial D} = \xi - \frac{\partial s^\star(D)}{\partial D} \cdot Pr[\theta_G|s^\star] \cdot E\Big[\min\{v, \bar{\delta}(s,\theta_G) - \min\{v, \bar{\delta}(s,\theta_B)\}|s^\star, \theta_G\Big] \cdot g(s^\star) \tag{17}$$

We have $\frac{\partial^2 W(D,\xi)}{\partial D \partial \xi} > 0$, so that $W(D,\xi)$ is supermodular in (D,ξ) and, thus, the optimal choice of D is monotone increasing in ξ (see Milgrom and Shannon, 1994). Moreover, from the definition of $s^\star(D)$ as the lowest signal satisfying (9), it follows that $\frac{\partial s^\star(D)}{\partial D} \geq 0$, with strict inequality when $D > D_{min}$, so that the second term is negative for all D. Hence, as $\xi \to 0$, we have $\frac{\partial W(D,\xi)}{\partial D} < 0$ for all $D > D_{min}$ and the regulator chooses $D = D_{min}$. As $\xi \to \infty$, we have $\frac{\partial W(D,\xi)}{\partial D} > 0$ and the regulator chooses D_{max}, as required.

Lemma 2

Suppose that the regulator has discretion, that the planner's choices $\langle A^\star, B^\star, D^\star, a^\star(s,\theta), r^\star(s,\theta)\rangle$ occur on the equilibrium path of a PBE, and that creditor beliefs satisfy the Intuitive Criterion. Consider regulator's choice at date 1 in a state $s < s^\star(D^\star)$ where the optimal policy is pooling. Let r' be the hypothetical interest rate offered to new creditors if the regulator instead revealed θ_G, that is, the solution of $E[\min\{v,(1+r')D\}|s,\theta_G] = D$. Let $a' = (1+r')D + B - \bar{\delta}(s,\theta_G)$ be the bail-in that would achieve a total debt burden of $\bar{\delta}(s,\theta_G)$ after this revelation. The interest rate on the equilibrium path rate solves $E[\min\{v,(1+r^\star(s,\theta))D\}|s] = D$ and therefore we have $r' \leq r^\star(s,\theta)$ (since, by MLRP, the expectation of an increasing function of v given (s,θ_G) is larger than the expectation given s alone). The (pooling) bail-in action on the equilibrium path is $a^\star(s,\theta) = (1+r^\star(s,\theta))D + B - \delta^\star(s,\theta_B)$, and noting that $\bar{\delta}(s,\theta_B) < \bar{\delta}(s,\theta_G)$ (by Equation (1)), we get $a' < a^\star(s,\theta)$.

Given s, the expected level of welfare at date 1 for the regulator with type θ_B is $E[v|s,\theta_B]$ on the equilibrium path, because the debt level is $\bar{\delta}(s,\theta_B)$ and, hence, the bank makes effort. If type θ_B deviates to a', the total debt burden rises to at least $\bar{\delta}(s,\theta_G) > \bar{\delta}(s,\theta_B)$ (depending on creditors' beliefs), and the bank shirks, strictly lowering expected welfare for type θ_B. Therefore, a' is equilibrium-dominated for θ_B, and $Pr[\theta_G|a',s] = 1$ must be creditors' equilibrium belief by the Intuitive Criterion. But under these beliefs, type θ_G has a strictly profitable deviation to a', because it leads to a debt level $\bar{\delta}(s,\theta_G)$ by construction, so that the bank still makes effort, but reduces the costs of intervention by $\kappa(a^\star(s,\theta) - a') > 0$. This contradicts equilibrium.

Proposition 3

We show by backward induction that the planner's choices $\langle A^\star, B^\star, D^\star, a^\star(s,\theta), r^\star(s,\theta)\rangle$ occur on the equilibrium path of a PBE. At date 1, consider first a public signal $s \geq s^\star(D)$ so that the optimal policy is separating. The bank has no incentive to deviate from $r^\star(s,\theta)$: a lower rate would be rejected by creditors and a higher rate would lower shareholder value. For the regulator's choice $a^\star(s,\theta)$ to be optimal, specify creditors' beliefs such that $Pr[\theta_G|a',s] = 1$ for all a' that are equilibrium-dominated for θ_B (this includes $a' = a^\star(s,\theta_G)$ by the argument in the proof of Lemma

2), and $Pr[\theta_G|a', s] = 0$ otherwise. These beliefs satisfy the Intuitive Criterion by construction. Under these beliefs, the regulator with type θ_G would not deviate to a lower action than $a^\star(s, \theta_G)$ because it results in shirking, nor to a higher action because it raises costs of intervention without affecting bank behavior. The regulator with type θ_B would not deviate to an equilibrium-dominated action by definition. Among the other actions, she would not deviate to a lower action than $a^\star(s, \theta_B)$ because it results in shirking, nor to a higher action because it raises costs of intervention without affecting bank behavior.

Next, consider a public signal so that the optimal policy is pooling. The regulator is tied by rules to execute the optimal policy, so we focus on the bank's behavior. For the bank's interest rate offer $r^\star(s, \theta)$ to be optimal, specify creditors' off-path beliefs so that $Pr[\theta_B|r', s] = 1$ for all $r' \neq r^\star(s, \theta)$. These beliefs satisfies the Intuitive Criterion because $r' > r^\star(s, \theta)$ is equilibrium-dominated for all types of bank, while $r' < r^\star(s, \theta)$ is equilibrium-dominated for no types. Under these beliefs, no type of bank has an incentive to deviate to any $r' \neq r^\star(s, \theta)$, since the lowest interest rate it could hope to get accepted is the solution to $E[\min\{v, (1 + r)\}|s, \theta_B]$, and this solution is strictly larger than $r^\star(s, \theta)$, thus lowering bank welfare.

At date 0, use $z = \langle A, B, D\rangle$ as shorthand for the bank's capital structure. We verify that there are no profitable one-shot deviations $z \neq z^\star$, taking as given optimal behavior on the equilibrium path at date 1. Let $\tilde{a}(s, \theta, z)$ and $\tilde{r}(s, \theta, z)$ be the (on- and off-equilibrium path) strategies of the regulator and the bank at date 1, which on the equilibrium path satisfy $\tilde{a}(s, \theta, z^\star) = a^\star(s, \theta)$ and $\tilde{r}(s, \theta, z^\star) = r^\star(s, \theta)$. The bank's profit-maximization problem in choosing z is equivalent to maximize the net value of its equity in Equation (1), subject to participation, refinancing and incentive compatibility constraints, and in addition, the constraint that $a(s, \theta) = \tilde{a}(s, \theta, z)$ and $r(s, \theta) = \tilde{r}(s, \theta, z)$ for all (s, θ). Hence, the bank solves a more constrained version of the planner's problem, and the planner's (less constrained) optimal choices $z^\star$ are in the feasible set. Hence, $z^\star$ is an optimal choice for the bank.

B Analysis of incentive compatibility

At date 1, the bank's shareholders choose its shirking decision $x \in \{0, 1\}$ so as to maximize their expected payoff:

$$U = \int_{\delta/(1-\alpha x)}^{\infty} (v(1 - \alpha x) - \delta) f(v|s, \theta) dv + \beta x \tag{18}$$

where δ is the total debt burden. Note that we have

$$\frac{\partial U}{\partial x} = \beta - \alpha \int_{\delta/(1-\alpha x)}^{\infty} v f(v|s, \theta) dv \tag{19}$$

This is increasing in δ. Moreover, the integral on the right-hand side is the expected value of $1_{v>\delta/(1-\alpha x)} \cdot v$, which is an increasing function of v. The MLRP implies first-order stochastic dominance, so that this expectation is increasing in both s and θ. Hence, $\frac{\partial U}{\partial x}$ is decreasing in s and θ. It follows that, $U(x)$ is supermodular in (x, δ) and submodular in (x, s) and (x, θ). A standard monotone comparative statics argument (Milgrom and Shannon, 1994) then implies that the optimal choice of x is increases in δ and decreases in s and θ.

C Discussion of participation constraints

In the specification of the planner's problem, we use an aggregated participation constraint (5). This constraint ensures that long-term and short-term creditors are jointly willing to contribute enough funds at date 0 to finance the bank's project. In this appendix, we show that any optimal allocation in this problem be implemented in a way that satisfies *separate* participation constraints for short-term and long-term creditors. Hence, no cross-subsidization between creditors is needed to implement the optimal allocation.

Consider an optimal allocation in the planner's problem, which (by definition) satisfies all relevant constraints. Short-term debt is repaid in full at date 1. Thus, short-term creditors derive utility $(1 + \lambda)D$ from holding this security between dates 0 and 1. Hence, the relevant participation

constraint, letting d_0 denote the payment from short-term creditors to the bank at date 0, is

$$d_0 \leq (1+\lambda)D \tag{20}$$

For long-term debt, note that the total repayment to (long-term and new short-term) creditors at date 2 is $\min\{v, \delta^\star(s,\theta)\}$, and that short-term creditors receive the senior debt tranche $\min\{v, (1+r^\star(s,\theta))D^\star\}$. Hence long-term creditors receive the residual debt claim:

$$\min\{v, \delta^\star(s,\theta)\} - \min\{v, (1+r^\star(s,\theta))D^\star\} \tag{21}$$

Let b_0 denote the payment from long-term creditors to the bank at date 0. The participation constraint for long-term debt is:

$$\begin{aligned} b_0 &\leq E\left[\min\{v, \delta^\star(s,\theta)\} - \min\{v, \delta^\star(s,\theta)\}\right] \\ &= E\left[\min\{v, \delta^\star(s,\theta)\}\right] - D \end{aligned} \tag{22}$$

where the second line follows from the refinancing constraint (24). The bank's budget constraint at date 0 is

$$b_0 + d_0 + A \geq 1 \tag{23}$$

It is now easy to see that, since the candidate allocation satisfies the planner's participation constraint (5), we can find payments b_0 and d_0 that satisfy all of the above constraints. Hence, no cross-subsidization between short-term and long-term creditors is required to implement the social planner's choice at date 0.

D Formal analysis of the model with bailouts

In this Appendix, we present the equivalent of Proposition 1 when the government has a bailout fund F, as described in Section 4. The planner's problem is as in Section 2, except that the regulator

has an additional choice $t(s,\theta) \in [0,F]$, and the refinancing constraint in (4) changes to:

$$D - t(s,\theta) = \begin{cases} E[\min\{v,(1+r(s,\theta))D\}|s], & \text{if pooling in state } s \\ E[\min\{v,(1+r(s,\theta))D\}|s,\theta], & \text{if separating in state } s \end{cases} \tag{24}$$

For a given D, a bailout is necessary if the regulator's policy is separating in state s and $s < s^\star(D)$. Separating is impossible (due to the limited bailout fund F) if $s > s^F(D)$, which is implicitly defined as the lowest s satisfying

$$D \leq E[\min\{v,\bar{\delta}(s,\theta_B)\}|s,\theta_B] + F \tag{25}$$

Moreover, a bailout is needed if pooling in state s and $s < s^P(D)$, implicitly defined as the lowest s satisfying

$$D \leq E[\min\{v,\bar{\delta}(s,\theta_B)\}|s] \tag{26}$$

We have $s^P(D) = \underline{s}$ whenever $D \leq D_{max}$. As mentioned in the text, we focus on the case where F is not too large: Specifically, we can find a limit $\bar{F}$ so that $s^P(D) \leq s^F(D)$ whenever $F \leq \bar{F}$. We will assume that $F \leq \bar{F}$ in the remainder of this Appendix. This guarantees that, when extending the separating region to $s < s^\star(D)$, the regulator is forced to stop before a bailout becomes necessary with pooling.[31]

We now characterize properties of the optimal policy, which confirm our illustration in Figure 4:

Proposition 4. *For a given short-term debt level D, there exists a feasible policy if and only if D satisfies*

$$0 \leq D \leq D_{max} + F \tag{27}$$

[31] In this range of public signals with $s > s^P(D)$, the net benefit of separating is monotone increasing in s and allows for a simple characterization below. When $F > \bar{F}$, there is an additional effect: If the regulator has extended the separating region to $s < s^P(D)$, the net benefit of separating can become decreasing in s (if we have to bailout with probability 1 anyway, it pays to fine-tune the bailout in bad states). An analysis of this case is available on request.

where D_{max} is defined as in Proposition 1. There exists a signal $s^{\star\star}(D) \in [s^F(D), s^\star(D))$ such that, for any optimal policy, the total state-contingent debt burden is

$$\delta^\star(s,\theta) = \begin{cases} \bar{\delta}(s,\theta), & s \geq s^{\star\star}(D), \\ \bar{\delta}(s,\theta_B), & s < s^{\star\star}(D) \end{cases} \tag{28}$$

and the optimal state-contingent bailout is

$$\begin{aligned} t^\star(s,\theta) = 1_{s\in[s^{\star\star}(D),s^\star(D)],\theta=\theta_B} \left(D - E[\min\{v, \bar{\delta}(s,\theta_B)\}|s,\theta_B]\right) \\ + 1_{s<s^P(D)} \left(D - E[\min\{v, \bar{\delta}(s,\theta_B)\}|s]\right) \end{aligned} \tag{29}$$

Proof. For $s > s^\star(D)$, the optimal policy from Proposition 1 is optimal with $t(s,\theta) = 0$ and, hence, remains optimal when bailouts are possible. For $s^F(D) \leq s < s^\star(D)$, the regulator can conduct a separating policy with a bailout, or the pooling policy from Proposition 1 without a bailout. If the regulator decides to separate and conduct a bailout, this has two opposing effects on welfare. On one hand, the bailout generates a direct expected deadweight cost of

$$\chi Pr[\theta_B|s](D - E[\min\{v, \bar{\delta}(s,\theta_B)\}|s,\theta_B]) \tag{30}$$

which is zero when $s = s^\star(D)$, and always decreasing in s: $Pr[\theta_B|s]$ is decreasing in s and the conditional expectation is decreasing in s (by MLRP). On the other hand, the ability to separate generates additional pledgeable income, which raises welfare by

$$\phi Pr[\theta_G|s] E\left[\min\{v, \bar{\delta}(s,\theta_G)\} - \min\{v, \bar{\delta}(s,\theta_B)\}|s,\theta_G\right] \tag{31}$$

which is always increasing in s: $Pr[\theta_G|s]$ is increasing in s and the conditional expectation is increasing in s (by MLRP). Thus, the net benefit of separation is positive when $s = s^\star(D)$, and increasing in s. Now defining $s^{\star\star}(D)$ as the lowest s such that the net benefit is positive and $s^F(D) \leq s < s^\star(D)$, we obtain the desired characterization of optimal policy in (28). The first term in (29) follows directly. The second term, for $s < s^B(D)$ follows because this bailout is the

minimum amount needed to satisfy the refinancing constraint with a pooling policy. To complete the proof, we show that (27) is necessary and sufficient for feasibility. For sufficiency, note that the policy characterized above is feasible for any D satisfying (27). For necessity, suppose that $D > D_{max} + F$. Then by definition of D_{max} and the refinancing constraint, for the worst public signal $\underline{s}$, we have $\delta(\underline{s}, \theta) > \bar{\delta}(\underline{s}, \theta)$ for some θ, contradicting incentive compatibility. □