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Runs versus Lemons: Information Disclosure and Fiscal Capacity[1]

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We study the optimal use of disclosure and fiscal backstops during financial crises. Providing information can reduce adverse selection in credit markets, but negative disclosures can also trigger inefficient bank runs. In our model governments are thus forced to choose between runs and lemons. A fiscal backstop mitigates the cost of runs and allows a government to pursue a high disclosure strategy. Our model explains why governments with strong fiscal positions are more likely to run informative stress tests, and, paradoxically, how they can end up spending less than governments that are more fiscally constrained.

Key words: Stress test, Bayesian persuasion, Fiscal capacity, Bailouts

JEL Codes: E5, E6, G1, G2

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Governments intervene in various ways during financial crises (Gorton, 2012). Some policies, such as liquidity support, credit guarantees, and capital injections are explicitly backed by the balance sheet of the government. Other policies, such as stress tests and asset quality reviews, do not rely directly on the fiscal capacity of the government but rather on its ability to (credibly) disclose information. Governments almost always use both types of interventions, yet the existing literature has only studied one or the other. Our goal is to provide a joint theory of optimal interventions.

One motivation for our analysis is the striking difference between the stress tests implemented in the U.S. and in Europe following the financial crisis of 2008-2009. In May 2009, the Federal Reserve publicly reported the results of the Supervisory Capital Assessment Program (SCAP). The SCAP was an assessment of the capital adequacy, under adverse scenarios, of a large subset of U.S. financial firms. The exercise is broadly perceived as having reduced uncertainty about the health of U.S. banks and helped restore confidence in financial markets.

European policy makers were keenly aware of the U.S. experience, and yet, after much hesitation, ended up designing significantly weaker stress tests. The Committee of European Banking Supervisors (CEBS) conducted E.U.-wide stress tests from May to October 2009 but chose not to disclose the results. The exercise was repeated a year later and the results were published, but the scope of the test was limited, especially with regard to sovereign exposures. Our theory suggests that the lack of a credible backstop made it risky for individual governments to conduct rigorous stress tests. Our theory is also consistent with the fact that the Asset Quality Review (AQR) run by the European Central Bank in 2014, *after* the introduction of financial backstops (ESM, OMT), was significantly more rigorous and probably on par with the American stress tests.[1]

We also argue, from a theoretical perspective, that fiscal backstops and information disclosure should be jointly studied because this comprehensive approach leads to new predictions and can overturn existing results. Most strikingly, we find that, once endogenous disclosure choices are taken into account, governments with strong fiscal positions can end up spending less on bailouts than governments with weak fiscal positions. This prediction is exactly the opposite of what one would conclude when considering only one policy at a time. Our main theoretical result is that governments with strong fiscal positions are more likely to run aggressive stress tests; these stress tests can then make bailouts unnecessary. This is an important empirical prediction, but also a relevant point when studying time consistency issues and the balance between rules and discretion.

Disclosure. Disclosure is typically motivated by the need to restore investor confidence in the health of financial firms. We capture this idea using a simple model of adverse selection, following Akerlof (1970) and Myers and Majluf (1984). Our economy is populated by financial intermediaries ("banks") who privately observe the quality of their existing assets, which may be high (type H) or low (L). The main state variable in our economy is the fraction of banks with high quality assets. Both types of banks have valuable investment opportunities and can raise external funds in credit markets. The riskiness of lending to a particular bank, however, depends on the quality of its existing assets, which creates the potential for adverse selection. When perceived asset quality is high, adverse selection is limited and credit markets operate efficiently. When the fraction of type H banks is believed to be low, credit markets are likely to freeze, and the government may be able to improve welfare by disclosing information about asset quality.

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[1] Ong and Pazarbasioglu (2014) provide a thorough overview of the details and perceived success of SCAP and the CEBS stress tests. See Véron (2012) for a discussion of the challenges facing European policy makers.

Alleviating adverse selection therefore pushes the government to disclose information about banks' balance sheets. Why, then, not disclose as much as possible? We argue that an important cost of disclosure is the risk of triggering a run on weak banks. We follow the standard approach of Diamond and Dybvig (1983) in modeling banks as being funded with runnable liabilities.[2] If short term creditors (depositors) learn that a particular bank is weak, they might decide to run. Runs are inefficient because they entail deadweight losses from liquidation and missed investment opportunities.

Disclosure then involves a trade-off between runs and lemons. We first solve for optimal disclosure without any fiscal intervention. We model disclosure as in the Bayesian persuasion model of Kamenica and Gentzkow (2011). The government and the private sector share some prior belief about the health of financial firms. The government chooses the precision of the signals that are generated. Each signal contains information about the quality of an individual bank.

Disclosure vs. Guarantees. Governments also extend guarantees to stop financial crises. In our model, the benefit from insuring runnable liabilities is to prevent the inefficient liquidation of long-term assets. However, guarantees expose the government to potential losses and, therefore, to deadweight losses from taxation.

The main contribution of our paper is then to analyze the interaction between fiscal capacity and optimal disclosure. We obtain two main results. First, we characterize optimal disclosure and deposit insurance in the "runs versus lemons" model. To do so, we map the model into a Bayesian persuasion framework and we show how to take into account fiscal policy. We can then prove our main result: all things equal, a government in a stronger fiscal position pursues a more aggressive disclosure policy.

To obtain our second main result we introduce some empirically relevant features: aggregate risk, a risk averse government, and a broader set of fiscal policies – credit guarantees, discount lending, recapitalization – that are routinely observed during financial crises. Our key insight is that fiscal capacity provides insurance against the risks created by disclosure when the government does not know the true quality of its banking sector (the fraction of H-types). Imposing meaningful transparency about balance sheets can still unfreeze credit markets, but it can also create large runs in some states of the world. A regulator with a strong fiscal backstop is more likely to choose a high-risk high-return strategy, i.e., high disclosure to unfreeze markets, but with the option to extend of deposit insurance if runs occur. Faced with the same dilemma, a fiscally constrained government might limit disclosure to avoid the risk of large runs, and instead provide other forms of bailouts (i.e., credit guarantees). This leads to what we call the *paradox of fiscal capacity.* When governments are risk averse, a government with limited fiscal capacity can end up spending *more* on average than a less constrained government. This happens when runs are rare but costly, and the insurance motive is strong. Constrained governments then opt for a low risk low return strategy: they maintain opacity to avoid runs, and they subsidize credit to avoid a complete market freeze.

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[2] We have in mind all types of short-term runnable liabilities: MMF, repo, ABCP, and, of course, large uninsured deposits. In the model, for simplicity, we always refer to all intermediaries as banks and to all runnable liabilities as deposits. We take the existence of these runnable claims as given. Our model does not address the deep and important issue of why financial firms issue these unstable liabilities in the first place. See Zetlin-Jones (2014) for a model where a bank optimally chooses a fragile capital structure that is subject to bank runs. See also Williams (2015) for an analysis of portfolio choice. A critical issue is then whether the privately chosen level of runnable claims is higher than the socially optimal one, which obviously depends on fire sales and other types of externalities. The goal of our paper is not to study these externalities, but it is easy to incorporate them, as in Philippon and Schnabl (2013) for instance. They would only change the optimal level of interventions without changing their design, which is the focus of our paper.

Related Literature. Our work builds on the corporate finance literature that studies asymmetric information, in particular Myers and Majluf (1984) and Nachman and Noe (1994), and on the bank runs literature started by Diamond and Dybvig (1983). Several recent papers shed light on how runs take place in modern financial systems: theoretical contributions include Uhlig (2010) and He and Xiong (2012); Gorton and Metrick (2012) provide a detailed institutional and empirical characterization of modern runs.

Several recent papers study specifically the trade-offs involved in revealing information about banks. Goldstein and Sapra (2014) review the literature on the disclosure of stress tests results. Goldstein and Leitner (2013) focus on the Hirshleifer (1971) effect: revealing too much information destroys risk-sharing opportunities between risk neutral investors and (effectively) risk averse bankers. These risk-sharing arrangements also play an important role in Allen and Gale (2000). Shapiro and Skeie (2015) study the reputation concerns of a regulator when there is a trade-off between moral hazard and runs. Bouvard et al. (2015) and Parlatore (2013), study disclosure in models of bank runs using the global game approach of Carlsson and van Damme (1993) and Morris and Shin (2000). Williams (2015) models disclosure using Bayesian persuasion and explores the implications of disclosure for banks' ex-ante portfolio choice.[3]

Another important issue is the credibility of disclosure by the government. Bouvard et al. (2015) focus on the commitment issue that arises when the government knows the true state of the world and may choose to reveal it or not. They find that the government chooses to reveal less information during bad times, but the private sector anticipates this behavior, resulting in a socially inefficient equilibrium. Angeletos et al. (2006) study the signaling consequences of governments' actions. In our model the government and the private sector share the same information about the aggregate state, and therefore there is no issue of commitment or signaling.[4]

In our setting, banks are not able to credibly disclose information about their type. Alvarez and Barlevy (2015) study disclosure and contagion in a banking network. They show that private disclosure choices are not always efficient and that mandatory disclosure can improve welfare. Hellwig and Veldkamp (2009), on the other hand, consider the endogenous acquisition of information. Gorton and Ordoñez (2014) consider a model where crises occur when investors have an incentive to learn about the true value of otherwise opaque assets. Chari et al. (2014) develop a model of secondary loan markets where adverse selection and inefficient pooling equilibria can persist in a dynamic setting due to reputation.

Our paper also relates to the large literature on bank bailouts. Gorton and Huang (2004) argue that the government can provide liquidity more effectively than private investors while Diamond (2001) emphasizes that governments should only bail out the banks that have specialized knowledge about their borrowers. Philippon and Skreta (2012) and Tirole (2012) formally analyze optimal interventions in markets with adverse selection. Mitchell (2001) analyzes interventions when there is both hidden action and hidden information. Landier and Ueda (2009)

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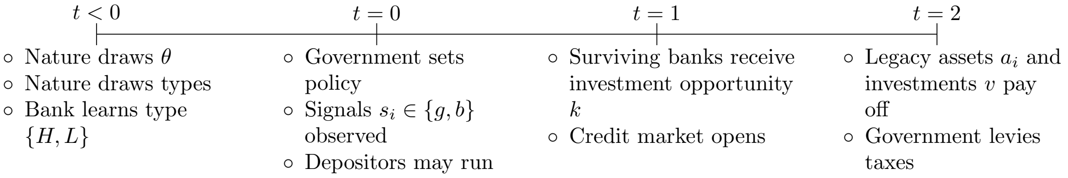
3. There is an important difference between runs-only models and our runs-versus-lemons model. In runs-only models disclosure is welfare improving only when there is a complete run. The logic is simple: if there is a run on all banks, the government can save at least the good ones by disclosing their identities. Absent an aggregate run that threatens even the strong banks, policy makers do not have an incentive to disclose information. Our analysis covers this particular case, but also emphasizes an entirely different tradeoff, which relates to the unfreezing of markets plagued by adverse selection. The evidence suggests that this tradeoff is empirically relevant. At least in the recent crisis, the stated goal of disclosure was to unfreeze credit markets, not to prevent runs on healthy banks. Policy maker wanted to boost credit, and runs were seen as a potential *cost* of disclosure. This is why we choose to emphasize the trade-off between runs and lemons.

4. Both cases are worth analyzing. Credibility and commitment are very important issues. However, since it is probably difficult for governments to conceal the results of stress tests, the best way to ensure that information does not become public knowledge is not to produce it in the first place. Moreover, it is common for governments to hire outside consultants to run stress tests, which is a form of commitment not to alter the results.

FIGURE 1

Model Timing



Note: θ is the fraction of type H banks, s_i is a signal about bank i's quality.

provide an overview of policy options for bank restructuring. Diamond and Rajan (2011) study the interaction of debt overhang with trading and liquidity. Philippon and Schnabl (2013) study the macroeconomic consequences of debt overhang in the financial sector. Another important strand of the literature studies the ex-ante efficiency of crises and bailouts, following the seminal work of Kareken and Wallace (1978). Chari and Kehoe (2013) show that time consistency issues are worse for a government than for private agents. Zetlin-Jones (2014) shows that occasional systemic crises can in fact be part of an efficient ex-ante equilibrium.

The paper is organized as follows. Section 1 presents the model. Section 2 describes the equilibrium without government interventions. Section 3 studies optimal disclosure and deposit insurance. Section 4 extends our model to aggregate risk and credit market interventions. Section 5 concludes.

1. DESCRIPTION OF THE MODEL

1.1. *Technology and Preferences*

There are three periods, $t = 0, 1, 2$, one good, and three types of agents: a continuum of mass 1 of households, a continuum of mass 1 of financial intermediaries (which we call banks for short), and a government. Government policies are studied in Sections 3 and 4. Figure 1 summarizes the timing of decisions and events in the model, which are explained in detail below.

Households receive an endowment $\bar{y}_1$ in period 1, and only value consumption in period 2. They have access to a storage technology to transfer resources from period 1 to period 2. This allows us to treat total output at time 2 as the measure of welfare that the government seeks to maximize. Households have deposits in the banks, can lend in the credit market in period 1, and are residual claimants of all banking profits in period 2.

Banks are indexed by $i \in [0, 1]$ and have pre-existing long-term assets (legacy assets) and redeemable liabilities (deposits). The legacy assets of bank i generate income a_i at time 2. Each bank may be of either type H or L, which is *privately* observed. H banks' assets have higher payoff than those of L banks (in a stochastic dominance sense, see footnote 6). Let $\mathcal{H}$ be the set of H banks, and $\mathcal{L}$ be the set of L banks. Nature draws $\mathcal{H}$ in two steps: it first draws the fraction of H-banks θ from the distribution $\pi(\theta)$, and each bank then has the same likelihood of being type H. The random variable θ is therefore both the fraction of H banks in the economy and the ex-ante probability that any given bank is type H,

$$\Pr(i \in \mathcal{H} \mid \theta) = \theta.$$

Depositors can withdraw their deposits at any time before period 2, which entitles them to receive 1 unit of consumption, or wait until period 2 and receive $D > 1$. Banks have access to a liquidation technology with deadweight loss $\delta \in (0,1)$. Bank i can liquidate its assets at any time before time 2 and receive $(1-\delta)\, a_i$. If a bank is unable to meet its short term obligations, depositors receive a pro rata share of the residual value. In period 1, surviving banks have access to an investment opportunity that costs a fixed amount k and delivers a random payoff v at time 2. Investment projects have positive net present value ($\mathbb{E}[v] > k$), and we assume that investment by all banks is feasible ($\bar{y}_1 > k$).[5]

For simplicity, we assume that the payoffs of legacy assets and new investments are binary, and that all the banks have the same investment opportunities. Our modeling choices for banking assets follow closely those in Philippon and Skreta (2012), and our results hold in their general setting using the same technical assumptions.[6] Legacy assets pay off $A^{\{H,L\}}$, with $A^L < A^H$; projects return V with probability q or 0 with probability $1-q$. The parameters A^H, A^L, k, q and V are all strictly positive and satisfy:

$$A^H - \frac{k}{q} > D > A^L > 0 \tag{1.1}$$

These inequalities imply that H-banks are safe even if they need to borrow at a high rate, while the deposits of L-banks are risky. Finally, investment projects have positive net present value so $qV > k$.

1.2. *Government policies*

The government in our model has access to two types of policies, which we call *information disclosure* and *fiscal interventions.* We impose an important restriction on government interventions:

1.2.0.1. *Assumption 1: Feasible Interventions.. The government cannot repudiate private contracts and must respect the participation constraints of all private agents.*

Assumption 1 is critical for our analysis as it restricts the set of feasible policies. Taxes and disclosure are the only tools that are allowed to violate participation constraints (i.e., the government has the right to disclose that a bank is weak even though it hurts the bank's shareholders). The government cannot force households to keep their deposits in the banks, nor can it force banks to issue claims they do not want to issue. We later discuss the implications of this assumption for bank regulations, such as forcing banks to raise equity.

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[5] For simplicity we assume that banks that liquidate lose their investment opportunity. This simplifies the exposition because we do not have to keep track of partially liquidated banks at the investment stage. Our main results also hold when the quality of new investment opportunities is correlated with the banks' type but this complicates the exposition.

[6] Formally, we assume that repayment schedules are non-decreasing in total income $a+v$, and that the distribution of $a+v$ satisfies the strict monotone hazard rate property with respect to bank types:

$$\frac{f(a+v \mid L)}{1-F(a+v \mid L)} > \frac{f(a+v \mid H)}{1-F(a+v \mid H)}.$$

where F and f are the *c.d.f.* and *p.d.f.* of $a+v$, respectively. Our simplified model satisfies these requirements. The important point is that the quality of legacy assets matters for new investment, which can be justified in several ways. Here we follow the standard corporate finance assumption that only total income $a+v$ is contractible. Tirole (2012) instead assumes that new projects are subject to moral hazard, so banks must pledge their existing assets as collateral. One could also assume that bankers can repudiate their debts, engage in risk shifting, etc. All these frictions motivate the role of existing assets as collateral for new loans and are equivalent in our framework. See Philippon and Skreta (2012) for a discussion of these issues.

1.2.1. Information disclosure. The government chooses at time 0 the precision of the signals $\{s_i\}_{i\in[0,1]}$ about banks' types.[7] Formally, the government chooses p^b and p^g in $[0,1]^2$, defined as:

$$\begin{aligned} p^b &\equiv \Pr\left(s_i = b \mid i \in \mathcal{L}\right) \\ p^g &\equiv \Pr\left(s_i = g \mid i \in \mathcal{H}\right) \end{aligned} \tag{1.2}$$

Define $\mathbf{p}$ as the vector of precisions: $\mathbf{p} \equiv \left\{p^g, p^b\right\}$. These signal precisions control the probability that signals b and g correctly identify banks of type L and H, respectively. An important issue is whether or not the government knows θ when it sets its disclosure policy. We will consider both cases in Section 3 and 4.

1.2.2. Fiscal interventions. The government can raise tax revenue in period 2 in order to finance interventions in earlier periods. Raising Ψ units of revenue creates a deadweight loss $\gamma\Psi^2$, where γ is our measure of (the inverse of) fiscal capacity. In the baseline model, we allow the government to insure bank deposits in order to prevent banks runs. In an extension, we consider interventions to alleviate adverse selection and facilitate new investments. Fiscal interventions are decided after θ is revealed.

1.3. *Welfare*

Given our assumptions about preferences and technology we can characterize the first best allocation. The first best level of consumption in aggregate state θ is

$$\bar{c}\left(\theta\right) = \mathbb{E}\left[a \mid \theta\right] + \bar{y}_1 + \mathbb{E}[v] - k, \tag{1.3}$$

which, given our assumptions, is simply $\bar{c}\left(\theta\right) = \theta A^H + (1-\theta)A^L + \bar{y}_1 + qV - k$. The first-best allocation has three simple features: (i) no assets are liquidated; (ii) all banks invest; and (iii) taxes are zero. Departures from the first best allocation are driven by information asymmetries, coordination failures, and government interventions. Ex-post consumption in the economy is given by

$$c\left(\theta\right) = \bar{c}\left(\theta\right) - \delta\int_{\Lambda} a_i - \int_{\Omega\cup\Lambda}\left(qV - k\right) - \gamma\Psi^2, \tag{1.4}$$

where Λ measures runs (the set of banks that are liquidated) and Ω measures adverse selection (the set of banks that are not liquidated but choose not to invest). The sets Λ and Ω are complex equilibrium objects that depend on the realization of θ and the policies chosen by the government. Our government chooses its policy to maximize $\mathbb{E}_\theta\left[u\left(c\left(\theta\right)\right)\right]$ where $u\left(.\right)$ is a concave function.[8] In Section 3, we assume that the government sets p after θ is revealed so the government simply

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[7] We have assumed that insiders cannot credibly disclose information about the quality of banks' assets, or equivalently, that they have already disclosed all they can, and our model is about residual uncertainty. It is natural to ask why and how the government can do better. There are two fundamental reasons for this. First, the government does not have the same conflict of interest as individual banks: imagine that there are two banks and that investors know that one is weak, but do not know which one. Both banks would always claim to be the strong one, whereas the government is indifferent about the identity of the weak bank. The government can therefore credibly reveal the identity of the weak bank if it chooses to do so. This advantage in commitment and credibility is deeply connected to the idea of Bayesian persuasion given a common aggregate signal. Second, the government can mandate costly stress tests and asset quality reviews, and can impose the same standards and procedures on all banks. As a result, it can compare the results across banks with greater ease than private investors. This can also explain why the government is able to disclose more information than the private sector.

[8] Note that the government cares only about aggregate consumption, so when we consider risk aversion we are implicitly assuming a large family model where families have diversified holdings of financial assets across banks.

maximizes $c(\theta)$. In Section 4, we study the consequences of risk aversion and uncertainty about θ for optimal policies.

2. EQUILIBRIUM WITHOUT INTERVENTIONS

Let us first characterize the equilibrium with exogenous signals and no interventions.

2.1. *Information*

Investors observe public signals $\{s_i\}_{i\in[0,1]}$ about bank types at the beginning of period 0. We denote by n^s the mass of banks receiving signal s. By definition, we have

$$\begin{aligned} n^b &= p^b (1-\theta) + (1-p^g)\theta, \\ n^g &= p^g\theta + \left(1-p^b\right)(1-\theta). \end{aligned}$$

Agents know p^b and p^g so in observing n^b and n^g they also learn the aggregate state θ. Let z^s denote the posterior belief that a bank is type H if receives signal s, $z^s \equiv \Pr(i \in \mathcal{H} \mid s_i = s)$. Using Bayes' rule,

$$z^b \equiv \Pr(H \mid s=b) = \frac{\Pr(s=b \mid H)\Pr(H)}{\Pr(s=b)} = \frac{(1-p^g)\theta}{p^b(1-\theta)+(1-p^g)\theta} \tag{2.5}$$

and

$$z^g \equiv \Pr(H \mid s=g) = \frac{\Pr(s=g \mid H)\Pr(H)}{\Pr(s=g)} = \frac{p^g\theta}{p^g\theta+(1-p^b)(1-\theta)} \tag{2.6}$$

Note that these posterior probabilities depend on the precisions p^b and p^g as well as on the realization of the aggregate state θ.

2.2. *Runs*

Our model of bank runs is entirely standard. Depositors can withdraw their deposits from banks at any time.[9] The liquidation technology yields $1-\delta$ per unit of asset liquidated and a bank that makes use of this technology loses the opportunity to invest in period 1. If a bank liquidates a fraction λ of its assets, it can satisfy $(1-\delta)\lambda a$ early withdrawals and has $(1-\lambda)a$ left at time 2. We assume that type H banks are liquid even under a full run while type L banks are not.

Assumption 2: Liquidity.. Type H banks are liquid, and type L banks are not

$$A^L < \frac{1}{1-\delta} < A^H$$

Suppose first that a bank is known to be type H. Withdrawing early yields 1 while waiting yields the promised payment D. Since $D>1$, the unique equilibrium is no-run. On the other hand, if the bank is known to be type L, a run equilibrium always exists because the bank would have no

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[9] We do not explicitly model households with liquidity shocks that motivate the existence of deposit contracts in the first place, nor do we address the question of whether a planner, assuming that it could, would choose to suspend convertibility. These issues have been studied at length and the trade-offs are well understood (see Gorton (1985), for example). When liquidity demand is random, suspending convertibility is socially costly. We assume that these costs are large enough that the government prefers to guarantee deposits. Note also that our broad interpretation of deposits in the model includes short-term wholesale funding, for which suspension would be difficult to implement in any case.

assets left to pay its patient depositors after a full run. Knowing this, no depositor would wait if they anticipate a run.

The decision to run depends on the belief z about the quality of a bank. Under Assumption 2, no-run is the only equilibrium when $z = 1$. Let z^R be the posterior belief above which no run is the unique equilibrium. This threshold is such that depositors are indifferent between running and waiting if all other depositors run. Therefore $z^R + \left(1 - z^R\right)(1-\delta) A^L = z^R D$, and

$$z^R = \frac{(1-\delta) A^L}{D + (1-\delta) A^L - 1}. \tag{2.7}$$

For beliefs in the set $\left[0, z^R\right]$ multiple equilibria exist. For simplicity, we select the run equilibrium for any bank whose posterior belief falls in the multiple equilibrium region. What matters for our results is that a run is possible in that range, not that it is certain.[10] We summarize our results in the following lemma.

Lemma 1. *The set of banks that are liquidated is*

$$\Lambda(\theta; \mathbf{p}, \emptyset) = \left\{ i \in [0,1] \mid z_i \leq z^R \right\},$$

where $\emptyset$ *denotes the absence of deposit insurance.*

Proof. See above.

2.3. *Lemons*

Banks receive valuable investment opportunities in period 1 but they must raise k externally. Under the assumptions of Section 1, we have the following standard result in optimal contracting:

Lemma 2. *Debt is a privately optimal contract to finance investment in period* 1.

Proof. See Nachman and Noe (1994) and Philippon and Skreta (2012).

If a bank borrows at rate r and invests, the payoffs of depositors, new lenders, and equity holders are

$$\begin{aligned} y^D &= \min(a + v, D) \\ y^l &= \min(a + v - y^D, rk) \\ y^e &= a + v - y^D - y^l \end{aligned}$$

These payoffs reflect the fact that deposits are senior, and equity holders are residual claimants. Adverse selection arises from the fact that banks know the payoffs of their legacy assets while lenders do not. Banks of type H know that they always pay back their debts, so they find it profitable to borrow at rate r only when $A^H - D + qV - rk \geq A^H - D$. These banks therefore invest if and only if the market rate is below r^H, where

$$r^H \equiv \frac{qV}{k}. \tag{2.8}$$

We are interested in situations where the information asymmetry can induce adverse selection in the credit market. This happens when the fair interest rate for L-banks, $1/q$, exceeds the maximum

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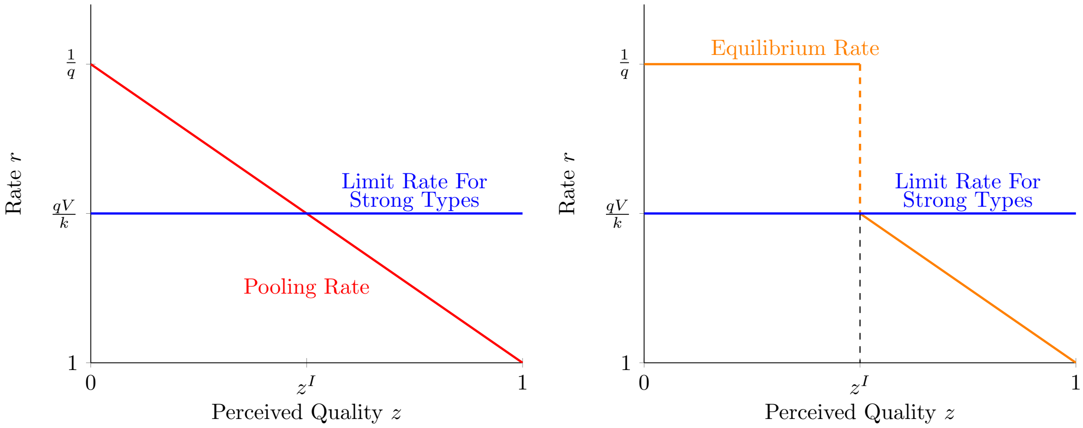
[10] We have solved our model under two alternative and often used equilibrium selection devices: dispersed information and sunspots. Our results are robust to using these alternative refinements.

FIGURE 2

Credit Market Equilibrium



This figure illustrates the equilibrium in credit markets by plotting the break-even rate for lenders r on the vertical axis, against the perceived quality of the pool of banks z in the horizontal axis. Due to strong banks opting out of participation in credit markets, the pooling rate on the left panel is not an equilibrium for $z < z^I$*. The right panel illustrates the equilibrium with adverse selection: below* z^I*, the equilibrium interest rate is* q^{-1} *and only type L banks participate in credit markets.*

interest rate at which H-banks are willing to invest: $1/q > r^H$, which is equivalent to imposing $q \leq \sqrt{\frac{k}{V}}$.[11] Adverse selection models can have multiple equilibria. For instance, if lenders expect only type L banks to invest, they set $r = 1/q$ and indeed, at that rate, strong banks do not participate. This multiplicity disappears when governments can intervene, however, because (as we show below) the government can costlessly implement the best pooling equilibrium by setting the interest rate appropriately. Without loss of generality, we therefore select the best pooling equilibrium.

The equilibrium rate must satisfy the break-even condition of lenders. Consider a pooling equilibrium where lenders have a belief z about the type of a bank in the pool. Given that the risk free rate at which lenders can store is one, the break-even condition is $k = zrk + (1-z)\,qrk$. Lenders know that there is a probability $1-z$ of lending to a type L bank that only repays with probability q. The pooling rate is therefore

$$\bar{r}\,(z) = \frac{1}{z + (1-z)\,q}. \tag{2.9}$$

Figure 2 illustrates the equilibrium conditions.

Finally, we need to check the consistency of the pooling equilibrium by requiring that $\bar{r}\,(z) < r^H$. This defines a threshold z^I such that the pooling equilibrium is sustainable if and only if $z > z^I$:

$$z^I \equiv \frac{\frac{k}{qV} - q}{1-q}. \tag{2.10}$$

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[11] Equity holders of weak banks earn nothing if they do not invest since their existing assets are insufficient to repay their depositors. As a result, type L banks always prefer to invest. Even in the absence of asymmetric information, however, underinvestment by type L banks could occur due to debt overhang, as in Philippon and Schnabl (2013). This is the case in our model if $\frac{k}{V-(D-A^b)} > q$. If type L banks never invest due to debt overhang, there is no adverse selection in credit markets.

The credit market in period 1 is thus characterized by a cutoff z^I on the perceived quality of any pool of banks. When $z > z^I$, both H and L types invest, and the interest rate is $r(z) = \bar{r}(z)$. When $z < z^I$, only L types invest, and the interest rate is $r^L = {}^1\!/_q$.[12] We summarize the credit market equilibrium in the following lemma.

Lemma 3. *The set of banks that opt out of credit markets is*

$$\Omega(\theta; p, \emptyset) = \left\{ i \in \mathcal{H} \mid z^R \leq z_i < z^I \right\}.$$

Proof. See above.

2.4. *Private Equilibrium*

The two cutoffs z^R and z^I depend on different parameters. We assume from now on that $z^R < z^I$. Empirically, this is a natural assumption since market freezes are observed before bank runs (Heider et al., 2010). Theoretically, our results also hold when $z^R \geq z^I$ but this case is trivial because liquidated banks do not invest. The equilibrium regions in the space of beliefs z are depicted in the left panel of Figure 3: banks with posterior belief lower than z^R suffer a run and are liquidated (these banks make up the set Λ); banks with posterior belief in the $\left[z^R, z^I\right]$ interval are not run on, but credit markets for these banks are affected by adverse selection (banks of type H in this interval make up the set Ω); finally, all banks with belief greater than z^I invest, since credit markets for these banks are free from adverse selection.

Consider a pool of banks with the same posterior belief z about asset quality. Investors are rational (Bayesian), so z is also the true probability of any bank in the pool being type H. Further, because there are a continuum of banks, z is also the fraction of H-types in the pool. Let $y(z)$ be the output generated by a pool of banks of quality z and $\bar{y}(z)$ be the first best level

$$\bar{y}(z) \equiv \bar{a}(z) + qV - k,$$

where $\bar{a}(z) = (1-z)A^L + zA^H$. The following proposition summarizes the equilibrium of our economy without government intervention.

Proposition 1. *In the private equilibrium, output is*

$$y(z) = \bar{y}(z) - \mathbf{1}_{z<z^R} \cdot \left(\delta \bar{a}(z) + qV - k\right) - \mathbf{1}_{z \in (z^R, z^I)} \cdot z\,(qV - k) \tag{2.11}$$

Proof. Follows from Lemmas 1 and 3.

Welfare depends on z not only through average asset quality, as in the first best, but also, and more importantly, via liquidation and lost investment opportunities.[13]

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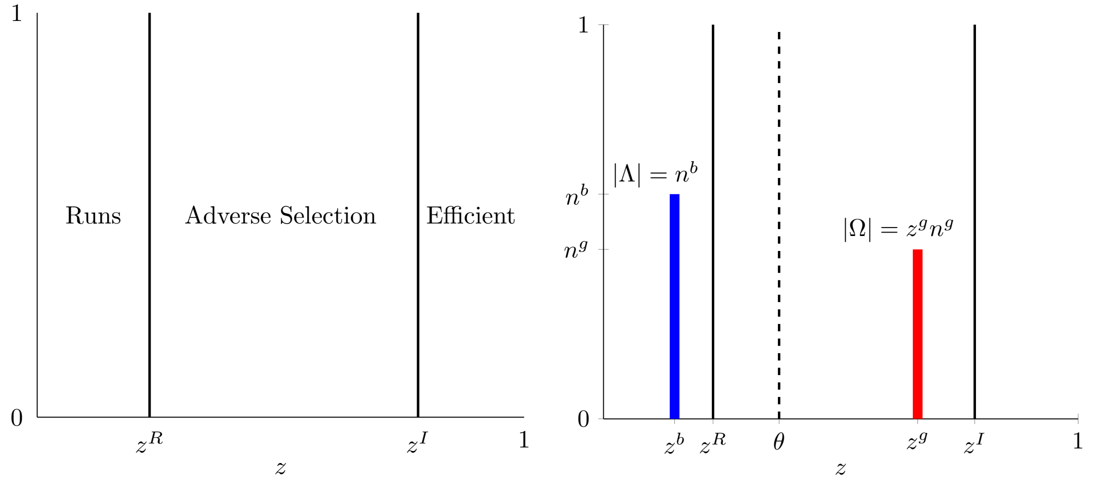
[12] We assume some anonymity in the credit market. Depositors do not observe how much their banks borrow in wholesale markets.

[13] Note that the voluntary issuance of equity is not an equilibrium outcome of the model once banks know their types. Issuing equity to finance investment is suboptimal by Lemma 2. Equity issuance is also suboptimal at time 0 since in addition to the usual negative signaling costs of equity, there is the possibility that a bad signal might trigger a run. A possible exception is when $\theta < z^R$ and a run on all banks can happen. However, as we show in Section 3, in that case the government would always disclose enough information to save at least the good banks.

A different question is whether a regulator might want to force all banks to raise equity. Notice, however, that the only virtue of such a policy is to force strong banks to subsidize weak ones. If that is the goal it is simpler and cheaper for the regulator to force strong banks to guarantee the deposits of weak banks. These policies are interesting, but they are of a different nature from the ones we want to study. We work under Assumption 1 and the government cannot force agents to take actions against their interests. Assumption 1 is not without loss of generality, but it covers a large set of relevant cases and delivers several new theoretical insights.

Figure 3

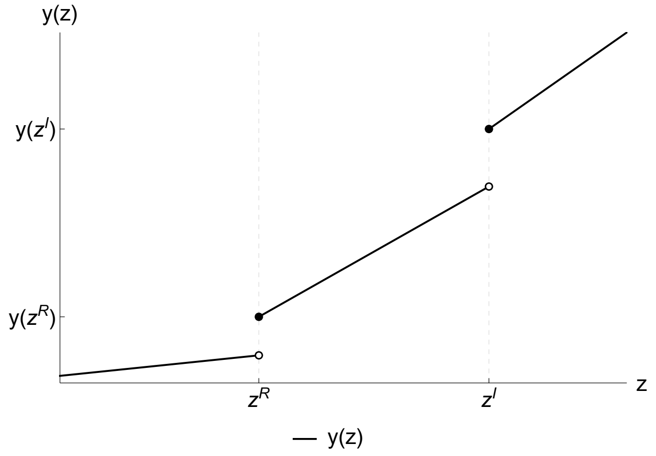
Equilibrium Regions



The left panel illustrates the equilibrium thresholds: for posteriors below z^R, banks suffer runs. For posteriors between z^R and z^I, the economy faces suboptimal investment, as only type L banks invest. For posteriors above z^I, all banks invest without facing adverse selection in credit markets. The right panel illustrates the posterior beliefs $z^{\{G,B\}}$ and mass of banks $n^{\{G,B]}$ at each posterior. Credit markets for banks that received the good signal feature adverse selection (leading to suboptimal investment). $|\Lambda| = n^B$ and $|\Omega| = z^G n^G$ since the strong banks in the adverse selection region (of which there are $z^G n^G$) opt out of investment.

Figure 4

Equilibrium Output



This figure plots equilibrium output $y(z)$ as defined in equation (2.11). Output is discontinuous at z^R, the threshold belief above which banks are not run and liquidated; and z^I, above which all banks invest.

3. DISCLOSURE AND DEPOSIT INSURANCE

In this section we characterize optimal disclosure, first as a standalone policy, and then jointly with deposit insurance. It is important to emphasize that there is no simple link between disclosure and runs. Depending on the regions in Figure 3, disclosure can increase or decrease runs. Similarly, we will show that optimal disclosure is not monotonic with respect to the fundamental θ. Our main result – that governments with strong fiscal positions choose to disclose more information – holds in all cases.

3.1. *Optimal Disclosure*

The government chooses signal precisions p^g and p^b, as defined in Section 1.2, after observing θ. Using Proposition 1, we can express the government's disclosure problem as a choice of posterior beliefs $z = \left\{z^g, z^b\right\}$ subject to Bayesian plausibility. Denoting by $y^*(\theta)$ the value of optimal disclosure, the government's program is:

$$\begin{aligned} y^*(\theta) \equiv \max_{\mathbf{z},n} \ & (1-n^g)\, y\left(z^b\right) + n^g y\left(z^g\right), \\ s.t. \ & (1-n^g)\, z^b + n^g z^g = \theta, \end{aligned}$$

where $y(z)$ is defined in equation 2.11. After solving for the optimal z^b and z^g we can solve for the optimal signal precisions p^b and p^g using Equations 2.5 and 2.6. Our disclosure problem conforms to the Bayesian persuasion framework studied by Kamenica and Gentzkow (2011) (KG), who provide a simple way to solve for optimal disclosure policy: KG show that $y^*(\theta)$ corresponds to the concave closure of the graph of $y(\theta)$.[14]

The top panels of Figure 5 plot $y(\theta)$ (red dashed line) and its concave closure $y^*(\theta)$ (black solid line). Notice that $y(\theta)$ simply corresponds to the case where the signals are uninformative, i.e., there is no disclosure. In that case, the posteriors equal the priors: $z^g = z^b = \theta$. Starting from this no-disclosure case, we can spread out the priors over $[0,1]$ while keeping the average posterior at θ. Information disclosure is optimal whenever $y^*(\theta) > y(\theta)$, and the optimal posteriors z^b and z^g are the nearest points at which $y^*\left(z^i\right) = y\left(z^i\right)$ to the left and right of θ, respectively.

There are two generic cases to consider. The left panel of Figure 5 corresponds to the case where $y\left(z^I\right)$ is relatively high. The government enables investment by type H banks by setting $z^b = 0$ and $z^g = z^I$ for all $\theta \in \left(0, z^I\right)$. We refer to this disclosure regime as *maximal disclosure*, because both posterior beliefs are maximally spread out (the government will never optimally set $z^g > z^I$, since investment is maximized at $z^g = z^I$ and increasing z^g further causes more runs). The fact that $z^b = 0$ implies that $1 - p^g = 0$, as shown in the bottom left panel of Figure 5. This also means that there is no type I error: a type H bank never receives a bad signal. To achieve $z^g = z^I$, p^b must be decreasing in θ. When θ is low, the government must "sacrifice" a large fraction of weak banks to convince the markets of the average quality of the remaining pool. For $\theta \geq z^I$, output is at first best and there is no benefit to information disclosure, so $p^g = 1$, $p^b = 0$, and $z^b = z^g = \theta$.

The second case, where $y\left(z^R\right)$ is relatively high, is shown in the right panel of Figure 5. In this case, the government optimally minimizes runs. When $\theta \in \left(0, z^R\right)$, runs cannot be avoided, and the run-minimizing strategy is to set $z^b = 0$ while setting at $z^g = z^R$. When $\theta \in \left(z^R, z^I\right)$, absent any disclosure, no runs occur in equilibrium, so the government optimally sets $z^b = z^R$ and $z^g = z^I$, which maximizes investment by H-banks subject to not causing runs on L-banks. We refer to this case as *limited or partial disclosure.* The corresponding signal precisions are displayed in the lower panel of Figure 5. When $\theta \in \left(0, z^R\right)$ we have $p^g = 1$ and p^b is decreasing in θ. In that region there is no investment by H-banks, but the mass of liquidated L-banks is as low as possible. The disclosure policy is sharply discontinuous around z^R. At z^R there is

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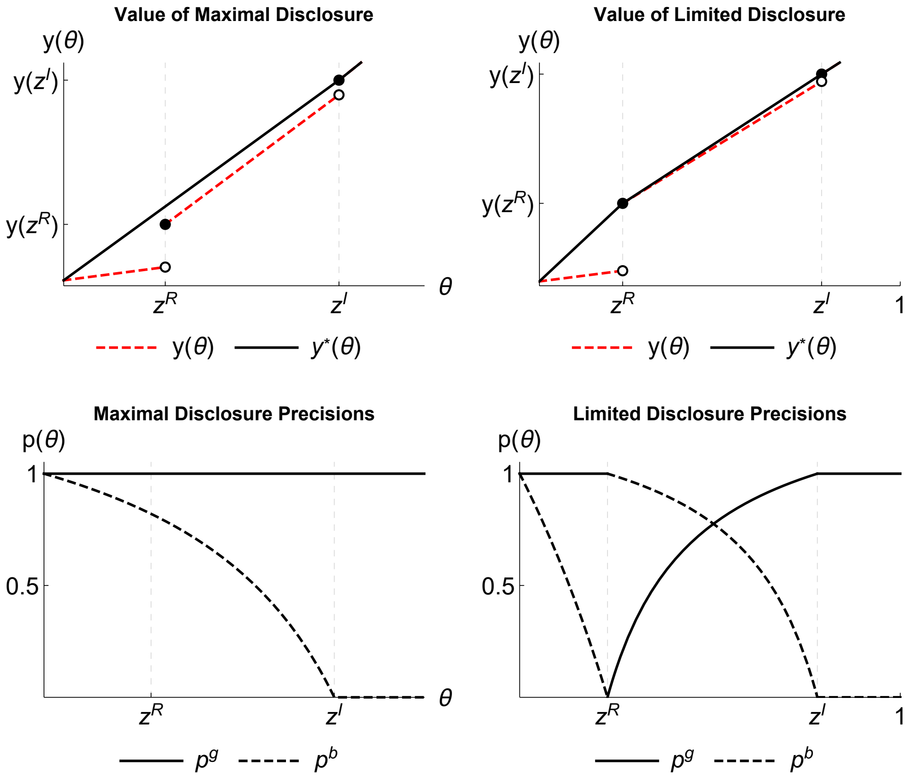
[14] The concave closure is the upper boundary of the convex hull of welfare as a function of beliefs.

FIGURE 5

Optimal Disclosure



The top panels plot the function $y(\theta)$ and its concave closure $y^*(\theta)$, which corresponds to the value of optimal disclosure. The bottom panels plot optimal signal precisions p^g and p^b. In the left (right) panels, optimal disclosure is maximal (limited).

no disclosure, $p^g = 1 - p^b$, but to the left this is achieved by giving all banks the good signal $\left(p^g = 1, p^b = 0\right)$. To the right of z^R the opposite is true, $p^g = 0, p^b = 1$.

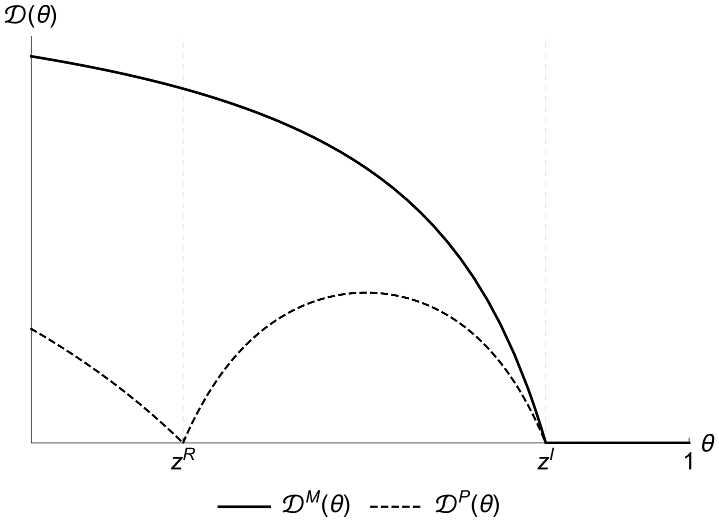
Disclosure is always zero for $\theta \in [z^I, 1)$ since the economy is already efficient. Proposition 2 summarizes the optimal disclosure policy when $\theta < z^I$.

Proposition 2. *Consider a prior $\theta \in \left(0, z^I\right)$. Maximal disclosure, with $\left\{z^b, z^g\right\} = \left\{0, z^I\right\}$, is optimal when the convex hull of the $y(z)$ strictly contains the point $\left(z^R, y\left(z^R\right)\right)$, as in the left panel of Figure 5. Limited disclosure is optimal when the concave closure is kinked at $\left(z^R, y\left(z^R\right)\right)$, as in the right panel of Figure 5, and the posteriors are $\left\{0, z^R\right\}$ when $\theta \in \left(0, z^R\right)$ and $\left\{z^R, z^I\right\}$ when $\theta \in \left(z^R, z^I\right)$.*

Proof. Proposition 1 (and Corollaries 1 and 2) in Kamenica and Gentzkow (2011).

The cutoffs $\left(z^R, z^I\right)$ and the payoff function $y(z)$ depend on the primitive parameters of the model. The following corollary to Proposition 2 sets out the condition under which it is optimal to use maximal disclosure.

Figure 6
Quantity of Disclosure



This figure plots $\mathcal{D}^M(\theta)$ and $\mathcal{D}^P(\theta)$, the optimal quantity of disclosure in the maximal and limited disclosure regimes, respectively.

Corollary 1. *Maximal disclosure is optimal when*

$$\frac{z^R - z^I(1-z^R)}{z^I - z^R} qV - k > \delta A^L \tag{3.12}$$

The corollary says that maximal disclosure is optimal when the benefits of investment exceed the costs of liquidation by a sufficient margin. To compare disclosure across different regimes, we define the *quantity* of disclosure as the variance of posterior beliefs relative to *full* disclosure:

$$\mathcal{D}\left(\theta, z^g, z^b\right) \equiv \frac{n^g\left(z^g-\theta\right)^2 + n^b\left(\theta - z^b\right)^2}{\theta\left(1-\theta\right)^2 + \left(1-\theta\right)\theta^2} \tag{3.13}$$

Note that full disclosure, in the denominator, simply corresponds to the case where $z^b = 0$ and $z^g = 1$. Further, we define $\mathcal{D}^{\{M,P\}}(\theta)$ as the optimal quantity of disclosure for each realization of θ in the two disclosure regimes, i.e. the value of (3.13) evaluated at the optimal z^g and z^b for each regime. Substituting the optimal posteriors for each disclosure regime into (3.13), we get

$$\mathcal{D}^M(\theta) = \mathcal{D}\left(\theta, 0, z^I\right) = \frac{z^I - \theta}{1-\theta}$$

and

$$\mathcal{D}^P(\theta) = \begin{cases} \mathcal{D}\left(\theta, 0, z^R\right) = \frac{z^R-\theta}{1-\theta} & \theta \in \left(0, z^R\right) \\ \mathcal{D}\left(\theta, z^R, z^I\right) = \frac{\left(z^I-\theta\right)\left(\theta - z^R\right)}{\theta(1-\theta)} & \theta \in [z^R, z^I) \end{cases}$$

Note that $\mathcal{D}^M(\theta) > \mathcal{D}^P(\theta)$ for all $\theta < z^I$, and, of course $\mathcal{D}^{\{M,P\}} = 0$, when $\theta > z^I$. Figure 6 plots the optimal quantity of limited and maximal disclosure in both cases.

3.2. *Disclosure with Deposit Insurance*

In this section we study the government's disclosure policy when it can also prevent runs by insuring deposits. Our goal is to understand how fiscal capacity influences disclosure choices. Deadweight losses from taxation make welfare a non-linear function of the prior θ, and so we need to extend the analysis in Kamenica and Gentzkow (2011) to solve our persuasion problem with fiscal capacity.

The government can prevent the liquidation of banks that are in the run region. Preventing runs is desirable because liquidation is costly, and because liquidated banks do not invest. Let $\alpha(z) \in [0, n(z)]$ be the number of banks with posterior z for which the government guarantees the repayment of the contractual deposit amount D at $t = 2$. The guarantee avoids asset liquidation but shifts credit risk to the balance sheet of the government.[15] The expected cost $\psi_d\left(z\right)$ of guaranteeing the deposits of a bank with posterior belief z is

$$\psi_d(z) \equiv (1-z)(1-q)\left(D - A^L\right)$$

where $1 - z$ is the fraction of type L, $1 - q$ the risk of investment failure, and $D - A^L$ the asset shortfall. Guaranteeing a bank prevents liquidation and increases investment by L-banks, but not by H-banks since $z^R < z^I$. The expected benefit $\omega_d\left(z\right)$ of guaranteeing a pool of banks with posterior z is therefore

$$\omega_d(z) \equiv \delta\bar{a}(z) + (1-z)(qV - k)$$

Aggregate output with the deposit guarantee policy is then

$$y(\theta; \mathbf{p}, \alpha) = \sum_{j\in\{g,b\}} n^j y\left(z^j\right) + \alpha\omega_d\left(z^j\right) - \gamma\left(\sum_{j\in\{g,b\}} \alpha^j \psi_d\left(z^j\right)\right)^2 \tag{3.14}$$

To proceed, we first establish in Lemma 4 that the set of optimal disclosure choices is the same with or without fiscal capacity.

Lemma 4. *Optimal disclosure with deposit insurance is either limited or maximal.*

Proof. See Appendix Appendix A

Lemma 4 implies that only L-bank deposits are ever guaranteed, since the only optimal posterior belief at which runs occur is $z^b = 0$. The cost and benefit of deposit insurance therefore simplify to $\psi_d \equiv (1-q)\left(D - A^L\right)$ and $\omega_d \equiv \delta A^L + qV - k$, respectively. Substituting these values into (3.14), taking the derivative with respect to α^b and solving for the optimal policy gives optimal deposit insurance policy as $\alpha^g = 0$ and

$$\alpha^b = \min\left(n^b, \alpha^*\right),$$

where $\alpha^* = \frac{\omega_d}{2\gamma\psi_d^2}$.

Our next task is to characterize when it is optimal for a government to switch from limited to maximal disclosure. Corollary 1 shows that maximal disclosure is optimal even without insurance when condition (3.12) is satisfied. When condition (3.12) is not satisfied, limited disclosure is optimal in the absence of deposit insurance. The following lemma shows the existence of a

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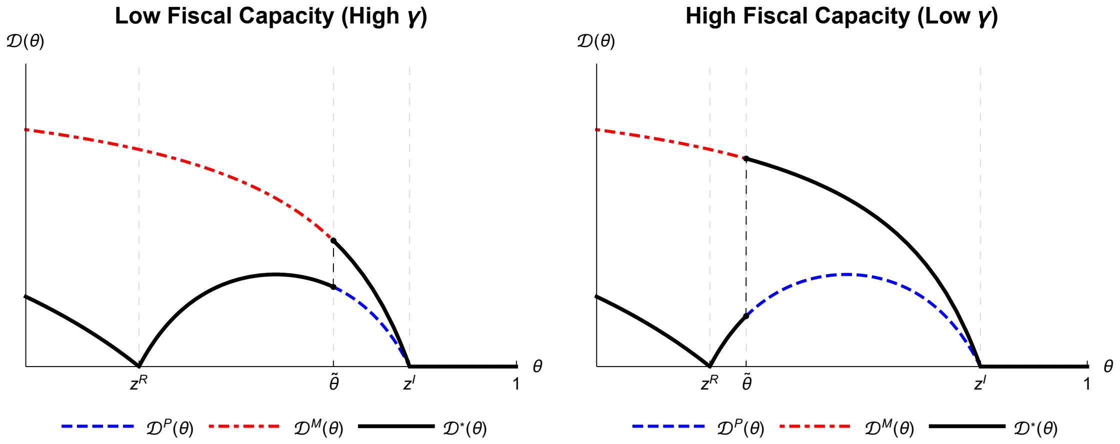
[15] Interpreting "banks" as broader classes of financial institutions, we can think of the choice of α by the government as the choice of which types of financial institutions to support, e.g. providing insurance and guarantees to money market mutual funds as an extraordinary measure.

FIGURE 7
Quantity of Disclosure with Deposit Insurance



This figure shows the optimal quantity of disclosure with deposit insurance for two different values of fiscal capacity γ. The red dashed dotted (blue dashed) line is the optimal quantity of disclosure in the maximal (limited) disclosure regime. The solid black line is the optimal quantity of disclosure with deposit insurance, which is the same as under limited disclosure for $\theta < \tilde{\theta}$ and the same as maximal disclosure for $\theta > \tilde{\theta}$. The threshold at which disclosure jumps from limited to maximal is increasing in γ. The left panel of the figure shows a case in which γ is high (fiscal capacity is low) and $\tilde{\theta}$ is high. As fiscal capacity increases, $\tilde{\theta}$decreases and the government follows maximal disclosure for a larger range of values of θ, as in the right panel.

threshold value $\tilde{\theta}$ above which it is optimal to choose maximal disclosure, and that $\tilde{\theta}$ is increasing in γ.

Lemma 5. *There exists a threshold $\tilde{\theta} \in \left(0, z^I\right)$ such that maximal disclosure is optimal if and only if $\theta > \tilde{\theta}$. Furthermore, $\tilde{\theta}$ is increasing in γ, $\frac{\partial \tilde{\theta}}{\partial \gamma} \geq 0$.*

Proof. See Appendix Appendix A.

Our main result, that greater fiscal capacity increases disclosure, follows.

Proposition 3. *Optimal disclosure is increasing in fiscal capacity: $\frac{\partial \mathcal{D}^*(\theta)}{\partial \gamma} \leq 0$.*

Proof. Lemma 5 establishes the existence of a threshold value $\tilde{\theta}$ above which disclosure is maximal and below which it is limited. This threshold is decreasing in fiscal capacity (increasing in γ). As shown above, $\mathcal{D}^M(\theta) > \mathcal{D}^P(\theta)$ for all $\theta \in \left(0, z^I\right)$. As γ decreases, disclosure jumps from limited to maximal for a set of θ to the left of the threshold $\tilde{\theta}$, and is unchanged at all other points. It follows that $\frac{\partial \mathcal{D}^*(\theta)}{\partial \gamma} \leq 0$.

Maximal disclosure causes fewer runs when θ is higher because only L-type banks suffer runs. Lemma 5 establishes the existence of a threshold $\tilde{\theta}$ at which the government is indifferent between maximal and limited disclosure: the θ at which the benefit of increased investment from eliminating adverse selection exactly offsets the cost of runs (above $\tilde{\theta}$, the benefit exceeds the cost, so maximal disclosure is optimal). This threshold is decreasing in fiscal capacity (increasing in γ), because fiscal capacity makes deposit guarantees affordable, which improves the net payoff to maximal disclosure for any given θ. As shown in Proposition 3, disclosure is therefore increasing in fiscal capacity: the lower is γ, the larger the set of θ for which maximal disclosure is optimal.

Figure 7 illustrates Proposition 3. The red dash-dotted (blue dashed) line is the optimal quantity of disclosure in the maximal (limited) regime. The solid black line is the optimal quantity of disclosure with deposit insurance. Given a fiscal cost parameter γ, there is a threshold $\tilde{\theta} \in \left(0, z^I\right)$ at which the optimal disclosure policy switches from limited to maximal. Optimal disclosure is limited below $\tilde{\theta}$ and maximal above $\tilde{\theta}$. The signal precisions $\left\{p^g, p^b\right\}$ and quantity of disclosure $\mathcal{D}^*$ are discontinuous at the threshold $\tilde{\theta}$. The left panel shows the case of low fiscal capacity (high γ). The right panel shows the case of high fiscal capacity (low γ). The threshold $\tilde{\theta}$ is lower in the right panel, and therefore disclosure is everywhere (weakly) higher.

4. AGGREGATE RISK AND THE PARADOX OF FISCAL CAPACITY

In this section we study the consequences of aggregate risk for disclosure and fiscal interventions. The main motivation is empirical relevance. The assumption that the regulator knows θ when designing the asset quality review yields clean theoretical insights, but it is also likely counter-factual. Policy makers typically do *not* know what results will come out of stress tests, especially when the tests are undertaken during a financial crisis[16]. We therefore assume that the government does not know θ when it chooses its disclosure policy. It only knows that θ is drawn from some distribution function $\pi(\theta)$ with support $[\underline{\theta}, \bar{\theta}]$.

Our second departure from the analysis of Section 3 is to extend the range of fiscal interventions. Guarantees on runnable claims (which we call deposit insurance for short) are only one of the tools used by governments during financial crises. Other interventions involve discount lending, credit guarantees, and capital injections, which are all essentially meant to foster new credit. These interventions have been recently analyzed by Philippon and Skreta (2012) and Tirole (2012). They are particularly interesting in the context of our paper because they interact differently with disclosure than deposit insurance does. As a result, we arrive at a new and unexpected insight: when the planner is risk averse, the expected size of the fiscal intervention can be *decreasing* in fiscal capacity. We call this result the Paradox of Fiscal Capacity.

4.1. *Aggregate Risk*

In this section, the government chooses signal precision $\mathbf{p}$ without knowing the fraction of H-banks, θ. All agents share a common prior belief about the distribution of θ, with probability density $\pi(\theta)$. The government's problem departs significantly from the Bayesian Persuasion framework and quickly becomes intractable. For tractability we restrict disclosure technology such that $p^g = 1$ as in the left panel of Figure 5. All H-banks receive good signals, and we let $p \equiv p^b$ be the one-dimensional control variable for the planner.[17] Given that H-types are always

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[16] During a crisis, the main risk is clearly that of runs on weaker institutions. The design of stress tests in 'normal' times involves different tradeoffs, such as learning and regulatory arbitrage.

[17] The important point about this information structure is that it avoids type I errors. A strong bank is never classified as weak, but a weak bank can pass as strong. This information structure is both realistic and theoretically appealing. It is realistic in the context of banking stress tests since problems actually uncovered by regulators are almost certainly there, and the main issue is to know which problems have been missed. One theoretical appeal is that it corresponds to the smooth case of Figure 5 so we do not need to deal with discontinuities in addition to risk. Another theoretical appeal is that this class of signal has the property that disclosure always (weakly) improves welfare in a pure adverse selection model. The general case is treated in Faria-e-Castro et al. (2015).

correctly identified, we have

$$n^b = p\left(1-\theta\right),$$

and $n^g = \theta + \left(1-p\right)\left(1-\theta\right)$. Agents know p and observe n^b, therefore they also learn the aggregate state θ when the test results are released. The posteriors for individual banks are $z^b = 0$, and

$$z^g = \frac{\theta}{\theta + \left(1-p\right)\left(1-\theta\right)} \equiv z\left(\theta; p\right).$$

Note that the posterior belief depends both on the precision p and on the realization of the aggregate state θ. In Online Appendix A, we show that, under certain regularity conditions on $\pi\left(\theta\right)$, our previous result regarding deposit insurance continues to hold: a planner with a strong fiscal position discloses more than a planner with a weak position. The special case where $\theta \in \left[z^R, z^I\right]$ is particularly relevant because it corresponds to the case where credit markets are inefficient due to adverse selection.[18] In that case, we can show that ex-ante disclosure decreases with γ.

4.2. *Credit Guarantees*

We now consider government interventions at at time 1. Adverse selection in credit markets leads to inefficiently low investment and provides room for welfare-improving policies. From Philippon and Skreta (2012) the optimal policy takes the form of a credit guarantee.

In our setup, this policy is only relevant for the pool of banks that receive a good signal at time 0 since banks with bad signals are all of same type (L). We use the following results from Philippon and Skreta (2012) and Tirole (2012):

Proposition 4. *Direct lending by the government, or the provision of guarantees on privately issued debts, are constrained efficient. The cost of any optimal intervention is equal to the rents of informed agents.*

Proof. See Philippon and Skreta (2012).

The proposition states that if the government chooses to intervene, it should either lend directly to banks or provide guarantees on new debt, as opposed to buying assets, injecting capital, etc. The optimal policy consists of lending at the rate r^H from equation (2.8), the highest rate at which banks of type H are willing to invest. Setting the rate above r^H is ineffective, and setting it below r^H offers an unnecessary subsidy. The benefit per loan from such a program is

$$\omega_c\left(z\right) = \mathbf{1}_{z\in[z^R, z^I]} \cdot z(qV-k)$$

The proposition also says that there is a minimum cost for any intervention, i.e. it it not possible to unfreeze credit markets for free. Proving this result is difficult because the space of interventions is large, but the intuition is rather clear. Bad banks can always mimic good banks and these informational rents are always paid in equilibrium. In the context of our model, the profit per loan k for the government is

$$z(r^H-1)k + (1-z)(qr^H-1)k = z(qV-k) + (1-z)(q^2V-k)$$

---

[18] It is also tractable because only banks with the bad signal (may) receive deposit insurance and only banks with the good signal (may) receive credit guarantees.

The best the government can do is to extract the surplus from the good bank. The informational rent is capture by the extra q term in the second term. It is easy to see that this profit is strictly negative as long as $z < z^I$.

The government also needs to decide the size of the intervention, measured by the number of banks β that benefit from the program. The total cost of the credit guarantee program is

$$\Psi^c(\beta; z) = \beta \{k - qV[z(1-q)+q]\} \equiv \beta\psi_a(z). \tag{4.15}$$

Finally, output with credit guarantees β is

$$y(\theta; \mathbf{p}, \beta) = n^b y(0) + n^g y(z^g) + \beta\omega_a(z^g) - \gamma[\beta\psi_a(z^g)]^2. \tag{4.16}$$

Note that the benefit is increasing in z (up to $z \leq z^I$), while the costs are decreasing in z. Since the intervention occurs after the stress test, the government takes the fraction of strong banks θ and the precision of the signal p as given when choosing the size of the intervention, solving the following program

$$\max_{\beta \in [0, n^g(\theta; p)]} y(\theta; \mathbf{p}, \beta),$$

and we get the following result.

Lemma 6. *The optimal number of credit guarantees is given by*

$$\beta = \min\left\{n^g(\theta; p), \frac{\omega_c(\theta; p)}{2\gamma\psi_c(\theta; p)^2}\right\}$$

for $z(\theta; p) < z^I$ and $\beta = 0$ otherwise.

Note that, taking other interventions as given, the size of the program decreases with γ; this result is overturned when we solve for all policies jointly.

The full analysis of disclosure and fiscal policy involves the solution to a relatively complex program with three dimensions of intervention and one dimension of risk. Due to the complexity of this problem, we proceed numerically to study how the optimal choice of disclosure changes with γ. The left panel of Figure 8 depicts this comparative static, for $\theta \sim \mathcal{U}[z^R, z^I]$. Optimal disclosure is (weakly) decreasing in γ as in our baseline result: high fiscal capacity translates into greater ability to provide credit and deposit guarantees - to "mop up" in case a bad state of the world materializes, leading the government to choose high levels of disclosure. As γ increases, and fiscal capacity becomes more limited, the government opts for intermediate levels of disclosure, eventually choosing no disclosure ($p = 0$) for γ high enough.

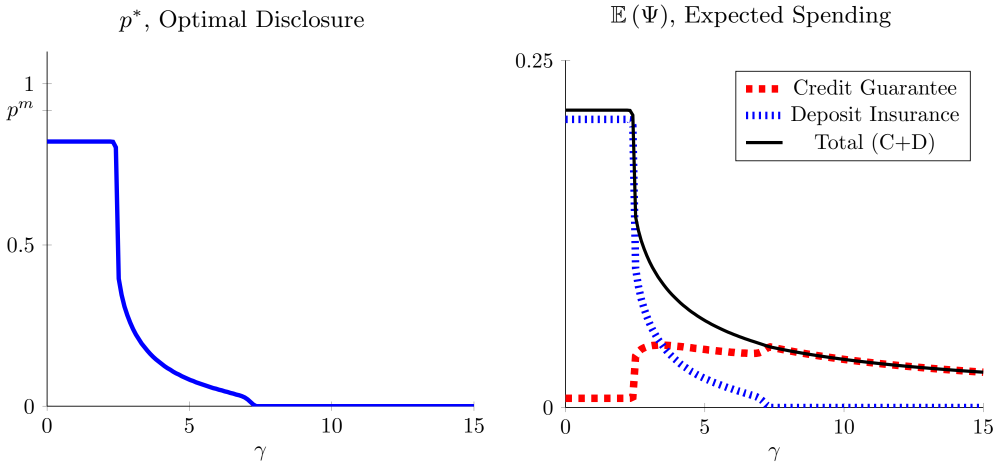
The right panel of Figure 8 plots expected government spending $\mathbb{E}_\theta[\Psi]$ by type of intervention. For low levels of γ, the planner chooses high disclosure, unfreezing markets and creating runs. It relies on deposit guarantees but not on credit guarantees. The logic is reversed when γ increases. As disclosure decreases, the planner no longer needs to offer deposit guarantees, but increases spending on credit guarantees.

An interesting result that arises from our analysis is therefore that a less fiscally constrained planner, by disclosing more, reduces the need to offer credit guarantees. In the next section, we show that this effect is magnified when the planner is risk-averse.

4.3. *Risk-Aversion and the Paradox of Fiscal Capacity*

Consider finally the case where the planner is risk-averse. Letting $y(\theta; \mathbf{p}, \alpha, \beta)$ denote the state-contingent level of consumption in the final period, the planner now solves the following problem:

FIGURE 8
Optimal Disclosure with Deposit Insurance and Credit Guarantees



This figure plots optimal disclosure and expected fiscal spending as a function of γ, the measure of fiscal capacity. The left panel plots p^*, the optimal disclosure policy. The right panel plots expected spending by policy.

$$\max_{p\in[0,1]} \mathbb{E}_\theta \left[\max_{\alpha,\beta} u\left(y\left(\theta; \mathbf{p}, \alpha, \beta\right)\right)\right],$$

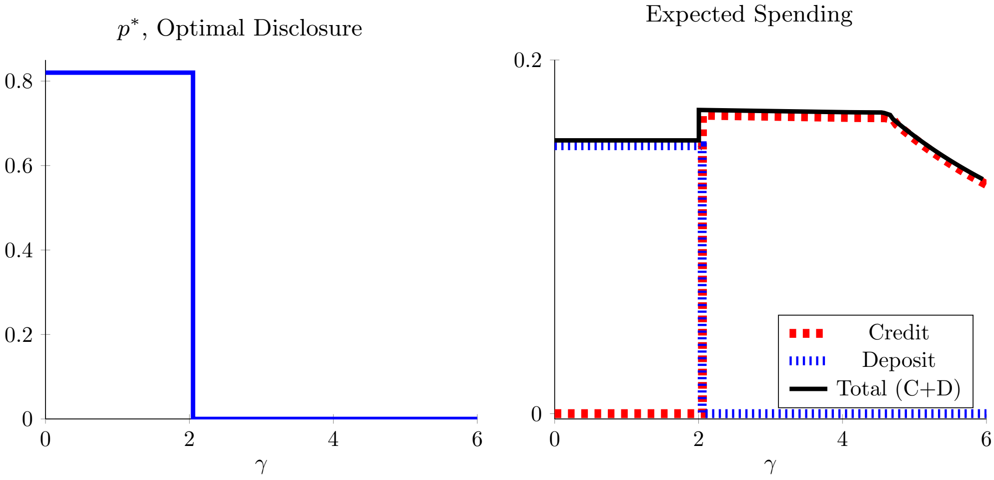
subject to feasibility constraints on (α, β). We consider the case of power utility, $u(c) = \frac{y^{1-\sigma}}{1-\sigma}$, where σ is the coefficient of relative risk-aversion. We show that making the planner risk-averse delivers the additional insight that increased fiscal capacity may be associated with lower expected spending. We call this the *paradox of fiscal capacity.* It relies on both risk-aversion and the fact that disclosure and ex-post guarantees are strategic substitutes.

We plot an instance of this comparative static in Figure 9. For this figure, we assumed that θ follows a two point distribution, with equal probability in each mass point. When fiscal capacity is high, the planner chooses to fully unfreeze the credit markets and to use its fiscal capacity to limit runs.[19]

For high enough γ, however, $p^* = 0$ because the planner does not have the capacity to deal with runs in the bad state of the world. The planner chooses instead to offer guarantees. The interesting point is that this policy is actually more expensive in expectation than the previous one, as the second panel shows. The reason for this is that while the average cost of deposit insurance is lower, it has a greater downside risk. To avoid this risk, the planner prefers to incur the higher average cost of low disclosure and guarantees.

[19] Given the restrictions we consider on the distribution, we show in the Online Appendix that maximal disclosure does not necessarily imply that $p = 1$. Rather, we derive a maximum level of disclosure p^m at which the planner is able to unfreeze markets with probability one, which we call full disclosure, and show that it is never optimal to exceed this level.

Figure 9
Paradox of Fiscal Capacity



This figure presents the paradox of fiscal capacity. We assume that $\sigma = 10$ *and that* θ *is distributed with equal probability on two mass points:* $\underline{\theta} = 0.8z^R + 0.2z^I$ *and* $\bar{\theta} = 0.2z^R + 0.8z^I$*. The left panel shows optimal disclosure as a function of fiscal capacity* γ*. The right panel plots expected spending on deposit guarantees, credit guarantees, and total expenditure (the sum of both policies) as a function of* γ*.*

5. DISCUSSION AND CONCLUSION

We have provided a first analysis of the interaction between fiscal capacity and disclosure during financial crises. We identify a fundamental trade-off for optimal disclosure. To reduce adverse selection it is often optimal to *increase* the variance of investors' posterior beliefs. To avoid runs, on the contrary, it is often optimal *not* to increase posterior variance. Fiscal capacity improves this trade-off because it gives the government the flexibility to deal with runs if they occur. Disclosure and deposit insurance are strategic complements and a government is more willing to disclose information when its fiscal position is strong.

On the other hand, aggressive disclosure can restore efficiency in private credit markets and make other forms of bailouts (credit guarantees, asset purchases, or capital injections) unnecessary. As a result, and somewhat paradoxically, more fiscally constrained governments can end up spending more on bailouts on average.

There are several potentially interesting extensions to our analysis. One would be to consider endogenous information acquisition by lenders, as in Hellwig and Veldkamp (2009). The nature of runs versus lemons can generate conflicting incentives for agents who are both depositors and creditors. On the one hand, they are strategic complements when it comes to runs, since a depositor would like to know who else intends to run when deciding to run or not. On the other hand, they are strategic substitutes in credit markets, since a creditor would like to be the only one to know that a particular bank is good.

Another important feature of our model is that government's actions do not have a signaling content. This is different from the models of Angeletos et al. (2006) and Angeletos et al. (2007). In our model the government and the private lenders share the same information set about the aggregate state.

Finally the point that fiscal flexibility increases disclosure has important implications for regulatory initiatives to reduce policy discretion with the goal of reducing fiscal intervention in the banking sector. Our results suggest that restricting fiscal flexibility may lead governments to disclose less and provide more support in credit markets instead.

REFERENCES

Akerlof, G. A. (1970). The market for 'lemons': Quality uncertainty and the market mechanisms. *Quarterly Journal of Economics 84*, 488–500.

Allen, F. and D. Gale (2000). Financial contagion. *Journal of Political Economy 108*(1), 1–33.

Alvarez, F. and G. Barlevy (2015, July). Mandatory Disclosure and Financial Contagion. NBER Working Papers 21328, National Bureau of Economic Research, Inc.

Angeletos, G.-M., C. Hellwig, and A. Pavan (2006, June). Signaling in a Global Game: Coordination and Policy Traps. *Journal of Political Economy 114*(3), 452–484.

Angeletos, G.-M., C. Hellwig, and A. Pavan (2007, 05). Dynamic Global Games of Regime Change: Learning, Multiplicity, and the Timing of Attacks. *Econometrica 75*(3), 711–756.

Bouvard, M., P. Chaigneau, and A. de Motta (2015, August). Transparency in the financial system: Rollover risk and crises. *Journal of Finance 70*(4), 1805–1837.

Carlsson, H. and E. van Damme (1993). Global games and equilibrium selection. *Econometrica 61*(5), 989–1018.

Chari, V. and P. J. Kehoe (2013, June). Bailouts, Time Inconsistency, and Optimal Regulation. NBER Working Papers 19192, National Bureau of Economic Research, Inc.

Chari, V. V., A. Shourideh, and A. Zetlin-Jones (2014). Reputation and persistence of adverse selection in secondary loan markets. *American Economic Review 104*(12), 4027–70.

Diamond, D. W. (2001). Should japanese banks be recapitalized? *Monetary and Economic Studies*, 1–20.

Diamond, D. W. and P. H. Dybvig (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy 91*, 401–419.

Diamond, D. W. and R. G. Rajan (2011). Fear of fire sales, illiquidity seeking, and credit freezes. *Quarterly Journal of Economics 126*(2), 557–591.

Faria-e-Castro, M., J. Martinez, and T. Philippon (2015). A note on information disclosure and adverse selection. Mimeo, New York University.

Goldstein, I. and Y. Leitner (2013). Stress tests and information disclosure. Working Papers 13-26, Federal Reserve Bank of Philadelphia.

Goldstein, I. and H. Sapra (2014, March). Should Banks' Stress Test Results be Disclosed? An Analysis of the Costs and Benefits. *Foundations and Trends(R) in Finance 8*(1), 1–54.

Gorton, G. (1985). Bank suspension of convertibility. *Journal of Monetary Economics 15*(2), 177 – 193.

Gorton, G. (2012). *Misunderstanding Financial Crises: Why We Don't See Them Coming.* Oxford University Press, Oxford, UK.

Gorton, G. and L. Huang (2004, June). Liquidity, efficiency, and bank bailouts. *American Economic Review 94*(3), 455–483.

Gorton, G. and A. Metrick (2012). Securitized banking and the run on repo. *Journal of Financial Economics 104*(3), 425–451.

Gorton, G. and G. Ordoñez (2014, February). Collateral crises. *American Economic Review 104*(2), 343–378.

He, Z. and W. Xiong (2012, 04). Rollover Risk and Credit Risk. *Journal of Finance 67*(2), 391–430.

Heider, F., M. Hoerova, and C. Holthausen (2010, March). Liquidity Hoarding and Interbank Market Spreads: The Role of Counterparty Risk. CEPR Discussion Papers 7762, C.E.P.R. Discussion Papers.

Hellwig, C. and L. Veldkamp (2009). Knowing What Others Know: Coordination Motives in Information Acquisition. *Review of Economic Studies 76*(1), 223–251.

Hirshleifer, J. (1971). The private and social value of information and the reward to inventive activity. *American Economic Review 61*(4), pp. 561–574.

Kamenica, E. and M. Gentzkow (2011). Bayesian persuasion. *American Economic Review 101*(6), 2590–2615.

Kareken, J. H. and N. Wallace (1978, July). Deposit insurance and bank regulation: A partial-equilibrium exposition. *Journal of Business* (51), 413–38.

Landier, A. and K. Ueda (2009, June). The Economics of Bank Restructuring; Understanding the Options. IMF Staff Position Notes 2009/12, International Monetary Fund.

Mitchell, J. (2001). Bad debts and the cleaning of banks' balance sheets: An application to transition economies. *Journal of Financial Intermediation 10*, 1–27.

Morris, S. and H. S. Shin (2000). Rethinking multiple equilibria in macroeconomic modeling. In B. S. Bernanke and K. Rogoff (Eds.), *NBER Macroeconomic Annual Macroeconomic Annual*, Volume 15, pp. 139–161.

Myers, S. C. and N. S. Majluf (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics 13*, 187–221.

Nachman, D. and T. Noe (1994). Optimal design of securities under asymmetric information. *Review of Financial Studies 7*, 1–44.

Ong, L. L. and C. Pazarbasioglu (2014, February). Credibility and Crisis Stress Testing. *International Journal of Financial Studies 2*(1), 15–81.

Parlatore, C. (2013). Transparency and bank runs. New York University Stern School of Business.

Philippon, T. and P. Schnabl (2013, 02). Efficient Recapitalization. *Journal of Finance 68*(1), 1–42.

Philippon, T. and V. Skreta (2012). Optimal interventions in markets with adverse selection. *American Economic Review 102*(1), 1–28.

Shapiro, J. and D. Skeie (2015). Information Management in Banking Crises. *Review of Financial Studies 28*(8), 2322–2363.

Tirole, J. (2012, February). Overcoming Adverse Selection: How Public Intervention Can Restore Market Functioning. *American Economic Review 102*(1), 29–59.

Uhlig, H. (2010). A model of a systemic bank run. *Journal of Monetary Economics 57*, 78–96.

Véron, N. (2012, August). The challenges of Europe's fourfold union. Policy Contributions 741, Bruegel.

Williams, B. (2015). Stress tests and bank portfolio choice.

Zetlin-Jones, A. (2014). Efficient Financial Crises. GSIA Working Papers 2014-E19, Carnegie Mellon University, Tepper School of Business.

APPENDIX A. PROOFS

Proof of Lemma 4. Notice first that there is no point in setting $z^g < z^R$ and we only need to consider policies with $z^g \geq z^R$. When $\theta < z^R$, it is also always optimal to set $z^b = 0$ because this increases n^g without affecting the cost of runs. Any disclosure choice such that $z^g \in \left(z^R, z^I\right)$ has strictly lower payoff than $\left\{z^b, z^g\right\} = \left\{0, z^R\right\}$, because it requires more runs and provides no benefit. It follows that for $\theta \in \left(0, z^R\right)$, $z^b = 0$ and $z^g \in \left\{z^R, z^I\right\}$. By analogous arguments, for $\theta \in \left(z^R, z^I\right)$, $z^g = z^I$ and $z^b \in \left\{0, z^R\right\}$. For $\theta \geq z^I$, there is no disclosure since first best output is attained.

Proof of Lemma 5. We prove the Lemma by directly characterizing the properties of the cutoff $\tilde{\theta}$. Another (indirect) strategy to prove the comparative statics result would rely on the super-modularity of the objective function and then show that there is a monotonic relation between spending and disclosure. We present the direct proof because it allows us to also discuss the nature of the optimal disclosure. Corollary 1 shows that maximal disclosure is optimal even without insurance when condition (3.12) is satisfied. In this case, we simply have $\tilde{\theta} = 0$. When condition (3.12) is not satisfied, limited disclosure is optimal in the absence of deposit insurance. When $\theta \in \left(0, z^R\right)$, the government makes use of deposit insurance under both disclosure regimes. The government is indifferent between limited and maximal disclosure when

$$\begin{aligned}
&\frac{\theta}{z^R}\left(A^H z^R + A^L\left(1 - z^R\right) + qV - k\right) + \left(1 - \frac{\theta}{z^R}\right)(1-\delta)A^L + \alpha_P^b\left(\delta A^L + qV - k\right) - \gamma\left(\psi\alpha_P^b\right)^2 = \\
&\qquad \frac{\theta}{z^I}\left(A^H z^I + A^L\left(1 - z^I\right) + qV - k\right) + \left(1 - \frac{\theta}{z^I}\right)(1-\delta)A^L + \alpha_M^b\left(\delta A^L + qV - k\right) - \gamma\left(\psi\alpha_M^b\right)^2 \qquad \text{(A17)}
\end{aligned}$$

Where $\alpha_P^b = \min\left(1 - \frac{\theta}{z^R}, \alpha^*\right)$ is the optimal deposit insurance policy with limited disclosure and $\alpha_M^b = \min\left(1 - \frac{\theta}{z^I}, \alpha^*\right)$ with maximal disclosure. We show first that any solution $\underline{\theta}$ to (A17) must be such that $\alpha_P^b = 1 - \frac{\theta}{z^R}$ and $\alpha_M^b = 1 - \frac{\theta}{z^I}$. Since $\alpha^* > 1 - \frac{\theta}{z^I} > 1 - \frac{\theta}{z^I}$, this implies $\underline{\theta} > (1 - \alpha^*)\, z^I$. The LHS and the RHS are increasing in θ and equal at $\theta = 0$. Further, the slope of the LHS in θ is greater than that of the RHS for $\theta < (1 - \alpha^*)\, z^I$ as long as inequality (3.12) is not satisfied. It follows that$\underline{\theta} > (1 - \alpha^*)\, z^I$. Substituting $\alpha_P^b = 1 - \frac{\theta}{z^R}$ and $\alpha_M^b = 1 - \frac{\theta}{z^I}$ into (A17) gives a quadratic in θ, with roots $\theta = 0$ and

$$\underline{\theta} = \frac{z^I z^R}{z^I + z^R}\left(2 - \frac{(qV - k)\, z^I z^R}{\gamma\psi^2\left(z^I - z^R\right)}\right) \qquad \text{(A18)}$$

It is easily verified that $\frac{\partial\underline{\theta}}{\partial\gamma} > 0$ so the maximal disclosure threshold is decreasing in fiscal capacity (increasing in γ).

We now solve for the value of $\theta \in \left(z^R, z^I\right)$ at which the planner is indifferent between limited disclosure and maximal disclosure with deposit insurance. Note that for $\theta \in \left(z^R, z^I\right)$, limited disclosure doesn't cause runs and therefore does not result in the use of deposit insurance. Equating welfare with limited disclosure (the LHS) and welfare with full disclosure and deposit insurance:

$$\begin{aligned}
&\frac{\theta - z^R}{z^I - z^R}\left(A^H z^I + A^L\left(1 - z^I\right) + qV - k\right) + \frac{z^I - \theta}{z^I - z^R}\left(A^H z^R + \left(1 - z^R\right)\left(A^L + qV - k\right)\right) \\
&\quad = \frac{\theta}{z^I}\left(A^H z^I + A^L\left(1 - z^I\right) + qV - k\right) + \left(1 - \frac{\theta}{z^I}\right)(1-\delta)A^L + \alpha^b\left(\delta A^L + qV - k\right) - \gamma\left(\psi\alpha^b\right)^2 \qquad \text{(A19)}
\end{aligned}$$

After maximal disclosure, $n^b = 1 - \frac{\theta}{z^I}$, so $\alpha^b = \min\left(1 - \frac{\theta}{z^I}, \alpha^*\right)$, and there are two cases to consider. Denoting by $\bar{\theta}$ the solution to (A19), either $z^R < \bar{\theta} < z^I\left(1 - \alpha^*\right)$ and $\alpha^b = \alpha^*$, or $\bar{\theta} \geq z^I\left(1 - \alpha^*\right)$ and $\alpha^b = 1 - \frac{\theta}{z^I}$. Substituting in $\alpha^b = n^b = 1 - \frac{\theta}{z^I}$ gives a quadratic in θ, the roots of which are $\theta = z^I$ and

$$\bar{\theta} = z^I\left(1 - \frac{(qV - k) z^I z^R}{\gamma\psi^2\left(z^I - z^R\right)}\right) \qquad \text{(A20)}$$

$\frac{\partial\bar{\theta}}{\partial\gamma} > 0$ so again the maximal disclosure threshold is decreasing in fiscal capacity (increasing in γ). For this to be a solution, it must be that $\min\left(1 - \frac{\bar{\theta}}{z^I}, \alpha^*\right) = 1 - \frac{\bar{\theta}}{z^I}$, or $\bar{\theta} > z^I\left(1 - \alpha^*\right)$. Substituting in for $\bar{\theta}$ and α^*, this reduces to $\frac{z^R - z^I\left(1 - z^R\right)}{\left(z^I - z^R\right)} qV - k < \delta A^L$, which is the converse of the condition derived in Corollary 1. The solution

TABLE 1

Parameter values used in examples

Parameter	Description	Value
A^g	Strong assets	10.3
A^b	Weak assets	0.9
D	Deposits	1.6
V	Project Payoff	10.9
q	Prob. Success	0.2
k	Investment Cost	1.8
$(1-\delta)$	Recovery Rate	0.2

is therefore valid as long as maximal disclosure is not optimal in the absence of deposit insurance, which is the case we are interested in. It is easily verified that the RHS of A19 exceeds the LHS for $\theta > \bar{\theta}$.

To establish that maximal disclosure is optimal for $\theta > \tilde{\theta}$ for $\theta \in \left(0, z^I\right)$ it suffices to show that the $\bar{\theta} > \underline{\theta}$, or $z^I\left(1-\frac{(qV-k)z^Iz^R}{\gamma\psi^2\left(z^I-z^R\right)}\right) \geq \frac{z^Iz^R}{z^I+z^R}\left(2-\frac{(qV-k)z^Iz^R}{\gamma\psi^2\left(z^I-z^R\right)}\right)$. This inequality reduces to $\bar{\theta} \geq z^R$. It follows that maximal disclosure is optimal for $\theta > \tilde{\theta}$, with

$$\tilde{\theta} = \begin{cases} \max\left(0, \frac{z^Iz^R}{z^I+z^R}\left(2-\frac{(qV-k)z^Iz^R}{\gamma\psi^2\left(z^I-z^R\right)}\right)\right) & \text{if } z^I\left(1-\frac{(qV-k)z^Iz^R}{\gamma\psi^2\left(z^I-z^R\right)}\right) < z^R \\ z^I\left(1-\frac{(qV-k)z^Iz^R}{\gamma\psi^2\left(z^I-z^R\right)}\right) & \text{otherwise} \end{cases}$$

APPENDIX B. PARAMETERS USED IN EXAMPLES