Runs versus Lemons:

Information Disclosure, Fiscal Capacity and Financial Stability*

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December 2014

Preliminary and Incomplete.

Abstract

We study how a government should optimally disclose information about banks' assets during a financial crisis. The government can also use its resources to stop runs and unfreeze credit markets. Disclosure improves welfare by reducing adverse selection, but it can also create runs on weak banks. A credible fiscal backstop mitigates these risks and allows the government to pursue efficient but risky strategies. A strong fiscal position makes it possible to provide a candid assessment of financial health while providing guarantees to banks that are run on. A weak fiscal position can make it optimal not to reveal too much information. We argue that our theory provides an explanation for the different choices that countries make in response to financial crises.

JEL: E5, E6, G1, G2.

1

Government interventions play an important role in stopping financial panics and alleviating the effects of financial crises (Gorton (2012)). The global financial crisis was no exception to this historical norm. Governments use various tools to intervene during crises, but different government use different tools and with varying degrees of success. Our goal is to model the tradeoffs faced by governments in desiging interventions and to shed light on how these tradeoffs shape policy and condition its effectiveness.

In October 2008, the US government decided to inject capital into banks under the Troubled Asset Relief Program. 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 US financial firms. The exercise is broadly perceived as having reduced uncertainty about the state of the US financial system and helped restore calm to financial markets.

The Committee of European Banking Supervisors (CEBS) also conducted EU-wide stress tests from May to October 2009 but announced that it would not 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. European stress tests were less effective than their US counterparts in restoring confidence to the financial sector.[1]

What explains the differences in the design and effectiveness of these stress tests? We propose a model that highlights the trade-offs faced by a regulator in deciding how much information about the financial system to make public, and we emphasize the role of fiscal capacity in shaping policy decisions.

We study optimal interventions by a planner in an economy that features adverse selection in the spirit of Akerlof (1970) and Stiglitz and Weiss (1981) as well as bank runs as in Diamond and Dybvig (1983). Our economy is populated by financial intermediaries that differ in the quality of their existing assets.[2] The quality of these legacy assets is private information of each bank. In order to invest in new projects with positive net present value, banks must raise additional funds from the credit market. Asymmetric information about the quality of existing assets creates the potential for adverse selection in the credit market, leading to inefficiently high interest rates and low investment in the decentralized equilibrium. In addition, if short term creditors (depositors) learn that a particular bank is bad, they might decide to run. Runs are inefficient for two reasons: there is a cost to liquidating assets, and liquidated banks cannot invest in new projects. Runs and adverse selection imply that the decentralized equilibrium in our economy is not necessarily constrained-efficient.

In this environment, a policy maker has two potentially welfare-improving tools at its disposal: information disclosure, and the ability to raise taxes. We first consider the case of pure disclosure without any fiscal intervention. Disclosing information mitigates adverse selection but might trigger runs on weaker banks. We find that the planner's disclosure problem is typically non-convex, so that it is often optimal to have either very little or a lot of disclosure.

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[1]Ong and Pazarbasioglu (2013) provide a thorough overview of the details and perceived success of SCAP and the CEBS stress tests.
[2]We have in mind all short term runnable liabilities: MMF, Repo, ABCP, and, of course, large uninsured deposits. In the model, for simplicity, we refer to intermediaries as banks and to liabilities as deposits.

We then study fiscal interventions, which are costly because they expose the balance sheet of the government to financial risks. The planner in our model must pay for its interventions with distortionary taxation, so it seeks to minimize the costs of its interventions. The planner provides deposit guarantees to stop bank runs. For the credit market intervention, we solve a mechanism design problem similar to the one in Tirole (2012) and Philippon and Skreta (2012). The optimal intervention takes the form of a debt guarantee. When markets are frozen, the government provides a credit-enhancing guarantee to banks who need to borrow. The two interventions draw on the same fiscal capacity, so when the government has to make a large deposit guarantee, it has fewer resources available to unfreeze the credit market.

Finally, we study how fiscal capacity shapes optimal disclosure. Our main result is that a planner's fiscal capacity is a key determinant of the optimal disclosure policy. Our key insight is that fiscal capacity provides insurance against the adverse effects of information disclosure. When fiscal capacity is high, it is optimal for the planner to reveal information and provide deposit guarantees to at least a subset of banks that are vulnerable to runs, so that these banks survive and are able to invest in profitable projects. When capacity is low, the planner prefers to avoid runs by not disclosing much information, and mitigate the resulting adverse selection in the credit market by providing credit guarantees. We then extend our analysis and allow for a "disaster scenario" in which system-wide runs are possible (every bank suffers a run). We study the impact o changes in the probability of this scenario and find that while our main result is robust for the baseline calibration, it can be reversed if the cost of a run on good banks is high enough: in this situation, for a high enough probability of a system-wide run, a planner with no fiscal capacity prefers to ensure that at least some good banks survive by fully disclosing the types of all banks, whereas a planner with some fiscal capacity can afford to disclose less information.

Our paper is organized as follows. Section 1 presents the model, and the decentralized equilibrium with no intervention. Section 2 focuses on the role of information disclosure by a benevolent planner. Section 3 discusses fiscal interventions. Section 4 combines information disclosure and fiscal interventions, and studies the optimal combination of the two types of policies. Section 5 concludes.

Related literature

We make two contributions relative to the literature. First, we model new lending and borrowing by banks in addition to bank runs. While existing papers capture some important aspects of information disclosure, they do not address what seems to be the main trade-off facing policy makers, between unfreezing credit markets and triggering bank runs.

Our second, and most important, contribution is to analyze the role of fiscal capacity in shaping information disclosure. Our model captures the idea that fiscal capacity is like an insurance policy that allows regulators to be more aggressive in their disclosure choices. Our model therefore provides an explanation for the difference in disclosure choices between Europe and the United States. Banking regulators in the US have a fiscal backstop

and hence are more willing to run tougher stress tests. Banking regulators in Europe do not have a common fiscal backstop (or at least, did not have one during the financial crisis), and so are less willing to expose potential weaknesses in their banking system.

Our work builds on the rich literature that studies asymmetric information, following Akerlof (1970), Spence (1974), and Stiglitz and Weiss (1981). If no information is revealed by the planner, our economy resembles the one studied by Philippon and Skreta (2012) and Tirole (2012). The optimal policy to mitigate adverse selection is similar to theirs. Since we add bank runs to an economy with asymmetric information, we also build on the large 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 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 (2013) study reputation concerns by a regulator in an environment characterized by a trade-off between moral hazard and runs.

Another set of papers study disclosure in models of bank runs. In this class of models, disclosure is a way to break pooling equilibria. Whether disclosure is good or bad then depends on whether the pooling equilibrium is desirable: if agents pool on the "no run" equilibrium then there is no reason to disclose information. This is more likely to happen in good times as Carlsson and van Damme (1993) and Morris and Shin (2000) show. On the other hand, in bad times, agents might run on all the banks, in which case it is better to disclose information to save at least the good banks. This is the basic result of Bouvard et al. (2012), who also consider ex-ante disclosure rules that allow pooling across macroeconomic states. Parlatore (2013) studies an economy with aggregate risk where more precise information about realizations of the aggregate state can lead to more bank runs.

In our setting, banks are not able to credibly disclose information about their type. Alvarez and Barlevy (2014) show, in a model with contagion of losses across banks and where moral hazard limits efficient investment, that even if banks have access to a costly technology that allows them to perfectly disclose their type, mandatory disclosure might be welfare improving. 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.

Our paper also relates to the theoretical literature on bank bailouts. Gorton and Huang (2004) argue that the government can bail out banks in distress because it can provide liquidity more effectively than private investors. Diamond and Rajan (2005) show that bank bailouts can backfire by increasing the demand for liquidity and causing further insolvency. Diamond (2001) emphasizes that governments should only bail out the banks that have specialized knowledge about their borrowers. Farhi and Tirole (2012) examine bailouts in a setting in which private leverage choices exhibit strategic complementarities due to the monetary policy reaction. Corbett and Mitchell

(2000) discuss the importance of reputation in a setting where a bank's decision to participate in a government intervention is a signal about asset values, and Philippon and Skreta (2012) formally analyze optimal interventions when outside options are endogenous and information-sensitive. Mitchell (2001) analyzes interventions when there is both hidden action and hidden information. Landier and Ueda (2009) provide an overview of policy options for bank restructuring. Philippon and Schnabl (2013) focus on debt overhang in the financial sector. Diamond and Rajan (2012) study the interaction of debt overhang with trading and liquidity. In their model, the reluctance to sell assets leads to a collapse in trading which increases the risks of a liquidity crisis.

Goldstein and Sapra (2014) review the literature on the disclosure of stress tests results. They explain that stress tests differ from usual bank examinations in four ways: (i) traditional exams are backward looking, while stress tests project future losses; (ii) the projections under adverse scenarios provide information about tail risks; (iii) stress tests use common standards and assumptions, making the results more comparable across banks; (iv) unlike traditional exams that are kept confidential, stress tests results are publicly disclosed. They list two benefits of disclosure: (i) enhanced market discipline; and (ii) enhanced supervisory discipline. Our model is based on yet another benefit: the unfreezing of the credit market. They list four costs of disclosure: (i) disclosure might prevent risk-sharing through the Hirshleifer (1971) effect, which is the focus of Goldstein and Leitner (2013); (ii) improving market discipline is not necessarily good for ex-ante incentives; (iii) disclosure might trigger runs; (iv) disclosure might reduce the ability of regulators to learn from market prices, as in Bond et al. (2010). Our model is based on cost (iii).
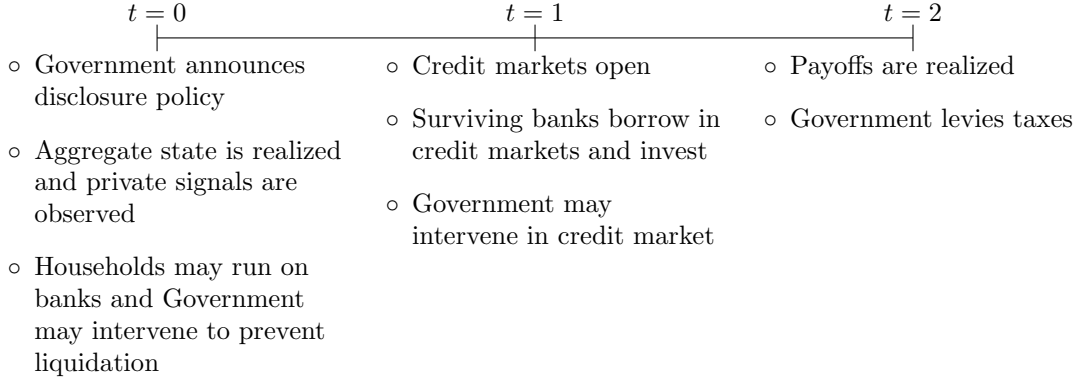
1 Model

1.1 Technology, preferences, and information

There are three dates, $t = 0, 1, 2$, and one good (consumption) at every period. The economy is populated by a continuum of households, a continuum of mass 1 of financial intermediaries (banks), and a government. Figure 1 summarizes the timing of decisions and events in the model, which are explained in detail below.

Households are risk-neutral and their utility depends only on consumption at $t = 2$. They receive an endowment $\bar{y}_1$ at $t = 1$. At periods 0 and 1 they have access to a storage technology that pays one unit of consumption at $t = 2$ per unit invested. There is no discounting. This allows us to treat total output at $t = 2$ (which equals total consumption) as the measure of welfare that the government seeks to maximize.

Banks are indexed by $i \in [0, 1]$ and may be of either good (g) or bad (b) type. A fraction θ of banks are of type g. Banks have pre-existing long-term assets and short-term liabilities. Legacy assets determine the quality of the bank. They deliver a payoff $a = A^i$ for $i \in \{g, b\}$ at $t = 2$. We refer to short-term liabilities as deposits for simplicity, but they are also meant to include money market funds, repo, etc. The short-term demand liabilities entitle a depositor to 1 at any time, and $D > 1$ at $t = 2$. Demand deposits are senior to any other claims on the

Figure 1: Model Timing

$t = 0$	$t = 1$	$t = 2$
∘ Government announces disclosure policy	∘ Credit markets open	∘ Payoffs are realized
∘ Aggregate state is realized and private signals are observed	∘ Surviving banks borrow in credit markets and invest	∘ Government levies taxes
∘ Households may run on banks and Government may intervene to prevent liquidation	∘ Government may intervene in credit market	

bank, and may be withdrawn at any time. This induces a maturity mismatch problem, and makes banks vulnerable to runs. Banks have access to a liquidation technology that yields $\delta \in [0,1]$ units of the consumption good per unit of asset liquidated. The liquidation value of assets is δA^i for $i \in \{g,b\}$. In the event of a run, banks use this liquidation technology to meet depositors' demand for funds. [3]

At $t = 1$, banks receive investment opportunities that cost a fixed amount k and deliver a random payoff v at $t = 2$. For simplicity, we assume that payoffs are binary: $v = V$ with probability q and 0 with probability $1 - q$, and do not depend on the bank type.[4] We impose the following ordering:

Assumption 1: *Good banks are fundamentally safe, while bad banks are fundamentally risky.*

$$A^g - \frac{k}{q} > D > A^b > 0,$$

This assumption implies that the existing debt of bad banks is risky: if bad banks do not invest, or if they invest and the project fails, they are unable to repay their senior debt. On the other hand, the legacy assets of good banks are large enough to cover all potential liabilities, including liabilities issued at $t = 1$ to finance new investments, even if investors are pessimistic about the quality of the pool of borrowers (in which case, as we will shortly discuss, the interest rate would be $1/q$).

At $t = 0$, the government chooses and announces its disclosure policy before it observes the aggregate state. The aggregate state θ, the fraction of good banks, is then realized and banks learn their types privately. The aggregate state follows some distribution $\theta \sim \pi(\theta)$ with support $[\underline{\theta}, \overline{\theta}]$. All agents observe this aggregate state, as well as a binary public signal $s_i \in \{0,1\}$ with precision $p \geq 0.5$ for each bank i. Signal precision is symmetric:

$$p \equiv \Pr(s_i = 1 \mid i = g) = \Pr(s_i = 0 \mid i = b)$$

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[3]We can interpret δ as the equilibrium outcome of a fire-sales process that can potentially depend on the magnitude of the fire sale, or the quantity of the asset that is liquidated/number of institutions that liquidate.

[4]See Philippon and Skreta (2012) for a discussion of the general case.

When we introduce optimal information disclosure in Section 2, the precision of the signal p will be chosen by the government as its disclosure policy. For the remainder of this section, we take the precision of the signal p as exogenous, and describe the equilibrium absent government intervention. We assume throughout that banks themselves are not able to credibly disclose any information about the quality of their assets. In our environment this will be the case if, for example, information disclosed by banks is unverifiable by outsiders or if disclosure is sufficiently costly[5]. Given the complexity of bank balance sheets, the patent failure of rating agencies and audit firms to inform the public about the state of bank balance sheets leading up to and during the financial crisis, and the reportedly large costs of complying with the post-crisis reporting environment[6], these assumptions are probably not farfetched.

Given the realization of the aggregate state and the signal for each bank, agents form posterior probabilities of each bank being good. Conditional on the realization of $s_i = s$, we define the posteriors as:

$$z_s(\theta, p) \equiv \Pr(g \mid s, \theta)$$

Since the signal is binary, and there is a common prior, banks are divided among those that received good ($s_i = 1$) and bad ($s_i = 0$) signals. Bayes' law then implies that

$$z_0(\theta, p) = \frac{(1-p)\theta}{(1-p)\theta + p(1-\theta)}$$
$$z_1(\theta, p) = \frac{p\theta}{p\theta + (1-p)(1-\theta)}$$

Note that these posterior probabilities depend both on the precision of the signal p and the realization of the aggregate state θ. Based on this information, depositors might decide to run on banks or not. If a bank is run, it must liquidate its assets to satisfy its depositors. If a bank survives, it receives an investment opportunity at period 1.

1.2 Bank runs

Depositors can withdraw their deposits from banks at any time. If this happens before $t = 2$, banks have to liquidate assets. The liquidation technology is inefficient: it yields $\delta \in [0,1]$ per unit of asset liquidated. To simplify the analysis, we assume that banks that make use of this technology lose the investment opportunity at $t = 1$.

We do not explicitly model households with liquidity shocks that motivate the existence of deposit contracts

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[5]In their survey of the literature on the corporate information environment, Beyer, Cohen, Lys, and Walther (Beyer et al.) review five conditions that underpin the "unraveling result" (all private information is disclosed because agents with favorable information want to avoid being pooled with inferior types) established by Grossman (1981) and Milgrom (1981): (1) disclosure is costless to the firm; (2) investors know that the firm has private information; (3) all investors interpret the firm's disclosure in the same way and the firm knows how investors will interpret the firm's disclosure; (4) the firm can credibly disclose its private information; and (5) the firm cannot commit ex-ante to a certain disclosure policy.

[6]For example, *Success in Fed stress tests comes with a cost* (http://www.risk.net/risk-magazine/feature/2357474/success-in-fed-stress-tests-comes-with-a-cost).

in the first place. We do not address the question of when a planner, assuming that it could, would choose to suspend convertibility. This is a well studied issue 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 "deposits" in the model include short-term wholesale funding, whose suspension would be difficult to implement in any case.

We denote by λ the fraction of assets that is liquidated and by x the fraction of depositors in a given bank that run. If a fraction λ of a bank's assets are liquidated, the cash flows are $\delta\lambda A^i$ at the time of liquidation, and $(1-\lambda)A^i$ at $t=2$. The bank can satisfy its customers if $\delta\lambda A^i \geq x$. We assume that, under a full run, good banks are safe and bad banks are not.

Assumption 2: *Good banks are liquid, while bad banks are not*

$$\delta A^g > 1, \qquad \delta A^b < 1$$

Consider the decision problem of a depositor in a bank that is known to be good. Withdrawing early yields 1 with certainty even if every other depositor runs. Waiting yields the minimum of the promised payment D and a pro-rata share of the residual value of the bank:

$$\min\left(D, \frac{(1-\lambda)A^g}{1-x}\right)$$

When a full run occurs, $x=1$ and $\lambda = \frac{1}{\delta A^g} < 1$, so the above expression is always equal to D. The implication is that even if every other depositor runs, a depositor prefers to wait because $D > 1$, so the unique equilibrium for a bank known to be good is no run, $x=0$ and $\lambda = 0$.

For bad banks, we have that $\delta A^b < 1$, and so $\lambda = 1$ when $x = 1$. That is, the bank has no assets left to repay depositors who decide to wait in case of a full run. This means that a full run is an equilibrium. Since the type of a bank is private information, the run decision is a function of the (posterior) belief about the quality of a bank. Clearly, if $z = 1$, no run is the only equilibrium. It is possible to derive a threshold posterior belief z^R above which no run is the unique equilibrium. This threshold must be such that depositors with this belief are indifferent between running and waiting if all other depositors run. This indifference condition is given by

$$z + (1-z)\delta A^b = zD$$

Rearranging yields

$$z^R \equiv \frac{\delta A^b}{D + \delta A^b - 1} \tag{1}$$

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. We summarize our results in the following lemma.

Lemma 1. *Depositors run on any bank whose perceived quality falls below z^R.*

Proof. See above. □

1.3 Credit market and investment in period 1

Banks receive investment opportunities at time 1. We assume that these investments have positive net present value, and that households' endowment $\bar{y}_1$ is enough to sustain full investment.

Assumption 3: *Investment projects have a positive net present value, and households have enough resources to sustain investment by all banks*

$$\mathbb{E}[v] = qV > k \ \text{ and } \ \bar{y}_1 > k$$

Banks must raise k externally in order to be able to invest. The important point is that lenders care about the quality of legacy assets. There are several ways to motivate this. For simplicity, we follow Philippon and Skreta (2012) in assuming that only total income at period 2, $y = a + v$ is contractible.[7] Under standard assumptions, we have the following standard result in optimal contracting:

Lemma 2. *Debt is an optimal contract to finance investment at time 1.*

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

Let $j = 0, 1$ be an indicator denoting the investment decision, and let r denote the (gross) interest rate on new loans. The respective payoffs of depositors, new lenders, and equity holders are:

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

Note that these payoffs capture the idea that deposits are senior, and that equity is the residual claim.

Adverse selection arises from the fact that banks know their own type, and therefore the payoffs of their legacy assets a, while lenders do not. Lenders have a belief about the type of a bank, given by z, defined above. This belief pins down the interest rate they will charge. Under Assumption 1, the debt issued by good banks is safe even at the highest possible interest rate. Good banks know that they always pay back their debts, and so the fair interest

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[7]Tirole (2012) 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 they are equivalent in our framework.

rate would be $r = 1$. For a given interest rate, good banks find it profitable to borrow at rate r and invest if and only if

$$A^g - D + qV - rk \geq A^g - D$$

This inequality implies a maximum interest rate r^g above which good banks would decide not to invest:

$$r \leq r^g \equiv \frac{qV}{k} \tag{2}$$

Bad banks earn nothing if they do not invest since their existing assets are insufficient to repay their depositors. As a result, they always want to invest. The question is whether there is enough income to repay the new lenders. Even in the absence of asymmetric information, underinvestment by bad banks could occur due debt overhang, as in Philippon and Schnabl (2013). We ensure that this is not the case by imposing $q \geq \frac{k}{V + A^b - D}$, which guarantees that

$$A^b - D + V - \frac{k}{q} \geq 0$$

So lenders break even by lending at rate $1/q$ to a bad bank.

We are interested in situations where information asymmetry induces adverse selection in the credit market. This happens when the interest rate for bad banks, q^{-1}, exceeds the maximum interest rate at which good types are willing to invest: $q^{-1} > r^g$, which is equivalent to imposing $q \leq \sqrt{\frac{k}{V}}$.

Assumption 3: *There is potential for adverse selection in the credit market*

$$\frac{k}{V - (D - A^b)} < q < \sqrt{\frac{k}{V}}$$

Adverse selection models often feature multiple equilibria. For instance, if lenders expect only bad banks to invest, they set $r = q^{-1}$ and indeed, at that rate, good banks would not participate. We rule this out by assuming that, in case multiple equilibria exist, the best pooling equilibrium is selected.[8] If both good and bad types invest for a certain posterior belief z, the interest rate must satisfy the break-even condition for the lender (whose outside option is zero net return storage)

$$k = zrk + (1 - z) qrk,$$

which can be rearranged to yield

$$r(z) = \frac{1}{z + (1 - z) q}.$$

Note that for good types to invest, the interest rate must satisfy equation (2). Equating good banks' participation

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[8]When we consider credit market interventions, this assumption is without loss of generality because the government would always be able to costlessly implement the best pooling by setting the interest rate appropriately.

constraint with lenders' break-even constraint we can define a threshold posterior z^I such that good banks invest if and only if $z > z^I$:

$$z^I \equiv \frac{\frac{k}{qV} - q}{1 - q}. \tag{3}$$

When $z < z^I$, only the bad types invest are tempted to invest, and the interest rate is $r = \frac{1}{q}$.[9] We summarize the credit market equilibrium in the following lemma.

Lemma 3. *The credit market at period 1 is characterized by a cutoff z^I about the perceived quality of any pool of banks. When $z > z^I$, both good and bad types invest, and the interest rate is $r(z) = \frac{1}{z+(1-z)q}$. When $z < z^I$, only bad types invest, and the interest rate is $r^b = \frac{1}{q}$.*

Proof. See above. □

1.4 Equilibrium without government interventions

We have shown that Bayesian updating of a common prior belief θ with realizations of a binary signal with precision p results in two posterior belief categories that we denote by $z_0(\theta, p)$ and $z_1(\theta, p)$. Equilibrium is characterized by how these posteriors compare to the thresholds z^R and z^I. Because banks that are run cannot invest, the case $z^R \geq z^I$ is not interesting.[10] We therefore make the following natural assumption

Assumption 4 *The threshold for bank runs is strictly smaller than the threshold for full investment: $z^R < z^I$, which requires*

$$\frac{\delta A^b}{D + \delta A^b - 1} \leq \frac{\frac{k}{qV} - q}{1 - q}$$

The equilibrium regions are depicted in Figure 2: banks with posterior belief lower than z^R (the run region, $\mathcal{R}$) suffer a run; banks with posterior belief in the $[z^R, z^I]$ interval are not run on, but credit markets for these banks are affected by adverse selection ($\mathcal{L}$); finally, all banks with belief greater than z^I invest, since credit markets for these banks are free from adverse selection (full investment region, $\mathcal{I}$).

Since $z_0(\theta, p) \leq z_1(\theta, p), \forall p, \theta$ and $z^R \leq z^I$, there are six possible outcomes, depending on the values of θ and p.

1. Both categories suffer a run, $z_1(\theta, p) \leq z^R, (\mathcal{R}, \mathcal{R})$;

2. Banks with the bad signal suffer a run, banks with the good signal face adverse selection, $z_0(\theta, p) \leq z^R \leq z_1(\theta, p) \leq z^I$, $(\mathcal{R}, \mathcal{L})$;

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[9]We assume here that depositors do not observe new borrowing decisions by banks. As a result, bad types can invest without creating a run. We have also solved the model under the alternative assumption.

[10]In this case, bank runs would be so severe so as to completely "clean" the credit market from any adverse selection.

Figure 2: Equilibrium Regions
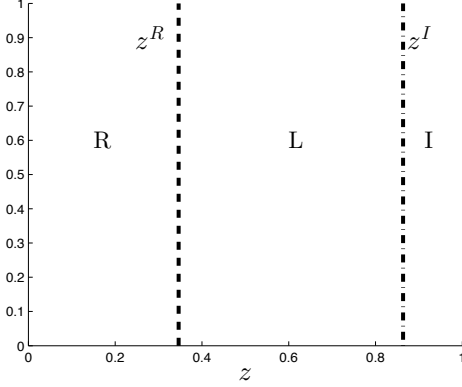
This figure illustrates the equilibrium thresholds: for posteriors below z^R, banks suffer runs ($\mathcal{R}$). For posteriors between z^R and z^I, the economy faces suboptimal investment, as only bad banks invest ($\mathcal{L}$). For posteriors above z^I, all banks invest without facing adverse selection in credit markets ($\mathcal{I}$).

3. Banks with the bad signal suffer a run, banks with the good signal fully invest, $z_0(\theta, p) \leq z^R \leq z^I \leq z_1(\theta, p)$, $(\mathcal{R}, \mathcal{I})$;

4. Both categories face adverse selection, $z^R \leq z_0(\theta, p) \leq z_1(\theta, p) \leq z^I$, $(\mathcal{L}, \mathcal{L})$;

5. Banks with the bad signal face adverse selection, banks with the good signal fully invest, $z^R \leq z_0(\theta, p) \leq z^I \leq z_1(\theta, p)$, $(\mathcal{L}, \mathcal{I})$;

6. Both categories fully invest, $z^R \leq z^I \leq z_0(\theta, p) \leq z_1(\theta, p)$, $(\mathcal{I}, \mathcal{I})$.

For a given precision of the signal p, the outcome depends on the realization of θ. Figures 3 and 4 illustrate two possible outcomes depending on the realization of θ: if the realization of this random variable is low (a scenario we call "bad macro news"), not only the mass of banks with the bad signal is high, but the posterior beliefs for both the banks with the bad and the good signal are low. If the realization is high ("good macro news") the posteriors will be higher and more mass will be placed on the good signal posterior.

More concisely, we can characterize the equilibrium for any pair (θ, p) using four thresholds: the minimum (aggregate) state for which category $s = \{0, 1\}$ avoids a run

$$\theta_s^R(p) = \min\left\{\theta \mid z_s(\theta, p) \geq z^R\right\}, \qquad \text{for} \quad s = \{0, 1\} \tag{4}$$

and the minimum (aggregate) state for which category $s = \{0, 1\}$ experiences full investment by good banks

$$\theta_s^I(p) = \min\left\{\theta \mid z_s(\theta, p) \geq z^I\right\}, \qquad \text{for} \quad s = \{0, 1\} \tag{5}$$

The precision of the signal p defines these thresholds, against which the realization of θ is compared to determine the equilibrium outcome. Note that the ordering of these four thresholds can change for different values of p. The

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Figure 3: Low θ (bad macro news)
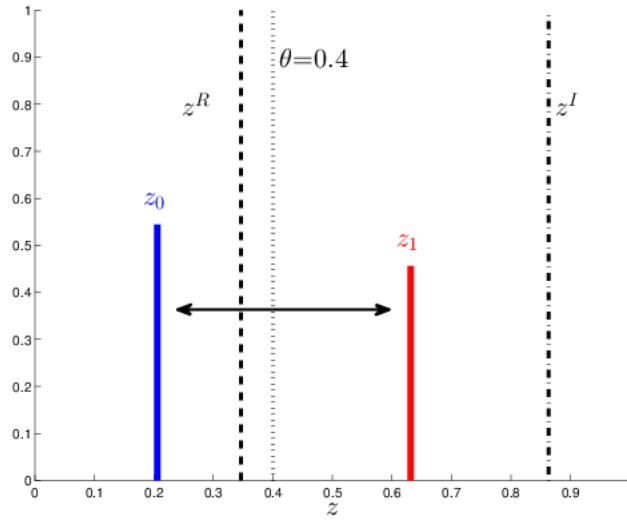
This figure illustrates the position and mass of the posteriors, $z_s(\theta, p), n_s(\theta, p)$ for $s = \{0, 1\}$. Precision p is taken as exogenous, and the realization of θ is low. The outcome is $(\mathcal{R}, \mathcal{L})$, with the banks that received the bad signal suffering a run, and credit markets for banks that received the good signal feature adverse selection (leading to suboptimal investment).

Figure 4: High θ (good macro news)
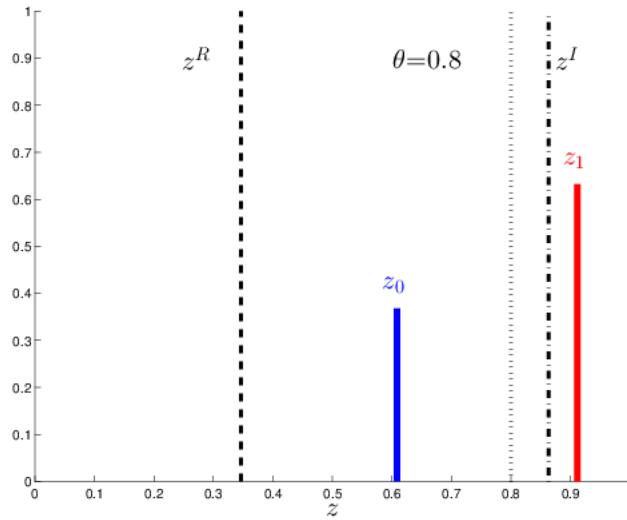
This figure illustrates the position and mass of the posteriors, $z_s(\theta, p), n_s(\theta, p)$, respectively, for $s = \{0, 1\}$. Precision p is taken as exogenous, and the realization of θ is high. The outcome is $(\mathcal{L}, \mathcal{I})$, with banks that received the bad signal facing suboptimal investment (but no run), and banks that received the good signal facing full investment.

Figure 5: Equilibrium Regions
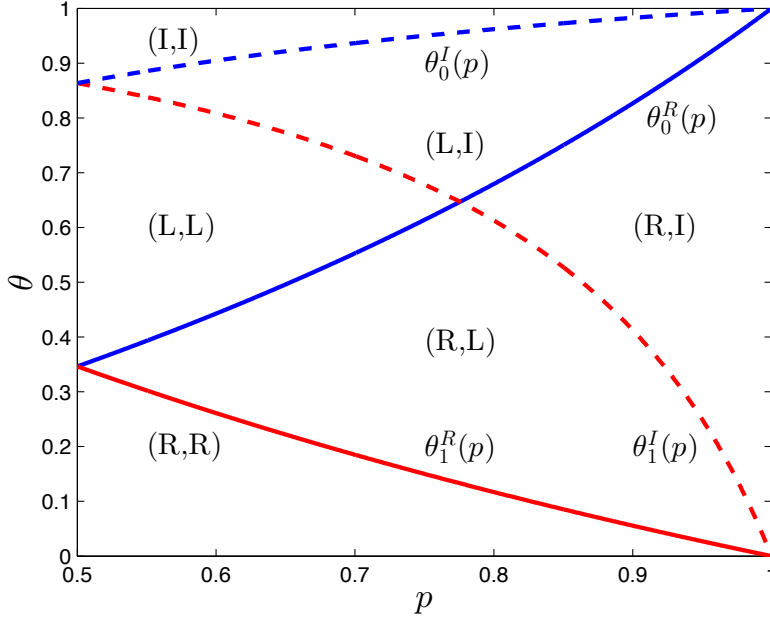
This figure illustrates the equilibrium regions in the (p, θ) space. The dashed lines are the investment thresholds, $\theta_s^I(p)$ while the solid lines are the run thresholds $\theta_s^R(p)$. The red (lighter) lines are the thresholds for the banks with the good signal $s = 1$, while the blue (darker) lines are the thresholds for the banks with the bad signal $s = 0$. In the equilibrium regions, the first letter corresponds to the outcome for the banks with the bad signal, while the second letter is the outcome for the banks with the good signal.

thresholds, and the possible equilibrium regions, are depicted in Figure 5. If θ is high enough and p is low enough, for example, both classes can feature full investment. However, for the same θ, this region shrinks as p increases, and the signal becomes more informative for good and bad banks alike. Setting a low p, however, not only maximizes the likelihood of the best possible outcome, $(\mathcal{I}, \mathcal{I})$, where all banks fully invest, but it also maximizes likelihood of a full run, $(\mathcal{R}, \mathcal{R})$, if the realization of θ happens to be low enough. As precision increases, $p \uparrow$, the likelihood of both the best and worst possible outcomes decreases, as the two posterior categories become more and more separated (and thus the likelihood of both falling in the same region becomes lower). In particular, two new regions appear: $(\mathcal{R}, \mathcal{L})$ and $(\mathcal{L}, \mathcal{I})$, which are the outcomes illustrated in Figures 3 and 4, respectively. If precision is high enough, the $(\mathcal{L}, \mathcal{L})$ region disappears and gives rise to a new region, $(\mathcal{R}, \mathcal{I})$: at this stage, the signal is so informative and the two posteriors are so far apart that banks with the low signal suffer a run and banks with the good signal fall in the full investment category. This region eventually comes to dominate as $p \to 1$, as the signal becomes perfectly informative: bad banks suffer runs while good banks survive and invest.

We summarize the description of the equilibrium without government intervention in proposition4.

Proposition 4. *With no government intervention, the private equilibrium is characterized by four thresholds* $\theta_s^R(p), \theta_s^I(p)$ *for* $s = \{0, 1\}$ *such that*

1. *If* $\theta \leq \theta_s^R(p)$, *all banks with signal* s *suffer a run,* $\mathcal{R}$

2. If $\theta \in \left[\theta_s^R(p), \theta_s^I(p)\right]$, all banks with signal s face adverse selection in the credit market, $\mathcal{L}$

3. If $\theta \geq \theta_s^I(p)$, all banks with signal s fully invest regardless of their type, $\mathcal{I}$.

The thresholds are

$$\theta_0^R(p) = \frac{pz^R}{pz^R + (1-p)(1-z^R)}$$

$$\theta_1^R(p) = \frac{(1-p)z^R}{p(1-z^R) + (1-p)z^R}$$

$$\theta_0^I(p) = \frac{pz^I}{pz^I + (1-p)(1-z^I)}$$

$$\theta_1^I(p) = \frac{(1-p)z^I}{p(1-z^I) + (1-p)z^I}$$

and satisfy the following properties

1. $\theta_s^R(p) \leq \theta_s^I(p), \forall s \in \{0,1\}, p \in \left[\frac{1}{2}, 1\right]$

2. $\theta_1^j(p) \leq \theta_0^j(p), \forall j \in \{R, I\}, p \in \left[\frac{1}{2}, 1\right]$

3. $\frac{\mathrm{d}\theta_0^j(p)}{\mathrm{d}p} > 0, \qquad \frac{\mathrm{d}\theta_1^j(p)}{\mathrm{d}p} < 0, \forall j \in \{R, I\}, p \in \left[\frac{1}{2}, 1\right]$

Proof. See Appendix B. □

For most of the analysis, we focus on the case $\left[\underline{\theta}, \bar{\theta}\right] = \left[z^R, z^I\right]$, in which case only the thresholds $\theta_0^R(p), \theta_1^I(p)$ are relevant. This is shown in Figure 6; by restricting $\theta \in \left[z^R, z^I\right]$ we are eliminating the extreme regions in which both categories fully invest and suffer a run, $(\mathcal{I}, \mathcal{I})$ and $(\mathcal{R}, \mathcal{R})$, respectively. For our chosen parametrization, a low signal precision results in both categories falling in the adverse selection region with certainty, $(\mathcal{L}, \mathcal{L})$, while high precision results in $(\mathcal{R}, \mathcal{I})$ with certainty. Low precision is a risk-free choice (from an *ex-ante* perspective), but the same is not true for high precision: while the planner can accurately forecast that banks with a bad signal will suffer a run, and banks with the good signal will fully invest, it is still exposed to uncertainty regarding θ that determines the size of the run and of investment. One can then see a high p as a gamble: a high realization of θ leads to a close to ideal outcome, with high investment and few runs, while a low realization of θ results in many banks being run and low investment.

In the presentation of the model we abstract from the possibility that banks issue equity either voluntarily or after being required to do so by the government. We argue that issuing equity is not an equilibrium outcome at any stage of the model. At $t = 1$ there are two motives for equity issuance: to finance the new investment opportunity or, for type b banks, to prevent default in the final period. The latter motive is absent in our model since default in the final period is not socially costly (a feature that could easily be changed). By lemma 2, financing the investment opportunity by issuing equity is suboptimal. At $t = 0$, before the realization of bank-specific signals but after banks know their types, bad banks may wish to issue equity to reduce leverage and prevent a run if they receive the

Figure 6: Equilibrium Regions, $\theta \in \left[z^R, z^I\right]$
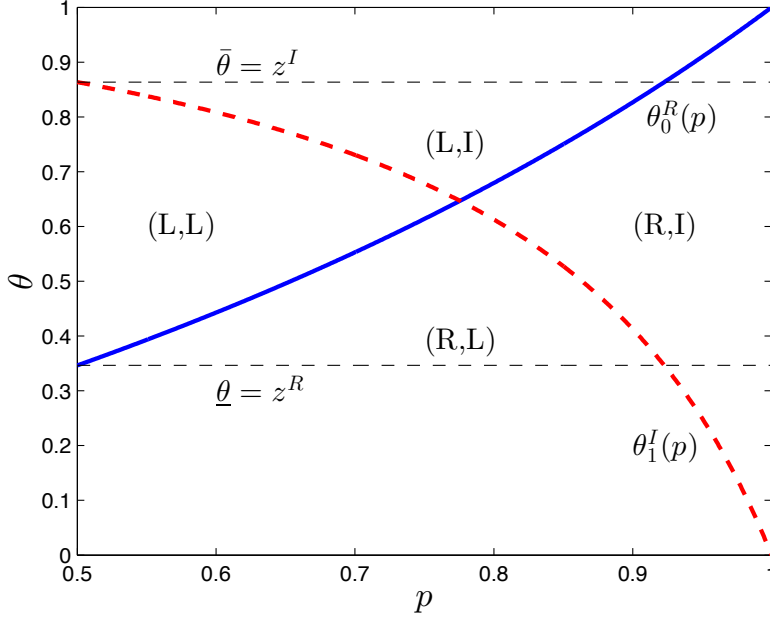
This figure illustrates the equilibrium regions in the (p, θ) space, for $\theta \in \left[z^R, z^I\right]$. The dashed lines are the investment thresholds, $\theta_s^I(p)$ while the solid lines are the run thresholds $\theta_s^R(p)$. The red (lighter) lines are the thresholds for the banks with the good signal $s = 1$, while the blue (darker) lines are the thresholds for the banks with the bad signal $s = 0$. In the equilibrium regions, the first letter corresponds to the outcome for the banks with the bad signal, while the second letter is the outcome for the banks with the good signal.

low signal. Attempting to do so would signal their type, which would lead to a run. The final possibility is that, anticipating the possibility of runs, banks issue equity before knowing their types. This is equivalent to allowing banks to optimize their capital structure which is outside the scope of this paper.

1.5   Welfare Function

New projects have positive net present value, bank runs entail costly asset liquidation, and taxation is distortionary. This means that in the first-best equilibrium, every bank invests and there is no distortionary taxation. First-best *ex-ante* welfare can then be written as

$$W^{FB} = \mathbb{E}\left[\theta\right] A^g + \left(1 - \mathbb{E}\left[\theta\right]\right) A^b + \bar{y}_1 + qV - k \tag{6}$$

Because of runs and adverse selection, the *laissez-faire* equilibrium may fall short of the first best. The government in our model has access to two technologies to modify the equilibrium: a *disclosure* technology (asset quality review) to reveal information about a banks assets, and the *ability to raise taxes at period 2* to provide deposit guarantees or to intervene in the credit market.

The disclosure policy is characterized by a choice of p, the precision of the public signals. We assume that the government chooses p at $t = 0$, before the aggregate state of the economy (the fraction of good banks θ) is realized. The advantage of disclosure, or increasing precision, is that by providing more precise information about

good banks, it may mitigate adverse selection in credit markets. However the government will be disclosing more precise information regarding bad banks, making them more vulnerable to runs. This policy is described in more detail in section 2.

Fiscal interventions are described in greater detail in section 2. To pay for the costs of honoring its guarantees of bank liabilities, the government levies distortionary taxes at $t = 2$. We assume that the deadweight costs of taxation are quadratic, and scaled by a parameter γ. Denoting by Ψ the costs of fiscal interventions, the total welfare loss from taxation is $\gamma \Psi^2$.

Since households are risk-neutral, aggregate welfare coincides with aggregate output net of distortionary costs. Given the realization of the aggregate state θ, and a signal p that induce a distribution of posteriors $(z_s, n_s)(\theta, p)$ for $s = 0, 1$, as well as government intervention with net cost Ψ, *ex-post* welfare can be written as

$$
\begin{aligned}
w(\theta, p, \Psi) = {} & \theta A^g + (1 - \theta) A^b + \bar{y}_1 + qV - k \\
& - \sum_{z_s \leq z^R} n_s (\theta, p) \left\{ (1 - \delta) z_s (\theta, p) A^g + (1 - \delta) [1 - z_s (\theta, p)] A^b + qV - k \right\} \\
& - (qV - k) \sum_{z_s \leq z^I} z_s (\theta, p) n_s (\theta, p) - \gamma \Psi^2
\end{aligned}
\tag{7}
$$

where $n_s (\theta, p)$ is the mass of banks with signal s in state (θ, p). There are three sources of losses relative to the first best. The first is the inefficient liquidation of assets for the banks are subject to a run, i.e., those with $z_s (\theta, p) \leq z^R$. The second is the foregone investment due to adverse selection when $z_s (\theta, p) < z^I$. The final term is the deadweight loss of taxation. For a given signal p, we can write expected welfare as the expectation over all possible realizations of θ of 7.

$$
W (p) = \int_{\underline{\theta}}^{\bar{\theta}} \pi (\theta) w (\theta, p, \Psi) \, d\theta = \mathbb{E}_\theta [w (\theta, p, \Psi)]
\tag{8}
$$

2 Information Disclosure

We model disclosure as the optimal choice by the government of the precision p of binary signals about bank types, which is set prior to the realization of the aggregate state θ (the fraction of good banks in the economy)[11]. We regard the choice of p as capturing a government's choice of informativeness of a stress test or asset quality review. We assume the government can commit to truthfully disclose the results of the stress test in the sense that, having chosen p, agents observe the realizations of signals without any further distortion.

The trade-off faced by the government in choosing the informativeness of disclosure is as follows: by emitting a low precision signal, if $\theta \in [z^R, z^I]$, the government is ensuring that the outcome will be $(\mathcal{L}, \mathcal{L})$, as depicted in Figure 6. That is, regardless of whether they receive the good or the bad signal, good banks face adverse selection

---

[11] Alternatively, we can interpret θ as being the market's prior regarding the state of the banking system, and the government choosing the precision of the stress test while being unaware of the market's perceptions regarding the quality of the banking system.

in credit markets. On the other hand, emitting a high precision signal ensures that the outcome will be $(\mathcal{R}, \mathcal{I})$: this can be seen as a riskier alternative, as depending on the realization of θ, the fraction of banks that receive the bad signal and suffer a run will vary. Maximum risk is achieved by setting an intermediate level of precision, in which case the government gambles between the worst possible outcome, $(\mathcal{R}, \mathcal{L})$ (where banks with the bad signal suffer a run and banks with the good signal face suboptimal investment), and the best possible one, $(\mathcal{L}, \mathcal{I})$ (where banks with the bad signal face suboptimal investment, but are saved from a run, and banks with the good signal fully invest).

The government's disclosure problem, before the aggregate state θ is realized, can be formulated as

$$\max_{p \in \left[\frac{1}{2}, 1\right]} \mathbb{E}_\theta \left[w \left(\theta, p, 0 \right) \right] \tag{9}$$

where $w(\theta, p, 0)$ is the *ex-post* welfare function defined in (7) without any government spending, $\Psi = 0$, since we ignore fiscal policy for now. The following proposition summarizes the solution to the government's program for the particular case where $\theta \in \left[z^R, z^I \right]$.

Proposition 5. *The expected welfare function is given by*

$$W\left(p\right) = \mathbb{E}\left[\theta\right] A^g + \left(1 - \mathbb{E}\left[\theta\right]\right)\left[A^b + \left(qV - k\right)\right]$$
$$+ p\left(qV - k\right)\left[\int_{\theta_1^I(p)}^{\bar{\theta}} \theta \mathrm{d}\Pi\left(\theta\right) - \int_{\underline{\theta}}^{\theta_0^R(p)} \left(1 - \theta\right) \mathrm{d}\Pi\left(\theta\right)\right]$$
$$- \left(1 - \delta\right)\left\{\left(1 - p\right) A^g \int_{\underline{\theta}}^{\theta_0^R(p)} \theta \mathrm{d}\Pi\left(\theta\right) + p A^b \int_{\underline{\theta}}^{\theta_0^R(p)} \left(1 - \theta\right) \mathrm{d}\Pi\left(\theta\right)\right\}$$

where Π is the cdf of the aggregate state θ. The expected welfare function is linear for $p \geq p_1$, $p_1 : \theta_0^R\left(p_1\right) = z^I$ and $\theta_1^I\left(p_1\right) = z^R$, given by

$$p_1 \equiv \frac{z^I\left(1 - z^R\right)}{z^I\left(1 - z^R\right) + z^R\left(1 - z^I\right)}$$

$$W\left(p\right)\big|_{p \in [p_1, 1]} = \mathbb{E}\left[\theta\right] A^g \left[p + \delta\left(1 - p\right)\right] + \left(1 - \mathbb{E}\left[\theta\right]\right) A^b \left[1 - p\left(1 - \delta\right)\right] + \left(qV - k\right)\left[p\mathbb{E}\left[\theta\right] + \left(1 - p\right)\left(1 - \mathbb{E}\left[\theta\right]\right)\right]$$

being potentially non-differentiable at this point. This second component of the welfare function has a local optimum at $p = 1$ if and only if

$$\mathbb{E}\left[\theta\right] \geq \frac{\left(1 - \delta\right) A^b + \left(qV - k\right)}{\left(1 - \delta\right)\left(A^g + A^b\right) + 2\left(qV - k\right)}$$

having a local optimum at $p = p_1$ otherwise. The first-order condition for the government's problem for $p \leq p_1$ is

given by

$$(qV - k) \left[\int_{\theta_1^I(p)}^{\bar{\theta}} \theta \, d\Pi(\theta) - p\theta_1^I(p) \pi \left[\theta_1^I(p) \right] \frac{d\theta_1^I}{dp}(p) \right] \tag{10}$$

$$+ (1 - \delta) A^g \left[\int_{\underline{\theta}}^{\theta_0^R(p)} \theta \, d\Pi(\theta) - (1 - p) \theta_0^R(p) \pi \left[\theta_0^R(p) \right] \frac{d\theta_0^R}{dp}(p) \right]$$

$$- \left[(1 - \delta) A^b + (qV - k) \right] \left[\int_{\underline{\theta}}^{\theta_0^R(p)} (1 - \theta) \, d\Pi(\theta) + p \left[1 - \theta_0^R(p) \right] \pi \left[\theta_0^R(p) \right] \frac{d\theta_0^R}{dp}(p) \right]$$

Proof. See Appendix C. □

The potential non-differentiability is better understood by looking at Figure 6: p_1 is the value of precision beyond which the potential outcome regions $(\mathcal{L}, \mathcal{I})$ and $(\mathcal{R}, \mathcal{L})$ disappear, and $(\mathcal{R}, \mathcal{I})$ becomes the only possible outcome. For $\theta \in \left[z^R, z^I \right]$, the two regions disappear at the same value of p, p_1. The first-order condition for disclosure choice, expression (10), shows the trade-off faced by the government in choosing p: it consists of three different terms (one on each line). The first term is the marginal benefit of mitigating adverse selection: by disclosing more, the government is ensuring that banks with the good signal are more likely to be good types and this contributes to unfreezing credit markets. Through the same mechanism, the government makes good banks less likely to suffer runs, and this is the marginal benefit captured by the second term. The third line represents the costs of disclosure: by raising p, the government increases the likelihood that banks with the bad signal are bad banks, and thus makes this category more susceptible to runs. Having bad banks suffer runs entails two costs: the cost of liquidating legacy assets, and the foregone net present value of investment, since in the credit market equilibrium bad banks always borrow and invest. The trade-off is illustrated in Figure 7, which plots the expected masses of runs and lemons for different values of p, assuming that $\pi(\theta) = \mathcal{U} \left[z^R, z^I \right]$. As p increases, the government decreases the expected mass of lemons in the economy, at the cost of causing runs.

The shape of the welfare function will, in general, depend on $\pi(\theta)$, the distribution of the aggregate state. Figures 8 and 9 show the shape of the welfare function for different choices of the distribution of θ. Figure 8 plots the welfare function as a function of p for $\theta \sim \mathcal{U} \left[z^R, z^I \right]$. In this case, the welfare function is convex, meaning that the government's program is non-convex: the government therefore prefers not to disclose, and set the signal's precision to $p = \frac{1}{2}$. Figure 9 shows a case where convexity of the government's problem is partially restored by changing the distribution of θ to one with a higher mean ($\theta \sim \mathcal{B}(5, 1)$ in the example, where this Beta distribution is rescaled so as to take values only on the $\left[z^R, z^I \right]$ interval). In this case, the government is willing to incur some risk by setting an intermediate disclosure level because the likelihood of the best outcome, $(\mathcal{L}, \mathcal{I})$, is greater than the likelihood of the worst outcome $(\mathcal{R}, \mathcal{L})$.

To better understand how does the choice of disclosure influence total risk faced by the planner, Figure 10 plots the variance of welfare as a function of p for the uniform case. As we would expect, variance is increasing until it attains a maximum before p_0, the point at which the $(\mathcal{L}, \mathcal{L})$ outcome disappears and gives place to $(\mathcal{R}, \mathcal{I})$. Variance

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Figure 7: Expected mass at $\mathcal{L}$ and $\mathcal{R}$, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$
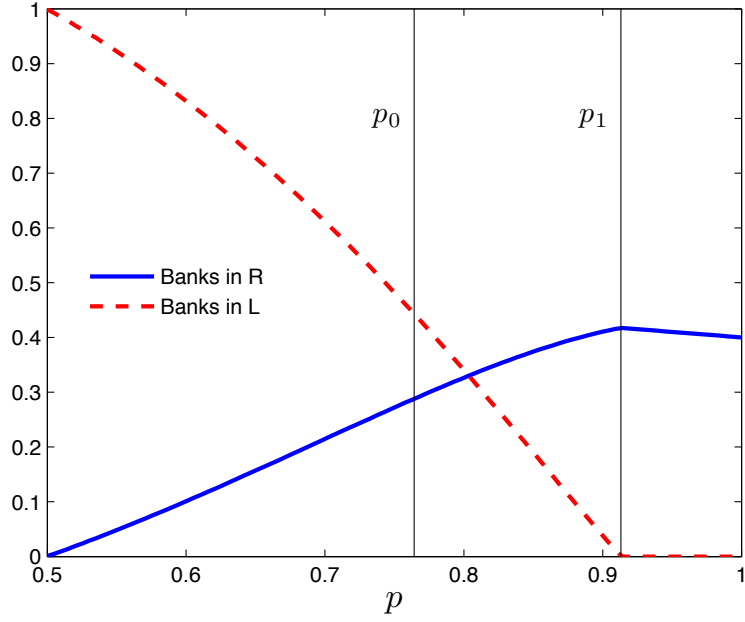
This figure plots the expected mass in region $\mathcal{L}$ (banks with posterior belief in the $\left[z^R, z^I\right]$ interval) and region $\mathcal{R}$ (banks with posterior belief in the $\left[0, z^R\right]$ interval) as a function of p, assuming a uniform distribution for the aggregate state $\pi\left(\theta\right) = \mathcal{U}\left[z^R, z^I\right]$.

Figure 8: Welfare Function, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$
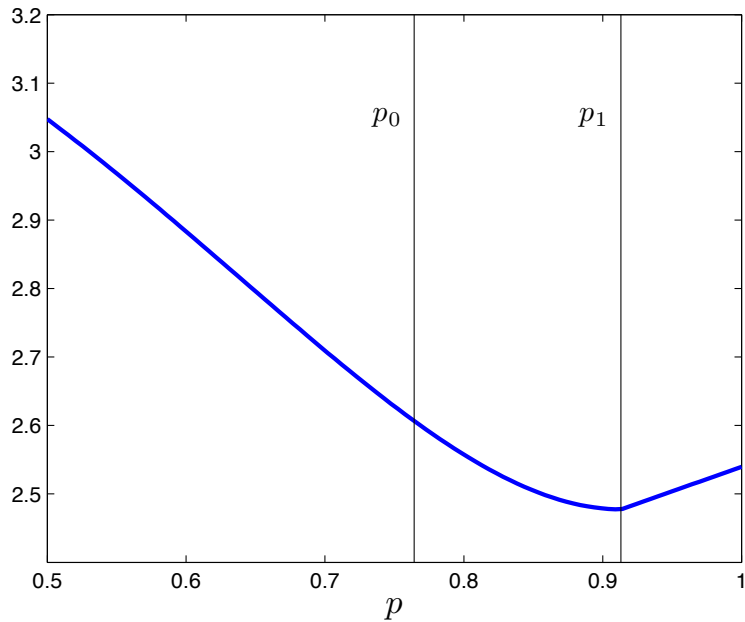
This figure plots the welfare function $W\left(p\right)$ for the uniform θ case. p_0 is such that $\theta_0^R\left(p_0\right) = \theta_1^I\left(p_0\right)$, and p_1 is such that $\theta_0^R\left(p_1\right) = z^I$ and $\theta_1^I\left(p_1\right) = z^R$.

Figure 9: Welfare Function, $\theta \sim \mathcal{B}(5,1)$
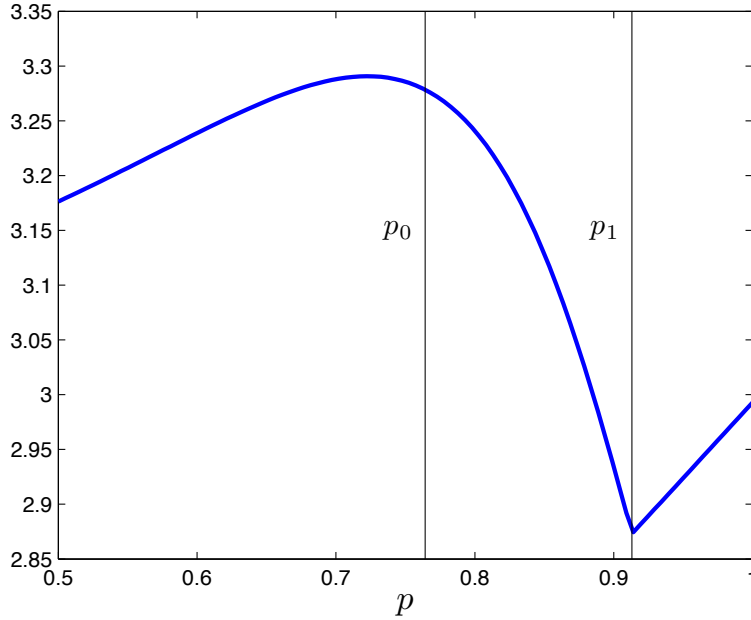
This figure plots the welfare function $W(p)$ for the uniform θ case. p_0 is such that $\theta_0^R(p_0) = \theta_1^I(p_0)$, and p_1 is such that $\theta_0^R(p_1) = z^I$ and $\theta_1^I(p_1) = z^R$.

is then decreasing, as the weight on the extreme outcomes $(\mathcal{R}, \mathcal{L})$ and $(\mathcal{L}, \mathcal{I})$ decreases, and starts increasing again for $p \geq p_1$. The reason is that after this point, the extreme outcomes are no longer possible, $(\mathcal{R}, \mathcal{I})$ is the only outcome and ex-post welfare is linear in p. Given our parametrization, both welfare and its variance are linearly increasing in the level of disclosure. [12]

In this section, we turn to describing in greater detail the fiscal interventions that the government can use to mitigate adverse selection and bank runs. We start by analyzing each type of fiscal intervention separately in the absence of information disclosure, and we proceed to analyze the two interventions jointly. Unlike disclosure, fiscal interventions are undertaken after the aggregate state θ is realized.

2.1 Optimal Intervention in Credit Markets

In the region $z_s \in [z^R, z^I]$ where banks do not suffer runs, but where credit markets are affected by adverse selection, the government may want to intervene to unfreeze the markets and increase investment. Philippon and Skreta (2012) and Tirole (2012) study how to design such an intervention in order to minimize its cost for tax payers. In our setup, we have the following result.

---

[12]In this range, the planner knows that banks with a bad signal suffer a run and banks with a good signal invest with certainty. The planner is then trading off the cost of having bad banks suffering runs and not investing for the benefit of having good banks not suffering a run and fully investing. Since the social value of investment is the same for good and bad banks, the planner is effectively trading runs on bad banks for no runs on good banks. Runs on good banks are costlier than runs on bad banks, and so the planner has incentives to fully disclose in this region, for reasonable parametrizations. As the planner decreases the amount of pooling, the variance of welfare also increases in this region.

Figure 10: Variance of Welfare, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$
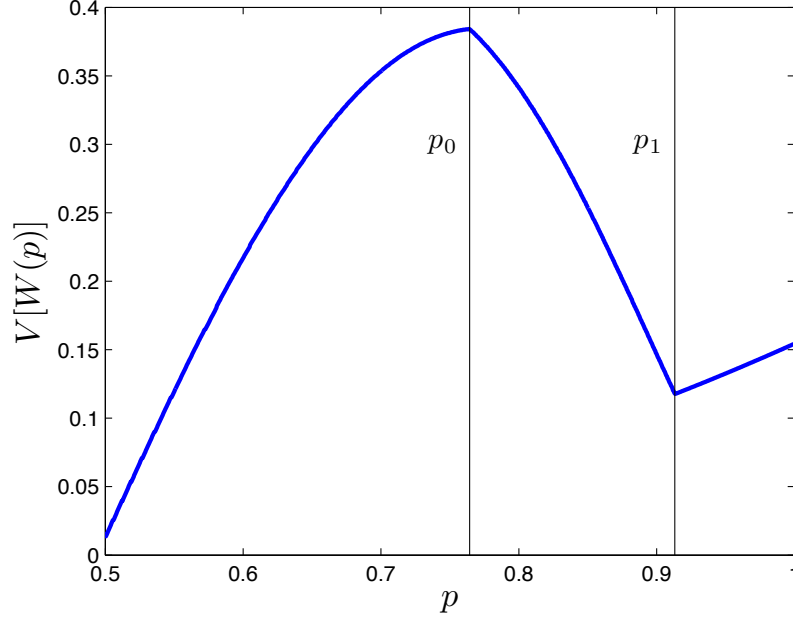
This figure plots the welfare function $W(p)$ for the uniform θ case. p_0 is such that $\theta_0^R(p_0) = \theta_1^I(p_0)$, and p_1 is such that $\theta_0^R(p_1) = z^I$ and $\theta_1^I(p_1) = z^R$.

Proposition 6. *The cost of intervention in markets with adverse selection equals the informational rents paid to informed parties. Under the assumptions of this model, direct lending by the government, or the provision of guarantees on privately issued debts, are constrained efficient.*

Proof. See Philippon and Skreta (2012). □

The proposition says that if the government chooses to intervene, it should either lend directly to the banks, or it should provide guarantees on new debts. For any category of posterior z_s, the optimal policy consists of choosing a number of banks α_s and guaranteeing loans made to those banks at interest rate $r_s = r^g = \frac{qV}{k}$, so that good banks become willing to invest. Note that the policy always consists on either setting $r = r^g$ or doing nothing, since (as explained below) setting $r \in \left(r^g, \frac{1}{q}\right]$ is costly on average for the government and does not contribute to mitigating adverse selection. Setting $r < \frac{qV}{k}$ is also costly and cannot increase investment further.

For a particular bank with posterior z, the cost of implementing the program is

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

the cost is strictly positive as long as $z \leq z^I$. The net marginal benefit of implementing this program is given by

$$z(qV - k)$$

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Note that the benefit is increasing in z, while the costs are decreasing in z. Given that the equilibrium is described by two categories of posteriors, $z_0(\theta, p), z_1(\theta, p)$, this means that the government will always strictly prefer to support banks in the good signal category $z_1(\theta, p)$ before starting to support banks in the bad signal category, since the marginal benefit is strictly greater and marginal costs are strictly lower.

The total cost of the credit guarantee program is given by

$$\Psi^k = \sum_{z_s(\theta,p)\in[z^R,z^I]} \alpha_s \{k - qV[z_s(\theta,p) + q(1 - z_s(\theta,p))]\} \tag{11}$$

With the ex-post welfare of implementing this policy being given by

$$
\begin{aligned}
w(\theta, p, \Psi^k) = \bar{y}_1 + &\sum_{z_s(\theta,p)\leq z^R} n_s(\theta,p)\,\delta\left\{z_s(\theta,p)A^g + [1 - z_s(\theta,p)]A^b\right\} \\
+ &\sum_{z_s(\theta,p)\in[z^R,z^I]} [n_s(\theta,p) - \alpha_s]\left\{z_s(\theta,p)A^g + [1 - z_s(\theta,p)]A^b + [1 - z_s(\theta,p)](qV - k)\right\} \\
+ &\sum_{z_s(\theta,p)\in[z^R,z^I]} \alpha_s\left\{z_s(\theta,p)A^g + [1 - z_s(\theta,p)]A^b + (qV - k)\right\} \\
+ &\sum_{z_s(\theta,p)\geq z^I} n_s(\theta,p)\left\{z_s(\theta,p)A^g + [1 - z_s(\theta,p)]A^b + (qV - k)\right\} \\
- &\gamma\left(\Psi^k\right)^2
\end{aligned}
\tag{12}
$$

Note that this expression is exactly like (7) except for two differences: in the second line, when accounting for the welfare contribution of classes that suffer adverse selection, the relevant mass becomes $n_s(\theta, p) - \alpha_s$, adjusting for the number of banks that the government decides to support. This gives rise to the term in the third line: the welfare contribution of the supported banks, which have belief $z_s(\theta, p) \in [z^R, z^I]$ but fully invest thanks to government support.

Since the intervention is ex-post, the government takes the aggregate state θ and the precision signal p as given when choosing the size of the intervention, solving the following program

$$\max_{\{\alpha_s\}_{s\in\mathcal{S}}} w\left(\theta, p, \Psi^k\right)$$

$$\text{s.t.}\quad \alpha_s \in [0, n_s(\theta, p)], \forall s \in \mathcal{S}$$

The following proposition summarizes the solution to this program.

Proposition 7. *The optimal credit guarantee for each posterior class $s \in \mathcal{S}$ is given by the following first-order condition*

$$z_s(\theta, p)(qV - k) - 2\gamma\left(\Psi^k\right)\{k - qV[z_s(\theta,p) + q(1 - z_s(\theta,p))]\} \leq 0$$

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In the binary signals case, for $z_0(\theta, p) \leq z_1(\theta, p)$, the optimal policy can be characterized as follows

$$\alpha_1 = \max\left\{0, \min\left\{n_1(\theta, p), \frac{z_1(\theta, p)(qV - k)}{2\gamma\{k - qV[z_1(\theta, p) + q(1 - z_1(\theta, p))]\}^2}\right\}\right\}$$

If $\alpha_1 < n_1(\theta, p)$, then $\alpha_0 = 0$. Otherwise,

$$\alpha_0 = \max\left\{0, \min\left\{n_0(\theta, p), \frac{z_0(\theta, p)(qV - k)}{2\gamma\{k - qV[z_0(\theta, p) + q(1 - z_0(\theta, p))]\}^2} - \frac{\{k - qV[z_1(\theta, p) + q(1 - z_1(\theta, p))]\}}{\{k - qV[z_0(\theta, p) + q(1 - z_0(\theta, p))]\}}n_1(\theta, p)\right\}\right\}$$

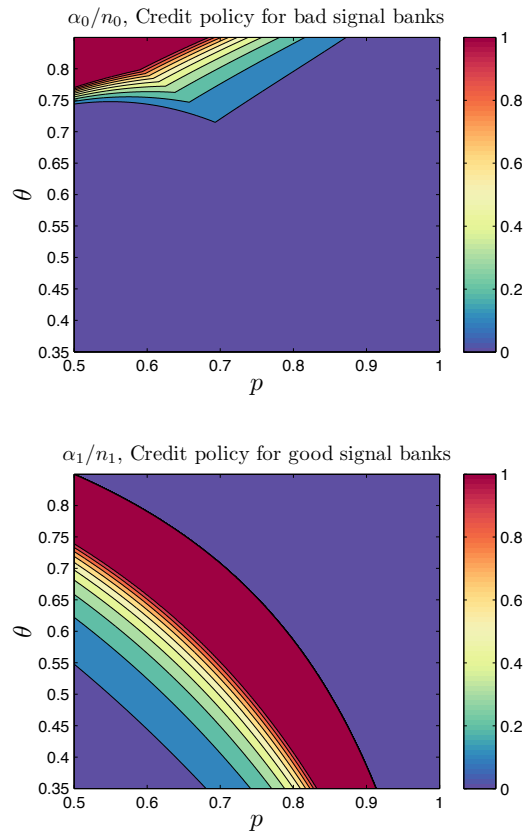*Proof.* See Appendix B. $\square$

The proposition describes the optimal policy as follows: since the marginal benefit of saving classes with higher posterior beliefs is greater, and the marginal cost of saving these classes is lower, the government first guarantees loans of banks with belief $z_1(\theta, p)$. Banks that receive the bad signal receive support only if either banks that received the good signal do not face adverse selection, or are fully supported, $\alpha_1 = n_1(\theta, p)$. The optimal policy for the uniform case, $\theta \sim \mathcal{U}[z^R, z^I]$ is illustrated in the (p, θ) space in Figure 11. The upper panel depicts the percentage of banks with the bad signal that are supported: full support is only optimal for high enough realizations of θ. This can be understood by looking at the lower panel, the fraction of banks with the good signal that receive guarantees. The contour of the $\theta_1^I(p)$ locus is evident: above this line, banks with the good signal never face adverse selection, so no support needs to be provided. Below this locus, banks with the good signal face adverse selection, and for a wide range of (p, θ) pairs full support is provided. As θ decreases, however, fewer and fewer banks are supported: as θ decreases, both the marginal benefit of supporting this category decreases, and the marginal cost increases. The figure plots optimal policies for a fixed level of fiscal capacity γ; α_0 and α_1 are decreasing in this parameter.

2.2   Deposit Guarantees

The government may also intervene to prevent liquidation by banks that are susceptible to runs (those with posterior $z < z^R$). Preventing runs on these banks is desirable both because liquidation is costly in itself, and also because banks that are run on are unable to invest at $t = 1$.

To prevent runs, the government announces deposit guarantees for a mass of banks β_s in posterior classes lower than z^R. For these banks, the government guarantees to repay depositors the contractual deposit amount D at $t = 2$. By offering this guarantee, the government prevents asset liquidation by assuming the risk of the deposit contract: it commits to pay D to the depositors, and demands D from the bank. As in the decentralized equilibrium, some banks may be unable to repay their senior debt, in which case the guarantee is costly for the government.

Figure 11: Optimal Credit Guarantee, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$

α_0/n_0, Credit policy for bad signal banks

α_1/n_1, Credit policy for good signal banks

This figure depicts the optimal credit guarantee policy in the (p,θ) space for a uniform θ. The top panel plots the percentage of bad signal banks that are supported by the policy, $\alpha_0/n_0\,(\theta,p)$. The bottom panel plots the percentage of good signal banks that are supported by the policy, $\alpha_1/n_1\,(\theta,p)$.

The cost of guaranteeing the deposits for a bank with posterior belief z is given by

$$D - zD - (1 - z) \left[qD + (1 - q) A^b \right]$$

That is, the government spends D regardless of the bank's type (the amount that it guarantees). If the bank is good, with probability z, then it is able to repay its senior debt in full. Otherwise, the bank is bad and only able to repay if the investment is successful, with probability q. With probability $1 - q$, the investment fails and the bad bank is only able to repay the value of its legacy assets A^b, in which case the government makes a loss (since it had guaranteed $D > A^b$). The government therefore breaks even if it guarantees good banks, but makes losses on guarantees of bad banks (in expectation).

The net benefit of guaranteeing bank with belief z is

$$(1 - \delta) \left[zA^g + (1 - z) A^b \right] + (1 - z) (qV - k)$$

The benefit has two components: first, legacy assets are not liquidated and, second, bad banks that are saved invest in the project.[13]

The total cost of the deposit guarantee policy is

$$\Psi^d = \sum_{s : z_s(\theta, p) \leq z^R} \beta_s \left(1 - z_s(\theta, p) \right) (1 - q) \left(D - A^b \right) \tag{13}$$

and ex-post welfare is

$$
\begin{aligned}
w(\theta, p, \Psi^d) = \bar{y}_1 &+ \sum_{z_s(\theta, p) \leq z^R} \left[n_s(\theta, p) - \beta_s \right] \delta \left\{ z_s(\theta, p) A^g + \left[1 - z_s(\theta, p) \right] A^b \right\} \\
&+ \sum_{z_s(\theta, p) \leq z^R} \beta_s \left\{ z_s(\theta, p) A^g + \left[1 - z_s(\theta, p) \right] A^b + \left[1 - z_s(\theta, p) \right] (qV - k) \right\} \\
&+ \sum_{z_s(\theta, p) \in [z^R, z^I]} n_s(\theta, p) \left\{ z_s(\theta, p) A^g + \left[1 - z_s(\theta, p) \right] A^b + \left[1 - z_s(\theta, p) \right] (qV - k) \right\} \tag{14} \\
&+ \sum_{z_s(\theta, p) \geq z^I} n_s(\theta, p) \left\{ z_s(\theta, p) A^g + \left[1 - z_s(\theta, p) \right] A^b + (qV - k) \right\} \\
&- \gamma \left(\Psi^d \right)^2
\end{aligned}
$$

The terms that differ with respect to expression 7 are in the first and second lines. In the first line, the welfare contribution of banks that suffer runs and are not saved has its weight reduced by β_s. The second line presents the welfare contribution of the banks that are saved from the run, but are then subject to suboptimal investment due

---

[13]Note that if the bank is good it will not invest, since $z \leq z^R < z^I$.

to adverse selection. The government solves the following program for this ex-post intervention

$$\max_{\{\beta_s\}_{s\in\mathcal{S}}} w\left(\theta, p, \Psi^d\right)$$

$$\text{s.t.} \quad \beta_s \in [0, n_s\left(\theta, p\right)], \forall s \in \mathcal{S}$$

The first-order condition for β_s is

$$(1-\delta)\left[z_s\left(\theta, p\right)A^g + (1 - z_s\left(\theta, p\right))A^b\right] + (1 - z_s\left(\theta, p\right))(qV - k) - 2\gamma\left(\Psi^d\right)(1 - z_s\left(\theta, p\right))(1 - q)\left(D - A^b\right) \leq 0$$

with the FOC being strictly negative if $\beta_s = 0$ and strictly positive if $\beta_s = n_s\left(\theta, p\right)$.

Proposition 8. *The optimal deposit guarantee for each posterior class $s \in \mathcal{S}$ is given by the following first-order condition. Define the net marginal benefit of supporting class with posterior s as*

$$MB_s \equiv (1-\delta)\left[z_s\left(\theta, p\right)A^g + (1 - z_s\left(\theta, p\right))A^b\right] + (1 - z_s\left(\theta, p\right))(qV - k)$$

and the net marginal cost of supporting the class as

$$MC_s \equiv (1 - z_s\left(\theta, p\right))(1 - q)\left(D - A^b\right)$$

In the optimal intervention, the government ranks the ratio of net marginal benefits to net marginal costs for all posterior classes, $s_1, s_2, \ldots$ such that

$$\frac{MB_{s_1}}{MC_{s_1}} \geq \frac{MB_{s_2}}{MC_{s_2}} \geq \ldots \geq \frac{MB_{s_N}}{MC_{s_N}}$$

and the optimal intervention can be characterized as follows: set $\beta_{s_i} = 0$ if $\beta_{s_{i-1}} < n_{s_{i-1}}\left(\theta, p\right)$ for $i > 1$. Otherwise,
set

$$\beta_{s_i} = \max\left\{0, \min\left\{n_{s_s}\left(\theta, p\right), \frac{MB_{s_i}}{2\gamma\left(MC_{s_i}\right)^2} - \sum_{j<i}\frac{MC_{s_j}}{MC_{s_i}}n_{s_j}\left(\theta, p\right)\right\}\right\} \tag{15}$$
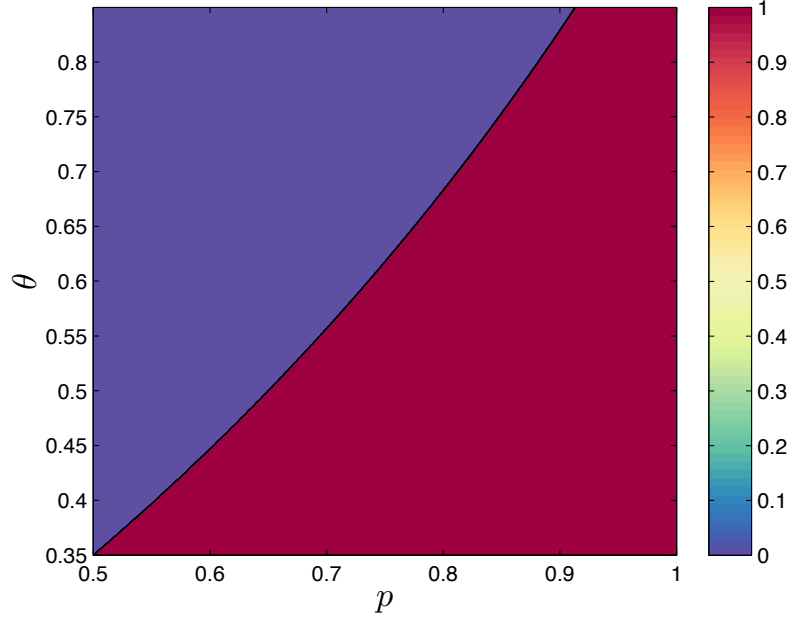
Proof. See Appendix B. □

The optimal policy for the case of binary signals, $s = \{0, 1\}$ follows as a corollary.

Corollary 9. *If signals are binary, and $z_0\left(\theta, p\right) \leq z_1\left(\theta, p\right)$, the optimal intervention consists of supporting banks that received the good signal first, and only then supporting banks that received the bad signal. That is,*

$$\beta_1 = \max\left\{0, \min\left\{n_1\left(\theta, p\right), \frac{MB_1}{2\gamma\left(MC_1\right)^2}\right\}\right\}$$

Figure 12: Optimal Deposit Guarantee, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$

This figure depicts the optimal deposit guarantee policy in the (p, θ) space for a uniform θ. The single panel plots the percentage of bad signal banks that are supported by the policy, $\alpha_0/n_0(\theta, p)$. Note that no banks with the good signal are ever supported, since they have zero probability of facing a run. This is due to the fact that $\theta \geq z^R \geq \theta_1^R(p), \forall p \in \left[\frac{1}{2}, 1\right]$.

and $\beta_0 = 0$ if $\beta_1 < n_1(\theta, p)$. Otherwise,

$$\beta_0 = \max\left\{0, \min\left\{n_0(\theta, p), \frac{MB_0}{2\gamma(MC_0)^2} - \frac{MC_1}{MC_0}n_1(\theta, p)\right\}\right\}$$

Proof. See Appendix B. □

Note that Proposition 7 can also be seen as a particular application of Proposition 8. In the particular case of the credit policy, and appropriately redefining marginal costs and marginal benefits, we have that $\frac{MB_1}{MC_1} > \frac{MB_0}{MC_0}$, and so classes with the good signal are always supported first (and must be fully supported before the government supports any bank in the posterior class that received the bad signal). Figure 12 depicts the optimal deposit policy in the (p, θ) space. Note that only β_0 is considered, since $\theta \sim \mathcal{U}\left[z^R, z^I\right]$ excludes, as discussed, the case in which banks with the good signal are subject to runs. For our chosen parametrization, the marginal benefits and costs of the policy are such that full support is provided for all regions where banks suffer runs. Note that the shape of the locus $\theta_0^R(p)$ is evident, in separating the no support from the full support regions (no runs take place in the region that corresponds to no support).

2.3 Combining deposit insurance and credit guarantees

To complete our description of equilibrium with fiscal intervention, we characterize the ex-post welfare function when the government can use both policies.

$$w(\theta, p, \Psi) = \bar{y}_1 + \sum_{z_s(\theta,p) \leq z^R} [n_s(\theta, p) - \beta_s] \delta \{z_s(\theta, p) A^g + [1 - z_s(\theta, p)] A^b\} \tag{16}$$

$$+ \sum_{z_s(\theta,p) \leq z^R} [\beta_s - \alpha_s] \{z_s(\theta, p) A^g + [1 - z_s(\theta, p)] A^b + [1 - z_s(\theta, p)] (qV - k)\}$$

$$+ \sum_{z_s(\theta,p) \in [z^R, z^I]} [n_s(\theta, p) - \alpha_s] \{z_s(\theta, p) A^g + [1 - z_s(\theta, p)] A^b + [1 - z_s(\theta, p)] (qV - k)\}$$

$$+ \sum_{z_s(\theta,p) \leq z^I} \alpha_s \{z_s(\theta, p) A^g + [1 - z_s(\theta, p)] A^b + (qV - k)\}$$

$$+ \sum_{z_s(\theta,p) \geq z^I} n_s(\theta, p) \{z_s(\theta, p) A^g + [1 - z_s(\theta, p)] A^b + (qV - k)\}$$

$$- \gamma (\Psi)^2$$

where $\Psi \equiv \Psi^k + \Psi^d$ is total spending. The first line corresponds to banks that face runs and are not supported by the deposit guarantee. The second line corresponds to banks that are saved from runs, but not supported by the credit guarantee. The third line are banks that face adverse selection and are not supported by the credit guarantee. The fourth line corresponds to all banks that are supported by the credit guarantee. The fifth line is the welfare contribution of banks that fully invest, while the sixth and last line corresponds to the deadweight costs of total spending.

Optimal joint fiscal policy is the solution to

$$\max_{\{\alpha_s, \beta_s\}_{s \in \mathcal{S}}} w(\theta, p, \Psi) \tag{17}$$

$$\text{s.t.} \quad \beta_s \in [0, n_s(\theta, p)], \forall s \in \mathcal{S}$$

$$\alpha_s \in [0, \mathbb{I}\{z_s \leq z^R\} \beta_s + \mathbb{I}\{z_s \geq z^R\} n_s(\theta, p)]$$

The government chooses $\{\alpha_s, \beta_s\}$ to maximize (16) subject to the constraints that $\beta_s \in [0, n_s(\theta, p)]$ and that α_s cannot exceed β_s in case the respective class was saved by a run (it is ineffective to offer credit guarantees to banks that are not saved from runs), or $n_s(\theta, p)$ otherwise. Optimal joint fiscal policy is summarized by Proposition 10 and depicted in Figure 13

Proposition 10. *(Optimal Joint Fiscal Policy) Define the marginal benefit from each policy as*

$$MB_s^{\alpha_s} \equiv z_s\left(\theta, p\right)\left(qV - k\right)$$

$$MB_s^{\beta_s} \equiv \left(1 - \delta\right)\left[z_s\left(\theta, p\right)A^g + \left(1 - z_s\left(\theta, p\right)\right)A^b\right] + \left(1 - z_s\left(\theta, p\right)\right)\left(qV - k\right)$$

and the marginal costs

$$MC_s^{\alpha_s} \equiv k - qV\left[z_s\left(\theta, p\right) + q\left(1 - z_s\left(\theta, p\right)\right)\right]$$

$$MC_s^{\beta_s} \equiv \left(1 - z_s\left(\theta, p\right)\right)\left(1 - q\right)\left(D - A^b\right)$$

The optimal policy consists of ranking policy-signal pairs $\left(\zeta_{s_1}, s_1\right), \left(\zeta_{s_2}, s_2\right), \ldots$ for $\zeta \in \{\alpha, \beta\}$ such that

$$\frac{MB_{s_1}^{\zeta_{s_1}}}{MC_{s_1}^{\zeta_{s_1}}} \geq \frac{MB_{s_2}^{\zeta_{s_2}}}{MC_{s_2}^{\zeta_{s_2}}} \geq \ldots \geq \frac{MB_{s_i}^{\zeta_{s_i}}}{MC_{s_i}^{\zeta_{s_i}}}$$

For $i = 1$, if $z_1\left(\theta, p\right) \geq z^R$ or $\zeta_{s_1} = \beta_{s_1}$, the optimal policy consists of setting

$$\zeta_{s_i} = \max\left\{0, \min\left\{n_{s_i}\left(\theta, p\right), \frac{MB_{s_i}^{\zeta_{s_i}}}{2\gamma\left(MC_{s_i}^{\zeta_{s_i}}\right)^2}\right\}\right\}$$

otherwise, if $z_1\left(\theta, p\right) < z^R$ and $\zeta_{s_1} = \alpha_{s_1}$, the optimal policy is

$$\alpha_{s_i} = \max\left\{0, \min\left\{\beta_{s_i}, \frac{MB_{s_i}^{\alpha_{s_i}}}{2\gamma MC_{s_i}^{\alpha_{s_i}}\left(MC_{s_i}^{\alpha_{s_i}} + MC_{s_i}^{\beta_{s_i}}\right)}\right\}\right\}$$

$$\alpha_{s_i} = \beta_{s_i}$$

For $i > 1$, if $\zeta_{s_{i-1}} < n_{s_{i-1}}\left(\theta, p\right)$, the optimal policy consists of setting $\zeta_{s_j} = 0, \forall j \geq i$. Otherwise, and if $\zeta_{s_{i-1}} = n_{s_{i-1}}\left(\theta, p\right)$, and $z_i\left(\theta, p\right) \geq z^R$ or $\zeta_{s_i} = \beta_{s_i}$, the optimal policy is

$$\zeta_{s_i} = \max\left\{0, \min\left\{n_{s_i}\left(\theta, p\right), \frac{MB_{s_i}^{\zeta_{s_i}}}{2\gamma\left(MC_{s_i}^{\zeta_{s_i}}\right)^2} - \sum_{j<i}\frac{MC_{s_j}^{\zeta_{s_j}}}{MC_{s_i}^{\zeta_{s_i}}}\zeta_{s_j}\right\}\right\}$$

Finally, for $i > 1$, if $\zeta_{s_{i-1}} = n_{s_{i-1}}\left(\theta, p\right)$, and $z_i\left(\theta, p\right) < z^R$, and $\zeta_{s_i} = \alpha_{s_i}$, the optimal policy is

$$\alpha_{s_i} = \max\left\{0, \min\left\{\beta_{s_i}, \frac{MB_{s_i}^{\alpha_{s_i}}}{2\gamma MC_{s_i}^{\alpha_{s_i}}\left(MC_{s_i}^{\alpha_{s_i}} + MC_{s_i}^{\beta_{s_i}}\right)} - \sum_{j<i}\frac{MC_{s_j}^{\zeta_{s_j}}}{\left(MC_{s_i}^{\alpha_{s_i}} + MC_{s_i}^{\beta_{s_i}}\right)}\zeta_{s_j}\right\}\right\}$$

$$\alpha_{s_i} = \beta_{s_i}$$

Proof. See Appendix B. □

The following Corollary applies Proposition 10 to our binary signal environment.

Corollary 11. *The government sets α_1 before setting α_0, and β_1 before setting β_0.*

Proof. See Appendix B. □

In general, it is not possible to rank α_1 and β_0, or even α_1 and β_1 without further restrictions on the parameters. Figure 13 depicts optimal joint fiscal policy. The top panels depict the fraction of banks with the bad signal and the good signal that are supported by the credit guarantee; the bottom left panel depicts the fraction of banks with the bad signal that are supported by the deposit guarantee (once again, no banks with the good signal ever face runs for this parametrization), while the final panel plots total spending $\Psi = \Psi^k + \Psi^d$. As can be seen from the bottom left panel, full deposit support is still optimal in the joint case. Note that the top panels are similar to the analysis with credit guarantees only (Figure 11), with the main difference being the discontinuity in the support for banks with the good signal. This discontinuity follows the $\theta_0^R(p)$ locus, and arises from the fact that in the present parametrization, the marginal benefit/cost ratio of providing deposits guarantees (for the bad signal banks) exceeds that of providing credit guarantees for good signal banks. Thus, when runs start taking place south of the $\theta_0^R(p)$ locus, fiscal resources devoted to credit guarantees are abruptly reduced. The final, bottom right, panel depicts total spending. Note that spending is greatest in two regions: around the $\theta_1^I(p)$ locus, when both full credit support is granted to banks with the good signal and full deposit support offered to banks with the bad signal; and in the northwestern region, where credit guarantees are offered to both types of banks, those that received the good and those that received the bad signals. Note that while the fraction of banks that is supported south of $\theta_0^R(p)$ and north of $\theta_1^I(p)$ (where only β_0 is active) does not change, total spending varies: this is due to the fraction of banks requiring support decreasing as θ increases.

Figure 14 illustrates joint policy looks from an ex-ante perspective, as a function of the fiscal capacity parameter γ. The left panel plots the expected credit policy support, $\mathbb{E}_\theta\left[\sum_{s\in\{0,1\}} n_s(\theta,p)\alpha_s\right]$, while the right panel plots the expected deposit policy support $\mathbb{E}_\theta\left[\sum_{s\in\{0,1\}} n_s(\theta,p)\beta_s\right]$ for different levels of disclosure, $p = \{0.5, 0.75, 1\}$. Naturally, the expected level of support declines with the value of γ. For $p = 0.5$, the outcome $(\mathcal{L}, \mathcal{L})$ is certain, so there are no runs (and no deposit guarantees). On the other hand, for $p = 1$, there is no adverse selection, and the credit policy is never used. For $p = 0.75$, there are both runs and lemons, and so the government uses both policies.

# 3 Disclosure with Fiscal Interventions

Having described the optimal ex-ante disclosure and ex-post fiscal policies separately, we characterize the problem of a government that has access to both types of policies. Note that the analysis of optimal fiscal policy undertaken in Section 2 applies: since fiscal policy is set after aggregate uncertainty has been realized, it is also set for a given

Figure 13: Optimal Joint Fiscal Policy, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$
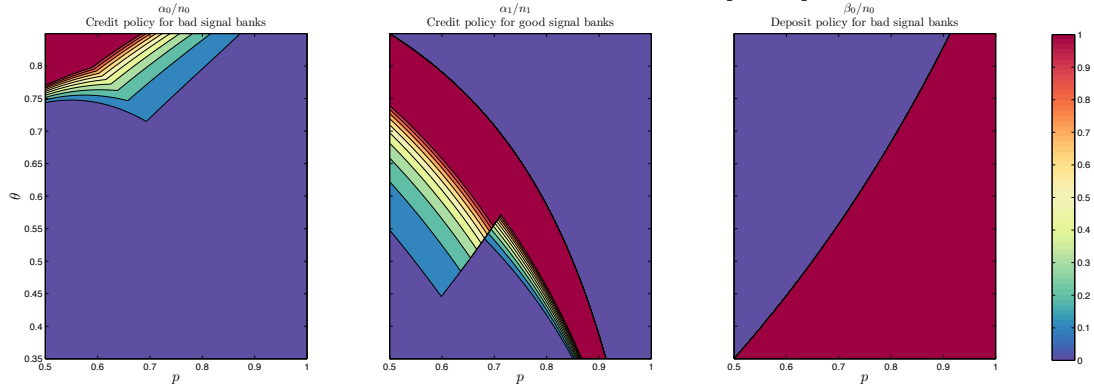
This figure depicts the optimal joint fiscal policy in the (p, θ)space for a uniform θ. The top left panel plots the percentage of bad signal banks that are supported by the credit policy, $\alpha_0/n_0\left(\theta, p\right)$. The top right panel plots the percentage of good signal banks that are supported by the credit policy, $\alpha_1/n_1\left(\theta, p\right)$. The bottom left panel plots the percentage of bad signal banks that are supported by the deposit guarantee policy, $\beta_0/n_0\left(\theta, p\right)$. The bottom right panel plots total spending $\Psi = \Psi^k + \Psi^d$.

Figure 14: Optimal Joint Fiscal Policy, $\theta \sim \mathcal{U}\left[z^R, z^I\right]$
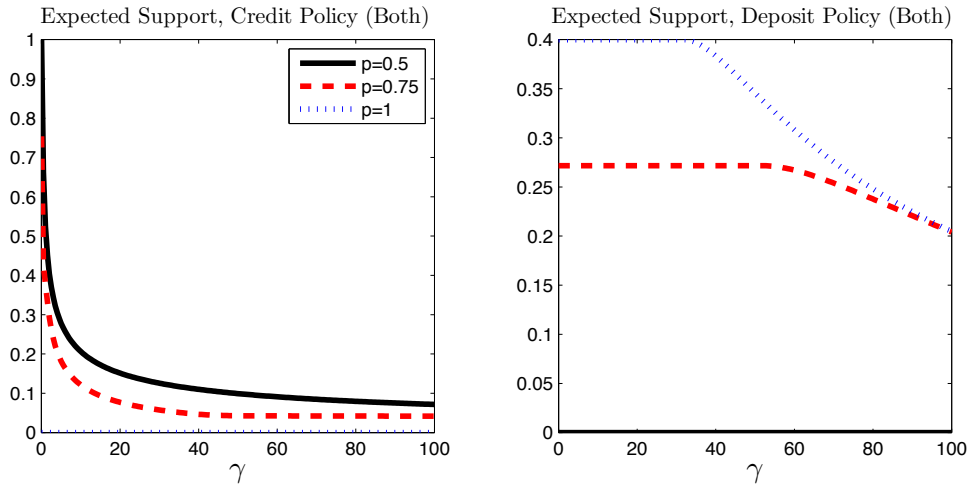
This figure depicts the optimal joint fiscal policy as a function of the fiscal capacity parameter γ, for different values of p. The left panel plots the expected number of banks that receive credit support, while the right panel plots the expected number of banks that receive deposit support.

level of disclosure p; the previous section characterized fiscal policy for arbitrary pairs (p, θ). The problem becomes then to choose the optimal signal precision p, taking as given the ex-post choice of fiscal policy. Formally, the government's problem can be written as

$$\max_{p \in \left[\frac{1}{2}, 1\right]} \mathbb{E}_\theta \left[\max_{\{\alpha_s, \beta_s\}_{s \in \mathcal{S}}} w\left(\theta, p, \Psi\right) \right] \tag{18}$$

$$\text{s.t.} \quad \beta_s \in \left[0, n_s\left(\theta, p\right)\right], \forall s, p, \theta$$

$$\alpha_s \in \left[0, \mathbb{I}\left\{z_s\left(\theta, p\right) \leq z^R\right\} \beta_s + \mathbb{I}\left\{z_s\left(\theta, p\right) \geq z^R\right\} n_s\left(\theta, p\right)\right], \forall s, p, \theta$$

where the ex-post welfare function is defined in (16).

The top left panel of Figure 15 depicts the optimal choice of disclosure, p^* for varying levels of γ, for $\theta \sim \mathcal{U}\left[z^R, z^I\right]$. Optimal disclosure is (weakly) decreasing in γ: high fiscal capacity translates into greater capability 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 starts choosing intermediate levels of disclosure, finally opting for no disclosure, $p = 0.5$, for γ high enough. The discontinuous nature of the optimal level of disclosure reflects the non-convex problem faced by the government. The top right panel depicts the likelihood of each outcome, conditional on the optimal disclosure policy: for high levels of fiscal capacity, the government ensures that banks with bad signals are in the run region and banks with good signals are in the investment region (the outcome is $(\mathcal{R}, \mathcal{I})$ with probability one). As pointed out previously, the government is exposed to random sizes of runs in this state, but fiscal capacity is high enough to tolerate substantial fluctuations in spending (due to high fluctuations in the level of support that the government must provide). As γ increases, the government moves to the left in diagram 6, and two new possible outcomes appear, $(\mathcal{L}, \mathcal{I})$ and $(\mathcal{R}, \mathcal{L})$, but with very low probability. As no disclosure becomes optimal, only the full adverse selection outcome $(\mathcal{L}, \mathcal{L})$ becomes feasible. The same conclusions can be taken from the bottom left panel of the Figure, which plots expected government spending, $\mathbb{E}_\theta\left[\Psi\right]$ given the optimal policy p^*. For low levels of γ, when full disclosure is optimal, no adverse selection ever takes place, so the only source of spending are deposit guarantees. As no disclosure becomes optimal, no more runs take place, but the economy becomes subject to adverse selection, and so the government provides credit guarantees. Also, as one would expect, expected spending is decreasing in γ. The final panel plots expected welfare, which is decreasing in γ. Note, however, that while the optimal policies are discontinuous, the same is not true of expected welfare. The changing slope reflects the transition from the high disclosure to the no disclosure region, welfare being less sensitive to changes in fiscal capacity in the latter.

To better understand the trade-offs faced by the planner, Figure 16 plots expected welfare with and without fiscal policy. The chosen levels of fiscal capacity, $\gamma = 10$ and $\gamma = 30$ imply full and interior disclosure as optimal policies, respectively. While in the baseline parametrization, the government chooses not to disclose at all, $p = \frac{1}{2}$, the availability of fiscal policy increases the incentives to disclose since the government becomes capable of solving

Figure 15: Optimal disclosure choice with fiscal policy
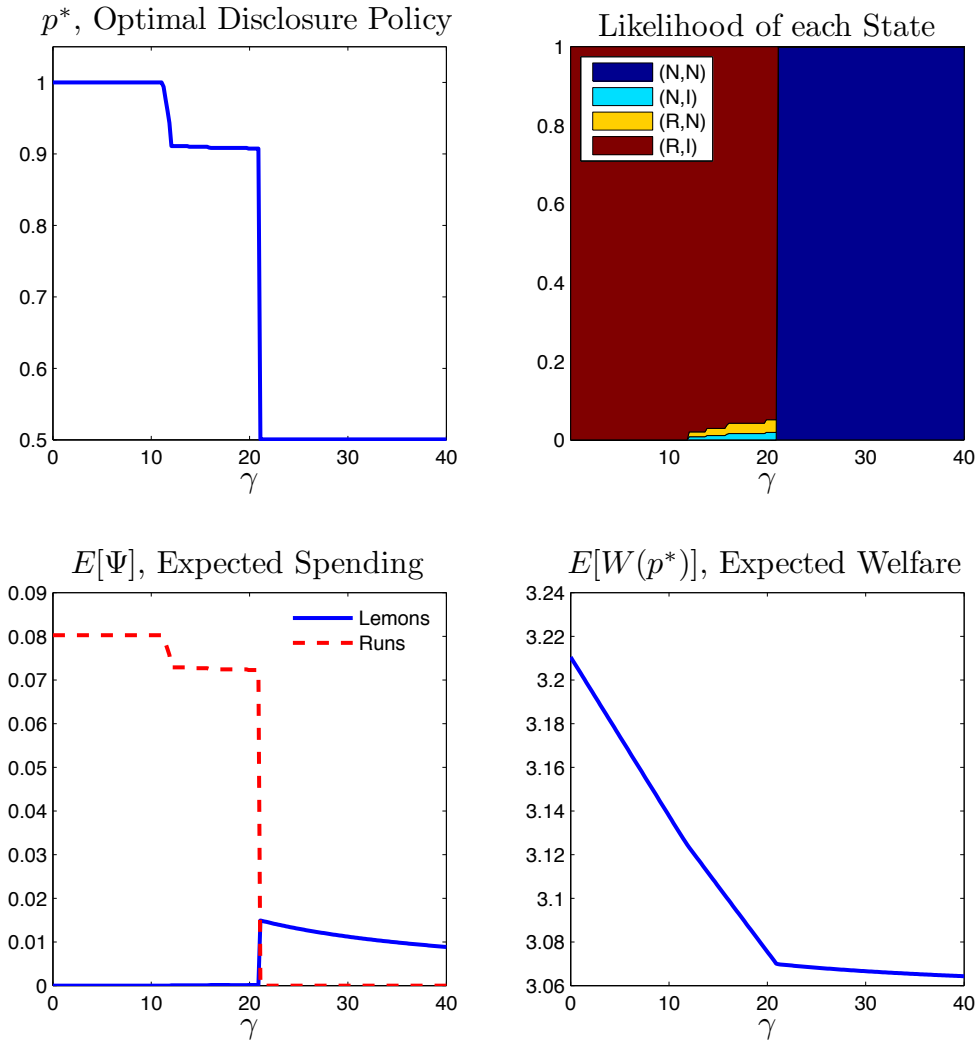
This figure plots several variables as a function of γ, the measure of fiscal capacity. The top left panel plots p^*, the optimal disclosure policy. The top right panel plots the likelihood of each possible outcome given the optimal disclosure policy. The bottom left panel plots expected spending, broken down by type of spending. The bottom right panel plots expected welfare given the optimal disclosure policy.

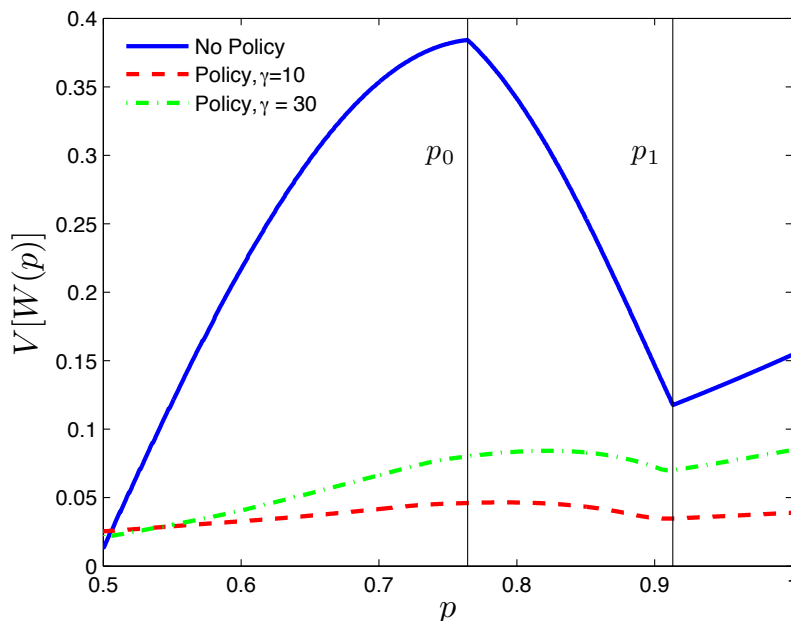Figure 16: Expected Welfare with and without Fiscal Policy
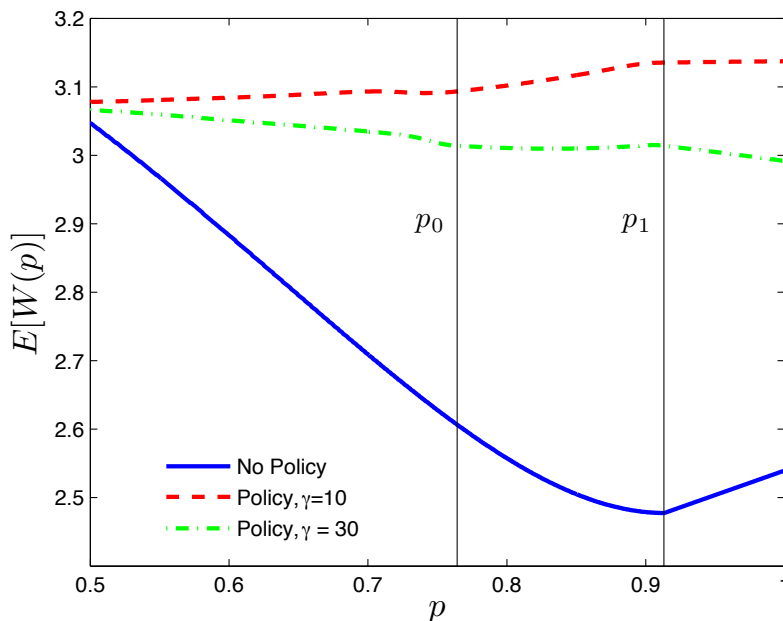
This figure plots expected welfare with optimal fiscal policy (red dashed line, for $\gamma = 10$, dotted green line for $\gamma = 30$) and without fiscal policy (blue solid line).

both the runs and adverse selection problems directly. This creates the incentives to optimally take on some more risk, and choosing an optimal $p \geq \frac{1}{2}$, where runs are possible in equilibrium. Figure 17 plots variance of welfare for the considered cases. Note that for $p = \frac{1}{2}$, the variance of welfare with policy is strictly greater than the variance of welfare without policy: with no policy, there is no uncertainty, but once credit policies become available, the size of the intervention depends on the realization of θ, and is thus uncertain. For all other values of p, however, the fiscal backstop substantially reduces the variance of welfare. The role of fiscal capacity as insurance is also highlighted in this figure: at the optimal levels of disclosure when fiscal capacity is available, the implied variance of welfare is strictly greater than the one chosen by the planner in the absence of fiscal policy.

3.1 Crisis Scenarios

We now analyze how the optimal disclosure policy changes in response to changes in the lower bound of the distribution of the aggregate state $\pi(\theta)$, which we interpret as capturing the severity of a financial crisis. Recall from Figures 5 and 6 that $\underline{\theta} = z^R$ eliminates the outcome in which both categories suffer a run. We focus on downside risk by studying how the optimal disclosure policy changes when $\underline{\theta} < z^R$, and a system-wide run, outcome $(\mathcal{R}, \mathcal{R})$ becomes a possibility. Recall from the aforementioned diagrams that the likelihood of this crisis state (as measured by the size of the region for a fixed choice of p, since the distribution of risk is uniform) decreases as signal precision p increases. The government can then eliminate the possibility of a systemic run by setting a high enough precision for the signal.

Figure 17: Variance of Welfare with and without Fiscal Policy

This figure plots the variance of welfare with optimal fiscal policy (red dashed line, for $\gamma = 10$, dotted green line for $\gamma = 30$) and without fiscal policy (blue solid line).

This change in the structure of the problem has the potential to considerably alter the government's incentives: previously, no disclosure $p = \frac{1}{2}$ was the "safe" option that ensured the predictable outcome of both classes simultaneously facing adverse selection but being saved from runs. Full disclosure, on the other hand, involved a risky bet: while the government was certain that banks with the good signal would be spared from runs and adverse selection, those with the bad signal faced a run, and the size of this run was variable and dependent on the realization of θ. This gamble now becomes more attractive: the formerly safe option of no disclosure is now very risky, since it maximizes the likelihood of the disaster outcome $(\mathcal{R}, \mathcal{R})$.

Figure 18 plots the optimal disclosure policy as a function of $\underline{\theta}$, for different levels of fiscal capacity. The blue solid line corresponds to the case where no fiscal policy is available (or $\gamma \to \infty$), while the red dashed line corresponds to high fiscal capacity, $\gamma = 10$, and the green dotted line to $\gamma = 30$. For the baseline parametrization, our results are robust to the possibility of disaster risk: the level of disclosure is monotonically increasing in fiscal capacity (decreasing in γ). Note, however, that the presence of disaster risk does create some incentives for disclosure: the planner with no fiscal capacity opts for a positive, albeit small, amount of disclosure. This is related to the fact described in the previous paragraph: no disclosure is no longer risk-free and may result in a system-wide run. By disclosing a small amount of information, the planner can reduce the probability of a full run taking place. This incentive is exacerbated when some fiscal capacity is available, as evidenced by the behavior of the green line. No disclosure is exactly optimal at $\underline{\theta} = z^R$ when fiscal capacity is limited, as this now ensures that no run will take place. As $\underline{\theta}$ increases beyond z^R, the disclosure function for low fiscal capacity becomes increasing. In fact, the

Figure 18: Optimal disclosure choice as a function of $\underline{\theta}$, Baseline
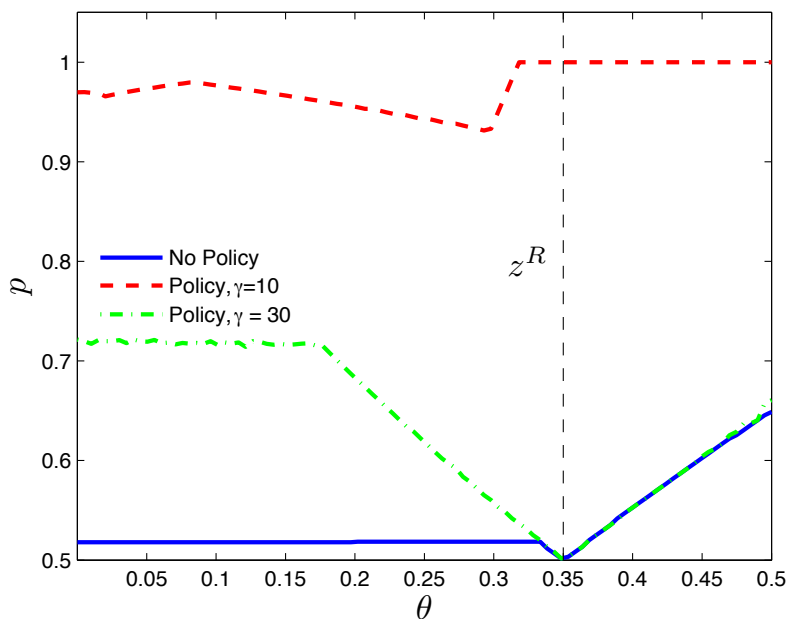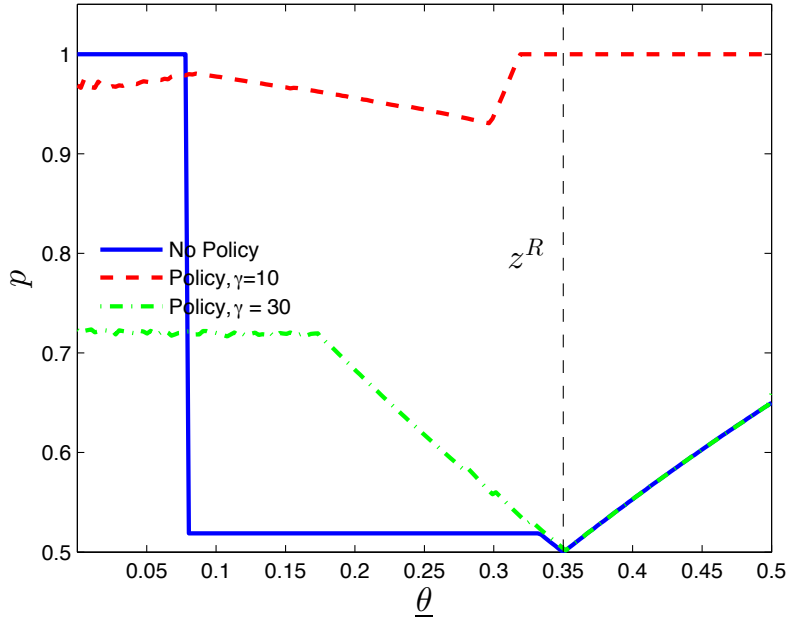
This figure plots the optimal disclosure policy as a function of the lower bound of the distribution of θ, $p\,(\underline{\theta})$. The blue solid line corresponds to the case with no fiscal policy, or low fiscal capacity $\gamma \to \infty$. The red dashed line corresponds to $\gamma = 10$, and the green dotted line to $\gamma = 30$.

function becomes exactly linear with a slope equal to one: for this region, the only possible outcome for $p = 0.5$ is still $(\mathcal{L}, \mathcal{L})$, but the planner can increase p in order to put positive probability on the $(\mathcal{L}, \mathcal{I})$ outcome without putting any positive probability on $(\mathcal{R}, \mathcal{L})$. So no disclosure becomes strictly dominated by some disclosure.

When fiscal policy is available, the structure of the optimal policy can change considerably. The red dashed line corresponds to $\gamma = 10$, or ample fiscal capacity. In this case, the planner finds it optimal to disclose almost fully. Due to ample fiscal capacity, the government is always able to deal with any adverse scenario through fiscal interventions. As fiscal capacity becomes more limited, this is no longer the case: the green dotted line plots the optimal policy for $\gamma = 30$. While the government decides to disclose less, the level of information that is revealed still dominates that of a fiscally incapable government. For $\underline{\theta} \geq z^R$, the behavior of the optimal policy obeys a logic that is similar to the one that prevails in the absence of policy: for this region: a full run becomes impossible, while less and less mass is placed on the $(\mathcal{R}, \mathcal{L})$ outcome. By fully disclosing, the government needs only to activate one policy instrument: deposit guarantees for banks that receive the bad signal (and whose set coincides with that of bad banks, since the signal is perfect). This turns out to be cheaper than revealing less information and having to activate credit guarantee policies.

We now show that changes in our parametrization can, in some cases, reverse our main result in the case of disaster risk. Figure 19 plots the optimal choice of disclosure for different levels of $\underline{\theta}$ for an alternative parameterization where we increase A^g, thus making runs on good banks costlier. Once again, the blue solid line corresponds to the case where no fiscal policy is available (or $\gamma \to \infty$), while the dashed red line corresponds to $\gamma = 10$, and

Figure 19: Optimal disclosure choice as a function of $\underline{\theta}$, High A^g

This figure plots the optimal disclosure policy as a function of the lower bound of the distribution of θ, $p(\underline{\theta})$, for a higher value of A^g. The blue solid line corresponds to the case with no fiscal policy, or low fiscal capacity $\gamma \to \infty$. The red dashed line corresponds to $\gamma = 10$, and the green dotted line to $\gamma = 30$.

the dotted green line to $\gamma = 30$. For a certain level of $\underline{\theta}$ onwards, the previous analysis applies. It is, however, interesting to note what happens when the probability of a disaster is very high (i.e., when $\underline{\theta}$ is very low). With no fiscal policy, the government opts for full disclosure if the lower bound on the support of θ is low enough: for a very low value of $\underline{\theta}$, the $(\mathcal{R}, \mathcal{R})$ region is large and decreasing in p. Thus maximizing welfare is equivalent to minimizing the likelihood of this outcome, and setting $p = 1$, full disclosure, is optimal. As $\underline{\theta}$ increases, however, the importance of this region becomes smaller, and the planner once again finds it optimal to choose lower disclosure. The cost of gambling over the size of a certain run becomes greater than the cost of gambling between no run and a full run. In the case of ample fiscal capacity (red dashed line), the planner finds it optimal to disclose almost fully. In this case, the government is always able to deal with any adverse scenario through fiscal interventions. Yet, the fiscally able government discloses less than the government with no fiscal capacity at all, and the level of disclosure becomes non-monotonic in γ, as the green dotted line ($\gamma = 30$) illustrates. With some fiscal capacity, the government can have incentives not to fully disclose even if a disaster is very likely. For sufficiently low values of θ, more fiscal capacity can then result in less disclosure: in the absence of any fiscal capacity, the government chooses to fully disclose to save all the (few) good banks in the economy. With limited fiscal capacity, the government can save some banks from runs, and this gives room for some bad banks to be saved from runs and receiving the good signal alongside good banks. Thus the fiscally able government can actually disclose less.

4 Conclusion

Our main result is that a planner's fiscal capacity is a key determinant of the optimal disclosure policy. When fiscal capacity is high, it is optimal for the planner to reveal information and provide deposit guarantees to at least a subset of banks that are vulnerable to runs, such that these banks survive and are able to invest in profitable projects. When capacity is low, the planner prefers to avoid runs by not disclosing much information, and then mitigate the resulting adverse selection in the credit market by providing credit guarantees.

In an extension to our main result, we consider the effect of increasing the probability of a "disaster scenario" in which every bank suffers a run, and we find that our logic still applies. The result can be reversed if: (i) Runs are costly enough, and (ii) the probability of a system-wide run is high enough. This reversal can be rationalized by noting that if a system-wide run is very costly, the planner prefers to ensure that at least some banks survive by fully disclosing the types of all banks, whereas a planner with some fiscal capacity can afford to disclose less information in order to take advantage of the pooling of bad with good institutions.

These apparently contradictory results can be reconciled by the insight that fiscal capacity provides insurance against the adverse effects of information disclosure, and that increasing the risk of a disaster scenario changes the nature of the gamble involved in disclosing information. When there is no possibility of a system-wide run, the safest option that is associated with a certain outcome is not to disclose any information. The alternative is to subject the economy to a run of uncertain size. As the probability of a system-wide run increases, the payoff from this otherwise safe scenario comes to dominate the planner's expected payoff, and full disclosure - which prevents system-wide runs by ensuring the survival of the good banks - becomes the safe choice. Interpreting fiscal capacity as insurance, a planner that has better access to fiscal resources will be more willing to accept this gamble.

Our model can help shed light on the different approaches towards disclosure and stress testing that were adopted on either side of the Atlantic. It is generally accepted that stress tests in the US involved greater levels of disclosure in Europe. Our model suggests that this difference in policies is related to the asymmetry in fiscal capacities between the two regions.

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A   Parameters used in examples

To generate the figures, we use the parametrization in the table below.

Table 1: Parametrization for Numerical Examples

Parameter	Description	Value
A^g	Good Assets	3.4
A^b	Bad Asset	2.3
D	Deposits	2.7
V	Project Payoff	7.3
q	Prob. Success	0.46
k	Investment Cost	3.1
δ	Recovery Rate	0.39

Unless otherwise noted, most examples use $\gamma = 5, \underline{\theta} = z^R, \bar{\theta} = z^I$.

B   Proofs

Proof of Proposition 4

Proof. Let the realization of the aggregate state and the precision of the signal be some arbitrary $(\theta, p) \in \left[\underline{\theta}, \bar{\theta}\right] \times \left[\frac{1}{2}, 1\right]$. This realization induces the posterior beliefs $z_0 (\theta, p)$ and $z_1 (\theta, p)$ for banks that received the bad and the good signal, respectively. Consider first banks that received the bad signal, with posterior belief $z_0 (\theta, p)$. Then, following Lemma 1, these banks suffer a run if and only if

$$z_0 (\theta, p) \leq z^R \Leftrightarrow \theta \leq \frac{pz^R}{pz^R + (1 - p)(1 - z^R)} \equiv \theta_0^R (p)$$

Likewise, these banks suffer from adverse selection in credit markets (but no run) if and only if

$$z_0 (\theta, p) \in \left[z^R, z^I\right] \Leftrightarrow \theta \in \left[\frac{pz^R}{pz^R + (1 - p)(1 - z^R)}, \frac{pz^I}{pz^I + (1 - p)(1 - z^I)}\right]$$

and so we define $\theta_0^I (p) \equiv \frac{pz^I}{pz^I + (1-p)(1-z^I)}$. Note that we have that $\theta_0^R (p) \leq \theta_0^I (p)$, and

$$\frac{\mathrm{d}\theta_0^j (p)}{\mathrm{d}p} = \frac{z^j (1 - z^j)}{[pz^j + (1 - p)(1 - z^j)]^2} > 0, \quad j = R, I$$

The derivation of $\theta_1^R (p), \theta_1^I (p)$ follows analogous steps for $z_1 (\theta, p)$. Once again, we have that $\theta_1^R (p) \leq \theta_1^I (p)$ for any p. We also have that

$$\frac{\mathrm{d}\theta_1^j (p)}{\mathrm{d}p} = -\frac{z^j (1 - z^j)}{[pz^j + (1 - p)(1 - z^j)]^2} < 0, \quad j = R, I$$

Finally, it is straightforward to see that

$$\theta_1^j(p) \le \theta_0^j(p)$$

for any $p \ge \frac{1}{2}$. $\qquad\square$

Proof of Proposition 7

Proof. The first-order condition follows from taking the derivative of (12) with respect to α_s. Let N be the size of the set $\mathcal{S}$, the number of possible signals (and, thus, of posterior classes). The optimal policy follows from noticing that the system of FOC with respect to α_s can be written as

$$\frac{MB_s}{MC_s} - 2\gamma \sum_{i \in \mathcal{S}} MC_i \alpha_i \le 0$$

where

$$MB_s = z_s(\theta, p)(qV - k)$$

$$MC_s = k - qV[z_s(\theta, p) + q(1 - z_s(\theta, p))]$$

are the marginal benefit and the marginal (fiscal) cost of supporting an additional bank in class with posterior belief s, respectively. If there were no restrictions on the choice set, the planner would simply set

$$\alpha_s = \frac{MB_s}{2\gamma MC_s^2} - \sum_{t \ne s} \frac{MC_t}{MC_s} \alpha_t$$

for each $s \in \mathcal{S}$. The planner is, however, restricted to choosing $\alpha_s \in [0, n_s(\theta, p)]$, where $n_s(\theta, p)$ is the number of banks with posterior $z_s(\theta, p)$. This involves solving the following system

$$\alpha_s = \max\left\{0, \min\left\{n_s(\theta, p), \frac{MB_s}{2\gamma MC_s^2} - \sum_{t \ne s} \frac{MC_t}{MC_s} \alpha_t\right\}\right\}$$

We can show how to solve this system by induction. Note that each equation in the system of first-order conditions consists of the marginal benefit-to-cost ratio of supporting an additional bank in class s minus a term that is common to all equations (2γ times the total fiscal cost). Note that $\alpha_s = 0, \forall s$ cannot be a solution, as then all first-order conditions would be ≥ 0. Since raising an arbitrary α_s has the same negative impact in all inequalities, the planner should first raise the α_{s_1} such that

$$\frac{MB_{s_1}}{MC_{s_1}} \ge \max_{t \in \mathcal{S}}\left\{\frac{MB_t}{MC_t}\right\}$$

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Thus setting

$$\alpha_{s_1} = \max\left\{0, \min\left\{n_{s_1}(\theta, p), \frac{MB_{s_1}}{2\gamma MC_{s_1}^2}\right\}\right\}$$

If α_{s_1} is not set to full capacity $n_{s_1}(\theta, p)$, then the FOC holds with equality and it is therefore not optimal to set any other $\alpha_t, t \neq s_1$. Otherwise, it is optimal to set the s_2 that yields the second best marginal benefit-to-cost ratio,

$$\frac{MB_{s_2}}{MC_{s_2}} \geq \max_{t \in \mathcal{S}\setminus\{s_1\}}\left\{\frac{MB_t}{MC_t}\right\}$$

in which case the FOC implies

$$\alpha_{s_2} = \max\left\{0, \min\left\{n_{s_2}(\theta, p), \frac{MB_{s_2}}{2\gamma MC_{s_2}^2} - \frac{MC_{s_1}}{MC_{s_2}}\alpha_{s_1}\right\}\right\}$$

We can continue until either the class that yields the worst marginal benefit-to-cost ratio, s_N, is reached, or $\alpha_{s_i} < n_{s_i}(\theta, p)$ for some $i \leq N$. This characterizes the optimal policy for an arbitrary number of signals.

Specializing to $N = 2$, the optimal policy follows as a corollary. It is straightforward to see that

$$\frac{MB_1}{MC_1} \geq \frac{MB_0}{MC_0}$$

so that the marginal benefit-to-cost ratio for supporting banks that received the good signal is always greater than the same ratio for banks that received the bad signal. Then, the optimal policy is characterized by

$$\alpha_1 = \max\left\{0, \min\left\{n_1(\theta, p), \frac{MB_1}{2\gamma MC_1^2}\right\}\right\}$$

and, if $\alpha_1 < n_1(\theta, p)$, $\alpha_0 = 0$. Otherwise, if all banks with the good signal are supported, the planner sets

$$\alpha_0 = \max\left\{0, \min\left\{n_0(\theta, p), \frac{MB_0}{2\gamma MC_0^2} - \frac{MC_1}{MC_0}\alpha_1\right\}\right\}$$

$\square$

Proof of Proposition 8

Proof. The proof is identical to the proof of Proposition 7. The first-order condition with respect to β_s is given by

$$(1 - \delta)\left[z_s(\theta, p)A^g + (1 - z_s(\theta, p))A^b\right] + (1 - z_s(\theta, p))(qV - k) - 2\gamma(\Psi^d)(1 - z_s(\theta, p))(1 - q)(D - A^b) \leq 0$$

Note that the marginal benefits and costs of supporting a class s are independent of the level of support for that

class, β_s. We can rewrite the first-order condition for the arbitrary class s as

$$\frac{MB_s}{MC_s} - 2\gamma \sum_s \beta_s MC_s \leq 0$$

If there were no restrictions in the choice space, the planner would simply set

$$\beta_s = \frac{MB_s}{2\gamma \left(MC_s\right)^2} - \sum_{t \neq s} \frac{MC_t}{MC_s} \beta_t$$

However, the planner is restricted to $\beta_s \in [0, n_s(\theta, p)]$. This amounts to solving the following system

$$\beta_s = \max \left\{ 0, \min \left\{ n_s(\theta, p), \frac{MB_s}{2\gamma \left(MC_s\right)^2} - \sum_{t \neq s} \frac{MC_t}{MC_s} \beta_t \right\} \right\}$$

Now, consider $\beta_s = 0, \forall s$. This cannot be a solution, as all FOC would then be positive. Since raising a single β_s has the same impact on all FOC, we conclude that it is optimal for the planner to first set the β_{s_1} such that

$$\frac{MB_{s_1}}{MC_{s_1}} \geq \max_{t \in \mathcal{S}} \left\{ \frac{MB_t}{MC_t} \right\}$$

This variable is set to either capacity, $n_{s_1}(\theta, p)$, or to an optimal level in which no other control is set to a positive value, that is

$$\beta_{s_1} = \max \left\{ 0, \min \left\{ n_{s_1}(\theta, p), \frac{MB_{s_1}}{2\gamma \left(MC_{s_1}\right)^2} \right\} \right\}$$

Now, if β_{s_1} is not set at capacity, it is clearly not optimal to set any other $\beta_{s_i} > 0, \forall i \neq 1$. Otherwise, it becomes optimal to set the second best, s_2, or

$$\frac{MB_{s_2}}{MC_{s_2}} \geq \max_{t \in \mathcal{S} \setminus \{s_1\}} \left\{ \frac{MB_t}{MC_t} \right\}$$

that is,

$$\beta_{s_2} = \max \left\{ 0, \min \left\{ n_{s_2}(\theta, p), \frac{MB_{s_2}}{2\gamma \left(MC_{s_2}\right)^2} - \frac{MC_{s_1}}{MC_{s_2}} \beta_{s_1} \right\} \right\}$$

This process continues until either s_N, the worst category is reached, or $\beta_{s_i} < n_{s_i}(\theta, p)$ for some $i \leq N$, resulting in expression (15). $\square$

Proof of Corollary 9

Proof. Follows from application of Proposition 8 and noticing that

$$\frac{MB_1}{MC_1} \geq \frac{MB_0}{MC_0} \Leftrightarrow (1 - \delta) A^g \left[z_1(\theta, p) - z_0(\theta, p)\right] \geq 0$$

given that $z_1(\theta, p) \geq z_0(\theta, p)$ for any $\theta \in [0, 1]$ and $p \geq \frac{1}{2}$. $\square$

Proof of Proposition 10

Proof. The proof is very similar to that of Proposition 8, with the caveat that now we have potentially different policies for each type of signal that banks receive. We can nevertheless write the system of first-order conditions for problem (17) as

$$\frac{MB_s^{\zeta_s}}{MC_s^{\zeta_s}} - 2\gamma \sum_{s,\zeta} MC_s^{\zeta_s} \zeta_s \leq 0$$

for $s \in \{0,1\}$ and $\zeta_s \in \{\alpha_s, \beta_s\}$. The same logic as in the previous proposition applies, with the planner comparing the ratio of marginal benefits to marginal costs of providing each type of support to each class of bank posteriors. The only difference arises when the marginal benefit/cost ratio of α_s exceeds that of β_s and posterior class s has suffered a run, $z_s(\theta, p) < z^R$. In this case, the regulator cannot set $\alpha_s > 0$ without setting $\beta_s > 0$. It is easy to see that the regulator chooses to set $\beta_s = \alpha_s$ and simply solves

$$\frac{MB_s^{\alpha_s}}{MC_s^{\alpha_s}} - 2\gamma \left[MC_{s_1}^{\zeta_{s_1}} \zeta_{s_1} + \ldots + MC_s^{\alpha_s} \alpha_s + MC_s^{\beta_s} \beta_s + \ldots \right] = 0$$

Plugging $\beta_s = \alpha_s$ and solving for this variable yields

$$\alpha_{s_i} = \max \left\{ 0, \min \left\{ \beta_{s_i}, \frac{MB_{s_i}^{\alpha_{s_i}}}{2\gamma MC_{s_i}^{\alpha_{s_i}} \left(MC_{s_i}^{\alpha_{s_i}} + MC_{s_i}^{\beta_{s_i}} \right)} - \sum_{j<i} \frac{MC_{s_j}^{\zeta_{s_j}}}{\left(MC_{s_i}^{\alpha_{s_i}} + MC_{s_i}^{\beta_{s_i}} \right)} \zeta_{s_j} \right\} \right\}$$

$$\alpha_{s_i} = \beta_{s_i}$$

$\square$

Proof of Corollary 11

Proof. Follows immediately from noticing that

$$\frac{MB_1^{\alpha_1}}{MC_1^{\alpha_1}} \geq \frac{MB_0^{\alpha_0}}{MC_0^{\alpha_0}}$$

and

$$\frac{MB_1^{\beta_1}}{MC_1^{\beta_1}} \geq \frac{MB_0^{\beta_0}}{MC_0^{\beta_0}}$$

$\square$

C   General Derivation of the Welfare Function for $\theta \in \left[\underline{\theta}, \bar{\theta}\right]$

Here we derive the welfare function, the government's objective function, for the general case in which $\theta \in \left[\underline{\theta}, \bar{\theta}\right]$. This extends the main text, that presents results for the particular case in which $\underline{\theta} = z^R$ and $\bar{\theta} = z^I$. It is easier to

derive the welfare contribution by each of the different regions first:

1. If $(\mathcal{R}, \mathcal{R})$, which happens when $\theta \leq \theta_1^R (p)$, the welfare contribution is

$$\delta \left[\theta A^g + (1 - \theta) A^b\right]$$

2. If $(\mathcal{R}, \mathcal{L})$, which happens when $\theta \in \left[\theta_1^R (p), \min \left\{\theta_1^I (p), \theta_0^R (p)\right\}\right]$, the welfare contribution is

$$\theta A^g \left[p + \delta (1 - p)\right] + (1 - \theta) A^b \left[1 - p (1 - \delta)\right] + (1 - \theta) (qV - k) (1 - p)$$

3. If $(\mathcal{L}, \mathcal{L})$, which happens when $\theta \in \left[\theta_0^R (p), \theta_1^I (p)\right]$, the welfare contribution is

$$\theta A^g + (1 - \theta) A^b + (1 - \theta) (qV - k)$$

4. If $(\mathcal{R}, \mathcal{I})$, which happens when $\theta \in \left[\theta_1^I (p), \theta_0^R (p)\right]$, the welfare contribution is

$$\theta A^g \left[p + \delta (1 - p)\right] + (1 - \theta) A^b \left[1 - p (1 - \delta)\right] + (qV - k) \left[p\theta + (1 - p) (1 - \theta)\right]$$

5. If $(\mathcal{L}, \mathcal{I})$, which happens when $\theta \in \left[\max \left\{\theta_1^I (p), \theta_0^R (p)\right\}, \theta_0^I (p)\right]$, the welfare contribution is

$$\theta A^g + (1 - \theta) A^b + (1 - \theta + p\theta) (qV - k)$$

6. If $(\mathcal{I}, \mathcal{I})$, which happens when $\theta \geq \theta_0^I (p)$, the welfare contribution is

$$\theta A^g + (1 - \theta) A^b + (qV - k)$$

Note then that the only potential point of discontinuity is p_0, defined as

$$p_0 : \theta_0^R (p_0) = \theta_1^I (p_0)$$

$$\Rightarrow p_0 = \frac{\sqrt{z^I (1 - z^R)}}{\sqrt{z^I (1 - z^R)} + \sqrt{z^R (1 - z^I)}}$$

For $p \leq p_0$, when $\theta_0^R(p) \leq \theta_1^I(p)$, welfare is defined as

$$W(p)|_{p \in \left[\frac{1}{2}, p_0\right]} = \int_{\underline{\theta}}^{\theta_1^R(p)} \delta \left[\theta A^g + (1-\theta) A^b\right] d\Pi(\theta)$$

$$+ \int_{\theta_1^R(p)}^{\theta_0^R(p)} \left\{\theta A^g \left[p + \delta(1-p)\right] + (1-\theta) A^b \left[1 - p(1-\delta)\right] + (1-\theta)(qV-k)(1-p)\right\} d\Pi(\theta)$$

$$+ \int_{\theta_0^R(p)}^{\theta_1^I(p)} \left[\theta A^g + (1-\theta) A^b + (1-\theta)(qV-k)\right] d\Pi(\theta)$$

$$+ \int_{\theta_1^I(p)}^{\theta_0^I(p)} \left[\theta A^g + (1-\theta) A^b + (1-\theta+p\theta)(qV-k)\right] d\Pi(\theta)$$

$$+ \int_{\theta_0^I(p)}^{\bar{\theta}} \left[\theta A^g + (1-\theta) A^b + (qV-k)\right] d\Pi(\theta)$$

while for $p \geq p_0$, we have that $\theta_1^I(p) \leq \theta_0^R(p)$ and thus

$$W(p)|_{p \in [p_0, 1]} = \int_{\underline{\theta}}^{\theta_1^R(p)} \delta \left[\theta A^g + (1-\theta) A^b\right] d\Pi(\theta)$$

$$+ \int_{\theta_1^R(p)}^{\theta_1^I(p)} \left\{\theta A^g \left[p + \delta(1-p)\right] + (1-\theta) A^b \left[1 - p(1-\delta)\right] + (1-\theta)(qV-k)(1-p)\right\} d\Pi(\theta)$$

$$+ \int_{\theta_1^I(p)}^{\theta_0^R(p)} \left[\theta A^g \left[p + \delta(1-p)\right] + (1-\theta) A^b \left[1 - p(1-\delta)\right] + (qV-k)\left[p\theta + (1-p)(1-\theta)\right]\right] d\Pi(\theta)$$

$$+ \int_{\theta_0^R(p)}^{\theta_0^I(p)} \left[\theta A^g + (1-\theta) A^b + (1-\theta+p\theta)(qV-k)\right] d\Pi(\theta)$$

$$+ \int_{\theta_0^I(p)}^{\bar{\theta}} \left[\theta A^g + (1-\theta) A^b + (qV-k)\right] d\Pi(\theta)$$

Some algebra allows us to conclude that the function is equal in both parts, and given by

$$W(p) = \int_{\underline{\theta}}^{\theta_1^R(p)} \delta \left[\theta A^g + (1-\theta) A^b\right] d\Pi(\theta) + \int_{\theta_0^I(p)}^{\bar{\theta}} \left[\theta A^g + (1-\theta) A^b + (qV-k)\right] d\Pi(\theta)$$

$$+ A^g \left[\int_{\theta_1^R(p)}^{\theta_0^I(p)} \theta \, d\Pi(\theta) - (1-p)(1-\delta) \int_{\theta_1^R(p)}^{\theta_0^R(p)} \theta \, d\Pi(\theta)\right]$$

$$+ A^b \left[\int_{\theta_1^R(p)}^{\theta_0^I(p)} (1-\theta) \, d\Pi(\theta) - p(1-\delta) \int_{\theta_1^R(p)}^{\theta_0^R(p)} (1-\theta) \, d\Pi(\theta)\right]$$

$$+ (qV-k) \left[\int_{\theta_1^R(p)}^{\theta_0^I(p)} (1-\theta) \, d\Pi(\theta) + p \int_{\theta_1^I(p)}^{\theta_0^I(p)} \theta \, d\Pi(\theta) - p \int_{\theta_1^R(p)}^{\theta_0^R(p)} (1-\theta) \, d\Pi(\theta)\right]$$

or, rewriting,

$$W\left(p\right) = \mathbb{E}\left[\theta\right] A^g + \left(1 - \mathbb{E}\left[\theta\right]\right) A^b + \left(1 - \mathbb{E}\left[\theta\right]\right)\left(qV - k\right)$$

$$- \left(1 - \delta\right)\left\{A^g\left[\int_{\underline{\theta}}^{\theta_1^R\left(p\right)}\theta\mathrm{d}\Pi\left(\theta\right) + \left(1 - p\right)\int_{\theta_1^R\left(p\right)}^{\theta_0^R\left(p\right)}\theta\mathrm{d}\Pi\left(\theta\right)\right] + A^b\left[\int_{\underline{\theta}}^{\theta_1^R\left(p\right)}\left(1 - \theta\right)\mathrm{d}\Pi\left(\theta\right) + p\int_{\theta_1^R\left(p\right)}^{\theta_0^R\left(p\right)}\left(1 - \theta\right)\mathrm{d}\Pi\left(\theta\right)\right]\right\}$$

$$+ \left(qV - k\right)\left\{\int_{\theta_0^I\left(p\right)}^{\bar{\theta}}\theta\mathrm{d}\Pi\left(\theta\right) - \int_{\underline{\theta}}^{\theta_1^R\left(p\right)}\left(1 - \theta\right)\mathrm{d}\Pi\left(\theta\right) + p\left[\int_{\theta_1^I\left(p\right)}^{\theta_0^I\left(p\right)}\theta\mathrm{d}\Pi\left(\theta\right) - \int_{\theta_1^R\left(p\right)}^{\theta_0^R\left(p\right)}\left(1 - \theta\right)\mathrm{d}\Pi\left(\theta\right)\right]\right\}$$

Note that the welfare function in Proposition 5 collapses to the one above under the assumption that $\underline{\theta} = z^R$ and $\bar{\theta} = z^I$.

C.1   First-Order Condition with respect to p

The first-order condition with respect to p is given by

$$\left(qV - k\right)\left\{\int_{\theta_1^I\left(p\right)}^{\theta_0^I\left(p\right)}\theta\mathrm{d}\Pi\left(\theta\right) - \left(1 - p\right)\theta_0^I\left(p\right)\pi\left(\theta_0^I\left(p\right)\right)\frac{\mathrm{d}\theta_0^I\left(p\right)}{\mathrm{d}p} - p\theta_1^I\left(p\right)\pi\left(\theta_1^I\left(p\right)\right)\frac{\mathrm{d}\theta_1^I\left(p\right)}{\mathrm{d}p}\right\}$$

$$+ \left(1 - \delta\right)A^g\left[\int_{\theta_1^R\left(p\right)}^{\theta_0^R\left(p\right)}\theta\mathrm{d}\Pi\left(\theta\right) - \left(1 - p\right)\theta_0^R\left(p\right)\pi\left(\theta_0^R\left(p\right)\right)\frac{\mathrm{d}\theta_0^R\left(p\right)}{\mathrm{d}p} - p\theta_1^R\left(p\right)\pi\left(\theta_1^R\left(p\right)\right)\frac{\mathrm{d}\theta_1^R\left(p\right)}{\mathrm{d}p}\right]$$

$$- \left[\left(1 - \delta\right)A^b + \left(qV - k\right)\right]\left[\int_{\theta_1^R\left(p\right)}^{\theta_0^R\left(p\right)}\left(1 - \theta\right)\mathrm{d}\Pi\left(\theta\right) + \left(1 - p\right)\left(1 - \theta_1^R\left(p\right)\right)\pi\left(\theta_1^R\left(p\right)\right)\frac{\mathrm{d}\theta_1^R\left(p\right)}{\mathrm{d}p} + p\left(1 - \theta_0^R\left(p\right)\right)\pi\left(\theta_0^R\left(p\right)\right)\frac{\mathrm{d}\theta_0^R\left(p\right)}{\mathrm{d}p}\right]$$

The first-order condition can be divided in three parts, one in each line. The first line is the benefit of disclosure for unfreezing credit markets: by disclosing more, the planner is increasing investment by increasing the perceived quality of good banks and making them more likely to invest. The second line is the benefit of disclosure for avoiding runs on good banks: by disclosing their type more accurately, the planner prevents them from suffering runs. The third and last term is the cost of runs over bad banks: by disclosing more, the planner is increasing the likelihood that banks that receive the bad signal suffer a run (and these banks are more likely to be the bad ones). This has two costs: the cost of liquidating legacy assets, and the opportunity cost of the investment opportunity (since bad banks would undertake it anyway).

Notice that the FOC is potentially discontinuous at several points: as $p \uparrow$, regions may disappear and thresholds become irrelevant. For example, for high enough p, $\theta_0^I\left(p\right) \geq \bar{\theta}$ and/or $\theta_1^R\left(p\right) \leq \underline{\theta}$, and all terms relating to these thresholds (including their derivatives with respect to p) become zero (unless the density function is continuous around the boundaries of the support). This implies that the first-order condition may have several roots that correspond to local maxima and/or minima (since we have not shown that the objective function is concave - and, indeed, it is not for some of our examples).

We can show that the first-order condition is exactly equal to zero for $p = \frac{1}{2}$. For $p = 1$, the FOC becomes independent of p (since the welfare function is linear on p when $\left(\mathcal{R}, \mathcal{I}\right)$ is the only possible outcome), and is given

by

$$\mathbb{E}\left[\theta\right] - \frac{(1-\delta)\,A^b + (qV - k)}{2\,(qV - k) + (1-\delta)\,(A^g + A^b)} \tag{19}$$

so that another potential solution exists in the $[p_1, 1]$ interval, where p_1 is defined as

$$p_1 = \inf\left\{p|\theta_1^I\left(p\right) \leq \underline{\theta} \text{ and } \theta_0^R\left(p\right) \geq \bar{\theta}\right\}$$

that is, the lowest value of p for which $(\mathcal{R}, \mathcal{I})$ becomes the only possible outcome. Depending on how 19 is signed, which is a parametric restriction, either $p = 1$ or $p = p_1$ are potential solutions (the former if the expression is positive, and the latter if negative). Several other solutions can exist in the $\left(\frac{1}{2}, p_1\right)$ interval. The optimal p can then be found by evaluating the welfare function $W\left(p\right)$ at each of these candidate solutions and choosing the one that maximizes it.

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