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Information Acquisition and Liquidity Dry-Ups

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Information Acquisition and Liquidity Dry-Ups*

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Abstract

We analyze a novel feedback mechanism between market and funding liquidity that causes self-fulfilling liquidity dry-ups. Financial firms facing funding withdrawals have an incentive to acquire information about their assets. Those with good assets gain by resorting to outside liquidity sources and withhold assets from secondary markets. This leads to adverse selection and lowers market prices. If prices fall by enough, funding withdrawals are amplified and market and funding illiquidity become mutually reinforcing. We compare different policy measures that can mitigate the risk of inefficient liquidity dry-ups. While outright debt purchases can implement the efficient allocation, liquidity injections may backfire and exacerbate adverse selection.

Keywords: Information Acquisition, Market Liquidity, Financial Crises

JEL Classifications: D82, G01, G12

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1 Introduction

A distinctive feature of the 2007-08 financial crisis was the pronounced shortage of liquidity in the "shadow banking" sector.[1] The first strains emerged in the market for asset-backed commercial paper (ABCP), a short-term financial instrument widely issued by shadow banks to fund their holdings of long-term securitized assets. During the second half of 2007, nearly one half of ABCP issuers experienced a run (Covitz et al., 2013). At the same time, the market for many securitized assets froze, forcing commercial and investment banks that were sponsoring ABCP issuers off-balance sheet to absorb their assets back onto their books.

What explains the sudden collapse of the shadow banking sector? After all, the shadow banking system was considered a safe place to invest before the crisis. This was largely due to liquidity and credit guarantees provided to shadow banks by their sponsoring financial institutions (Pozsar et al., 2010). As a result, their debt was widely perceived as safe and *informationally insensitive*: i.e. market participants felt little need to expend resources to investigate the quality of the assets being financed.[2] Gorton (2010) argues that the collapse of the ABCP and other wholesale funding markets resulted from widespread concerns about the value of shadow banks' assets. As debt ceased to be informationally insensitive, information frictions led to a collapse in market liquidity. Runs ensued due to investors' doubts about the solvency of the shadow banks and that of their sponsors.

This compelling view of the run on the shadow banking system leaves a number of questions unanswered. First, what explains the sudden switch from a regime without information production to a regime where it becomes profitable to acquire information? In other words, what determines agents' incentives to acquire information? Second, how are these incentives affected by changes in market and funding liquidity? In particular,

[1]The term "shadow banks" employed in this paper refers to off-balance sheet *conduits*, e.g. Structured Investment Vehicles (SIVs). These conduits are shell companies primarily used by commercial banks and other financial institutions to avoid regulatory capital requirements imposed on assets directly booked on their own balance sheet, including corporate loans and mortgages (Acharya et al., 2013b).

[2]Gorton & Pennacchi (1990) were the first to tie the liquidity properties of debt securities to their "informational insensitivity." In particular, they argue that banks and other financial institutions produce such securities in order to protect uninformed investors from adverse selection.

do funding withdrawals increase agents' incentives to produce information? And does information acquisition amplify these withdrawals? This paper proposes a theoretical model that provides answers to these questions.

Overview of the Model. We consider a three-period model with three types of risk-neutral agents: financial firms, wholesale creditors, and deep-pocketed investors. Financial firms can be interpreted as structured investment vehicles (SIVs) or similar types of off-balance sheet *conduits*. They enter the economy with long-term assets, financed by short- and long-term debt. Assets differ in terms of their payoff at maturity: some yield a high return (*good*), while others yield a low return (*bad*). Although assets' return is initially unknown, firms can expend resources in the initial period to privately learn their asset's future return.[3] Creditors, which can be viewed as money market funds or other wholesale investors, hold the long- and short-term debt. They are subject to idiosyncratic preference shocks that may lead them to withdraw their short-term claims before firms' assets mature. In the intermediate period, a competitive market opens where firms can sell assets to investors to obtain liquidity.[4]

Motivated by the institutional arrangements of SIVs, we assume that firms benefit from recourse to the balance sheet of an outside sponsoring institution. This recourse arises in two ways. First, instead of selling assets, firms can access a private *liquidity line* in the intermediate period at a fixed cost per unit of liquidity withdrawn. Second, the sponsoring institutions provide firms with a *partial credit enhancement* that guarantees a fraction of creditors' outstanding debt.[5]

[3] The assumption that firms do not know the return of their assets *ex ante* is motivated by the fact that SIVs hold highly complex and opaque securitized assets, a large share of which have not been originated by their sponsoring institution but by other financial intermediaries (Pozsar et al., 2010).

[4] SIVs rely on so-called "dynamic liquidity management" strategies to manage their funding risk, meaning that they sell assets in order to obtain liquidity when unable to roll over maturing commercial paper (Covitz et al., 2013).

[5] These assumptions closely mirror the guarantees that conduits benefit from in practice. These include *liquidity enhancements*, or private liquidity lines through which sponsoring institutions repurchase performing assets if conduits fail to roll over maturing commercial paper. Conduits also benefit from *credit enhancements*, or commitments on the part of their sponsoring financial institutions to cover losses on non-performing assets. A distinctive feature of SIVs, compared to other conduits, is that these credit guarantees only cover a fraction of their outstanding liabilities. SIVs therefore also issue longer term liabilities, e.g. medium term notes, in order to compensate for their higher risk (Acharya et al., 2013b).

Firms' balance sheet structure implies that they are subject to a standard maturity mismatch problem, as funding may be withdrawn before assets mature. To cover these withdrawals, firms must decide whether to obtain the required liquidity by selling assets or by tapping their outside liquidity source. The value from acquiring information in this environment stems from firms' ability to hold on to good assets by resorting to their liquidity lines rather than selling them at a relatively low price.[6] Information acquisition thereby leads to an adverse selection problem in secondary markets that impedes the provision of market-based liquidity (i.e. lowers asset prices).[7] This leads to a novel feedback from market prices to information acquisition as lower prices reduce firms' opportunity costs of using their liquidity lines if they know they have good assets.

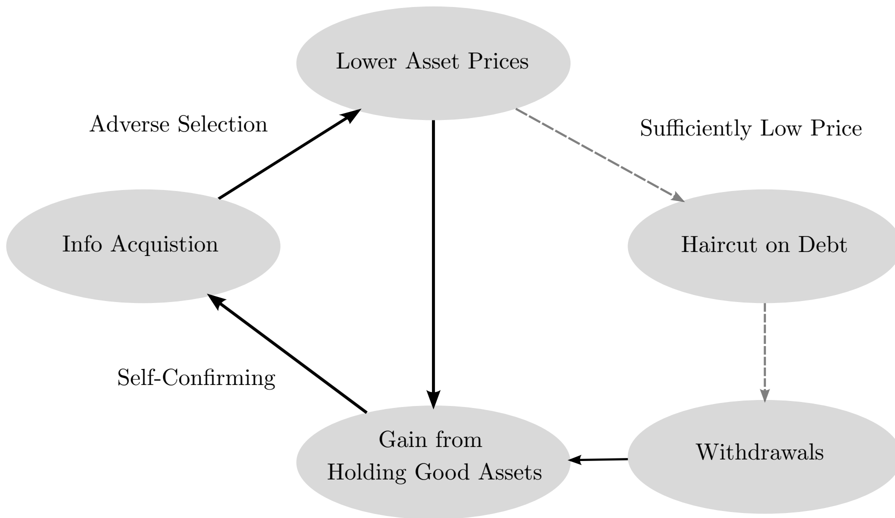
Firms' access to outside liquidity lines induces *strategic complementarities* in information acquisition which can, in turn, generate self-fulfilling dry-ups in market liquidity. To illustrate the underlying mechanism, suppose a firm faces withdrawals and believes that others have acquired information (see Figure 1). If informed firms with good assets opt to use their liquidity lines, the relative share of bad assets in the secondary market increases, and assets trade at a price below their *ex ante* expected value. This "lemons discount" increases the value from withholding good assets from the market, and *a fortiori*, the gain from acquiring information. Hence, the mere belief that others acquire information increases each firm's individual incentive to do so, spurring self-fulfilling market illiquidity.

This information-induced market illiquidity can also amplify firms' funding liquidity risk by increasing creditors' incentives to withdraw their short-term debt. Given the credit guarantees provided by firms' sponsoring institutions, creditors always obtain the full face value of their debt if assets trade at their *ex ante* expected value. When prices are high, creditors' withdrawal decisions only depend on their relative preference for early or late consumption. However, firms relying on the market to obtain liquidity have to sell increasingly large quantities of assets as the price falls, eroding the residual value of

[6]As in Hirshleifer (1971), information acquisition has no social value in our model as it only serves to redistribute rents across agents and does not affect the productive capacity of the economy.

[7]Contrary to standard "lemons" models à la Akerlof (1970) the degree of asymmetric information in our model is endogenous as it is determined by firms' information acquisition decisions.

Figure 1: Model Mechanism



their assets. As the credit guarantees only cover a fraction of outstanding debt, creditors may therefore incur losses if assets trade at a sufficiently low price. In this case, early withdrawals dilute late creditors' claims and increase each creditor's individual incentive to withdraw early.[8] Additional withdrawals increase firms' incentives to acquire information, which further pushes down the price, sparking additional withdrawals, etc. For sufficiently low prices, market illiquidity thus spills over and amplifies firms' funding liquidity risk.[9]

The strategic complementarities in firms' information acquisition and creditors' withdrawal decisions can lead to multiple Pareto-ranked equilibria. Equilibria *without* information acquisition are characterized by high secondary market prices and low roll–over risk. Equilibria *with* information acquisition are instead characterized by low market prices and sudden withdrawals of short-term funding. In order to select a unique equilibrium and study the effects of different types of policy interventions, we employ global game techniques, adapting the methodology of Goldstein (2005).[10] Previewing our results, we show

[8]The channel leading to strategic complementarities in creditors' withdrawal decisions is conceptually similar to the mechanism studied by Brunnermeier & Oehmke (2013) to model the unraveling of firms' debt maturity structure.

[9]Brunnermeier & Pedersen (2009) also study this link. However, the interaction between market and funding liquidity in their model stems from margin requirements imposed on traders and the feedback from higher margins on market liquidity.

[10]The global games refinement embeds a complete information game with multiple equilibria into an

that depending on the parameters of the model, two different regimes can occur: a *weak dependence* and a *strong dependence* regime. In the former, withdrawals of short-term creditors can spur firms to acquire information and thereby lead to a dry-up in market liquidity. However, no reverse feedback exists and firms' funding liquidity risk only depends on creditors' idiosyncratic preference shocks. In the latter regime, market and funding illiquidity mutually reinforce each other. In particular, the belief of not obtaining the full face value of their debt leads short-term creditors to withdraw in more states than those justified by their idiosyncratic preference shocks (see Figure 1).

We analyze a number of policy measures that can be used to mitigate these inefficient liquidity dry-ups. Inspired by the measures adopted by the Federal Reserve in 2007-08 to shore up wholesale funding markets, we focus on four specific policy interventions: creditor guarantees, asset purchases, liquidity injections and outright debt purchases. We obtain three key results. First, asset purchases are more cost-effective than public creditor guarantees if the policymaker's objective is to shield creditors from losses when firms default. Second, if the policymaker's objective is to boost both market and funding liquidity, then outright debt purchases can implement the efficient allocation. Lastly, liquidity injections that reduce the cost of outside liquidity lines can backfire as they exacerbate the adverse selection problem that causes market liquidity to dry-up in the first place.

In general, our model provides a new framework studying the interaction between market liquidity, information acquisition and roll-over risk that helps explain the fragility of the shadow banking sector. Our paper differs from most of the existing bank run literature as we focus on collateralized debt markets.[11] In particular, the presence of credit enhancements imply that bank debt is safe as long as market liquidity is abundant - i.e. there is no strategic coordination problem among creditors when prices are high because their claims are individually backed by firms' sponsors.[12] Creditor runs only emerge in

incomplete information environment and allows to explicitly model agents' strategic uncertainty. See Carlsson & van Damme (1993); Morris & Shin (2003).

[11]See Diamond & Dybvig (1983) and Goldstein & Pauzner (2005) for classic bank run models with demand deposits. Another paper studying the fragility of collateralized short-term debt markets is Kuong (2015). The source of fragility in his paper differs from ours as it relies on the feedback between initial margins and the market value of collateral.

[12]In standard bank run models, the structure of deposit contracts immediately leads to strategic con-

our framework because information acquisition leads to an adverse selection problem in secondary markets, leading to dry-ups in market liquidity. Our paper therefore highlights the fragility of financial institutions that heavily rely on market-based liquidity provision to manage their funding liquidity risk.

Related Literature. Our paper relates to a growing literature on information acquisition in financial markets. Dang et al. (2013) show that the value of information acquisition for a seller is the minimum of either the information rent from selling a low payoff security at a high price, or the gain from not selling a high payoff security at a low price. In our model, firms' surplus from information acquisition is similar to the latter. In contrast to Dang *et al.*, who solve an optimal security design problem, we study the feedback between information acquisition incentives and market prices when assets are traded in a competitive secondary market.

Dang et al. (2015) study information acquisition by buyers. Gorton & Ordonez (2014) use this framework as the backbone of a dynamic model where heterogenous collateral of unknown quality needs to be used to support lending. The value of information in their model corresponds to an information rent that accrues to creditors from liquidating bad collateral at a pooling price.[13] Importantly, the feedback between market prices and information acquisition stemming from this information rent induces strategic substitutatbility (rather than strategic complementarity) in information production. Hence, the self-fulfilling liquidity dry-ups that are the focus of our paper cannot arise in Gorton & Ordonez's model.

Bolton et al. (2015) analyze investors' incentives to acquire information about assets that trade in over-the-counter (OTC) markets. They show that information acquisition generates a negative externality as investors that acquire information "cream skim" good assets from the market, thereby worsening the residual pool of assets offered to uninformed

siderations in withdrawal decisions due to their first-come-first-served nature. It is less clear why such considerations apply to collateralized debt contracts, hence the difficulty of using standard bank run models to explain the run on ABCP issuers during the 2007-08 financial crisis (Gorton, 2012).

[13]Such an information rent also arises in our model if we dispense with the assumption that trading volumes are observable. See Appendix A2 for more details.

investors. In a related model, Fishman & Parker (2015) show how strategic complementarities in information production can give rise to multiple equilibria. The mechanism responsible for this multiplicity is conceptually different from the one studied here as it operates through the rents informed investors extract when buying assets. Feijer (2015) considers the interaction between information acquisition and contracting frictions caused by a risk-shifting problem. The feedback mechanism in his model is distinct from the one here, as it operates through initial borrowing costs rather than the price at which assets are sold in secondary markets.

Our paper also builds on the literature studying how adverse selection can lead to self-fulfilling market freezes. Malherbe (2014), building on Eisfeldt (2004), shows how liquidity hoarding imposes a negative pecuniary externality on secondary market traders by exacerbating adverse selection frictions. This externality can lead to self-fulfilling dry-ups in secondary market liquidity. The channel through which this occurs is noticeably different than in our model as it depends on the return agents enjoy from holding cash. Plantin (2009) shows that "learning by holding", i.e. obtaining private information by holding an asset, can lead to a coordination problem among investors who face exogenous liquidity shocks. In contrast, liquidity shocks in our model are endogenously determined by creditors' decisions to roll over their claims, which allows us to study the link between market and funding liquidity.

Finally, our paper also draws from the large literature on global games that interprets liquidity dry-ups as the result of a coordination failure.[14] Our paper explores a novel channel as it explicitly ties market liquidity risk to an adverse selection problem caused by firms' information acquisition behavior. Moreover, our model deviates from most global game models as it features strategic complementarities within and across two groups of agents. Methodologically, our analysis is closely related to the twin crises model of Goldstein (2005) who first extended global game techniques to a setting with two types of agents and a common fundamental.

[14] See Morris & Shin (2004a); Rochet & Vives (2004); Eisenbach (2013) for bank and creditor runs, or Morris & Shin (2004b) for market dry-ups.

2 Model

2.1 Description of the Economy

We consider a three period exchange economy, with time indexed by $t \in \{0, 1, 2\}$. The economy is populated by a continuum of risk-neutral firms indexed by $j \in [0, 1]$, and a continuum of risk-neutral creditors indexed by $i \in [0, 1]$.

Firms. Each firm is endowed with a risky long-term asset that returns $\tilde{R} \in \{R_l, R_h\}$ in $t = 2$, where $R_h > R_l$ and $\pi \equiv \mathbf{Pr}(\tilde{R} = R_h)$. The *ex ante* expected return of the asset is

$$\mathbf{E}_0[\tilde{R}] = \pi R_h + (1 - \pi) R_l$$

In $t = 0$, each firm has the option to acquire private information about the future return of its asset. For simplicity, we assume that by acquiring information firms perfectly observe the future return of their asset. We denote by $\Omega_j \in \{n, h, l\}$ firm j's information set conditional on not acquiring information (n), or acquiring information and verifying asset returns to be high (h) or low (l). Correspondingly, $\mathbf{E}[\tilde{R}|\Omega_j] \in \{E_0[\tilde{R}], R_h, R_l\}$ denotes firms' beliefs about their asset's return at maturity given their information set.

Information acquisition requires firms to incur a fixed cost $\psi > 0$. These costs can be interpreted as the value of an outside investment opportunity that firms forgo if they invest in information acquisition. Let $\sigma_j \in [0, 1]$ denote the probability that firm j acquires information, and denote by $\sigma \in [0, 1]$ the fraction of firms acquiring information.

Creditors. Creditors hold legacy debt previously issued by firms to finance their assets. A fraction $(1 - \alpha)$ of this debt is long-term and cannot be withdrawn before $t = 2$, while a fraction α is short-term and can be withdrawn upon demand. Creditors that withdraw in $t = 1$ obtain D_1. Creditors that withdraw in $t = 2$ obtain $D_2 > D_1$ if the firm is able to repay the full face value of the debt, and some (endogenous) recovery value ℓ otherwise.

Creditors are subject to idiosyncratic liquidity shocks at the beginning of $t = 1$ that affect their valuation for $t = 2$ consumption. Formally, creditors' preferences are

$$U(c_1, c_2) = c_1 \left(1 + \frac{\hat{\eta} - \eta}{D_1}\right) + c_2 \qquad (1)$$

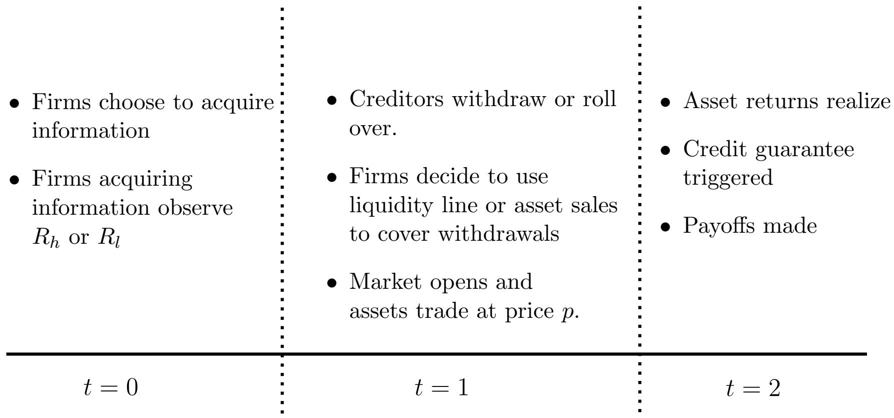
where $\eta > 0$. This variable can be interpreted as cash inflows that reduce creditors' liquidity needs in $t = 1$. Similarly, interpreting $\hat{\eta} > 0$ as (deterministic) cash outflows, the difference $\hat{\eta} - \eta$ corresponds to creditors' net outflows. The magnitude of these net outflows determines creditors' marginal rate of substitution between consumption in $t = 1$ and $t = 2$. Let $\lambda_i \in [0, 1]$ denote the probability that creditor i withdraws his funds, and denote by $\lambda \in [0, 1]$ the fraction of creditors withdrawing in $t = 1$.

Market Structure. The balance sheet structure described above implies that firms are subject to a standard maturity mismatch problem: while asset returns do not realize until $t = 2$, firms must meet funding withdrawals in $t = 1$. Firms can meet these withdrawals in one of two ways. First, they can access a private liquidity line at the cost of $\beta^{-1} > 1$ per unit of funds withdrawn.[15] Second, they can sell asset shares on a (competitive) secondary market that opens in $t = 1$. The buyers in the secondary market are deep-pocketed risk-neutral investors who purchase assets at the price $p = \mathbf{E}_1[\tilde{R}] \geq R_l$, where $\mathbf{E}_1[\cdot]$ denotes investors' expectations about asset returns at the beginning of $t = 1$. Figure 2 summarizes the timing of the model.

Default Risk. We assume that firms are *ex ante* solvent but that the face value of their debt exceeds the return on bad assets. Formally: $\mathbf{E}_0[\tilde{R}] > D_2$ and $R_l < D_1$. In line with the institutional features of SIVs discussed above, we assume that each firm benefits from a *partial credit enhancement* provided by an (outside) sponsoring financial institution. In particular, if the face value of outstanding debt exceeds firms' cash flows in either $t = 1$

[15] The assumption that liquidity lines are costly is realistic, and can be justified for a number of reasons. For example, tapping liquidity lines may imply that the sponsoring financial institution must pass on valuable investment opportunities in order to access the required liquidity. Notwithstanding these costs, firms may prefer to use liquidity lines rather than maintaining cash balances since liquidity lines allow firms to avoid paying the liquidity premium implied by holding liquid assets in states of the world where they do not face a liquidity shortfall (Acharya et al., 2013a).

Figure 2: Sequence of Events



or $t = 2$, the sponsor guarantees losses up to a maximum value of $(D_2 - R_l)$ per claim, while losses in excess of $(D_2 - R_l)$ are borne by creditors.[16]

The credit enhancement ensures that firms never default in $t = 1$ so that short-term debt is safe.[17] Debt that matures in $t = 2$, however, may not be safe. If too many assets are sold at low prices in $t = 1$, the residual value of firms' assets (after selling $\alpha\lambda D_1/p$ shares) may fall below the value guaranteed by the credit enhancement. Formally, firms default in $t = 2$ whenever the *per capita* value of their assets falls below R_l. That is,

$$\frac{R_i \max\left\{1 - \frac{\alpha\lambda D_1}{p}, 0\right\}}{1 - \alpha\lambda} < R_l, \quad \forall i \in \{h, l\}$$

Because of this default risk, remaining creditors in $t = 2$ obtain

$$\ell_i(p) = D_2 - \max\left\{R_l - \frac{R_i \max\left\{1 - \frac{\alpha\lambda D_1}{p}, 0\right\}}{1 - \alpha\lambda}, 0\right\}, \quad \forall i \in \{h, l\} \tag{2}$$

Equation (2) implies that firms never default if $p \geq D_1$. If $p < D_1$, then firms with bad

[16]Together with being a realistic institutional feature of ABCP conduits, the credit enhancements imply that creditors' withdraw decisions are global strategic complements. See the discussion in Appendix A2.

[17]Even if early withdrawals cannot be fully covered by selling *all* assets, the credit enhancement is always sufficient to cover the remaining liabilities of early creditors. Formally,

$$\max\left\{\frac{\alpha\lambda D_1 - p}{\alpha\lambda}, 0\right\} < D_2 - R_l$$

assets always default while those with good assets only default if the fraction of short-term debt is sufficiently high. To simplify the exposition of the model, we impose the following assumption on firms' debt maturity structure.

Assumption 1. *The fraction of short-term debt is such that*

$$\alpha \leq \overline{\alpha} \equiv \frac{1-\rho}{\frac{D_1}{R_l} - \rho}, \quad \textit{where } \rho \equiv \frac{R_l}{R_h}$$

This assumption ensures that the fraction of long-term debt is sufficiently large so that firms with good assets never default: i.e. $\ell_h(p) = D_2$ for all $p \geq R_l$.[18] It also implies that firms opting to finance outflows using asset sales are always able to meet early withdrawals in full, *even if* all short-term creditors withdraw ($\lambda = 1$) and asset prices are at their lower bound ($p = R_l$). Hence, the assumption ensures that the credit enhancement is never triggered in $t = 1$.

2.2 Liquidity Lines versus Asset Sales

Firms need liquidity to cover withdrawals in $t = 1$. They can obtain liquidity in one of two ways, either by selling assets in the market or by resorting to their sponsor's liquidity line at a per unit cost of β^{-1}. Firms choose between asset sales or outside liquidity in order to maximize their profits. Given Assumption 1, the value of a firm that faces withdrawals of $\alpha\lambda D_1$ and covers these by selling assets is

$$V^{AS}(\Omega_j; p) = \mathbf{E}[\tilde{R}|\Omega_j]\left(1 - \frac{\alpha\lambda D_1}{p}\right) - (1-\alpha\lambda)\mathbf{E}[\tilde{\ell}(p)|\Omega_j] \tag{3}$$

If instead firms resort to the liquidity line, the cash flows from their assets in $t = 2$ are unaffected. This implies that the credit enhancements cover the full face value of outstanding liabilities in $t = 2$ even if asset returns are low. Firms using their costly liquidity lines therefore never default on their debt. The value of firms using their liquidity

[18] This is a simplifying assumption and does not affect the qualitative nature of our results. In particular, firms' information acquisition choice and creditors' withdraw decisions still exhibit global strategic complementarities even if we allow for default of firms with good assets. See Appendix A2.

lines is equal to

$$V^{LL}(\Omega_j;\beta) = \mathbf{E}[\tilde{R}|\Omega_j] - \frac{\alpha\lambda D_1}{\beta} - (1-\alpha\lambda)D_2 \tag{4}$$

It follows from equations (3) and (4) that firms' preference between liquidity lines and asset sales depends on the secondary market price, p. In order to fix their preference ordering, we impose the following assumption on asset returns.

Assumption 2. *Asset returns are such that*

$$\rho \equiv \frac{R_l}{R_h} \in \left(\frac{\beta\pi}{1-\beta(1-\pi)}, \frac{\beta-\pi}{1-\pi}\right) \quad \Leftrightarrow \quad \beta R_h > \mathbf{E}_0[\tilde{R}] \quad \textit{and} \quad \beta\mathbf{E}_0[\tilde{R}] < R_l$$

The upper bound on ρ corresponds to a standard "lemons condition." It implies that even if assets trade at their *ex ante* expected value ($p = \mathbf{E}_0[\tilde{R}]$), informed firms holding good assets prefer to meet early withdrawals by tapping their liquidity lines. The lower bound on ρ, on the other hand, implies that even if assets trade at the lowest price ($p = R_l$), uninformed firms still prefer to meet early withdrawals by selling assets.[19]

Lemma 1. *Given Assumptions 1 and 2, informed good firms always prefer the liquidity line, while informed bad firms and uninformed firms always prefer asset sales.*

2.3 Secondary Market Price

Given firms' choice between liquidity lines and asset sales, we now turn to the determination of the secondary market price. Investors that purchase assets in the secondary market must break even. Their participation constraint is given by

$$p \leq \mathbf{E}_1[\tilde{R}] = \tau R_h + (1-\tau)R_l \tag{5}$$

where $\tau \in [0,1]$ denotes the fraction of good assets that are supplied to the market. Competition among investors ensures that condition (5) holds with equality in equilibrium.

[19] This assumption guarantees the existence of an equilibrium in firms' information acquisition game. Relaxing the lower bound on ρ breaks the global strategic complementarities in firms' information acquisition choice. See the discussion in Appendix A2.

Given Lemma 1, only uninformed and informed bad firms supply their assets to the market, since informed good firms always prefer to use their liquidity line. Hence, whenever some firms acquire information, the share of good assets traded in the secondary market will be strictly less than the share of good assets in the economy: i.e. $\tau < \pi$. This implies that uninformed firms will never choose to sell more than $\alpha\lambda D_1/p$ shares, as their assets' expected return $\mathbf{E}_0[\tilde{R}]$ strictly exceeds the market price.

As some firms may be better informed about their assets' return than investors, the secondary market price also depends on whether or not investors can observe firms' order flows. We assume here that firms cannot split their sales, implying that trading volumes are observable.[20] Consequently, bad firms cannot sell more than $\alpha\lambda D_1/p$ shares since otherwise investors would be able to infer assets' return based on the quantity firms supply to the market. Given this, the fraction of good assets in the market equals

$$\tau(\sigma) = \frac{(1-\sigma)\pi}{1-\pi\sigma} \leq \pi \tag{6}$$

and the market price (5) can be rewritten as

$$p(\sigma) = \mathbf{E}_0[\tilde{R}] - (\pi - \tau(\sigma))(R_h - R_l)$$

Notice that the share of good assets traded in the market is strictly decreasing in the fraction of informed firms, i.e. $\tau'(\sigma) < 0$. By acquiring information, firms effectively introduce a degree of asymmetric information into the economy, which leads informed firms with good assets to withhold these from the market. The resulting adverse selection problem leads assets to trade at a discount.

Lemma 2. *The secondary market price is strictly decreasing in the fraction of informed firms: i.e. $p'(\sigma) < 0$.*

[20] Relaxing this assumption introduces an additional motive for acquiring information; namely, the ability to sell bad assets at the (relatively high) pooling price. See Appendix A2 for a discussion.

2.4 Information Acquisition Game

We begin by characterizing firms' optimal information acquisition choice for a given fraction of early withdrawals. Firms' information acquisition decision in $t = 0$ induces a distribution of informed and uninformed firms in the economy. Given their beliefs about the fraction of informed firms, investors update their beliefs about the share of good assets supplied to the secondary market. In equilibrium, firms' information acquisition choice and the resulting equilibrium price have to be mutually consistent.

In what follows, it will be useful to express firm j's best response $\sigma_j^*(\sigma)$ in terms of the expected surplus from acquiring information. Given Lemma 1, if a firm does not acquire information, it prefers to meet early withdrawals by selling assets. The value of remaining uninformed is therefore equal to $V^{AS}(n;p)$. If a firm acquires information, then with probability π the asset is verified to be good, and with probability $1-\pi$ the asset is verified to be bad. Again, by Lemma 1, good firms always prefer to use their liquidity lines, while bad firms opt to sell assets. The expected surplus from acquiring information is therefore given by

$$S(\sigma;\lambda) \equiv \pi V^{LL}(h;\beta) + (1-\pi)V^{AS}(l;p) - V^{AS}(n;p)$$

Using equations (3) and (4), this expression can be rewritten as

$$S(\sigma;\lambda) = \alpha\lambda D_1 \left(\frac{1}{p(\sigma)} - \frac{1}{\beta R_h}\right)\pi R_h \tag{7}$$

The value from acquiring information consists of the option value from holding good assets rather than selling them at the (relatively low) pooling price.[21] It arises because informed firms with good assets prefer to meet early withdrawals using their liquidity lines.

As shown by Lemma 2, the market price declines as more firms become informed. This lowers the opportunity cost of using liquidity lines and increases the value from acquiring information and withholding good assets from the market. This implies that

[21] Default (of bad firms) does not affect the surplus from acquiring information since it symmetrically lowers the expected $t = 2$ repayment for both informed bad and uninformed firms.

firms' information acquisition choices are *strategic complements*: firm j's incentive to acquire information is increasing in the fraction of informed firms.

Lemma 3. *Firms' surplus from acquiring information is strictly increasing in the fraction of informed firms: i.e.* $S_\sigma(\sigma;\lambda) > 0$.

We characterize the equilibrium of the information acquisition game in terms of the cost parameter, ψ. Firm j's best respondence correspondence must satisfy

$$\sigma_j^*(\sigma) = \begin{cases} 0 & \text{if } S(\sigma;\lambda) < \psi \\ \in (0,1) & \text{if } S(\sigma;\lambda) = \psi \\ 1 & \text{if } S(\sigma;\lambda) > \psi \end{cases}$$

We focus on symmetric equilibria whereby all firms adopt the same strategy in $t = 0$. Solving for the equilibrium therefore reduces to solving the fixed point $\sigma_j^*(\sigma) = \sigma$.[22]

Proposition 1. *There exist threshold costs* $\underline{\psi}(\lambda) \equiv S(0;\lambda)$ *and* $\overline{\psi}(\lambda) \equiv S(1;\lambda)$ *such that* $\underline{\psi}(\lambda) < \overline{\psi}(\lambda)$ *for all* λ. *The equilibria of the information acquisition game are:*

1. *No information acquisition,* $\sigma^* = 0$, *where assets trade at the ex ante pooling price* $p^*(0) = \mathbf{E}_0(\tilde{R})$ *if and only if* $\psi \geq \underline{\psi}(\lambda)$*;*

2. *Partial information acquisition,* $\sigma^* \in (0, 1)$, *such that* $p^*(\sigma^*) \in (R_l, \mathbf{E}_0[\tilde{R}])$ *if and only if* $\psi \in (\underline{\psi}(\lambda), \overline{\psi}(\lambda))$*;*

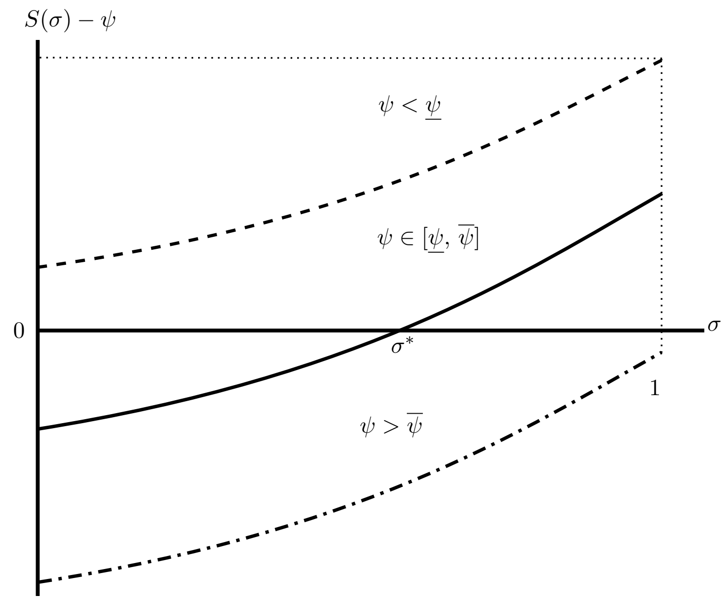
3. *Full information acquisition,* $\sigma^* = 1$, *where the asset price collapses to* $p^*(1) = R_l$ *if and only if* $\psi \leq \overline{\psi}(\lambda)$.

There exist multiple equilibria for values of $\psi \in (\underline{\psi}(\lambda), \overline{\psi}(\lambda))$.

For $\psi > \overline{\psi}$, information costs are so high that firms never acquire information, implying that assets trade at the *ex ante* pooling price $\mathbf{E}_0[\tilde{R}]$ and all firms use the secondary

[22] Since the surplus function (7) is continuous in σ, it follows that firms' best response correspondence $\sigma_j^*(\sigma)$ is convex valued and has a closed graph. The existence of a fixed point thus follows directly from application of Kakutani's fixed point theorem.

Figure 3: Surplus from acquiring information $S(\sigma)$ for fixed λ.



market to meet early withdraws. For $\psi < \underline{\psi}$, information costs are so low that firms always acquire information, leading good assets to be withheld from the market and the price to fall to R_l. For $\psi \in (\underline{\psi}, \overline{\psi})$, multiple equilibria arise due to strategic complementaries in information acquisition. In particular, if a firm believes that others acquire information, it expects the market price to fall below $\mathbf{E}_0[\tilde{R}]$. This raises its expected surplus from acquiring information. Because of strategic complementarities in information acquisition, the fraction of informed firms must increase, thereby lowering the market price and vindicating the initially held belief. We refer to this type of phenomena as a *self-fulfilling (market) liquidity dry-up*. Figure 3 plots firms' surplus function in terms of σ.

A distinctive feature of firms' information acquisition incentives is that they are strictly increasing in the fraction of debt that is withdrawn in $t = 1$. Higher withdrawals increase the option value of holding good assets since informed firms avoid selling more of these at the pooling price.

Lemma 4. *The surplus from acquiring information is strictly increasing in the fraction of early withdrawals: i.e.* $S_\lambda(\sigma; \lambda) > 0$.

2.5 Roll–Over Game

We now characterize the roll over/withdrawal decision of short-term creditors for a given fraction of informed firms. Recall that creditors' preferences (1) imply that their marginal rate of substitution between $t = 1$ and $t = 2$ consumption depends on the magnitude of their net outflows, $\hat{\eta} - \eta$. Given the debt contract (D_1, D_2) and the value of claims in case of default (2), creditors choose to withdraw their funds in $t = 1$ whenever

$$D_1 + (\hat{\eta} - \eta) > \mathbf{E}_1[\min\{D_2, \tilde{\ell}(p)\}]$$

Using equation (2), creditors' expected surplus from withdrawing early equals

$$W(\lambda; \sigma) = D_1 - (D_2 - X(\lambda; \sigma)) \tag{8}$$

where

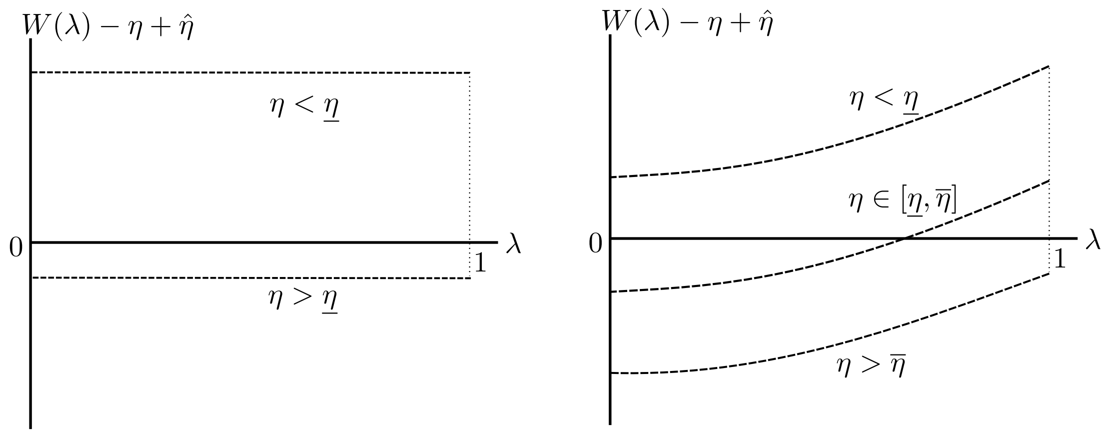
$$X(\lambda; \sigma) = (1 - \pi) \max \left\{ R_l - \frac{R_l \left(1 - \frac{\alpha \lambda D_1}{p(\sigma)}\right)}{1 - \alpha \lambda}, 0 \right\}$$

corresponds to creditors' loss-given-default. For prices above D_1, firms never default and creditors always receive the full face value of their claims if they roll over. If prices fall below D_1, however, outstanding creditors in $t = 2$ take a haircut on claims held against firms with bad assets.

As in the information acquisition game, creditors' withdraw decisions can be strategic complements. The presence of strategic complementarities depends on the price at which firms sell assets in the secondary market. When $p \geq D_1$, firms have to sell assets *less* than one-for-one to match the withdrawals of early creditors. Regardless of the amount of early withdrawals, firms – supported by the credit enhancement that protects creditors from assets' "fundamental" risk – always have sufficient funds to pay back late creditors in full. In this case, creditor i's payoff from withdrawing is independent of other creditors' withdrawal decision.

This strategic independence among creditors' roll over decisions does not carry through

Figure 4: Surplus from withdrawing $W(\lambda)$ for fixed σ.



Panel (a): Case where $p(\sigma) \geq D_1$. **Panel** (b): Case where $p(\sigma) < D_1$.

when $p < D_1$. In this case, firms have to sell assets *more* than one-for-one to meet early withdrawals, leading the residual value of firms' assets to decline if they meet these withdrawals by selling assets. Notwithstanding the credit enhancements, firms with bad assets are unable to repay late creditors the full face value of their claims in $t = 2$. Importantly, creditors' loss-given-default is increasing in the fraction of early withdrawals since more assets must be sold as λ increases. This explains the strategic complementarity in creditors' decisions: i.e. creditor i's incentive to withdraw is strictly increasing in the fraction of early withdrawals in $t = 1$. Figure 4 depicts these two cases by plotting creditors' surplus function in terms of λ.

Lemma 5. *Creditors' surplus from withdrawing funds early is weakly increasing in the fraction of withdrawals: i.e.* $W_\lambda(\lambda; \sigma) \geq 0$.

We characterize the equilibrium in terms of creditors' net inflows, $\eta - \hat{\eta}$. If net inflows are high, then creditors always prefer consumption in $t = 2$ compared to $t = 1$. If, instead, net inflows are low, then creditors prefer consuming in $t = 1$ rather than $t = 2$. Creditor

i's best respondence correspondence therefore satisfies

$$\lambda_i^*(\lambda) = \begin{cases} 0 & \text{if } W(\lambda;\sigma) < \eta - \hat{\eta} \\ \in (0,1) & \text{if } W(\lambda;\sigma) = \eta - \hat{\eta} \\ 1 & \text{if } W(\lambda;\sigma) > \eta - \hat{\eta} \end{cases}$$

As for the information acquisition game, we focus on symmetric equilibria where all creditors adopt the same strategy in $t = 1$.[23]

Proposition 2. *There exist thresholds* $\underline{\eta} \equiv W(0;\sigma) > 0$ *and* $\overline{\eta}(\sigma) \equiv W(1;\sigma) > 0$ *such that* $\underline{\eta} < \overline{\eta}(\sigma)$ *if and only if* $p(\sigma) < D_1$*. The equilibria of the roll over game are:*

1. *No withdrawals,* $\lambda^* = 0$*, if and only if* $\eta > \underline{\eta}$*.*
2. *Partial withdrawals,* $\lambda^* \in (0,1)$*, if and only if* $\eta \in (\underline{\eta}, \max\{\underline{\eta}, \overline{\eta}(\sigma)\})$*.*
3. *Full withdrawals,* $\lambda^* = 1$*, if and only if* $\eta < \max\{\underline{\eta}, \overline{\eta}(\sigma)\}$*.*

When $p(\sigma) < D_1$*, there exist multiple equilibria for values of* $\eta \in (\underline{\eta}, \overline{\eta}(\sigma))$*.*

Similarly to firms' information acquisition incentives, which depend on the fraction of early withdrawals, creditors' withdrawal incentives also depend on the fraction of informed firms *via* its effect on the secondary market price. As more firms acquire information, the market price decreases due to informed firms withholding good assets from the market. This increases the quantity of assets that must be sold to meet early withdrawals, and thereby raises creditors' loss-given-default when asset returns are low.

Lemma 6. *The surplus from withdrawing early is weakly increasing in the fraction of informed agents: i.e.* $W_\sigma(\lambda;\sigma) \geq 0$*.*

[23] As for the information acquisition game, the existence of an equilibrium is guaranteed by application of Kakutani's fixed point theorem.

3 Unique Equilibrium

The model exhibits two forms of strategic complementarities. The first relates to strategic complementarities *within* groups of agents. In particular, firms' incentives to acquire information are increasing in the fraction of informed firms. Similarly, creditors' incentives to withdraw their funds are increasing in the fraction of early withdrawals. Strategic complementarities also operate *between* groups of agents: i.e. firms' incentives to acquire information (creditors' incentives to withdraw their funds early) are increasing in the fraction of early withdrawals (the fraction of informed firms).

These strategic complementarities can give rise to multiple equilibria. For intermediate values of ψ and η, the optimal behavior of agents depends on their beliefs about the behavior of other agents. In particular, beliefs by firms and creditors that all creditors roll over and no firm acquires information lead to an equilibrium where asset markets are liquid and short-term debt is rolled over. The opposite beliefs – i.e. that all firms acquire information and all creditors withdraw – give rise to another equilibrium where market and funding liquidity both dry up. Both equilibria are self-fulfilling in the sense that the equilibrium outcomes vindicate agents' initial beliefs. This equilibrium indeterminacy is a consequence of the assumption that the model and its parameters are common knowledge and that agents can perfectly coordinate their actions and beliefs in equilibrium (Morris & Shin, 2003).

3.1 Global Game Environment

Private Types. To overcome this equilibrium indeterminacy, we abandon the assumption of common knowledge about ψ and η and instead assume that firms have idiosyncratic opportunity costs and creditors face idiosyncratic inflows in $t = 1$. Formally, we assume that agents' *types* are given by

$$\psi_j = \theta + \epsilon_j \quad \text{and} \quad \eta_i = \theta + \epsilon_i$$

where $\epsilon_k \sim U[-\epsilon, \epsilon]$ for all $k \in \{i, j\}$ and $\theta \sim U[\underline{\theta}, \overline{\theta}]$. The common component θ can be interpreted as a macroeconomic state that simultaneously affects all firms' opportunity costs and all creditors' cash inflows, and ϵ_k as an idiosyncratic component affecting only agent k.[24] While the distributions of both components are common knowledge, their respective realizations are not. Thus, even though firms and creditors observe their respective types, they are uncertain about their position in the overall distribution of types, and hence face uncertainty about the behavior of other agents.

Strategies and Payoffs. In this modified model, a strategy for agent k consists of a mapping $s_k : \mathbb{R}_+ \to \{0, 1\}$ that assigns to each type a decision of whether or not to acquire information (for firms) or to withdraw funds (for creditors). Each group of agents uses symmetric strategies when $s_j(\cdot) = s^f(\cdot)$ for all j and $s_i(\cdot) = s^c(\cdot)$ for all i. Strategies are said to be monotone when $\{s^f(\cdot), s^c(\cdot)\}$ can be summarized by joint thresholds $\{\psi^*_\epsilon, \eta^*_\epsilon\}$ such that agents acquire information or withdraw their funds if and only if their types are below their respective threshold. In what follows, we restrict attention to equilibria in monotone strategies.[25]

If agents use montone strategies around the thresholds ψ^*_ϵ and η^*_ϵ, the law of large numbers implies that the fraction of informed firms and the fraction of early withdrawals (given some realization of the state variable θ) are equal to

$$\begin{aligned} \sigma(\theta, \psi^*_\epsilon) &= \mathbf{Pr}(\psi_j < \psi^*_\epsilon | \theta) = F\left(\frac{\psi^*_\epsilon - \theta + \epsilon}{2\epsilon}\right), \\ \text{and} \quad \lambda(\theta, \eta^*_\epsilon) &= \mathbf{Pr}(\eta_i < \eta^*_\epsilon | \theta) = F\left(\frac{\eta^*_\epsilon - \theta + \epsilon}{2\epsilon}\right) \end{aligned} \tag{9}$$

where $F(x) = \min\{\max\{x, 0\}, 1\}$. The surplus from acquiring information for a firm of type ψ_j is then $\mathbf{E}_\theta[S(\sigma(\theta, \psi^*_\epsilon); \lambda(\theta, \eta^*_\epsilon))|\psi_j]$ and the surplus from withdrawing for a creditor of type η_i is $\mathbf{E}_\theta[W(\lambda(\theta, \eta^*_\epsilon); \sigma(\theta, \psi^*_\epsilon))|\eta_i]$.

[24] For simplicity, we assume that these idiosyncratic components are identically distributed across groups. These distributional assumptions are only made for the sake of analytical convenience.

[25] As shown in Proposition 3, this restriction is without loss of generality.

3.2 Equilibrium Characterization

To constitute a monotone equilibrium, the thresholds $(\psi_\epsilon^*, \eta_\epsilon^*)$ must be such that agents whose types are just equal to the thresholds are indifferent between either action. That is, the thresholds simultaneously solve

$$\psi_\epsilon^* = \mathbf{E}_\theta[S(\sigma(\theta,\psi_\epsilon^*);\lambda(\theta,\eta_\epsilon^*))|\psi_\epsilon^*] \quad \text{and} \quad \eta_\epsilon^* = \mathbf{E}_\theta[W(\lambda(\theta,\eta_\epsilon^*);\sigma(\theta,\psi_\epsilon^*))|\eta_\epsilon^*] \tag{10}$$

Given the uniform prior assumptions, the posterior distribution of θ for an agent of type $\phi^* \in \{\psi_\epsilon^*, \eta_\epsilon^*\}$ is uniform over $[\phi^* - \epsilon, \phi^* + \epsilon]$. The expected surplus from acquiring information given ψ_ϵ^* is thus equal to

$$\mathbf{E}_\theta[S(\sigma(\theta,\psi_\epsilon^*);\lambda(\theta,\eta_\epsilon^*))|\psi_\epsilon^*] = \frac{1}{2\epsilon}\int_{\psi_\epsilon^*-\epsilon}^{\psi_\epsilon^*+\epsilon} S(\sigma(\theta,\psi_\epsilon^*),\lambda(\theta,\eta_\epsilon^*))\,\mathrm{d}\theta$$

Changing the variable of integration using equation (9) allows to rewrite this condition as

$$\psi_\epsilon^*(\eta_\epsilon^*) = \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta_\epsilon^* - \psi_\epsilon^*(\eta_\epsilon^*)}{2\epsilon}\right)\right)\mathrm{d}\sigma \tag{11}$$

Similarly, expressing creditors' indifference condition in terms of λ, we obtain

$$\eta_\epsilon^*(\psi_\epsilon^*) = \hat{\eta} + D_1 - D_2 + \int_{\max\{0,\lambda^D(\psi_\epsilon^*)\}}^{\max\{1,\lambda^D(\psi_\epsilon^*)\}} X\left(\lambda, F\left(\lambda + \frac{\psi_\epsilon^* - \eta_\epsilon^*(\psi_\epsilon^*)}{2\epsilon}\right)\right)\mathrm{d}\lambda \tag{12}$$

where $\lambda^D(\psi_\epsilon^*) = F\left(\sigma^D + \frac{\eta_\epsilon^*(\psi_\epsilon^*)-\psi_\epsilon^*}{2\epsilon}\right)$ and $\sigma^D \equiv \frac{\mathbf{E}_0[\tilde{R}]-D_1}{\pi(R_h-D_1)}$ is such that $p(\sigma^D) = D_1$.

The thresholds defined by conditions (11) and (12) are bounded from above and from below. These bounds are given by agents' expected surplus under "extreme beliefs." For firms, they correspond to the expected surplus from acquiring information if firms believe no (every) creditor withdraws. Similarly, for creditors, they correspond to the expected surplus from withdrawing if creditors believe no (every) firm acquires information. Using the surplus functions derived above, these bounds can be written as

$$\underline{\psi}^* = \int_0^1 S(\sigma, 0)\,\mathrm{d}\sigma = 0 \quad \text{and} \quad \overline{\psi}^* = \int_0^1 S(\sigma, 1)\,\mathrm{d}\sigma,$$

$$\underline{\eta}^* = \hat{\eta} - (D_2 - D_1) \quad \text{and} \quad \overline{\eta}^* = \hat{\eta} - (D_2 - D_1) + \int_0^1 X(\lambda, 1)\mathrm{d}\lambda$$

Assumption 3. *The volume of outflows is such that $\hat{\eta} > D_2 - D_1$.*

Assumption 3 ensures the existence of a strict lower dominance region in creditors' rollover game. It implies that there exists values of the state variable θ such that creditors find it optimal to withdraw their funds, *irrespective* of the withdraw decision of other creditors or the information acquisition choice of firms.[26]

Equations (11) and (12) jointly characterize the two equilibrium thresholds, $\psi_\epsilon^*(\eta_\epsilon^*)$ and $\eta_\epsilon^*(\psi_\epsilon^*)$. The presence of strategic complementarities within and across groups implies that $\psi_\epsilon^*(\eta_\epsilon^*)$ strictly increases in η_ϵ^* and $\eta_\epsilon^*(\psi_\epsilon^*)$ weakly increases in ψ_ϵ^*. Thus, when creditors choose to roll over for a larger set of states (i.e. lower their threshold), this leads firms to acquire information for a smaller set of states, and *vice versa* if η_ϵ^* increases in ψ_ϵ^*. This can lead market and funding liquidity to be mutually reinforcing. Figure 3 plots the optimal threshold functions for both firms and creditors.

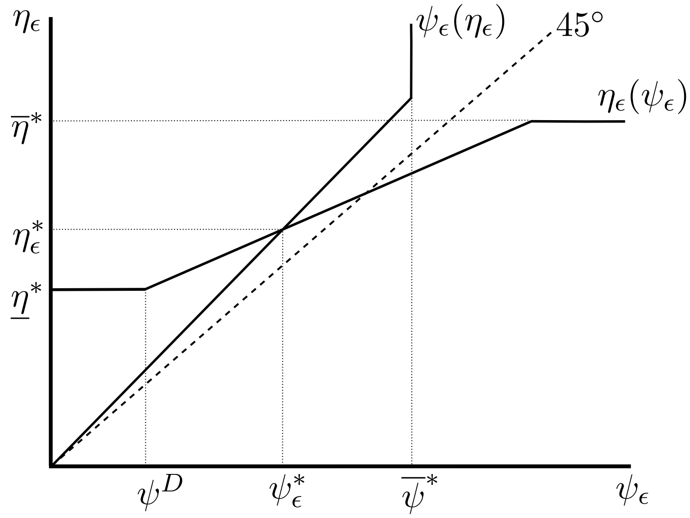
Proposition 3. *Under Assumption 3, there exists a unique equilibrium in monotone strategies and equilibrium thresholds are such that $\psi_\epsilon^* \leq \eta_\epsilon^*$. Moreover, there are no other equilibria in non-monotone strategies.*

3.3 Global Game Solution

To facilitate the characterization of the equilibrium, we focus on the *global game solution* where the idiosyncratic component becomes negligibly small, $\epsilon \to 0$. In this case, the equilibrium behavior of agents becomes degenerate around the realized state. In particular, all firms acquire information if and only if $\theta \leq \psi_\epsilon^*$ and abstain from information acquisition

[26]Our results do not require net outflows to be large. That is, we can have $\hat{\eta} \leq \eta(\theta)$ in almost all states. What is important is that there exist at least some values of θ such that creditors strictly prefer consumption in $t = 1$ relative to consumption in $t = 2$ even if $D_2 > D_1$.

Figure 3: Best response thresholds and threshold equilibrium for the case where $\underline{\eta}^* < \overline{\psi}^*$.



otherwise. Similarly, all creditors choose to withdraw their funds if and only if $\theta \leq \eta_\epsilon^*$ and otherwise always roll over their debt. The equilibrium outcome depends on the ordering of the extreme bounds. There are two cases to consider: $\overline{\psi}^* < \underline{\eta}^*$ and $\underline{\eta}^* < \overline{\psi}^*$. Following the terminology of Goldstein (2005), we refer to the former as a *weak dependence* regime and to the latter as a *strong dependence* regime.

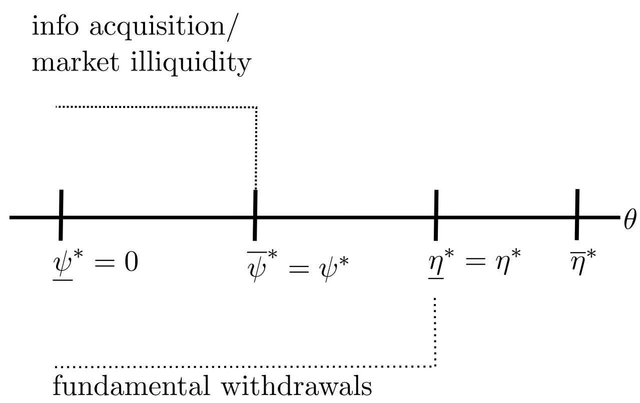
Proposition 4. *For vanishing noise, the equilibrium thresholds ψ_ϵ^* and η_ϵ^* are such that*

1. *Weak dependence: $\psi_\epsilon^* \to \overline{\psi}^*$ and $\eta_\epsilon^* \to \underline{\eta}^*$ as $\epsilon \to 0$ if and only if $\overline{\psi}^* < \underline{\eta}^*$.*

2. *Strong dependence: $\psi_\epsilon^* \to \eta_\epsilon^*$ and $\eta_\epsilon^* \to \eta^* \in [\underline{\eta}^*, \overline{\psi}^*]$ as $\epsilon \to 0$ if and only if $\overline{\psi}^* \geq \underline{\eta}^*$.*

In the *weak dependence* regime, creditors' equilibrium threshold is at its lower bound ($\underline{\eta}^*$). Withdrawal decisions in this case are purely driven by creditors' idiosyncratic balance sheet shocks and are unaffected by firms' information acquisition behavior. These "fundamental" withdrawals are nonetheless sufficient to incentivize firms to acquire information whenever $\theta < \overline{\psi}^*$. However, for values of $\theta \in (\overline{\psi}^*, \underline{\eta}^*)$, firms find it optimal to abstain from information acquisition despite creditors continuing to withdraw their short-term debt. Funding outflows in this case are covered by asset sales at the *ex ante*

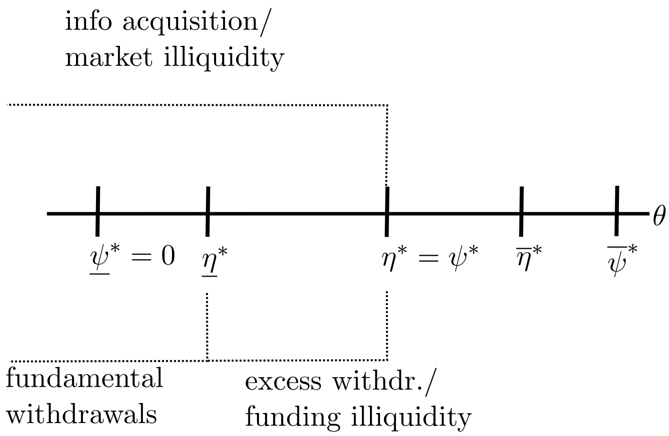
Figure 4: Case of weak dependence: $\overline{\psi}^* < \underline{\eta}^*$.



pooling price $\mathbf{E}_0[\tilde{R}]$, implying that no firm defaults since the cash flow generated by their residual assets (plus the credit guarantees) always suffice to pay off outstanding debt in $t = 2$. Hence, in the weak dependence case, the coordination failure in firms' information acquisition does not amplify funding withdrawals (see Figure 4).

Things are different in the *strong dependence* regime, where firms' and creditors' thresholds converge such that $\psi^* \to \eta^*$. In this case, funding and market illiquidity coincide and reinforce each other. Sudden withdrawals of short-term debt are always accompanied by market liquidity dry-ups due to adverse selection frictions caused by firms' information acquisition. Low market prices reduce the residual value of firms' assets, which leads low return firms to default on their outstanding debt in $t = 2$. In this case, market liquidity risk also increases creditors' incentives to withdraw as outstanding creditors in $t = 2$ are no longer guaranteed to receive the full face value of their claims even if $\theta > \underline{\eta}^*$. As a result, creditors prefer to withdraw their debt in more states than those justified by their idiosyncratic balance sheet shocks ($\eta^* \geq \underline{\eta}^*$). Thus, in the strong dependence case, the coordination failure among firms "spills over" and generates a coordination failure among creditors, thereby amplifying funding liquidity risk (see Figure 5).

Figure 5: Case of strong dependence (amplification): $\underline{\eta}^* < \overline{\psi}^*$.



3.4 Strong versus Weak Dependence

Whether the weak or the strong dependence regime obtains depends on the characteristics of the economy, such as firms' debt maturity structure, the cost of outside liquidity or the riskiness of firms' assets. Proposition 4 implies that the *strong dependence* regime obtains whenever

$$\overline{\psi}^* > \underline{\eta}^* \quad \Leftrightarrow \quad \int_0^1 S(\sigma, 1)\mathrm{d}\sigma > \hat{\eta} - (D_2 - D_1)$$

Given equation (7), this condition is easier to satisfy if the share of short-term debt α is high and the cost of liquidity lines β^{-1} is low. This suggests that an economy is more susceptible to be in the strong dependence regime when the fraction of short-term debt is relatively high, and when issuing banks can access outside liquidity at low costs.[27] Higher asset risk also increases the surplus from information acquisition and, consequently, the susceptibility to be in the strong dependence regime.[28]

[27] The result pertaining to firms' debt maturity structure suggests that financial fragility caused by excessive reliance on short-term financing - e.g. Stein (2012), Brunnermeier & Oehmke (2013) or König & Pothier (2016) - can be amplified by information-induced market illiquidity.

[28] We measure asset risk as a mean preserving spread of assets' random return $\tilde{R}$. Formally, this corresponds to a reduction in ρ while keeping $\mathbf{E}_0[\tilde{R}]$ unchanged.

3.5 Welfare

Efficient Thresholds. When defining the relevant welfare benchmark, we restrict attention to allocations that maximize aggregate utility from consumption subject to the exogenous debt contract (D_1, D_2).[29] The problem faced by the social planner consists of choosing thresholds $(\psi_{sp}, \eta_{sp}) \in \mathbb{R}^2_+$ that maximize the sum of firms' value and creditors' utility given some realized state θ.

Definition 1. *Given thresholds ψ_{sp} and η_{sp}, and associated values $\sigma(\theta, \psi_{sp})$ and $\lambda(\theta, \eta_{sp})$, aggregate utility from consumption given the debt contract (D_1, D_2) is*

$$\mathcal{W}(\sigma, \lambda; \theta) = \mathbf{E}_0[V(\Omega_j)] - \sigma\psi(\theta) + U(\lambda D_1, (1-\lambda)D_2; \eta(\theta))$$

Using firms' value functions (3) and (4), and creditors' utility function (1), we can rewrite the social welfare function as follows

$$\mathcal{W}(\sigma, \lambda; \theta) = \left(\mathbf{E}_0[\tilde{R}] - \sigma\pi\left(\frac{1}{\beta} - 1\right)\alpha\lambda D_1\right) - \sigma\psi(\theta) + \alpha\lambda(\underline{\eta}^* - \eta(\theta))$$

Even without taking into account the opportunity cost of information acquisition, social welfare when $\sigma > 0$ is always strictly less than when $\sigma = 0$. This is because information acquisition leads firms with good assets to pay back withdrawing early creditors using their liquidity lines rather than selling assets. Consequently, not all gains from trade are realized as these liquidity lines require firms to forego β^{-1} units of consumption per unit of liquidity. Information acquisition is thus unambiguously inefficient in this economy.

Proposition 5. *Given the debt contract (D_1, D_2), the Pareto efficient thresholds are such that $\psi_{sp} = 0$ and $\eta_{sp} = \underline{\eta}^*$.*

In the absence of market liquidity risk, it is optimal to allow short-term creditors to withdraw their funds when their valuation for $t = 1$ consumption exceeds the interest

[29] Relaxing this assumption would allow the social planner to increase welfare by redistributing resources across creditors and firms in some states. Since the focus of our paper is not to characterize the optimal contract between firms and creditors, we require the planner to use this exogenous debt contract even though it is generically inefficient.

foregone from withdrawing early. These early withdrawals do not reduce the expected value of firms when $\psi_{SP} = 0$ since the absence of information acquisition allows them to sell assets without incurring a liquidity discount.

Inefficiency of the Market Equilibrium. The nature of the inefficiencies afflicting the market allocation depends on whether a regime of *weak* or *strong dependence* obtains. In both regimes, the information acquisition threshold is inefficiently high. This inefficiency results from the collapse in market liquidity when firms acquire information. The externality distorting firms' incentives operates through changes in the market price. In particular, individual firms that acquire information and withhold good assets from the market do not internalize how their behavior affects other firms' option value from holding on to good assets. While firms' value would be unambiguously greater if they refrained from acquiring information, in equilibrium information acquisition is always privately optimal for sufficiently small realizations of θ.

Contrary to firms' information acquisition behavior, creditors' decisions need not be inefficient. In the *weak dependence* regime, they coordinate on the efficient threshold and only withdraw if their net outflows exceed the foregone interest implied by the debt contract. The inefficient information acquisition decisions of firms, and the associated market liquidity risk, do not distort creditors' incentives in this case. This is no longer true in the *strong dependence* regime, as both firms' and creditors' thresholds are inefficiently high. This arises because market liquidity risk induces a coordination failure among short-term creditors which leads to excessive withdrawals. This coordination failure operates through creditors' loss-given-default. More specifically, individual creditors that refuse to roll over their funds do not internalize how their withdrawal decision affects the residual value of firms' assets. This leads creditors to withdraw in more states than those justified by their idiosyncratic balance sheet shocks.

4 Policy Implications

4.1 Policy Measures: In Practice

Beginning in August 2007, the US Federal Reserve (Fed) adopted a number of policy measures to shore up wholesale funding markets including the ABCP market. At first, "conventional" liquidity injections were implemented *via* a lowering of central bank discount rates and short-term repurchase transactions.[30] These liquidity injections, however, failed to stop the precipitous fall in outstanding ABCP. They also did not prevent the run on money market funds that followed the bankruptcy of Lehman Brothers.

In response to the run, the US Treasury announced that it would temporarily guarantee all assets held by money market funds. While this succeeded in stopping the run, it failed to prop up the further collapsing ABCP market. This led the Fed to provide large amounts of non-recourse loans to commercial banks in order for them to purchase ABCP from money market funds. A few weeks later, the Fed also began purchasing commercial paper directly from issuers.[31] These policy measures specifically targeting the ABCP market were also accompanied by outright purchases of asset-backed securities.[32]

Our model allows to evaluate the efficacy of different policy measures aimed at minimizing the risk of market and funding liquidity dry-ups. Largely inspired by the measures adopted by the Federal Reserve summarized above, we focus attention on four specific types of policies: (i) public guarantees that protect creditors from default risk, (ii) asset purchase programs that place a floor on the price at which assets trade, (iii) liquidity injections that reduce the cost of private liquidity lines, and (iv) outright purchases of debt securities. Below, we compare the effects of each of these measures in turn.

[30] In the euro area, the ECB injected EUR 95 billion into overnight lending markets on August 9, 2007. Over the following few days, the Fed followed suit and injected $62 billion. On September 18, 2007 the Fed supplemented these measures by launching the Term Auction Facility (TAF) which conducted longer-term repurchase transactions totaling $100 billion (Kacperczyk & Schnabl, 2010).

[31] The non-recourse loans were administered by the Boston Fed's liquidity facility (AMLF) and purchased roughly $150 billion worth of commercial paper in its first two week of activity. Outright debt purchases were carried out by the Commercial Paper Funding Facility (CPFF) which purchased over $300 billion worth of commercial paper. Through these two facilities, the Fed ended up holding about 25% of outstanding commercial paper by the end of 2008 (Kacperczyk & Schnabl, 2010).

[32] The Fed extended non-recourse loans to buyers of both newly issued ABSs and legacy mortgage-backed securities through its Term Asset-Backed Securities Loan facility (TALF) (Ashcraft et al., 2012).

4.2 Policy Measures: In Theory

Creditor Guarantees versus Asset Purchases. We begin by assessing the relative efficacy of creditor guarantees and asset purchase programs in minimizing firms' default risk. While default in our model is not inefficient *per se*, one may imagine it to be associated with potentially very large dead-weight social costs. Given these (unmodeled) costs, a government may be willing to expend resources in order to protect creditors from default risk.

Consider first the effect of public guarantees that cover any loss incurred by creditors in case firms are unable to repay the full face value of debt in $t = 2$. In the context of the model, this can be thought of as a commitment to make a transfer to creditors in case of default, thereby setting creditors' loss-given-default $X = 0$. Such a policy clearly breaks the strategic complementarities in creditors' withdrawal decisions, since their payoff no longer depends on the fraction of early withdrawals. While this policy also reduces the likelihood of market liquidity dry-ups in the *strong dependence* regime, it has no effect on market liquidity risk in the *weak dependence* regime. Since these public guarantees do not eliminate the risk of market liquidity dry-ups, the government may have to expend resources under this scheme. In particular, by failing to eliminate firms' incentives to acquire information, the government is forced to transfer resources to creditors whenever $\theta < \min\{\overline{\psi}^*, \underline{\eta}^*\}$.

Corollary 1. *Guarantees that protect creditors from default risk eliminate the risk of excessive withdrawals (i.e. $\eta^*_\epsilon = \underline{\eta}^*$). The expected cost of creditor guarantees is equal to:*

$$C^{\mathcal{CG}} = \int_{\underline{\theta}}^{\min\{\overline{\psi}^*, \underline{\eta}^*\}} \alpha(1-\pi)(D_1 - R_l)\mathrm{d}\theta$$

Next, consider the effect of a government commitment to purchase assets at a reservation price $q > R_l$. By placing a floor on asset prices, this policy reduces firms' incentives to acquire information by lowering the option value from withholding good assets from the market. Moreover, it also reduces creditors' incentives to withdraw early by lowering their loss-given-default. If the government sets $q > D_1$, it prevents firms from defaulting and eliminates the coordination failure among creditors (i.e. $\eta^*_\epsilon = \underline{\eta}^*$). Similarly to the creditor guarantees, asset purchases require the government to make a loss in some states. Even though the floor on asset prices reduces firms incentives to acquire information, it does not fully eliminate market liquidity risk since firms find it strictly dominant to acquire information for sufficiently small values of θ.[33] Thus, any price guarantee $q > R_l$ requires the government to buy bad assets at a price above their fundamental value in some states.

Corollary 2. *Asset price guarantees that bound prices above D_1 eliminate the risk of excessive withdrawals (i.e. $\eta^*_\epsilon = \underline{\eta}^*$). The expected cost from purchasing assets at price $q = D_1$ is equal to:*

$$C^{\mathcal{AP}} = \int_{\underline{\theta}}^{\min\{\overline{\psi}^*_q, \underline{\eta}^*\}} \alpha(1-\pi)(D_1 - R_l)\mathrm{d}\theta \;\leq\; C^{\mathcal{CG}}$$

Corollaries 1 and 2 imply that asset purchases are more cost-effective than creditor guarantees in eliminating creditors' loss-given-default. This is because asset purchases directly lower firms' surplus from acquiring information by reducing the cost from using the secondary market to obtain liquidity. As a result, asset price guarantees succeed in lowering market liquidity risk in both *weak* and *strong dependence* regimes.

Liquidity Injections versus Outright Debt Purchases. We now assess the relative efficacy of liquidity injections and outright purchases of debt securities in boosting *both* market and funding liquidity, and not just protecting creditors from default (as above).

We first consider the effect of liquidity injections, e.g. lowering interest rates, that reduce the cost of firms' liquidity lines (β^{-1}). Maintaining the bounds on β implied by Assumption 2, such a policy unambiguously *increases* the likelihood of market liquidity dry-ups. The reason for this seemingly paradoxical result is that, by lowering the cost of

[33] Formally, given some reservation price $q \in [D_1, \mathbf{E}_0[\tilde{R}]]$, firms acquire information for all θ such that

$$\psi(\theta) < \psi^*_q \equiv \min\left\{\int_0^1 \alpha D_1 \pi R_h \left(\frac{1}{\max\{q, p(\sigma)\}} - \frac{1}{\beta R_h}\right)\mathrm{d}\sigma, \underline{\eta}^*\right\}$$

liquidity lines, liquidity injections increase the value of holding on to good assets rather than selling them. This amplifies the adverse selection problem in the secondary market and exacerbates the coordination failure among firms. Moreover, if the economy finds itself in the *strong dependence* regime, such liquidity injections further amplify the coordination failure among creditors and thus also increase funding liquidity risk.

Corollary 3. *Liquidity injections that lower the cost of liquidity lines (strictly) increase market liquidity risk and (weakly) increase funding liquidity risk:* $\frac{d\psi_\epsilon^*}{d\beta} > 0$ *and* $\frac{d\eta_\epsilon^*}{d\beta} \geq 0$*.*

Finally, we consider the effect of outright purchases of debt securities, such as those conducted by the Federal Reserve using the AMLF and CPFF. In the context of the model, this can be thought of as lowering the fraction of short-term debt. By committing to purchase short-term debt securities in case creditors are unwilling to roll-over, the government effectively protects firms from funding liquidity risk. In so doing, it lowers firms' incentives to acquire information. By raising market liquidity, debt purchases also reduce creditors' incentives to withdraw early.

Corollary 4. *Debt purchases that lower the fraction of short-term debt (strictly) decrease market liquidity risk and (weakly) decrease funding liquidity risk:* $\frac{d\psi_\epsilon^*}{d\alpha} > 0$ *and* $\frac{d\eta_\epsilon^*}{d\alpha} \geq 0$*. Completely eliminating funding liquidity risk (*$\alpha = 0$*) implements the efficient allocation.*

If its purchases are unbounded (so that setting $\alpha = 0$ is feasible), the government can completely eliminate market liquidity risk and ensure that no firm acquires information in equilibrium. Such debt purchases can therefore be used to implement the efficient allocation described above. Moreover, if claims held by the government benefit from the same credit guarantees as those held by private agents, such a policy never requires the government to incur a loss. While the government has to step in and absorb all outstanding short-term debt on its balance sheet in $t = 1$ if $\theta < \underline{\eta}^*$, it is always paid back in full in $t = 2$ when assets mature.

5 Conclusion

This paper presents a model of liquidity dry-ups based on a novel feedback mechanism between market and funding liquidity. Financial firms hold assets of initially unknown quality, financed by short- and long-term wholesale debt. Early withdrawals increase firms' incentives to acquire information about their assets. When learning that their assets are good, firms prefer to cover withdrawals by using outside liquidity lines and withhold their assets from the market. A classic adverse selection problem emerges leading assets to trade at a "lemons discount". Moreover, if prices fall by enough, creditors that roll-over their short-term debt may no longer receive the full face value of their claims. This can spark further withdrawals and produces an amplification between funding and market liquidity dry-ups. Two distinct regimes emerge which differ in terms of the feedback between market and funding liquidity.

We also study different policy interventions that can mitigate the risk of inefficient liquidity dry-ups. First, we find that asset purchases are a more cost-effective measure than public debt guarantees if the policy maker seeks to minimize creditors' loss in case of default. Second, outright debt purchases can implement the efficient allocation and boost both market and funding liquidity. Third, liquidity injections that lower the cost of outside liquidity lines can backfire as they exacerbate the adverse selection problem causing market liquidity to dry-up.

While the firms in our model resemble shadow banking arrangements that were prevalent prior to the 2007-08 financial crisis, the model is not necessarily confined to such financial structures. One may interpret our firms more broadly as financial institutions funded by collateralized debt. In this case, the credit enhancements may represent additional non-marketable assets on firms' balance sheets that can be transferred to creditors in case of default. Similarly, the outside liquidity lines may be interpreted as the interbank market or the central bank's discount window. From this perspective, our model highlights the fragility of financial institutions that hold complex and opaque securities financed by short-term debt and rely on market-based liquidity to cover funding shortfalls.

Appendix

A1 Proofs

Proof of Lemma 1. Notice that

$$V^{LL}(\Omega_j;\beta) \gtrless \mathbf{E}[\tilde{R}|\Omega_j]\left(1-\frac{\alpha\lambda D_1}{p}\right)-(1-\alpha\lambda)D_2 \quad \Leftrightarrow \quad \beta\mathbf{E}[\tilde{R}|\Omega_j] \gtrless p$$

From Assumption 2, it follows that for all $p \in [R_l, \mathbf{E}_0[\tilde{R}]]$, good firms prefer the liquidity line while bad firms and uninformed firms prefer asset sales for $p \geq D_1$. For $p < D_1$, the expected repayment in $t = 2$ for good firms is unchanged since $\mathbf{E}[\tilde{\ell}|h] = D_2$, and they still prefer to use the liquidity line for $p < D_1$. Since $\mathbf{E}[\tilde{\ell}|\Omega_j] < D_2$ for all $\Omega_j \in \{n, b\}$, bad firms and uninformed firms also prefer asset sales for $p < D_1$. □

Proof of Proposition 3. We first show that there exists a unique montone equilibrium where thresholds are such that $\psi^*_\epsilon \leq \eta^*_\epsilon$. Second, we show that there are no equilibria in non-monotone strategies.

1. Unique Monotone Equilibrium

Suppose that agents use monotone strategies around ψ^*_ϵ and η^*_ϵ. Let

$$\lambda^D(\psi^*_\epsilon) \in \begin{cases} 1 & \text{if } \psi^*_\epsilon \leq \eta^*_\epsilon - 2\epsilon(1-\sigma^D) \\ [0,1) & \text{if } \psi^*_\epsilon > \eta^*_\epsilon - 2\epsilon(1-\sigma^D) \end{cases}$$

From condition (12) follows that

$$\eta^*_\epsilon(\psi^*_\epsilon) = \begin{cases} \underline{\eta}^* & \text{if } \psi^*_\epsilon \leq \underline{\psi}^D_\epsilon \\ \underline{\eta}^* + \int_{\max\{0,\lambda_D(\psi^*_\epsilon)\}}^1 X\left(\lambda, F\left(\lambda + \frac{\psi^*_\epsilon - \eta^*_\epsilon(\psi^*_\epsilon)}{2\epsilon}\right)\right) d\lambda & \text{if } \psi^*_\epsilon > \underline{\psi}^D_\epsilon \end{cases} \tag{A1}$$

where $\underline{\psi}^D_\epsilon \equiv \underline{\eta}^* - 2\epsilon(1-\sigma^D)$. For a given ψ^*_ϵ, the optimal withdraw threshold is therefore $\eta^*_\epsilon = \underline{\eta}^*$ if $\psi^*_\epsilon \leq \underline{\psi}^D_\epsilon$. For values of $\psi^*_\epsilon > \underline{\psi}^D_\epsilon$, the optimal withdraw threshold is strictly increasing in ψ^*_ϵ with slope

$$\frac{d\eta^*_\epsilon}{d\psi^*_\epsilon} = \frac{\int_{\max\{0,\lambda_D\}}^1 X_\sigma(\cdot)\, d\lambda}{2\epsilon + \int_{\max\{0,\lambda_D\}}^1 X_\sigma(\cdot)\, d\lambda} < 1, \quad \forall\, \sigma \in (0,1) \quad \text{and} \quad \psi^*_\epsilon > \underline{\psi}^D_\epsilon$$

where the condition follows from application of the implicit function theorem, Lemma 6 which implies that $X_\sigma(\cdot) > 0$ and the fact that $X(\lambda^D, \sigma^D) = 0$. Since the slope of the threshold function is less than unity, we must have $\eta^*_\epsilon(\psi^*_\epsilon) < \psi^*_\epsilon + 2\epsilon(1-\sigma^D)$ for all $\psi^D_\epsilon > \underline{\psi}^D_\epsilon$, so that condition (A1) uniquely determines creditors' optimal threshold as a function of ψ^*_ϵ.

Turning now to the optimal information acquisition threshold, condition (11) implies

$$\psi_\epsilon^* = G(\psi_\epsilon^*) \equiv \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta_\epsilon^*(\psi_\epsilon^*) - \psi_\epsilon^*}{2\epsilon}\right)\right) d\sigma$$

Notice that

$$G(\underline{\psi}^*) = \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta_\epsilon^*(\underline{\psi}^*) - \underline{\psi}^*}{2\epsilon}\right)\right) d\sigma > \underline{\psi}^*$$

since $\underline{\eta}^* > 0$ and $\underline{\psi}^* = 0$. Furthermore, by Corollary 4,

$$G(\overline{\psi}^*) = \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta_\epsilon^*(\overline{\psi}^*) - \overline{\psi}^*}{2\epsilon}\right)\right) d\sigma \leq \int_0^1 S\left(\sigma, 1\right) d\sigma \equiv \overline{\psi}^*$$

since $F(\cdot) \in [0,1]$. Hence, by application of the intermediate value theorem, the function $G(\psi_\epsilon^*)$ must intersect ψ_ϵ^* at least once for values of $\psi_\epsilon^* \in (\underline{\psi}^*, \overline{\psi}^*]$. Since $\frac{d\eta_\epsilon^*}{d\psi_\epsilon^*} < 1$, we have that

$$G'(\psi_\epsilon^*) = \frac{1}{2\epsilon}\int_0^1 S_\lambda(\cdot)\left(\frac{d\eta_\epsilon^*}{d\psi_\epsilon^*} - 1\right) d\sigma < 0, \quad \forall \lambda \in (0,1)$$

implying that there exists a unique value of $\psi_\epsilon^* \in (0, \overline{\psi}^*]$ that solves $\psi_\epsilon^* = G(\psi_\epsilon^*)$.

Finally, we show that $\psi_\epsilon^* < \eta_\epsilon^*$. By application of the implicit function theorem we have that

$$\frac{d\psi_\epsilon^*}{d\eta_\epsilon^*} = \frac{\int_0^1 S_\lambda(\cdot) d\sigma}{2\epsilon + \int_0^1 S_\lambda(\cdot) d\sigma} < 1, \quad \forall \lambda \in (0,1)$$

where the condition follows from Lemma 4 since $S_\lambda(\cdot) > 0$. Since $\underline{\psi}^* = 0$, the unique fixed point must be such that $\psi^* < \eta^*$.

2. No Equilibria in Non-Monotone Strategies

Next, we establish that no equilibria in non-monotone strategies exist by using an argument similar to Goldstein (2005). Towards a contradiction, suppose that an alternative non-monotone equilibrium exists where firms acquire information for some $\psi_j > \psi_\epsilon^*$ and where creditors withdraw for some $\eta_i > \eta_\epsilon^*$. Due to the existence of dominance regions, there exists a value ψ_N such that firms never acquire information for $\psi_j > \psi_N$. Similarly, there exists a value η_N such that creditors always roll over for $\eta_j > \eta_N$. Let σ_N denote the fraction of firms who acquire information in this non-monotone equilibrium and denote by λ_N the fraction of creditors who withdraw their funds. These fractions satisfy

$$\sigma_N(\theta) \leq F\left(\frac{\psi_N - \theta}{2\epsilon}\right) \quad \text{and} \quad \lambda_N(\theta) \leq F\left(\frac{\eta_N - \theta}{2\epsilon}\right)$$

A firm whose type is just $\psi_j = \psi_N$ must be indifferent between acquiring and not acquiring information. That is,

$$\psi_N - \frac{1}{2\epsilon}\int_{\psi_N - \epsilon}^{\psi_N + \epsilon} S(\sigma_N(\theta), \lambda_N(\theta)) d\theta \,=\, 0$$

Since the surplus from information acquisition is increasing in σ_N and λ_N, it follows that

$$\psi_N - \frac{1}{2\epsilon}\int_{\psi_N-\epsilon}^{\psi_N+\epsilon} S\left(F\left(\frac{\psi_N-\theta}{2\epsilon}\right), F\left(\frac{\eta_N-\theta}{2\epsilon}\right)\right) d\theta \leq 0$$

Changing variables of integration yields,

$$\psi_N - \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta_N - \psi_N}{2\epsilon}\right)\right) d\sigma \leq 0$$

Comparing this with equation (11) in the text implies the following inequality

$$\psi_N - \psi_\epsilon^* \leq \int_0^1 \left[S\left(\sigma, F\left(\sigma + \frac{\eta_N - \psi_N}{2\epsilon}\right)\right) - S\left(\sigma, F\left(\sigma + \frac{\eta_\epsilon^* - \psi_\epsilon^*}{2\epsilon}\right)\right)\right] d\sigma$$

Since $\psi_N - \psi_\epsilon^* > 0$, the latter only holds if

$$\eta_N - \psi_N \ > \ \eta_\epsilon^* - \psi_\epsilon^* \tag{A2}$$

Repeating this line of reasoning for the expected surplus from withdrawing versus rolling over implies

$$\eta_N - \eta_\epsilon^* \leq \int_{\lambda_N^D(\psi_N,\eta_N)}^1 \left[X\left(\lambda, F\left(\lambda + \frac{\psi_N - \eta_N}{2\epsilon}\right)\right) - X\left(\lambda, F\left(\lambda + \frac{\psi_\epsilon^* - \eta_\epsilon^*}{2\epsilon}\right)\right)\right] d\sigma$$

where $\lambda_N^D(\psi_N, \eta_N) \equiv F\left(\sigma_D + \frac{\eta_N - \psi_N}{2\epsilon}\right)$. Since $\eta_N > \eta_\epsilon^*$ and $X_\sigma > 0$, this inequality only holds if

$$\psi_N - \eta_N \ > \ \psi_\epsilon^* - \eta_\epsilon^* \tag{A3}$$

As inequality (A3) contradicts inequality (A2), a non-monotone equilibrium cannot exist. □

Proof of Proposition 4. The structure of the proof follows that of Proposition 2 in Goldstein (2005). We first show that $\psi_\epsilon^* \to \overline{\psi}^*$ and $\eta_\epsilon^* \to \underline{\eta}^*$ if and only if $\overline{\psi}^* < \underline{\eta}^*$. We prove that this condition is sufficient by construction. From condition (11), if $\psi_\epsilon^* < \eta_\epsilon^*$ as $\epsilon \to 0$, we have

$$\lim_{\epsilon\to 0} \psi_\epsilon^*(\eta_\epsilon^*) = \overline{\psi}^*$$

Similarly, from condition (12), we have

$$\lim_{\epsilon\to 0} \eta_\epsilon^*(\psi_\epsilon^*) = \underline{\eta}^*$$

where the limit follows from the fact that $\lim_{\epsilon\to 0}\lambda^D(\psi_\epsilon^*) = 1$ if $\psi_\epsilon^* < \eta_\epsilon^*$ as $\epsilon \to 0$. To prove necessity, notice that we cannot have $\psi_\epsilon^* < \eta_\epsilon^*$ if $\overline{\psi}^* \geq \underline{\eta}^*$.

We next show that $\psi_\epsilon^* \to \eta_\epsilon^*$ if and only if $\overline{\psi}^* \geq \underline{\eta}^*$. We proceed to prove that the claim is sufficient by contradiction. From above, we know that $\psi_\epsilon^* \not< \eta_\epsilon^*$ if $\overline{\psi}^* \geq \underline{\eta}^*$. Next, assume that $\psi_\epsilon^* > \eta_\epsilon^*$ as $\epsilon \to 0$.

From condition (11) follows

$$\lim_{\epsilon\to 0} \psi^*_\epsilon(\eta^*_\epsilon) = \underline{\psi}^* = 0$$

Similarly, from condition (12) follows

$$\lim_{\epsilon\to 0} \eta^*_\epsilon(\psi^*_\epsilon) = \overline{\eta}^* > 0$$

where the limit follows from the fact that $\lim_{\epsilon\to 0} \lambda^D(\psi^*_\epsilon) = 0$ if $\psi^*_\epsilon > \eta^*_\epsilon$ as $\epsilon \to 0$. But then we must have $\psi^*_\epsilon < \eta^*_\epsilon$, a contradiction. Hence, if $\overline{\psi}^* \geq \underline{\eta}^*$, it must be that $\psi^*_\epsilon \to \eta^*_\epsilon$ as $\epsilon \to 0$.

Finally, we show that $\eta^*_\epsilon \to \eta^* \in [\underline{\eta}^*, \overline{\psi}^*]$ as $\epsilon \to 0$ when $\psi^*_\epsilon \to \eta^*_\epsilon$. From condition (12), we have

$$\lim_{\epsilon\to 0} \eta^*_\epsilon(\psi^*_\epsilon) = \underline{\eta}^* + \lim_{\epsilon\to 0}\left(\int_{\max\{0,\lambda^D(\psi^*_\epsilon)\}}^{\max\{1,\lambda^D(\psi^*_\epsilon)\}} X\left(\lambda, F\left(\lambda + \frac{\psi^*_\epsilon - \eta^*_\epsilon(\psi^*_\epsilon)}{2\epsilon}\right)\right) d\lambda\right) \geq \underline{\eta}^*$$

where the inequality follows from $\lim_{\epsilon\to 0} \lambda^D(\psi^*_\epsilon) \in [0,1]$ as $\epsilon \to 0$. Similarly, using condition (11)

$$\lim_{\epsilon\to 0} \psi^*_\epsilon(\eta^*_\epsilon) = \lim_{\epsilon\to 0}\int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta^*_\epsilon - \psi^*_\epsilon(\eta^*_\epsilon)}{2\epsilon}\right)\right) d\sigma \leq \int_0^1 (S(\sigma,1) = \overline{\psi}^*$$

where the inequality follows from $\lim_{\epsilon\to 0} F\left(\sigma + \frac{\eta^*_\epsilon - \psi^*_\epsilon(\eta^*_\epsilon)}{2\epsilon}\right) \in [0,1]$ as $\epsilon \to 0$ and Lemma 4. Since $\psi^*_\epsilon \to \eta^*_\epsilon$ as $\epsilon \to 0$, it follows that $\eta^*_\epsilon \to \eta^* \in [\underline{\eta}^*, \overline{\psi}^*]$. Clearly, this interval is empty if $\overline{\psi}^* < \underline{\eta}^*$. This proves that the condition is also necessary.

□

Proof of Proposition 5. Given some value $\sigma \in [0,1]$, the expected value of firms (net of the information acquisition costs) is given by

$$\mathbf{E}_0[V(\Omega_j)] = \sigma(\pi V^{LL}(h;\beta) + (1-\pi)V^{AS}(b;p)) + (1-\sigma)V^{AS}(n;p)$$

Similarly, given some value $\lambda \in [0,1]$, creditors' aggregate utility is given by

$$U(\lambda D_1, (1-\lambda)D_2;\theta) = \alpha\lambda\left(D_1\left(1 + \frac{\hat{\eta} - \eta(\theta)}{D_1}\right) - (D_2 - D_1)\right) + (1-\alpha\lambda)D_2$$

Summing these two equations and simplifying yields

$$\mathcal{W} + \sigma\psi(\theta) = \mathbf{E}_0[R] - \sigma\pi\frac{\alpha\lambda D_1}{\beta} - \frac{\alpha\lambda D_1}{p(\sigma)}((1-\sigma)\pi R_h + (1-\pi)R_l) + \alpha\lambda(D_1 + \hat{\eta} - \eta(\theta) - (D_2 - D_1))$$

Substituting for $p(\sigma)$ and rearranging yields

$$\mathcal{W}(\sigma,\lambda;\theta) = \left(\mathbf{E}_0[\tilde{R}] - \sigma\pi\left(\frac{1}{\beta} - 1\right)\alpha\lambda D_1\right) - \sigma\psi(\theta) + \alpha\lambda\left(\underline{\eta}^* - \eta(\theta)\right)$$

Obviously, $\mathcal{W}_\sigma(\sigma,\lambda;\theta) < 0$ for all $\lambda \in [0,1]$. Given the definition of $\sigma(\theta)$, it follows that $\psi_{sp} = \underline{\psi}^* = 0$ and

$\sigma(\theta) = 0$ for all θ. Differentiating the welfare function with respect to λ, we obtain

$$\mathcal{W}_\lambda(\sigma, \lambda; \theta) = \alpha \left(\underline{\eta}^* - \eta(\theta) - \sigma\pi \left(\frac{1}{\beta} - 1 \right) D_1 \right)$$

Evaluating this function at $\sigma = 0$ implies

$$\mathcal{W}_\lambda(\sigma, \lambda; \theta) \Big|_{\sigma=0} \gtrless 0 \quad \Leftrightarrow \quad \underline{\eta}^* \gtrless \eta(\theta)$$

Given the definition of $\lambda(\theta)$, it follows immediately that we must have $\eta_{sp} = \underline{\eta}^*$. □

Proof of Corollaries 1-4. The equilibrium thresholds solve the following system of equations

$$A(\psi_\epsilon^*, \eta_\epsilon^*) \equiv \psi_\epsilon^* - \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\eta_\epsilon^* - \psi_\epsilon^*}{2\epsilon}\right)\right) \mathrm{d}\sigma = 0 \tag{A4}$$

$$B(\psi_\epsilon^*, \eta_\epsilon^*) \equiv \eta_\epsilon^* - \underline{\eta}^* - \int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}} X\left(\lambda, F\left(\lambda + \frac{\psi_\epsilon^* - \eta_\epsilon^*}{2\epsilon}\right)\right) \mathrm{d}\lambda = 0 \tag{A5}$$

1. Creditor Guarantees. If the government guarantees to cover creditors' loss given default (X), the condition determining creditors' equilibrium threshold (A5) becomes

$$B^{\mathcal{CG}}(\psi_\epsilon^*, \eta_\epsilon^*) \equiv \eta_\epsilon^* - \underline{\eta}^* = 0 \Rightarrow \eta_\epsilon^* = \underline{\eta}^* \tag{A6}$$

Consequently, the condition determining firms' equilibrium threshold (A4) simplifies to

$$A^{\mathcal{CG}}(\psi_\epsilon^*, \underline{\eta}^*) \equiv \psi_\epsilon^* - \int_0^1 S\left(\sigma, F\left(\sigma + \frac{\underline{\eta}^* - \psi_\epsilon^*}{2\epsilon}\right)\right) \mathrm{d}\sigma = 0$$

Taking the limit as $\epsilon \to 0$, we obtain

$$\lim_{\epsilon \to 0} \psi_\epsilon^* = \begin{cases} \overline{\psi}^* & \text{if } \overline{\psi}^* < \underline{\eta}^* \\ \underline{\eta}^* & \text{if } \overline{\psi}^* \geq \underline{\eta}^* \end{cases}$$

It follows that creditor guarantees eliminate the risk of excessive withdrawals, reduce market liquidity risk in the *strong dependence* regime, but have no effect on market liquidity risk in the *weak dependence* regime. Since this policy does not eliminate market liquidity risk, firms still default in equilibrium for values of $\theta < \min\{\overline{\psi}^*, \underline{\eta}^*\}$. The expected cost of such creditor guarantees is therefore equal to

$$C^{\mathcal{CG}} = \int_{\underline{\theta}}^{\overline{\theta}} (1 - \alpha\lambda(\theta, \underline{\eta}^*)) X(\lambda(\theta, \underline{\eta}^*), \sigma(\theta, \min\{\overline{\psi}^*, \underline{\eta}^*\})) d\theta > 0$$

which simplifies to

$$C^{\mathcal{CG}} = \int_{\underline{\theta}}^{\min\{\overline{\psi}^*, \underline{\eta}^*\}} \alpha(1-\pi)(D_1 - R_l)d\theta$$

2. Asset Purchase Programs. Given an asset price guarantee $q \geq D_1$, we must have $\lambda^D(\psi_\epsilon^*) = 1$ for all ψ_ϵ^* since $\max\{q, p(\sigma)\} \geq D_1$. It follows that the condition determining creditors' equilibrium threshold is the same as under the creditor guarantee discussed above and given condition by (A6). Using the definition of firms' surplus function, $S(\sigma;\lambda)$, firms' equilibrium threshold in this case solves

$$A^{\mathcal{AP}}(\psi_\epsilon^*, \underline{\eta}^*) = \psi_\epsilon^* - \int_0^1 \alpha\lambda(\underline{\eta}^*, \psi_\epsilon^*)D_1\pi R_h \left(\frac{1}{\max\{q, p(\sigma)\}} - \frac{1}{\beta R_h}\right) d\sigma = 0$$

Taking the limit as $\epsilon \to 0$, we obtain

$$\lim_{\epsilon\to 0} \psi_\epsilon^* = \begin{cases} \overline{\psi}_q^* & \text{if } \hat{\psi}_q^* < \underline{\eta}^* \\ \underline{\eta}^* & \text{if } \overline{\psi}_q^* \geq \underline{\eta}^* \end{cases}, \quad \text{with} \quad \overline{\psi}_q^* = \int_0^1 \alpha D_1 \pi R_h \left(\frac{1}{\max\{q, p(\sigma)\}} - \frac{1}{\beta R_h}\right) d\sigma$$

where $\overline{\psi}_q^* < \overline{\psi}^*$ since $q > R_l$. It follows that asset price guarantees strictly decrease market liquidity risk in both *weak* and *strong dependence* regimes. However, firms still acquire information for values of $\theta < \min\{\overline{\psi}_q^*, \underline{\eta}^*\}$, implying that the government will be forced to purchase bad assets at an inflated price in those states. Given some price floor $q \in [D_1, \mathbf{E}_0[\tilde{R}]]$, the expected cost of asset price guarantees equals

$$C^{\mathcal{AP}} = \int_{\underline{\theta}}^{\overline{\theta}} \alpha\lambda(\theta, \underline{\eta}^*)D_1(1 - \pi\sigma(\theta, \min\{\overline{\psi}_q^*, \underline{\eta}^*\})) \max\left\{1 - \frac{p(\sigma(\theta, \min\{\overline{\psi}_q^*, \underline{\eta}^*\}))}{q}, 0\right\} d\theta > 0$$

which simplifies to

$$C^{\mathcal{AP}} = \int_{\underline{\theta}}^{\min\{\overline{\psi}_q^*, \underline{\eta}^*\}} \frac{\alpha D_1(1-\pi)}{q}(q - R_l)d\theta$$

3. Liquidity Injections. The Jacobian of the system of equations (A4)-(A5) is given by

$$\mathbf{J} = \begin{bmatrix} A_{\psi_\epsilon^*}(\psi_\epsilon^*, \eta_\epsilon^*) & A_{\eta_\epsilon^*}(\psi_\epsilon^*, \eta_\epsilon^*) \\ B_{\psi_\epsilon^*}(\psi_\epsilon^*, \eta_\epsilon^*) & B_{\eta_\epsilon^*}(\psi_\epsilon^*, \eta_\epsilon^*) \end{bmatrix} = \begin{bmatrix} 1 + \frac{1}{2\epsilon}\int_0^1 S_\lambda(\sigma, \cdot)d\sigma & -\frac{1}{2\epsilon}\int_0^1 S_\lambda(\sigma, \cdot)d\sigma \\ -\frac{1}{2\epsilon}\int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}} X_\sigma(\lambda, \cdot)d\lambda & 1 + \frac{1}{2\epsilon}\int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}} X_\sigma(\lambda, \cdot)d\lambda \end{bmatrix}$$

and its determinant is equal to

$$|\mathbf{J}| = 1 + \frac{1}{2\epsilon}\left(\int_0^1 S_\lambda(\sigma, \cdot)d\sigma + \int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}} X_\sigma(\lambda, \cdot)d\lambda\right) > 0$$

where the inequality follows from Lemmas 4 and 6. Application of the implicit function theorem implies that the derivative of the system of equations (A4)-(A5) with respect to β satisfies

$$\mathbf{J}\begin{bmatrix}\frac{d\psi_\epsilon^*}{d\beta}\\ \frac{d\eta_\epsilon^*}{d\beta}\end{bmatrix}=\begin{bmatrix}-\frac{\partial A}{\partial\beta}\\ -\frac{\partial B}{\partial\beta}\end{bmatrix}$$

where $\frac{\partial A}{\partial\beta}=-\int_0^1 S_\beta(\sigma,\cdot)d\sigma<0$ by the definition of $S(\sigma,\lambda)$ and $\frac{\partial B}{\partial\beta}=0$ by the definition of $X(\lambda,\sigma)$. By Cramer's rule, we therefore have that

$$\frac{d\psi_\epsilon^*}{d\beta}=\frac{1}{|\mathbf{J}|}\begin{vmatrix}\int_0^1 S_\beta(\sigma,\cdot)d\sigma & -\frac{1}{2\epsilon}\int_0^1 S_\lambda(\sigma,\cdot)d\sigma\\ 0 & 1+\frac{1}{2\epsilon}\int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}}X_\sigma(\lambda,\cdot)d\lambda\end{vmatrix}>0$$

Similarly, we have that

$$\frac{d\eta_\epsilon^*}{d\beta}=\frac{1}{|\mathbf{J}|}\begin{vmatrix}1+\frac{1}{2\epsilon}\int_0^1 S_\lambda(\sigma,\cdot)d\sigma & \int_0^1 S_\beta(\sigma,\cdot)d\sigma\\ -\frac{1}{2\epsilon}\int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}}X_\sigma(\lambda,\cdot)d\lambda & 0\end{vmatrix}\geq 0$$

where the sign of the inequality depends on whether $\lambda_D\leq 1$.

4. Outright Debt Purchases. We consider outright debt purchases that reduce the fraction of short-term debt, α. Differentiating the system of equations (A4)-(A5) with respect to α, we obtain

$$\frac{\partial A}{\partial\alpha}=-\int_0^1 S_\alpha(\sigma,\cdot)d\sigma<0\quad\text{and}\quad\frac{\partial B}{\partial\alpha}=-\int_{\max\{0,\lambda^D\}}^{\max\{1,\lambda^D\}}X_\alpha(\lambda;\cdot)d\lambda\leq 0$$

where the second inequality depends on whether $\lambda_D\leq 1$. By the implicit function theorem, we have

$$\frac{d\psi_\epsilon^*}{d\alpha}>0\quad\text{and}\quad\frac{d\eta_\epsilon^*}{d\beta}\geq 0$$

so that market liquidity and funding liquidity risk are both increasing in the fraction of short-term debt. For $\alpha=0$, the equilibrium thresholds that solve (A4)-(A5) simplify to $\psi_\epsilon^*=0$ and $\eta_\epsilon^*=\underline{\eta}^*$. □

A2 Robustness and Extensions

No Credit Enhancements

Without the credit enhancements, firms default whenever the *per capita* value of their assets falls below D_2. We show below that while the absence of credit enhancements does not affect firms' information acquisition incentives, it breaks the strategic complementarities in creditors' withdrawal decisions when $p > D_1$. As in the main text, we restrict attention to environments where good firms never default. Assumption 1 now becomes

Assumption A1. *The fraction of short-term debt is be such that*

$$\alpha \leq \frac{R_l - \rho D_2}{D_1 - \rho D_2}$$

The absence of credit enhancements implies that firms holding bad assets may default even if they use their liquidity line to meet early withdrawals. The value of outstanding debt claims in $t = 2$ for bad firms using their liquidity lines and selling assets, respectively, are given by

$$\ell_l^{CL}(p) = \min\left\{D_2, \frac{R_l}{1-\alpha\lambda}\right\} \quad \text{and} \quad \ell_l^{AS}(p) = \min\left\{D_2, \frac{R_l\left(1 - \frac{\alpha\lambda D_1}{p}\right)}{1-\alpha\lambda}\right\}$$

It follows that default of firms using their liquidity lines implies default of firms using asset sales, but not *vice versa*. Notwithstanding these different default conditions, the absence of credit enhancements does not qualitatively change firms' preference ordering, so that Lemma 1 still holds.

Lemma A1. *Given Assumptions A1 and 2, informed good firms always prefer the liquidity line, while informed bad firms and uninformed firms always prefer asset sales in the absence of credit enhancements.*

Proof. Since good firms never default, the proof that informed firms holding good assets always prefer the liquidity line is the same as in the proof of Lemma 1. Similarly, in cases where bad firms selling assets default but those using their liquidity lines do not, the proof that informed bad firms and uninformed firms prefer asset sales is the same as in the proof of Lemma 1. It therefore remains to show that both prefer asset sales if bad firms using their liquidity line also default. In this case, the payoff difference between asset sales and the liquidity line for all $\Omega_j \in \{n, l\}$ is given by

$$V^{LL}(\Omega_j; \beta) - V^{AS}(\Omega_j; p) = \alpha\lambda D_1 \left(\frac{\mathbf{E}[\tilde{R}|\Omega_j]}{p} - \frac{1}{\beta}\right) - (1-\alpha\lambda)(\mathbf{E}[\tilde{\ell}^{CL}|\Omega_j] - \mathbf{E}[\tilde{\ell}^{AS}|\Omega_j]) < 0$$

where the inequality follows from Assumption 2 and $(\mathbf{E}[\tilde{\ell}^{CL}|\Omega_j] - \mathbf{E}[\tilde{\ell}^{AS}|\Omega_j]) \geq 0$ for all $\Omega_j \in \{n, l\}$. $\square$

The absence of credit enhancements thus has no effect on the secondary market price and Lemma 2 still holds. Also, firms' surplus from acquiring information is unchanged and still given by condition (7).

The absence of credit enhancements does, however, change creditors' expected surplus from withdrawing their funds in $t = 1$. In particular, creditors' loss given default now becomes

$$X(\lambda;\sigma) = \begin{cases} (1-\pi)\max\left\{D_2 - \frac{R_l\left(1-\frac{\alpha\lambda D_1}{p(\sigma)}\right)}{1-\alpha\lambda}, 0\right\} & \text{if } p(\sigma) \geq D_1 \\ (1-\pi)\left(D_2 - \frac{R_l\left(1-\frac{\alpha\lambda D_1}{p(\sigma)}\right)}{1-\alpha\lambda}\right) & \text{if } p(\sigma) < D_1 \end{cases}$$

Without credit enhancements, firms holding bad assets may default even if $p \geq D_1$. This additional default risk arises because a low fraction of early withdrawals increases the face value of firms' liabilities since $D_2 > D_1$. Consequently, even if secondary market prices are high, firms default in $t = 2$ if too few creditors opt to withdraw their funds in $t = 1$. This additional source of default risk leads creditors' withdraw decisions to become strategic substitutes when prices are high. To see this formally, notice that the derivative of creditors' loss-given-default with respect to λ for $p \geq D_1$ is given by

$$X_\lambda(\lambda;\sigma) = \begin{cases} -(1-\pi)\frac{\alpha R_l(p(\sigma)-D_1)}{(1-\alpha\lambda)^2 p(\sigma)} < 0 & \text{if } \lambda < \hat{\lambda}(\sigma) \\ 0 & \text{if } \lambda \geq \hat{\lambda}(\sigma) \end{cases}, \quad \text{where} \quad \hat{\lambda}(\sigma) = \frac{D_2 - R_l}{D_2 - \frac{D_1}{p(\sigma)}R_l}$$

Even though global strategic complementarities in creditors' withdrawal decisions no longer obtain in this case, the counteracting effect described above never arises for sufficiently low secondary market prices. In particular, if there are no credit enhancements and the the fraction of informed firms is such that

$$\sigma > \frac{\mathbf{E}_0[\tilde{R}] - D_1}{\pi(R_h - D_1)} \equiv \sigma^D$$

then creditors' surplus from withdrawing early is strictly increasing in the fraction of early withdrawals.

Default of Good Firms

Relax Assumption 1 and set $\alpha = 1$ so that firms' assets are entirely financed by short-term debt that can be withdrawn in $t = 1$.[34] Then, there exists a threshold $\underline{\lambda}$ such that good firms default on their outstanding claims in $t = 2$ if $\lambda > \underline{\lambda}$ and $p < D_1$. Moreover, there exists a second threshold $\overline{\lambda} > \underline{\lambda}$ such that firms cannot fully meet early withdrawals by selling assets and default in $t = 1$ if $\lambda > \overline{\lambda}$. In this case, the value of firms using asset sales is given by

$$V^{AS}(\Omega_j;p) = \begin{cases} \mathbf{E}[\tilde{R}|\Omega_j]\left(1 - \frac{\lambda D_1}{p}\right) - (1-\lambda)D_2 & \text{if } p \geq D_1 \\ \mathbf{E}[\tilde{R}|\Omega_j]\left(1 - \frac{\lambda D_1}{p}\right) - (1-\lambda)\mathbf{E}[\tilde{\ell}(p)|\Omega_j] & \text{if } p \in (\lambda D_1, D_1) \\ -(\lambda D_1 - p) - (1-\lambda)(D_2 - R_l) & \text{if } p \leq \lambda D_1 \end{cases}$$

[34] Setting $\alpha = 1$ is without loss of generality, and serves only to simply notation. The results presented below immediately carry through for all values of $\alpha > \overline{\alpha}$.

The value of firms using liquidity lines is unchanged, and still given by condition (4). Relaxing Assumption 1 does not qualitatively change firms' preference ordering between liquidity lines and asset sales, implying that Lemma 1 still holds.

Lemma A2. *Given Assumption 2, informed good firms always prefer the liquidity line, while informed bad firms and uninformed firms always prefer asset sales when* $\alpha = 1$.

Proof. As in the proof of Lemma 1, notice that the definition of ℓ_i for all $i \in \{h, l\}$ implies $D_2 \geq \mathbf{E}[\tilde{\ell}|\Omega_j]$. Thus, bad firms and uninformed firms prefer asset sales for $p \in (\lambda D_1, D_1)$. We also have that

$$V^{LL}(\Omega_j;\beta) \gtrless -(\lambda D_1 - p) - (1-\lambda)(D_2 - R_l) \quad \Leftrightarrow \quad \beta\mathbf{E}[\tilde{R}|\Omega_j] \gtrless \beta p + (1-\beta)\lambda D_1 + \beta(1-\lambda)R_l$$

Since $\beta p + (1-\beta)\lambda D_1 > p$ and $(1-\lambda)\beta R_l > 0$, it follows that bad and uninformed firms must still prefer asset sales for $p \leq \lambda D_1$. Moreover, Assumption 2 implies

$$V^{LL}(h;\beta) = \frac{1}{\beta}(\beta R_h - (\lambda D_1 + (1-\lambda)\beta D_2)) > 0$$

where the inequality follows from the fact that $\lambda D_1 + (1-\lambda)\beta D_2 < \mathbf{E}_0[\tilde{R}]$. Hence, good firms prefer the liquidity line for $p \leq \lambda D_1$ as the payoff from asset sales is always negative in this case. It remains to show that good firms prefer the liquidity line when $p \in (\lambda D_1, D_1)$ and $\ell_h < D_2$ (since otherwise the payoff from asset sales is the same as when $p \geq D_1$). Given Assumption 2, the payoff difference between the liquidity line and asset sales in this case satisfies

$$V^{LL}(h;\beta) - V^{AS}(h;\beta) = \frac{1}{\beta}(\beta R_h - (\lambda D_1 + (1-\lambda)\beta R_l)) > 0$$

Again, where the inequality follows from the fact that $\lambda D_1 + (1-\lambda)\beta R_l < \mathbf{E}_0[\tilde{R}]$. □

Hence, relaxing Assumption 1 has no effect on the secondary market price and Lemma 2 still holds. Given the change in the value of firms from selling assets, the surplus from acquiring information, previously condition (7), now becomes

$$S(\sigma;\lambda) = \begin{cases} \lambda D_1 \left(\frac{1}{p(\sigma)} - \frac{1}{\beta R_h}\right)\pi R_h & \text{if } \sigma \leq \underline{\sigma}(\lambda) \\ \left(1 - \frac{\lambda D_1}{\beta R_h}\right)\pi R_h - (1-\lambda)\pi R_l & \text{if } \sigma \in (\underline{\sigma}(\lambda), \overline{\sigma}(\lambda)) \\ \left(1 - \frac{\beta p(\sigma) + (1-\beta)\lambda D_1}{\beta R_h}\right)\pi R_h - (1-\lambda)\pi R_l & \text{if } \sigma \geq \overline{\sigma}(\lambda) \end{cases}$$

where

$$\underline{\sigma}(\lambda): \quad p(\underline{\sigma}(\lambda)) = \frac{\lambda D_1}{1-(1-\lambda)\rho} \quad \text{and} \quad \overline{\sigma}(\lambda): \quad p(\overline{\sigma}(\lambda)) = \lambda D_1$$

Proposition A1. *For* $\alpha = 1$, *firms' surplus from acquiring information is weakly increasing in the fraction of informed firms: i.e.* $S_\sigma(\sigma;\lambda) \geq 0$.

It follows that strategic complementarities in information acquisition still obtain if we allow firms with good assets to default. Hence, self-fulfilling market liquidity dry-ups can still obtain even after relaxing Assumption 1.

Similarly, we show that creditors' withdrawal incentives are qualitatively unchanged if we allow firms with good assets to default. In this case, creditors' loss-given-default when $p < D_1$ is equal to

$$X(\lambda;\sigma) = \begin{cases} (1-\pi)\left(R_l - \frac{R_l\left(1-\frac{\lambda D_1}{p(\sigma)}\right)}{1-\lambda}\right) & \text{if } \lambda \leq \underline{\lambda}(\sigma) \\ (1-\pi)\left(R_l - \frac{R_l\left(1-\frac{\lambda D_1}{p(\sigma)}\right)}{1-\lambda}\right) + (1-\sigma)\pi\left(R_l - \frac{R_h\left(1-\frac{\lambda D_1}{p(\sigma)}\right)}{1-\lambda}\right) & \text{if } \lambda \in \left(\underline{\lambda}(\sigma), \overline{\lambda}(\sigma)\right) \\ (1-\sigma\pi)R_l & \text{if } \lambda \geq \overline{\lambda}(\sigma) \end{cases}$$

where

$$\underline{\lambda}(\sigma) \equiv \frac{1-\rho}{\frac{D_1}{p(\sigma)} - \rho} \quad \text{and} \quad \overline{\lambda}(\sigma) = \frac{p(\sigma)}{D_1}$$

Creditors' withdraw decisions thus remain strategic complements for values of σ such that $p(\sigma) < D_1$.

Proposition A2. *For $\alpha = 1$, creditors' surplus from withdrawing funds early is weakly increasing in the fraction of withdrawals: i.e. $W_\lambda(\lambda;\sigma) \geq 0$.*

Different Preference Ordering

Assumption 2 in the main text served to fix firms' preferences between using their liquidity lines and selling assets in order to meet early withdrawals. Relaxing the lower bound on ρ implies that there exists a critical price below which uninformed firms prefer using their liquidity lines rather than continuing to sell assets in the secondary market. In other words, Lemma 1 no longer holds. In order for uninformed firms to prefer selling assets rather than tapping their liquidity lines, we must have

$$V^{AS}(n;p) \geq V^{LL}(n;\beta) \Leftrightarrow \alpha\lambda D_1\left(\frac{1}{\beta\mathbf{E}_0[\tilde{R}]} - \frac{1}{p(\sigma)}\right) + (1-\alpha\lambda)(D_2 - \ell_l(p)) > 0$$

In what follows, we focus on the case where $\beta\mathbf{E}_0[\tilde{R}] > D_1$ (so that $\ell_l = D_2$ when $p(\sigma) = \beta\mathbf{E}_0[\tilde{R}]$).[35] Uninformed agents thus switch between asset sales to tapping their liquidity lines whenever

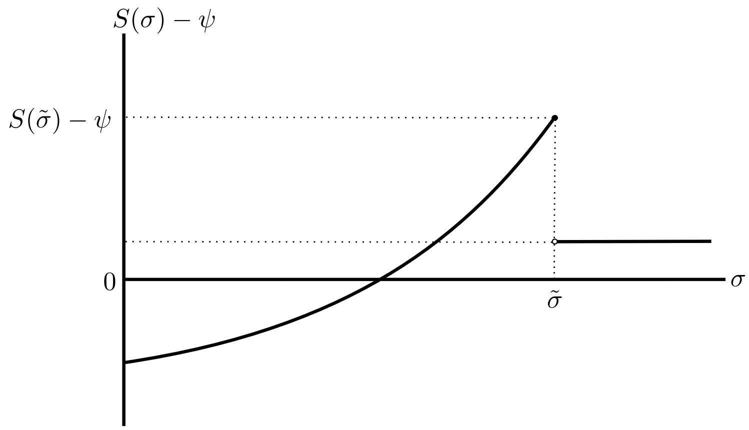
$$p(\sigma) < \beta\mathbf{E}_0[\tilde{R}] \Rightarrow \sigma > \tilde{\sigma} \equiv \frac{\pi - \Gamma}{\pi(1-\Gamma)}, \quad \text{where } \Gamma \equiv \frac{\pi\beta(1-\rho)-(1-\beta)\rho}{1-\rho} < \pi$$

implying that the fraction of good assets supplied to the secondary market now satisfies

$$\tau(\sigma) = \begin{cases} \frac{(1-\sigma)\pi}{1-\pi\sigma} & \text{if} \quad \sigma \leq \tilde{\sigma} \\ 0 & \text{if} \quad \sigma > \tilde{\sigma} \end{cases}$$

[35] This is done to simplify the exposition. Similar arguments hold for values of $\beta\mathbf{E}_0[\tilde{R}] \in [R_l, D_1]$.

Figure A1: Surplus function $S(\sigma;\lambda)$ if $\beta\mathbf{E}_0[\tilde{R}] > R_l$.



Lemma A3. *If $\beta\mathbf{E}_0[\tilde{R}] > D_1$, then there exists a threshold value $\tilde{\sigma} \in (0,1)$ such that uninformed firms prefer meeting early withdrawals using asset sales if and only if $\sigma \leq \tilde{\sigma}$.*

The fact that uninformed agents drop out of the secondary market for sufficiently high values of σ implies that firms' surplus from acquiring information (7) becomes

$$S(\sigma;\lambda) = \begin{cases} \alpha\lambda D_1\left(\frac{1}{p(\sigma)} - \frac{1}{\beta R_h}\right)\pi R_h & \text{if} \quad \sigma \leq \tilde{\sigma} \\ \alpha\lambda D_1\left(\frac{1}{\beta R_l} - \frac{1}{D_1}\right)(1-\pi)R_l & \text{if} \quad \sigma > \tilde{\sigma} \end{cases} \tag{A7}$$

When the share of informed firms exceeds $\tilde{\sigma}$, uninformed firms no longer trade in the secondary market and the price collapses to R_l. Although the option value from withholding good assets disappears (since both informed firms with good assets and uninformed firms prefer using their liquidity lines), the expected surplus from acquiring information is still positive. This arises because information acquisition allows firms with bad assets to sell these (at their fundamental price R_l) rather than using their costly liquidity lines to pay back early creditors.

It is straightforward to show that firms' surplus from information acquisition is no longer increasing in σ in this case since the gains from trading only bad assets are always strictly less than the option value that otherwise accrues to informed firms. This leads the surplus function $S(\sigma;\lambda)$ to jump down discontinuously at $\tilde{\sigma}$ when uninformed firms exit the market (see Figure A1). This discontinuity in firms' payoff functions implies that an equilibrium in the information acquisition game is no longer guaranteed to exist. In particular, an equilibrium may fail to exist for low values of ψ if the gains from trading only bad assets is sufficiently low. Barring this technical detail, however, self-fulfilling market liquidity dry-ups are still feasible even under this alternate preference ordering.

Proposition A3. *Self-fulfilling (market) liquidity dry-ups can still obtain in equilibrium if $\beta\mathbf{E}_0[\tilde{R}] > D_1$.*

Proof. We begin by showing that the surplus function jumps down discontinuously at $\sigma = \tilde{\sigma}$.

Claim A1. *The surplus function (A7) is such that* $S(\tilde{\sigma};\lambda) > \lim_{\sigma\to\tilde{\sigma}^-} S(\sigma;\lambda)$.

Proof. By definition, we have $p(\tilde{\sigma}) = \beta \mathbf{E}_0[\tilde{R}]$. Evaluating the surplus function at this price, we obtain

$$S(\tilde{\sigma}) = \alpha\lambda D_1 \left(\frac{1}{\beta \mathbf{E}_0[\tilde{R}]} - \frac{1}{\beta R_h}\right)\pi R_h$$

This implies that

$$S(\tilde{\sigma};\lambda) - \lim_{\sigma\to\tilde{\sigma}^-} S(\sigma;\lambda) = \alpha\lambda D_1 \left(\frac{1}{\beta \mathbf{E}_0[\tilde{R}]} - \frac{1}{\beta R_h}\right)\pi R_h - \alpha\lambda D_1\left(\frac{1}{\beta R_l} - \frac{1}{D_1}\right)(1-\pi)R_l$$

which simplifies to

$$\alpha\lambda D_1 \left(\frac{\pi R_h}{\beta \mathbf{E}_0[\tilde{R}]} + \frac{(1-\pi)R_l}{D_1} - \frac{1}{\beta}\right) > 0$$

where the inequality follows directly from the assumption that $\beta \mathbf{E}_0[\tilde{R}] > D_1$. □

We next show that the discontinuity of the surplus function $S(\sigma;\lambda)$ at $\tilde{\sigma}$ implies that an equilibrium need not always exist.

Claim A2. *An equilibrium may fail to exist in the information acquisition game if* $\beta \mathbf{E}_0[\tilde{R}] > D_1$.

Proof. Note that the discontinuity of the surplus function at $\tilde{\sigma}$ implies that firms' best response correspondence $\sigma_j^*(\sigma)$ does not have a closed graph. Consequently, Kakutani's fixed point theorem does not apply and a mixed strategy equilibrium need not exist. Moreover, $\lim_{\sigma\to\tilde{\sigma}^-} S(\sigma) < S(0)$ whenever

$$\beta > \frac{\mathbf{E}_0[\tilde{R}]}{\pi R_h + \frac{\mathbf{E}_0[\tilde{R}]}{D_1}(1-\pi)R_l} \tag{A8}$$

In this case, we have $S(1) < S(0)$ since $S_\sigma(\sigma;\lambda) = 0$ for all $\sigma > \tilde{\sigma}$. Hence, firms' best response correspondence in pure strategies $\sigma_j^*(\sigma) : \{0,1\} \to \{0,1\}$ can be weakly *decreasing* in σ, implying that Tarski's fixed point theorem does not apply and a pure strategy equilibrium need not exist either.

We proceed to prove the claim by construction. Assume that condition (A8) holds and consider values of $\psi \in [S(1), S(0)]$. Then $S(0) - \psi > 0$ and $\sigma_j^*(0) = 1$, implying that firms' best response to no firm acquiring information is to acquire information. Similarly, $S(1) - \psi < 0$ and $\sigma_j^*(1) = 0$, implying that firms' best response to all firms acquiring information is to *not* acquire information. Hence, for these values of ψ no pure strategy equilibria exist. To see that no equilibrium exists in mixed strategies either, notice that $S_\sigma(\sigma;\lambda) > 0$ for all $\sigma \leq \tilde{\sigma}$. Hence, we also have $S(\sigma;\lambda) > \psi$ for all values of $\sigma \leq \tilde{\sigma}$. □

Notwithstanding this potential non-existence problem, multiple equilibria can also arise in this case. For example, there always exist values of $\psi \in [S(0), S(\tilde{\sigma})]$ such that one pure strategy and one mixed strategy equilibrium obtain. □

Unobservable Trades

If firms are able to split their asset sales, then investors can no longer infer assets' quality based on the quantity firms supply to the market. In this case, since $p \geq R_l$, informed firms with bad assets will always find it optimal to sell all their assets on the secondary market. The share of good assets supplied to the secondary market (6) is now given by

$$\tau(\sigma, p) = \frac{(1-\sigma)\pi \frac{\alpha\lambda D_1}{p}}{(1-\sigma)\frac{\alpha\lambda D_1}{p} + (1-\pi)\sigma}$$

with $\tau_\sigma(\sigma, p) < 0$ and $\tau_p(\sigma, p) < 0$. The secondary market price is now implicitly defined by the following condition

$$\mathcal{F}(p, \sigma) \equiv p - (R_l + \tau(\sigma, p)(R_h - R_l)) = 0 \tag{A9}$$

Allowing for unobservable trades does not qualitatively change the properties of the price function: i.e. the secondary market price is still decreasing in the fraction of informed firms so that Lemma 2 still holds.

Lemma A4. *If trades are unobservable, there exists a unique secondary market price $p(\sigma)$ and $p'(\sigma) < 0$.*

Proof. To prove the uniqueness of the secondary market price, note first that

$$\mathcal{F}(\sigma, R_l) = -\tau(\sigma, R_l)(R_h - R_l) \leq 0$$

$$\mathcal{F}(\sigma, \mathbf{E}_0[\tilde{R}]) = (\pi - \tau(\sigma, \mathbf{E}_0[\tilde{R}])(R_h - R_l)) \geq 0$$

Since $\tau_p(\sigma, p) < 0$, we also have that

$$\mathcal{F}_p(\sigma, p) = 1 - \tau_p(\sigma, p)(R_h - R_l) > 0$$

It follows that, for any value of $\sigma \in [0, 1]$, there exists a unique value of $p \in [R_l, \mathbf{E}_0[\tilde{R}]]$ that satisfies condition (A9). Application of the implicit function theorem yields

$$p'(\sigma) = -\frac{\mathcal{F}_\sigma(\sigma, p)}{\mathcal{F}_p(\sigma, p)} < 0$$

where the inequality follows from $\mathcal{F}_\sigma(\sigma, p) = -\tau_\sigma(\sigma, p)(R_h - R_l) > 0$ since $\tau_\sigma(\sigma, p) < 0$. □

Allowing for unobservable trades does not change firms' value from using liquidity lines, but it does change the value from using asset sales for informed firms with bad assets. In particular, condition (3) now becomes

$$V^{AS}(l, p) = p - \alpha\lambda D_1 - (1 - \alpha\lambda)\mathbf{E}[\tilde{\ell}(p)|l]$$

where

$$\mathbf{E}[\tilde{\ell}(p)|l] = D_2 - \max\left\{R_l - \frac{p - \alpha\lambda D_1}{1 - \alpha\lambda}, 0\right\}$$

Given this, the surplus from acquiring information, previously condition (7), now becomes

$$S(\sigma;\lambda)=\begin{cases}\alpha\lambda D_1\left(\frac{1}{p(\sigma)}-\frac{1}{\beta R_h}\right)\pi R_h+(1-\pi)\left((p(\sigma)-R_l)\left(1-\frac{\alpha\lambda D_1}{p(\sigma)}\right)\right) & \text{if } \sigma\leq\sigma^D\\ \alpha\lambda D_1\left(\frac{1}{p(\sigma)}-\frac{1}{\beta R_h}\right)\pi R_h+(1-\pi)((p(\sigma)-R_l)-\alpha\lambda(D_1-R_l)) & \text{if } \sigma\in(\sigma^D,\hat{\sigma})\\ \alpha\lambda D_1\left(\frac{1}{p(\sigma)}-\frac{1}{\beta R_h}\right)\pi R_h & \text{if } \sigma\geq\hat{\sigma}\end{cases}$$

where

$$\sigma^D:\quad p(\sigma^D)=D_1\quad\text{and}\quad\hat{\sigma}:\quad p(\hat{\sigma})=\alpha\lambda D_1+(1-\alpha\lambda)R_l$$

Assuming that trades are unobservable therefore introduces an additional term in firms' surplus function. This additional term corresponds to the *information rent* informed firms with bad assets enjoy from offloading these at the the pooling price in the secondary market. A distinctive feature of this information rent is that it is *increasing* in the secondary market price, and therefore *decreasing* in σ. This effect weakens the strategic complementarities in information acquisition that result from the option value of withholding good assets (the channel studied in the main text). To see this formally, notice that the derivative of the surplus function with respect to σ is given by

$$S_\sigma(\sigma;\lambda)=\begin{cases}-p'(\sigma)\left(\frac{\alpha\lambda D_1\mathbf{E}_0[\tilde{R}]}{p^2(\sigma)}-(1-\pi)\right)\gtrless 0 & \text{if } \sigma\leq\sigma^D\\ -p'(\sigma)\left(\frac{\alpha\lambda D_1\pi R_h}{p^2(\sigma)}-(1-\pi)\right)\gtrless 0 & \text{if } \sigma\in(\sigma^D,\hat{\sigma})\\ -p'(\sigma)\frac{\alpha\lambda D_1\pi R_h}{p^2(\sigma)}>0 & \text{if } \sigma\geq\hat{\sigma}\end{cases}$$

Notwithstanding the fact that the information rent effect may break the global strategic complementarities in firms' information acquisition decisions, it is straightforward to show that this information rent effect is always dominated by the option value motive if the fraction of early withdraws is sufficiently high. In particular, if trades are unobservable and the fraction of early withdrawals is such that

$$\lambda>(1-\pi)\max\left\{\frac{\mathbf{E}_0[\tilde{R}]}{\alpha D_1},\frac{D_1}{\alpha\pi R_h}\right\}$$

then firms' surplus from acquiring information is strictly increasing in the fraction of informed firms.

The information rent derived above (in the absence of default) corresponds to the private value of information acquisition studied by (Gorton & Ordonez, 2014). Contrary to the option value from withholding good assets studied in our paper, it cannot in itself explain self-fulfilling dry-ups in market liquidity. In particular, increases in the fraction of informed firms lower secondary market prices due to adverse selection, but this fall in the price leads to a *reduction* in firms' incentives to acquire information as it reduces the information rents obtained from selling bad assets.

Bibliography

Acharya, V., Almeida, H., & Campello, M. (2013a). Aggregate risk and the choice between cash and lines of credit. *The Journal of Finance*, 68(5), 2059–2116.

Acharya, V. V., Schnabl, P., & Suarez, G. (2013b). Securitization without risk transfer. *Journal of Financial Economics*, 107(3), 515–536.

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

Ashcraft, A., Malz, A., & Pozsar, Z. (2012). *The Federal Reserve's Term Asset-Backed Security Loan Facility*. Frbny economic policy review, Federal Reserve Bank of New York.

Bolton, P., Santos, T., & Scheinkman, J. A. (2015). Cream skimming in financial markets. Working Paper.

Brunnermeier, M. K. & Oehmke, M. (2013). The maturity rat race. *The Journal of Finance*, 68(2), 483–521.

Brunnermeier, M. K. & Pedersen, L. H. (2009). Market liquidity and funding liquidity. *Review of Financial studies*, 22(6), 2201–2238.

Carlsson, H. & van Damme, E. (1993). Global Games and Equilibrium Selection. *Econometrica*, 61(5), 989–1018.

Covitz, D., Liang, N., & Suarez, G. (2013). The Evolution of a Financial Crisis: Collapse of the Asset-Backed Commercial Paper Market. *Journal of Finance*, 68(3), 815–848.

Dang, T. V., Gorton, G., & Holmström, B. (2013). The information sensitivity of a security. Working Paper.

Dang, T. V., Gorton, G., & Holmström, B. (2015). Ignorance, debt, and financial crises. Working Paper.

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

Eisenbach, T. M. (2013). *Rollover risk as market discipline: a two-sided inefficiency*. Staff Reports 597, Federal Reserve Bank of New York.

Eisfeldt, A. L. (2004). Endogenous liquidity in asset markets. *The Journal of Finance*, 59(1), 1–30.

Feijer, D. (2015). Information panics and liquidity crises. mimeo.

Fishman, M. & Parker, J. (2015). Valuation, adverse selection, and market collapses. *Review of Financial Studies*.

Goldstein, I. (2005). Strategic complementarities and the twin crises. *Economic Journal*, 115(503), 368–390.

Goldstein, I. & Pauzner, A. (2005). Demand deposit contracts and the probability of bank runs. *Journal of Finance*, 60(3), 1293–1328.

Gorton, G. (2010). *Slapped by the invisible hand: The panic of 2007*. Oxford University Press.

Gorton, G. & Ordonez, G. (2014). Collateral crises. *The American Economic Review*, 104(2), 343–378.

Gorton, G. & Pennacchi, G. (1990). Financial intermediaries and liquidity creation. *The Journal of Finance*, (pp. 49–71).

Gorton, G. B. (2012). *Some Reflections on the Recent Financial Crisis*. Technical report, National Bureau of Economic Research.

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

Kacperczyk, M. & Schnabl, P. (2010). When Safe Proved Risky: Commercial Paper during the Financial Crisis of 2007-2009. *Journal of Economic Perspectives*, 24(1), 29–50.

König, P. J. & Pothier, D. (2016). Too Much of a Good Thing? - A Theory of Short-Term Debt as a Sorting Device. *Journal of Financial Intermediation*, 26, 100–114.

Kuong, J. C.-F. (2015). Self-fulfilling fire sales: Fragility of collateralised short-term debt markets. Working Paper.

Malherbe, F. (2014). Self-fulfilling liquidity dry-ups. *The Journal of Finance*, 69(2), 947–970.

Morris, S. & Shin, H. S. (2003). Global games: theory and applications. In L. P. Hansen, S. J. Turnovsky, & M. Dewatripont (Eds.), *Advances in Economics and Econometrics* (pp. 56–114). Cambridge University Press.

Morris, S. & Shin, H. S. (2004a). Coordination risk and the price of debt. *European Economic Review*, 48(1), 133–153.

Morris, S. & Shin, H. S. (2004b). Liquidity Black Holes. *Review of Finance*, 8(1), 1–18.

Plantin, G. (2009). Learning by Holding and Liquidity. *Review of Economic Studies*, 76(1), 395–412.

Pozsar, Z., Adrian, T., Ashcraft, A. B., & Boesky, H. (2010). *Shadow banking.* Staff Reports 458, Federal Reserve Bank of New York.

Rochet, J.-C. & Vives, X. (2004). Coordination Failures and the Lender of Last Resort: Was Bagehot Right After All? *Journal of the European Economic Association*, 2(6), 1116–1147.

Stein, J. C. (2012). Monetary policy as financial stability regulation. *The Quarterly Journal of Economics*, 127, 57–95.

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