Debt Maturity and Information Production

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Abstract

The maturity of a firm's liabilities affects the information financiers produce about the firm's assets. In my model, long-term financing creates an excessive tendency for financiers to acquire information and screen out lower quality borrowers. In contrast, short-term financing deters information production at origination but induces it when firms are forced to liquidate, depressing the market value of assets due to adverse selection. Through the feedback effect between firms' maturity structures and asset prices, increases in uncertainty can impair the aggregate volume of short-term financing and investment. The analysis can jointly rationalize i) the widespread use of short-term debt by financial firms, ii) periodic disruptions in short-term funding markets and iii) regulations that curb short-term funding markets in normal times and support them in periods of market stress.

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1 Introduction

Short-term debt is used pervasively by many types of financial firms. While commercial banks' access to deposits can rationalize their use of short-term financing, it is less clear why other financial institutions, such as hedge funds, non-bank broker-dealers, mortgage REITs and mortgage originators also rely so heavily on it. This reliance on short-term debt seems puzzling given that it exposes financial firms to potentially costly asset liquidations. Indeed, many observers have argued that the extensive use of short-term debt by financial firms may adversely affect asset prices, investment and the functioning of short-term funding markets.[1]

In this paper, I present a model in which the maturity of firms' liabilities affects the incentives of financiers to produce information about firms' assets. When financiers provide long-term financing, they tend to produce an excessive amount of information. Since firms ultimately bear the cost of inefficient information production, they have an impetus to deter it by borrowing short-term. Specifically, short-term financing limits financiers' exposure to the underlying quality of firms' assets, reducing their incentives to produce information. However, the downside of short-term financing is that firms may face costly asset liquidations when they refinance.[2]

I first characterize the choice between long and short-term financing in a security design problem in which liquidation costs are exogenous. I then show how these costs arise endogenously when buyers of assets can produce information when firms liquidate. Specifically, while short-term financing deters information production at origination, it triggers information production in the asset market, creating adverse selection. However, since firms' maturity choices ultimately depend on liquidation costs, a severe enough adverse selection problem impairs the aggregate volume of short-term financing. Furthermore, I show that firms' maturity structures can be either inefficiently short or long depending on the slope of the demand curve in the asset market.

[1]E.g. see Geithner (2006). For a detailed discussion of the malfunctioning of short-term debt markets in the 2008/2009 financial crisis see Brunnermeier (2009) and Krishnamurthy (2010).

[2]Henceforth, I will refer to liquidation and refinancing interchangeably. Liquidation costs may encompass actual costs of transferring assets or any other cost related to the issuance of financial securities.

Formally, I consider a three period model in which a firm seeks financing for an asset from a lender. The asset's return depends on its type (good or bad) which is initially unknown to both the firm and lender, and an aggregate state that occurs at the interim date. There are two key ingredients in the model: 1) at the interim date the firm can liquidate a portion of the asset in a competitive outside financial market and 2) before committing funds to finance the asset, the lender can privately incur a cost to learn the asset's type. Information production is inefficient, i.e. the cost of learning the asset's type exceeds the social value of avoiding financing the bad asset; however, the lender cannot commit to not doing so. I show that when providing long-term financing, the lender's private value of information always exceeds the social value of information. Intuitively, the lender bears the full downside of financing the asset but only receives a portion its cash flows, which makes screening out the bad asset more attractive for the lender. As a result, the lender may acquire information despite it being inefficient.

In some cases the optimal security, which can be interpreted as short-term financing, forces the firm to liquidate a portion of the asset at the interim date following a negative shock. Asset liquidations blunt the lender's incentives to acquire information by reducing the lender's expected losses from the bad asset. Hence, the firm uses short-term financing when the benefit of deterring inefficient information production exceeds the expected cost of liquidation. Otherwise, the firm uses long-term financing which inefficiently reduces its investment scale or triggers information production.

Next, I examine a market equilibrium in which there are many firms whose financing decisions affect the size of liquidation costs. When firms liquidate at the interim date, an outside informed investor can incur a cost to acquire information about individual assets and make anonymous offers to buy them. If a firm does not sell its asset to the informed investor, it sells it in a competitive pool of uninformed investors. Information is privately valuable to the informed investor because it allows it to buy good assets at a reduced price. However, this "cream skimming" worsens the quality of assets that flows to the uninformed, leading to adverse selection and higher liquidation costs. Consequently, firms' initial financing choices both affect and are affected by the adverse selection at liquidation. Shorter maturities incentivize more information production in the asset market which results in higher liquidation costs. When the adverse selection problem in the asset market is mild, all firms use short-term financing. However, in some cases, if all firms were to use short-term financing, liquidation costs would be too high to sustain any short-term financing. Hence, some firms resort to long-term financing, resulting in a reduced level of aggregate short-term financing and investment.

Finally, I perform a normative analysis by asking whether a planner that changes the number of firms using short-term financing can increase welfare. While firms internalize the social cost of inefficient information production at origination, they do not at liquidation because asset prices are market-determined. However, firms also do not internalize how higher levels of short-term financing raise the profits of the informed investor by allowing it to buy more assets at a cheap price. The relative magnitude of these two forces, which can be summarized by the slope of the demand curve, determines the efficiency of the equilibrium. Intuitively, the more downward sloping the demand curve is, the more wasteful information production is induced by a marginal increases in aggregate short-term financing. However, if the demand curve is flat, increasing aggregate short-term financing simply results in a transfer between firms and the informed investor, which has no effect on total welfare. Therefore, when the demand curve is sufficiently downward sloping the planner prefers lower levels of aggregate short-term debt. In contrast, when only a portion of firms use short-term financing and the demand curve is sufficiently flat, the planner prefers higher levels of short-term financing.

Several of the model's implications are consistent with stylized facts. First, the model can rationalize the widespread use of short-term debt by many types of financial firms. For example, Figure 1 shows that over 80% of hedge funds, mortgage originators and mortgage REITs' debt is short-term, compared to just over 20% for industrial firms. In practice, financial firms borrow extensively from other financial institutions.[3] These types of lending relationships may be particularly prone to inefficient information generation because the lender has the ability to evaluate the same types of assets as the borrower.[4] Furthermore, financial assets are generally less costly to liquidate than real assets.[5] Hence, the trade-off between inefficient information production and liquidation costs may make short-term debt particularly attractive for financial firms.

Second, the endogenous relationship between asset prices and the volume of short-term financing can help explain the disruptions in short-term funding markets observed in periods of heightened uncertainty. For example, during the 2008/2009 financial crisis, both the total volume and maturity of short-term debt decreased across a variety of markets.[6] In my model, higher uncertainty increases individual lenders' incentives to acquire information. Firms respond by shortening their debt maturities to deter information production. However, shorter debt maturities lead to higher liquidation costs through information production in the asset market. If liquidation costs become large enough, the aggregate volume of short-term debt becomes impaired.

Third, the normative analysis implies that firms' maturity structures may be inefficiently short, resulting in too little information production by financiers at origination and too much information production in the asset market. This implication is consistent with policymakers' concerns that there is insufficient credit analysis by institutions that

[3]For example hedge funds predominantly borrow from prime brokers within large banks (Ang, Gorovyy, and Van Inwegen (2011)), and mortgage REITs and mortgage originators borrow extensively from banks (Pellerin, Sabol, and Walter (2013b) and Kim et al. (2018)). This raises the question as to why financial firms borrow from banks in the first place. Given their expertise in evaluating financial assets, banks are likely best suited to perform due diligence on other financial firms. However, this expertise can be a double-edged sword in that lenders may be tempted to collect too much information while performing due diligence. In practice prime brokers appear to engage in due diligence on hedge funds (Aikman (2010)).

[4]The following statement by the former head of the Financial Services Authority is consistent with this idea, "I find it difficult, if not impossible, to identify an activity carried out by a hedge fund manager which is also not carried out by the proprietary trading desk within a large bank, insurance company or broker dealer" McCarthy (2006).

[5]Although I consider an information-based liquidation cost, real assets may also be subject to second-best user costs (e.g. Shleifer and Vishny (1992)).

[6]See Hördahl and King (2008), Krishnamurthy (2010), Covitz, Liang, and Suarez (2013), Gorton, Metrick, and Xie (2014), Gabrieli and Georg (2014) and Pérignon, Thesmar, and Vuillemey (2018) for evidence of shortening maturities and Hördahl and King (2008), Gorton and Metrick (2012a), Gorton and Metrick (2012b) Kim et al. (2018) for evidence on reductions in the volume of short-term debt. Gallagher et al. (2020) find evidence of information production by informed investors as debt markets dry up in the context of money market funds.

lend to financial firms.[7] However, I also show that firms may use too little short-term financing when short-term funding markets become impaired. This result is consistent with policymakers efforts to support short-term funding markets during the LTCM crisis and the 2008/2009 financial crisis.[8] If adverse selection is already severe and increased asset sales do not induce substantially more information production, the model would suggest that policymakers should support short-term funding markets.

There are two main strands of literature rationalizing financial institutions borrowing short-term. In one class of models, financial firms produce short-term liabilities to meet investors' liquidity needs (e.g. Diamond and Dybvig (1983) and Goldstein and Pauzner (2005)), or demand for safe assets (e.g. Stein (2012), Krishnamurthy and Vissing-Jorgensen (2012) and Diamond (2016)). Short-term debt can also provide a disciplining role for banks (e.g. Calomiris and Kahn (1991), Flannery (1994), Diamond and Rajan (2001) and Eisenbach (2017)).[9] While the aforementioned models tend to be used to understand banks borrowing short-term from depositors, I argue that my model helps to understand lending between financial institutions in which lenders are predisposed to produce information about borrowers' assets.

In a more general context, debt maturity can be used to avoid or induce debt overhang (e.g. Myers (1977), Shleifer and Vishny (1992), Hart and Moore (1995) and Diamond and He (2014)). Firms may also borrow short-term to signal their quality when information arrives over time (e.g. Flannery (1986), Diamond (1991), Titman (1992) and Stein (2005)). While in signaling models it is generally irrelevant which party refinances the initial loan, in my setting the firm must refinance from an outside party to induce the initial lender to not acquire information. This contractual feature resembles the ubiq-

[7]For example in referring to banks' lending practices prior to the LTCM episode: "There was a lack of balance between the key elements of the credit risk management process... banks compromise[d] other critical elements of effective credit risk management, including upfront due diligence,... ongoing monitoring of counterparty exposure" and "In managing relationships with [hedge funds], banks clearly relied on significantly less information on the financial strength... of these counterparties than is common for other types of counterparties" Basel Committee on Banking Supervision (1999).

[8]For instance, the Federal Reserve imposed the Term Auction Facility, Term Securities Lending Facility and the Primary Dealer Credit Facility offered short-term financing during the 2008/2009 financial crisis (see Gorton, Laarits, and Metrick (2018) for more details).

[9]Short-term debt can also be used as a disciplining device (Leland (1998), Benmelech (2006), Diamond (2004) and Cheng and Milbradt (2012)).

uitous variation margins used by financial firms in practice. Finally, Brunnermeier and Oehmke (2013) show that if firms lack commitment in their debt maturity decisions debt maturities may be inefficiently short.[10]

This paper builds on the literature analyzing security design to prevent endogenous adverse selection. Gorton and Pennacchi (1990) show that risk-free debt can prevent informed traders from taking advantage of uninformed investors with liquidity needs. When assets are risky, Dang, Gorton, and Holmström (2012) find that debt is the optimal security to induce counterparties to not acquire information. Under general assumptions about the information acquisition technology, standard debt is the uniquely optimal security to avoid endogenous adverse selection (Yang (2019)).[11] I build on this literature by focusing on the role of maturity to deter information production. I also show how inefficient information production not only leads firms to use short-term debt, but can generate fire sales when firms raise new funds to repay their lenders.[12]

Building on the microfoundations of Dang, Gorton, and Holmström (2012), Gorton and Ordonez (2014) analyze the dynamics of information production in debt markets and its macroeconomic implications. Information about collateral decays over time producing a credit and output boom; however, after an aggregate shock, lenders may suddenly have an incentive to produce information, which can lead to a large drop in output. My model differs in several respects. First, in Gorton and Ordonez (2014) there can only be short-term debt because generations live for one period, while in my model firms choose between short-term and long-term financing. Second, I incorporate endogenous information production in the asset market, to study the interaction between debt maturity, asset prices and aggregate investment. Third, I show that debt maturities can be both inefficiently short or long, depending on the slope of the demand curve in the asset market.

[10]Other models of dynamic debt maturity include He and Milbradt (2016), Huang, Oehmke, and Zhong (2019) and Geelen (2019).

[11]Other models relating investors' endogenous or exogenous information to security design include Boot and Thakor (1993), Fulghieri and Lukin (2001), Inderst and Mueller (2006), Axelson (2007), Farhi and Tirole (2012b) and Yang and Zeng (2018). In Dang et al. (2017) banks can create liquid, information-insensitive liabilities by keeping assets on the balance sheet.

[12]In the context of securitization, Pagano and Volpin (2012) show how an issuer's decision to withhold information helps liquidity in the primary market but hurts it in the secondary market.

The link between debt maturity and asset prices relates to the literature examining financial contracts and market liquidity (e.g. Myers and Rajan (1998), Gromb and Vayanos (2002), Brunnermeier and Pedersen (2008), Acharya and Viswanathan (2011), He and Milbradt (2014) and Biais, Heider, and Hoerova (2018)).[13] In my setting, the feedback effect between information production at origination and liquidation jointly determines debt maturity and asset market liquidity.

This paper also relates to the body of literature in which information production generates adverse selection in financial markets. In Fishman and Parker (2015) buyers information production can generate credit crunches and multiple equilibria in the primary market and in Bolton, Santos, and Scheinkman (2016) the equilibrium acquisition of information is generically inefficient in OTC markets. In the context of primary market securitization, Hanson and Sunderam (2013) show that originators' production of informationally-insensitive assets ex-ante leads to too little informed capital ex-post.

Finally, a growing literature explores the macroeconomic implications of adverse selection (e.g. Eisfeldt (2004), Kurlat (2013), Malherbe (2014), Bigio (2015), Moreira and Savov (2017), Neuhann (2017) and Asriyan, Fuchs, and Green (2018)). A distinction between my model and the existing literature is that I consider how adverse selection endogenously arising from firms' financing choices affects output.

The paper is organized as follows. Section 2 describes the baseline model setup. Section 3 analyzes the model. Section 4 introduces the market equilibrium and Section 5 concludes. All proofs are in the Appendix unless otherwise stated.

2 Model Setup

There are three dates, (t = 0, 1, 2) and three agents: a *firm* that raises funds from a *lender* at $t = 0$ and can raise funds from an *outside financial market* at $t = 1$. All agents are risk-neutral and there is no discounting.

[13]The market equilibrium also relates to models of fire sales and pecuniary externalities (e.g. Shleifer and Vishny (1992), Kiyotaki and Moore (1997), Lorenzoni (2008), Shleifer and Vishny (2011), Stein (2012), Malherbe (2014), Kurlat (2016), Dávila and Korinek (2017), Biais, Heider, and Hoerova (2018), Dow and Han (2018) and Kurlat (2018)).

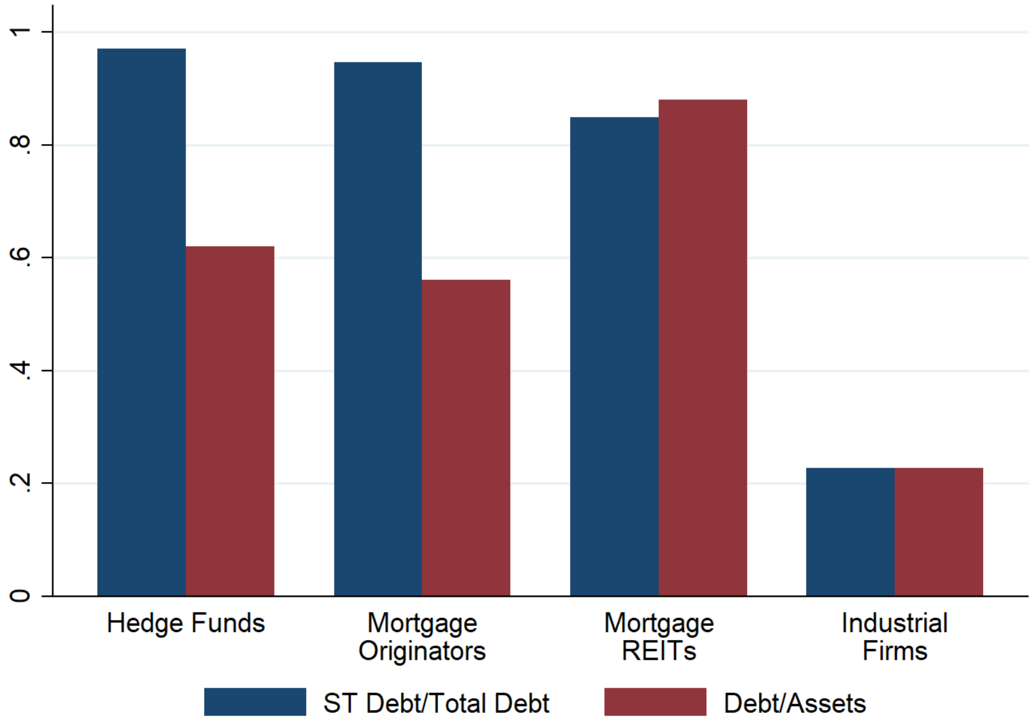

Figure 1: Debt Maturity and Leverage. See the Appendix for a detailed description of the data sources and variable definitions.

2.1 Agents and Technology

2.1.1 Firm

The firm has no wealth and limited liability. In addition, the firm has access to a technology that requires an investment $k \in [0, 1]$ at $t = 0$ to produce a random output $k\tilde{R}$ at $t = 2$. The per-unit output $\tilde{R}$ can take values R (success) or 0 (failure). Although I refer to the investment technology as a single project, in the case of a financial firm it can be thought of as an investment strategy or portfolio of assets. Two factors affect the project's probability of success: i) the project's type and ii) a publicly observable state at $t = 1$. Specifically, there are two project types $v \in \{g, b\}$ (good and bad) which occur with the following probabilities

$$v = \begin{cases} g & \text{with prob. } \theta \in (0,1) \\ b & \text{with prob. } 1 - \theta. \end{cases}$$

The project's type is initially unknown to all agents. There are two states $z \in \{h, l\}$ (high or low), which occur with the following probabilities

$$z = \begin{cases} h & \text{with prob. } \pi_h \in (0,1) \\ l & \text{with prob. } \pi_l \equiv 1 - \pi_h. \end{cases}$$

The good project succeeds with certainty regardless of the state. In contrast, the bad project succeeds with certainty if the state is high and with probability $\mu \in (0,1)$ if the state is low.[14] Figure 2 provides a visual description of the project's probability of success. I define ϕ_z the probability that the ex-ante average project succeeds following state z

$$\phi_h \equiv 1, \quad \phi_l \equiv \theta + (1-\theta)\mu.$$

I make the following assumptions

Assumption 1.

1. $(\pi_h + \pi_l \mu)R < 1$,
2. $(\pi_h + \pi_l \phi_l)R > 1$.

Assumption 1.1 says that the bad project is NPV negative, while Assumption 1.2 says the ex-ante, average project is NPV positive.[15]

2.1.2 Lender

The firm borrows from a single, deep-pocketed lender that belongs to a competitive pool of lenders. The lender has access to an information acquisition technology at $t = 0$,

[14]The probability of success need not be 1 for the good project in both states and the bad project in the high state. The key is that there is a difference in the probability of success across project types in one of the states.

[15]The assumption that the bad project is NPV negative (Assumption 1.1) is not strictly necessary; however, it simplifies the exposition by ensuring it is without loss of generality to focus on a single contract rather than a menu. It also ensures that the lender's participation constraint always binds at the optimum, which further limits the number of forms the optimal contract can take. In the Appendix, I characterize the optimal contract in the case where this assumption is relaxed and show the model's main qualitative predictions regarding the use of short-term contracts remain.

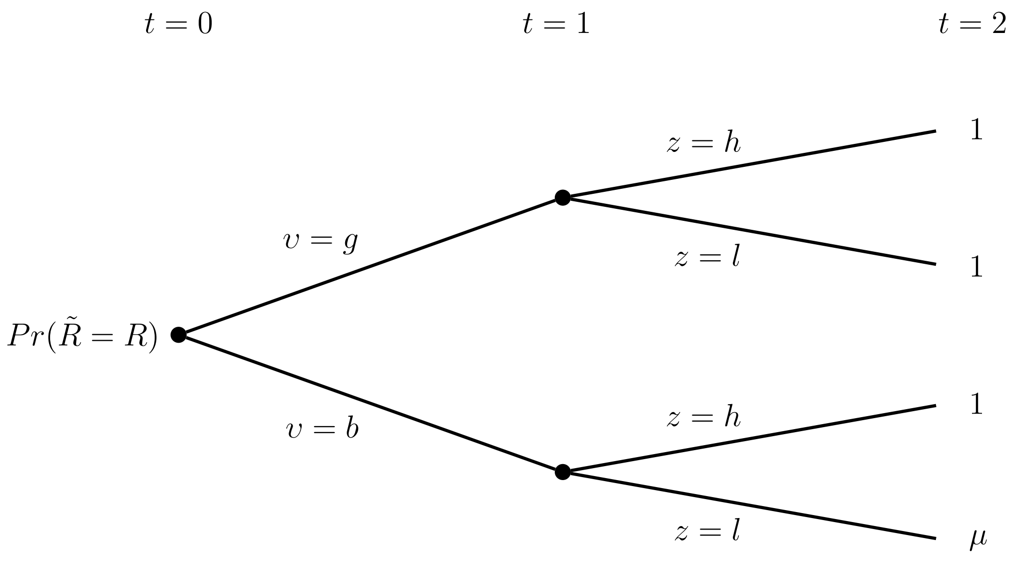

Figure 2: Payoff Summary.

whereby incurring a cost $c \geq 0$ it learns the project's type υ. I denote the lender's information acquisition decision by $a \in \{0, 1\}$ where $a = 0$ refers to the lender not acquiring information and $a = 1$ refers to the lender acquiring information. For convenience, I assume if $a = 1$, υ becomes public knowledge at the end of $t = 0$.[16] In addition, I focus the analysis on the case where c is within the following bounds:

Assumption 2. *The cost of information acquisition c is between $\underline{c}$ and $\bar{c}$, $c \in (\underline{c}, \bar{c})$, where*

$$\underline{c} \equiv (1-\theta)(1-\pi_h R - \pi_l \mu R), \quad \bar{c} \equiv \frac{\theta(1-\phi_l)(1-\pi_h R)}{\phi_l}.$$

As shown below, this assumption implies that information acquisition is inefficient, but the cost of information acquisition is sufficiently low to materially affect the financial contracting problem.

[16] This assumption eliminates the possibility of signaling problems in the outside financial market and is also made in Gorton and Ordonez (2014). All of the results go through if I relax this assumption and impose reasonable off-equilibrium beliefs for the outside financial market.

2.1.3 Outside Financial Market

At $t = 1$ the firm can raise additional funds from a competitive outside financial market. The firm can raise funds by: i) new claims on the existing project's output, i.e. securities, or ii) the sale of a portion of its existing project, i.e. asset sales. For ease of exposition, I refer to asset sales as the method of raising funds.[17]

Formally, at $t = 1$ in state z the firm sells a portion of its project $q_z \in [0, k]$ for a price $p_z^a = (1 - \gamma_z^a)\mathbb{E}[\tilde{R}|\mathcal{F}]$ where $\gamma_z^a \in [0, 1]$ is a liquidation cost that can depend on the state and the lender's information acquisition decision and $\mathbb{E}[\tilde{R}|\mathcal{F}]$ is the expected value of the project given all public information after z has been realized at $t = 1$. Although in principle there can be numerous sources of the liquidation cost, a relevant friction for financial assets is adverse selection, which is what I consider in Section 4.

2.2 Financial Contracts

At $t = 0$ the firm offers the lender a financial contract $\mathcal{C}$, which consists of an investment level and state-contingent liquidations and payments from the firm to the lender at each date. For simplicity, I restrict focus on contracts in which the firm only raises funds for investment at $t = 0$ and does not store funds across periods, which I show is without loss of generality in the Appendix. In addition, Assumption 1.1 ensures it is without loss of generality for the firm to offer the lender a single contract rather than a menu.[18] Formally,

Definition 1. *A financial contract* $\mathcal{C} \equiv \{k, q_h, q_l, d_{1h}, d_{1l}, d_{2h}, d_{2l}\}$ *consists of an investment level* k*, state-contingent liquidations* q_z *and state-contingent payments* d_{1z} *and* d_{2z} *from the firm to the lender at* $t = 1, 2$*, respectively for each state* z*.*

After $\mathcal{C}$ has been offered, and before the lender accepts or rejects it, the lender decides whether to acquire information; however, $\mathcal{C}$ cannot be made contingent on the lender's

[17] In the context of the model there is no difference between asset sales and issuing securities because of the project's binary payoff.

[18] If the lender acquires information and discovers the project is bad, the initial cost of financing cannot be recouped in expectation regardless of the terms of the contract.

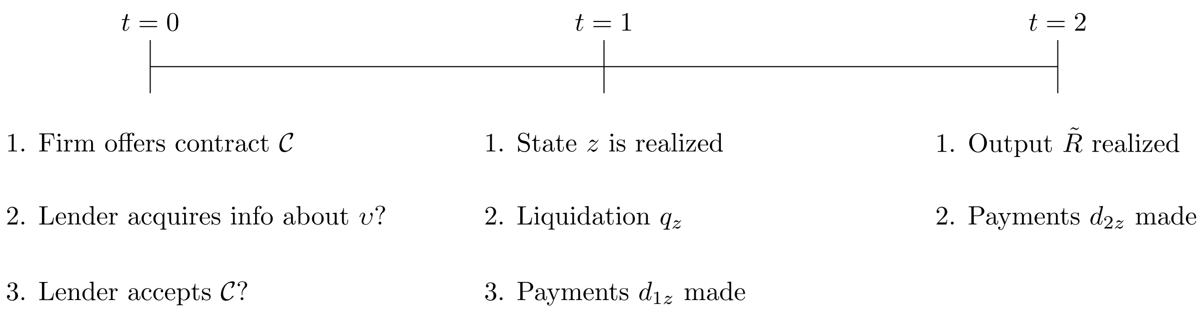

Figure 3: Model Timing.

information acquisition decision a. As shown below, this friction implies that the lender will have an excessive tendency to acquire information.

I assume that the firm cannot contract with the outside financial market at $t = 0$.[19] Furthermore, the firm and lender can commit to not renegotiate $\mathcal{C}$.[20] If the firm fails to make the contractual payments at $t = 1$ the remainder of the project is liquidated in the outside financial market and all proceeds are given to the lender. Since contracts are state-contingent, it is without loss of generality to focus on cases where default does not occur in equilibrium. Figure 3 displays the timing of the model.

2.3 Baseline Model Discussion

In this section I discuss some of the main features of the baseline model. An important assumption is the firm and lender begin symmetrically uninformed. One rationale for this occurring in financial markets is that lenders and firms both invest in the same types of assets. For instance, banks employ traders and research analysts that have expertise in the same securities as the hedge funds they lend to. Nonetheless, in the Appendix I analyze the case in which the firm is endowed with private information about its project quality and show the main qualitative results remain so long as the initial information is not too precise.

[19] This assumption can be rationalized if the lender must incur an initial cost of due diligence which is too costly for the outside financial market to incur. A cost of due diligence can also rationalize the firm borrowing from a single lender at $t = 0$ to avoid duplicative monitoring costs (e.g. Diamond (1984)).

[20] As shown in Section 4, the specific form of liquidation cost I focus on is information-based; hence, the lender's value of the asset at $t = 1$ coincides with that of the outside financial market, eliminating the incentive to refinance with the lender at $t = 1$.

What type of information could be socially inefficient to produce? While financial firms certainly generate information about their own assets, certain pieces of information may not be worth producing. For instance, a hedge fund would probably not pay their analysts to investigate individual houses before purchasing a mortgage-backed security. As I show below, however, a bank lending long-term to that hedge fund may want to investigate the houses. Consistent with this example, I show in the Appendix that if the firm is also given the option to acquire information about the project, the firm does not.

3 Model Analysis

3.1 Benchmark: Information Acquisition is Contractible

To gain intuition, I first analyze the case in which the lender's information acquisition decision is contractible. For information acquisition to be efficient, the value from acquiring information (i.e. the avoiding financing the bad project) must offset its cost. Formally this occurs when

$$k(1-\theta)(1-\pi_h R-\pi_l \mu R) \geq c. \tag{1}$$

Assumption 2 and $k \leq 1$ imply that (1) does not hold. Therefore, information acquisition is inefficient. Because information acquisition is contractible, the firm can induce the lender to not acquire information by offering sufficiently low payments if the lender acquires information.[21] The firm's problem is

$$\max_{\mathcal{C}} \sum_z \pi_z \Big[q_z p_z^0 - d_{1z} + \phi_z \left((k - q_z) R - d_{2z} \right) \Big] \tag{2}$$

$$s.t.$$

$$k \leq 1, \tag{3}$$

$$k \leq \sum_z \pi_z (d_{1h} + \phi_z d_{2h}), \tag{4}$$

$$q_z \in [0, k], \quad d_{1z} \leq q_z p_z^0, \quad d_{2z} \leq (k - q_z) R \quad z = h, l, \tag{5}$$

$$p_z^0 = (1 - \gamma_z^0) \phi_z R \quad z = h, l. \tag{6}$$

The firm chooses a contract to maximize its expected profits subject to investment not exceeding the maximum scale (3), the lender's participation constraint (4), which states that the expected payments the lender receives when it does not acquire information must be at least as large as the firm's initial investment, and the promised payments at $t = 1$ and $t = 2$ not exceeding the available funds from liquidation and the project's output (5). Finally, (6) reflects the asset prices in each state when the lender does not acquire information.

Proposition 1. *When information acquisition is contractible, the lender does not acquire information and the optimal contract $\mathcal{C}^{FB}$ is*

$$\mathcal{C}^{FB} \equiv \{k^{FB}, q_h^{FB}, q_l^{FB}, d_{1h}^{FB}, d_{1l}^{FB}, d_{2h}^{FB}, d_{2l}^{FB}\} = \{1, 0, 0, 0, 0, d_{2h}^{FB}, d_{2l}^{FB}\},$$

where

$$\sum_z \pi_z \phi_z d_{2z}^{FB} = 1,$$

$$d_{2z}^{FB} \in [0, R] \quad z = h, l,$$

[21] More specifically, the firm could offer a contract in which the lender breaks even from financing the good project if $a = 1$. If $a = 1$ the lender's profits would be $-c$, so the lender would never acquire information.

and the firm's expected profits are

$$V^{FB} = (\pi_h + \pi_l\phi_l)R - 1.$$

Because the asset price in both states is always less than the expected output of the project $p_z^0 = (1-\gamma_z^0)\phi_z R \leq \phi_z R$, liquidations reduce the firm's expected profits. Hence there are no liquidations or payments at $t = 1$. The firm also invests at full scale because investment is NPV positive. Since the firm has all of the bargaining power, any feasible combination of d_{2h} and d_{2l} that leads (4) to bind constitutes an optimal benchmark contract. The firm's profits V^{FB} equal the expected value of the ex-ante, average project at the full investment scale, which I henceforth refer to as the first-best level of surplus.

3.2 Information Acquisition Non-Contractible

In this section, I show that when information acquisition is non-contractible, if the firm offers the lender $\mathcal{C}^{FB}$, the lender acquires information. In order for the lender to not acquire information, the lender's payoff from acquiring information must be less than its cost. Formally,

$$(1-\theta)\left[k - \pi_h(d_{1h} + d_{2h}) - \pi_l(d_{1l} + \mu d_{2l})\right] \leq c. \tag{7}$$

If we insert the terms of $\mathcal{C}^{FB}$ into (7) we have

$$\frac{\theta(1-\phi_l)(1-\pi_h d_{2h}^{FB})}{\phi_l} \leq c. \tag{8}$$

The LHS of of (8) is at least as large as $\bar{c}$ because $d_{2h}^{FB} \leq R$. However, this implies that (8) is violated because Assumption 2 states that c is less than $\bar{c}$. Thus, the lender would acquire information if the firm offered the lender $\mathcal{C}^{FB}$.

Lemma 1. *When information acquisition is non-contractible, if the firm offers the lender the optimal benchmark contract $\mathcal{C}^{FB}$, the lender acquires information and accepts $\mathcal{C}^{FB}$ if the project is good ($\upsilon = g$) and rejects it otherwise. The firm earns profits strictly less* *than* V^{FB}.

To gain more intuition for why the lender acquires information if offered $\mathcal{C}^{FB}$, compare the lender's private benefits to the social benefits of information acquisition for any contract in which there are no $t = 1$ payments $d_{1h} = d_{1l} = 0$

$$\underbrace{(1-\theta)(k - \pi_h d_{2h} - \pi_l \mu d_{2l})}_{\text{Lender's benefits}} \geq \underbrace{k(1-\theta)(1 - \pi_h R - \pi_l \mu R)}_{\text{Social benefits}}.$$

Because of limited liability, the contract must pay the lender less than the full output of the project when it succeeds $d_{2z} \leq kR$. Intuitively, when deciding whether to produce information, the lender does not internalize the loss in the firm's expected profits from the bad project which can be seen from subtracting the social benefits of information from the lender's benefits

$$\underbrace{(1-\theta)(k - \pi_h d_{2h} - \pi_l \mu d_{2l})}_{\text{Lender's benefits}} - \underbrace{k(1-\theta)(1 - \pi_h R - \pi_l \mu R)}_{\text{Social benefits}}$$
$$= \underbrace{(1-\theta)\left[\pi_h(kR - d_{2h}) + \pi_l \mu(kR - d_{2l})\right]}_{\text{Firm's profits from bad project}}.$$

Given that the project yields R when it succeeds regardless of its type, the lender's private benefits of information acquisition only coincide with the social benefits when the firm earns zero profits. Assumption 2 ensures that c is small enough so that this misalignment of incentives materially affects the financial contracting problem. As shown below, contracts with payments at $t = 1$ can be a way to improve the incentives of the lender because they reduce the lender's expected loss from financing the bad project.

3.3 Second-Best Financial Contract

In this section, I characterize the optimal contract when information acquisition is non-contractible. I separate the search for the optimal contract into two cases i) the optimal contract in which the lender finds it optimal to not acquire information $\mathcal{C}^{0*}$ and ii) the optimal contract in which the lender finds it optimal to acquire information $\mathcal{C}^{1*}$. I then compare the profits between $\mathcal{C}^{0*}$ and $\mathcal{C}^{1*}$ to find the optimal contract $\mathcal{C}^{*}$. Contracts which include payments at $t = 1$, I refer to as "short-term", while contracts that do not I refer to as "long-term".[22]

3.3.1 Optimal Contract that Deters Information Acquisition

To find the optimal contract that deters information acquisition $\mathcal{C}^{0*}$, the firm faces the benchmark problem (2) with the addition of the lender's incentive compatibility constraint (7). It is useful to first establish the following lemma.

Lemma 2. *In the optimal contract that deters information acquisition,*

i) $q_h^{0^*} = d_{1h}^{0^*} = 0$

ii) $d_{2h}^{0^*} = k^{0^*} R$

iii) $d_{1l}^{0^*} = q_l^{0^*} p_l^0$

iv) The incentive compatibility constraint (7) *binds.*

Liquidations and payments at $t = 1$ when $z = h$ lead to liquidation costs but do not affect the lender's incentives (given that the project succeeds regardless of its type). The reason that all output is paid to the lender in the high state, $d_{2h}^{0^*} = k^{0^*} R$ can be seen from the LHS of (8). Fixing the expected payments to the lender at $t = 2$, the private benefits from the lender acquiring information are decreasing in d_{2h}. Hence, the optimal contract includes as large a value of d_{2h} as possible to minimize risky payments in the low state.[23] Finally, the firm only liquidates enough of the project to meet $t = 1$ payments in the low state because the incentives of the lender do not improve if the firm keeps the proceeds from liquidation. The following proposition characterizes $\mathcal{C}^{0*}$.

Proposition 2. *In the optimal contract that deters information acquisition the participation constraint* (4) *binds and the contract and respective profits take two forms depending*

[22] This definition is consistent with regulatory standards where the maturity is tied to when the lender *can* demand repayment versus the unconditional repayment date (see SEC (2019b)).

[23] Since the bad project is NPV negative it must be the case that $\pi_h R < 1$. Therefore, the contract must include payments in the low state for the lender to break-even.

on parameter values:

$$
\begin{aligned}
\mathcal{C}^{0*} = \mathcal{C}^{0L} &\equiv \{k^{0L}, q_h^{0L}, q_l^{0L}, d_{1h}^{0L}, d_{1l}^{0L}, d_{2h}^{0L}, d_{2l}^{0L}\} \\
= &\left\{ \frac{c\phi_l}{\theta(1-\phi_l)(1-\pi_h R)}, 0, 0, 0, 0, k^{0L}R, \frac{c}{\theta\pi_l(1-\phi_l)} \right\}, \\
V^{0^*} = V^{0L} &= k^{0L}\left(\pi_h R + \pi_l \phi_l R - 1\right),
\end{aligned}
$$

or

$$
\begin{aligned}
\mathcal{C}^{0*} = \mathcal{C}^{0S} &\equiv \{k^{0S}, q_h^{0S}, q_l^{0S}, d_{1h}^{0S}, d_{1l}^{0S}, d_{2h}^{0S}, d_{2l}^{0S}\} \\
= &\left\{ 1, 0, \frac{d_{1l}^{0S}}{p_l^0}, 0, \frac{1-\pi_h R - \frac{c\phi_l}{\theta(1-\phi_l)}}{\pi_l}, R, \frac{c}{\theta\pi_l(1-\phi_l)} \right\}, \\
V^{0^*} = V^{0S} &= \pi_l \left(\phi_l \left(R - d_{2l}^{0S}\right) - \frac{d_{1l}^{0S}}{1-\gamma_l^0} \right).
\end{aligned}
$$

There are two potential channels to deter the lender from acquiring information. First, reducing investment k lowers the expected payments required for the lender to break-even. This makes it more difficult for the lender to recoup c through avoiding financing the bad project. Hence, when $\mathcal{C}^{0*} = \mathcal{C}^{0L}$ investment is reduced just enough so that the incentive compatibility constraint (7) binds.

More centrally to the paper, holding the expected payments to the lender constant, shifting payments from $t = 2$ to $t = 1$ in the low state, deters the lender from acquiring information. Because payments at $t = 1$ are independent of the project's quality, shifting payments to $t = 1$ decreases the lender's expected loss from financing the bad project, which in turn lowers the lender's private value of information. Hence, for parameters in which $\mathcal{C}^{0*} = \mathcal{C}^{0S}$, the firm fully invests and the contract includes the minimum payment d_{1l} so that (7) binds.

In summary, the optimal contract that deters information acquisition either includes reduced investment or interim liquidations and payments.

3.3.2 Optimal Contract that Induces Information Acquisition

To find the optimal contract that induces information acquisition $\mathcal{C}^{1*}$, the firm faces the following problem

$$\max_{\mathcal{C}} \theta \sum_z \pi_z \left(q_z p_z^1 - d_{1z} + (k - q_z)R - d_{2z} \right) \tag{9}$$

$$s.t.$$

$$k \leq 1,$$

$$c \leq \theta \left(\sum_z \pi_z (d_{1z} + d_{2z}) - k \right), \tag{10}$$

$$c \leq (1-\theta) \left[k - \pi_h (d_{1h} + d_{2h}) - \pi_l (d_{1l} + \mu d_{2l}) \right], \tag{11}$$

$$q_z \in [0, k], \quad d_{1z} \leq q_z p_z^1, \quad d_{2z} \leq (k - q_z) R \quad z = h, l,$$

$$p_z^1 = (1 - \gamma_z^1) R \quad z = h, l. \tag{12}$$

The main differences between (9) and the problem that deters information acquisition are i) the participation constraint (10) which reflects the lender's payoff if it acquires information, ii) the incentive compatibility constraint (11) which states that the lender must prefer to acquire information and iii) asset prices (12) because the lender only finances the good project when $a = 1$. As in the benchmark case, there are no benefits of liquidations, demanding payments at $t = 1$ or reducing investment. Hence, (11) is slack (i.e. the lender will always acquire information) and (10) binds and the firm captures the full surplus.

Proposition 3. *The optimal contract that induces information acquisition takes the fol-*

lowing form:

$$\mathcal{C}^{1*} = \mathcal{C}^{1L} \equiv \{k^{1L}, q_h^{1L}, q_l^{1L}, d_{1h}^{1L}, d_{1l}^{1L}, d_{2h}^{1L}, d_{2l}^{1L}\} = \{1, 0, 0, 0, 0, d_{2h}^{1L}, d_{2l}^{1L}\},$$

where

$$\theta\left(\sum_z \pi_z d_{2z}^{1L} - 1\right) = c,$$

$$d_{2z}^{1L} \in [0, R] \quad z = h, l.$$

The firm's expected profits $V^{1^*} = V^{1L}$ *where:*

$$V^{1L} = \theta(R-1) - c.$$

The firm ultimately bears the cost of the lender's inefficient information production and its profits are strictly less than the first-best $V^{1L} < V^{FB}$.

3.3.3 Optimal Contract

The optimal contract can be found by comparing the expected profits between the three classes of contracts ($\mathcal{C}^{0S}$, $\mathcal{C}^{0L}$ and $\mathcal{C}^{1L}$).

Proposition 4. *Let* $V^* \equiv \max\{V^{0S}, V^{0L}, V^{1L}\}$. *The optimal contract* $\mathcal{C}^*$ *is:*

$$\mathcal{C}^* = \begin{cases} \mathcal{C}^{0S} & \text{if } V^* = V^{0S} \\ \mathcal{C}^{0L} & \text{if } V^* = V^{0L} \\ \mathcal{C}^{1L} & \text{if } V^* = V^{1L} \end{cases}$$

Figure 4 depicts example regions of the parameter space in which each of the candidate contracts is optimal, varying the probability of the low state π_l and the liquidation cost in the low state when the lender does not acquire information γ_l^0. Henceforth, I refer to $\mathcal{C}^{0S}$ as the short-term contract and $\mathcal{C}^{0L}$ and $\mathcal{C}^{1L}$ as long-term contracts.

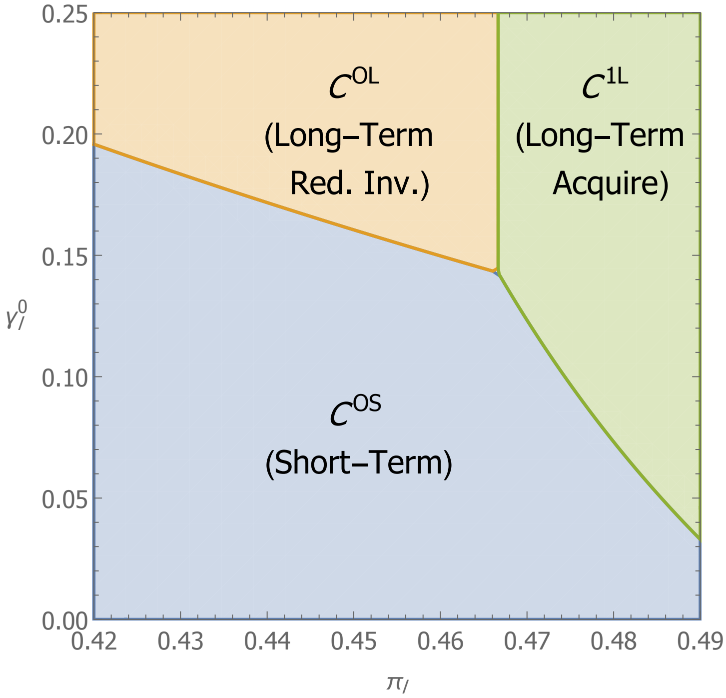

Figure 4: Optimal Contract. This figure depicts regions of the parameter space in which each of the candidate contracts is optimal ($\mathcal{C}^{0S}$, $\mathcal{C}^{0L}$ and $\mathcal{C}^{1L}$) for the example parameters: $\theta = \mu = 0.5, R = 1.2, c = 0.05$, varying π_l and γ_l^0.

3.4 Comparative Statics and Discussion

In this section, I discuss comparative statics and particular features of the short-term contract.

Proposition 5. *The lower the liquidation cost in the low state when the lender does not acquire information γ_l^0, the more likely the short-term contract is optimal $\mathcal{C}^* = \mathcal{C}^{0S}$.*

The profits from the short-term contract V^{0S} are decreasing in γ_l^0, while the profits of both of the long-term contracts are unaffected by γ_l^0. Hence, the lower γ_l^0 the more likely the firm chooses the short-term contract. In reality, financial assets likely have lower liquidation costs than real assets which makes short-term debt a cost-effective method to deter inefficient information production for financial firms. This result will also play an important role in market equilibrium where certain shocks can cause an endogenous increase in the liquidation cost, which then affects firms' decisions to use short-term financing.

I now analyze the maturity of the short-term contract $\mathcal{C}^{0S}$ where I refer to its maturity being "shorter" if d_{1l}^{0S} is larger. A higher probability of the low state π_l leads to a shorter maturity of the short-term contract.[24]

Proposition 6. *The maturity of the short-term contract is decreasing in the probability of the low state, i.e.* d_{1l}^{0S} *is increasing in* π_l*.*

There is only uncertainty in payoffs across project types in the low state; thus, as π_l increases, the lender's value of information increases. In order to induce the lender not to acquire information, the interim payment in the low state must increase.[25] Because firms must liquidate more assets as the interim payment increases, a higher probability of the low state also makes the short-term contract less likely to be optimal as can be see in Figure 4. This result also plays a role in the market equilibrium as the aggregate maturity structure will endogenously affect liquidation costs.

The payment from the firm to the lender at the $t = 1$ in the low state resembles the variation margins used by financial firms which require counterparties to post cash collateral when the value of their assets drops. This form of short-term debt is distinct from standard short-term debt contracts that can be rolled over by any party (e.g. Flannery (1986) and Diamond (1991)). In my setting it is key that the initial lender does not refinance the interim payment, otherwise the lender would anticipate this and acquire information at $t = 0$. Hence, the particular form of short-term financing that arises in this setting shares the feature of short-term loans used by financial firms in practice.

4 Market Equilibrium

In this section I incorporate information acquisition in the outside financial market to endogenize liquidation costs. Since there is no uncertainty in payoffs across project types in the high state, I focus the analysis on information production in the low state at $t = 1$.

[24] This is also true if maturity is defined as the relative ratio of payments in the low state $\frac{d_{1l}^{0S}}{d_{2l}^{0S}+d_{1l}^{0S}}$.

[25] To isolate the effect from higher uncertainty, one can easily show that this result holds if the NPV of the project $(\pi_h + \pi_l \phi_l)R - 1$ is held constant while π_l varies.

4.1 Market Equilibrium Setup

There is a unit mass of firms indexed by i that are distributed uniformly in the interval $[0, 1]$. Firms' project qualities $\upsilon(i)$ are iid and have the same distribution as in the baseline model. Each firm makes an offer to a single lender at $t = 0$ where $a(i)$ refers to firm i's lender's information acquisition decision at $t = 0$. The outside financial market is composed of a single deep-pocketed, informed investor and a competitive fringe of uninformed investors. I assume there is one informed investor rather than many to avoid a the potential for a multiplicity of equilibrium in the outside financial market (e.g. Fishman and Parker (2015) and Bolton, Santos, and Scheinkman (2016)) and to simplify the exposition. The timing is the same as the baseline model; however the investor in the outside financial market can acquire information at $t = 1$, which affects the endogenously determined liquidation costs.

After the low state has been realized at $t = 1$, the informed investor can randomly match with a measure of $\eta \geq 0$ firms by incurring $\kappa(\eta) > 0$, where $\kappa(\cdot) > 0$ is a strictly increasing and convex function of η. If the investor matches with firm i, both parties learn the firm's project type and the informed investor makes an offer to buy its assets for sale $q_l(i)$ for $q_l(i)p_l(i)$. Matching and offers are anonymous so the uninformed investors cannot observe which firms previously received offers from the informed investor. Therefore, a firm that does not sell its asset to the informed investor can sell its assets to the uninformed investors for the competitively determined market price p_l^a, where there can be different prices received by firms whose lenders have acquired information and those that have not (i.e. p_l^0 and p_l^1). Figure 5 displays the timing in the liquidation stage.[26] I make the following assumptions regarding the cost function $\kappa(\cdot)$.

Assumption 3 (Cost Function)**.**

1. $\kappa'(1) > \frac{d_{1l}^{0S}\theta(1-\phi_l)\left(1-\theta(1-\phi_l^2)\right)}{\phi_l(1-\theta(1+(1-\phi_l)\phi_l))}$

[26] The discussed mechanisms are a stylized representation of how trading occurs in reality. Financial assets trade in several different ways. For example most stocks trade in organized exchanges, convertible bonds trade in dealer markets and structured products may trade in even less transparent ways through bilateral agreements. The key ingredient is that the informed investor is able to distinguish good assets from bad when they buy them at the market price. In the Appendix, I show that an auction yields the same asset prices as the market mechanism in the main text.

1. State $z = l$ is realized
2. Informed investor incurs $\kappa(\eta)$ to the quality of η projects
3. Informed investor make offers to buy firms' assets
4. Any unsold assets are sold to uninformed for p_l^a

Figure 5: Liquidation Stage Timing at t = 1.

2. $\kappa''(\eta) > \frac{d_{1l}^{0S}\theta^2(1-\phi_l)}{(1-\eta\theta(1+(1-\phi_l)\phi_l))^2} \; \forall \eta$

Assumption 3.1 ensures the marginal value of producing information about more projects is negative once the informed investor produces information about all projects.[27] Assumption 3.2 ensures that the informed investor's profits are concave in η, which allows for interior solutions.

The informed investor can be thought of as another financial firm with sufficient funds to purchase assets in the low state. For instance Mitchell, Pedersen, and Pulvino (2007) show that multi-strategy hedge funds become net buyers of convertible bonds when convertible arbitrage hedge funds become distressed. Uninformed investors can represent less sophisticated institutional investors. For example Ben-David, Franzoni, and Moussawi (2012) find that insurance companies, pension funds and retail investors stepped in to buy assets sold by hedge funds during the 2008/2009 financial crisis. Although each firm has one project, it is best to think of firms liquidating individual assets within their portfolio to meet interim payments and the informed investor producing information about these individual assets rather than the portfolio as a whole.

4.2 Market Equilibrium Analysis

In this section I characterize equilibrium asset prices, investors' decisions to become informed and firms' financial contracts. In the high state, both good and bad projects pay off R with certainty; hence, there is no potential for adverse selection and $p_h^0 = p_h^1 = R$.

[27] This assumption is not strictly necessary but simplifies the exposition so that I can ignore corner solutions in which all investors become informed.

Define $\mathcal{I}^0$ the set of firms whose their lenders do not acquire information at $t = 0$ and $\mathcal{I}^1$ the set of firms whose their lenders do acquire information

$$\mathcal{I}^0 \equiv \{i : a(i) = 0\}, \quad \mathcal{I}^1 \equiv \{i : a(i) = 1\}.$$

Firms $i \in \mathcal{I}^1$ are financed only if the project is good, implying that the uninformed are willing to pay $p_l^1 = R$. Therefore, if the informed investor matches with a firm $i \in \mathcal{I}^1$ in the low state, the informed investor offers $p_l(i) = p_l^1 = R$ and the firm accepts. If a firm $i \in \mathcal{I}^1$ does not match with the informed investor, it sells its assets to the uninformed for $p_l^1 = R$. Hence, regardless of matching outcomes all firms $i \in \mathcal{I}^1$ receive $p_l^1 = R$.

The remaining price to characterize is p_l^0. Since the informed investor's matching and offers are anonymous, uninformed investors cannot distinguish the quality of individual assets in the pool sold by firms $i \in \mathcal{I}^0$. Therefore, $p_l^0 \in [pR, R]$ where p_l^0 depends on the inferred proportion of good assets sold to the uninformed. Consider a firm $i \in \mathcal{I}^0$ that matches with the informed investor. If its project is good its expected payoff R is always greater than p_l^0. Since each firm's outside option is p_l^0, the informed investor offers $p_l(i) = p_l^0$ and the firm accepts. In contrast, if the project is bad its expected payoff is pR which is always less than p_l^0.[28] Thus, the firm rejects any offer the informed investor makes and sells the asset to the uninformed investors for p_l^0.[29] A firm that does not match with the informed investor also sells its assets to the uninformed for p_l^0. Summarizing,

Lemma 3.

1. *If the informed investor matches with a firm $i \in \mathcal{I}^1$ at $t = 1$ it buys the asset at $p_l^1 = R$*

2. *If the informed investor matches with a firm $i \in \mathcal{I}^0$ at $t = 1$,*

   (a) *it buys the asset at p_l^0 if the asset is good*

   (b) *it does not buy the asset otherwise.*

[28] I confirm in equilibrium that the inequality is strict.

[29] Note that even if the firm does not keep any of the proceeds itself, it would default if $pRq_l(i) < d_{1l}(i)$ which means it always prefers selling the assets for a higher price.

Table 1: Liquidation Costs

	$a = 1$	$a = 0$
$z = h$	$\gamma_h^1 = 0$	$\gamma_h^0 = 0$
$z = l$	$\gamma_l^1 = 0$	$\gamma_l^0 = \frac{\eta\theta(1-\phi_l)}{(1-\eta\theta)\phi_l} \geq 0$

3. *Any assets that go unsold to the informed investor are purchased at* p_l^a *by the uninformed investors*

Lemma 3 implies that the market price received by firms $i \in \mathcal{I}^0$ is

$$p_l^0(\eta) = \Big(1 - \underbrace{\frac{\eta\theta(1-\phi_l)}{(1-\eta\theta)\phi_l}}_{\gamma_l^0 \text{ (Adverse selection)}}\Big) \underbrace{\phi_l R}_{\text{Expected value}}, \tag{13}$$

where $p_l^0(\eta)$ is decreasing in η as a larger portion of low quality assets flow to the uninformed due to the informed investor "cream skimming" good assets. Table 1 summarizes the liquidation costs in each state borne by firms whose lenders acquire and do not acquire information.

Next, I turn to the informed investor's decision to produce information taking firms' contracts as given. Define the aggregate asset sales and payments made by firms $i \in \mathcal{I}^0$

$$Q \equiv \int_{\mathcal{I}^0} q_l(i)di, \quad D \equiv \int_{\mathcal{I}^0} d_{1l}(i)di.$$

The expected payoff from the informed investor producing information about η firms is

$$\Pi(\eta) = \int_0^\eta \Big(\underbrace{\theta Q \left(R - p_l^0(\eta)\right)}_{\text{Information rents}} d\eta\Big) - \kappa(\eta). \tag{14}$$

If the the informed investor matches with a firm $i \in \mathcal{I}^1$ it pays $p_l^1 = R$ for $q_l(i)$ units of the asset and earns zero profits. If the informed investor matches with a firm $i \in \mathcal{I}^0$ there is a θ probability the firm's asset is good in which case the investor pays $p_l^0(\eta)$ for $q_l(i)$

units of the asset that yield R with certainty where (14) integrates over all firms $i \in \mathcal{I}^0$. From Lemma 2, $d_{1l}^{0*} = q_l^{0*} p_l^0$, so for convenience (14) can be written as

$$\Pi(\eta) = \int_0^{\eta} \theta D \left(\frac{R}{p_l^0(\eta)} - 1 \right) d\eta - \kappa(\eta). \tag{15}$$

Assumption ensures that (15) is concave in η.[30] Hence, if $\Pi(0) < 0$ then the informed investor does not produce information about any projects $\eta^* = 0$. Otherwise, η^* solves $\Pi'(\eta^*) = 0$. It immediately follows that η^* is increasing in D. Formally,

Lemma 4. *Shorter aggregate maturities induce the informed investor to produce information about a larger number of projects, i.e.* $\frac{d\eta^*}{dD} \geq 0$*, where the inequality is strict when* $\eta^* > 0$.

Shorter aggregate maturities in turn affect equilibrium asset prices which can be seen by differentiating $p_l^0(\eta^*)$ with respect to D

$$\frac{dp_l^0(\eta^*)}{dD} = \frac{\partial p_l^0}{\partial \eta^*} \frac{d\eta^*}{dD} \leq 0. \tag{16}$$

The first term is negative and $\frac{d\eta^*}{dD}$ is positive, and strictly positive when $\eta^* > 0$, from Lemma 4. In summary when $\eta^* > 0$, as D increases, the informed investor produces information about more projects, which causes $p_l^0(\eta^*)$ drops. Hence, the informed investor's information production yields a downward sloping demand curve in the asset market.

Now that I have established the main properties of the liquidation stage, I can define the market equilibrium.

Definition 2. *A market equilibrium consists of contracts* $\mathcal{C}(i)$ *for all* i*, information acquisition decisions by each firm's lender* $a(i)$ *for all* i*, a mass of firms* η^* *that the informed investor produces information about at* $t = 1$ *when* $z = l$*, and asset prices* $\{p_z^a\}_{z=h,l,\, a=0,1}$*, such that:*

1. *Firms' contracts are optimal* $\mathcal{C}(i) = \mathcal{C}^*$ *for all* i

[30] This can clearly be seen by replacing D with the largest amount of $t = 1$ aggregate payments in the low state d_{1l}^{0S}.

2. *Lenders information acquisition decisions are optimal given contracts*

3. *The informed investor's decision to produce information is optimal given firms' contracts and asset prices*

4. *Asset markets clear in each state.*

The following definitions will be useful for characterizing the equilibrium.

Definition 3. *The long-term contract that yields the highest profits and its corresponding profits are*

$$\mathcal{C}^{L*} = \begin{cases} \mathcal{C}^{0L} & \text{if } V^{0L} \geq V^{1L} \\ \mathcal{C}^{1L} & \text{otherwise,} \end{cases}$$

and

$$V^{L*} = \max\{V^{0L}, V^{1L}\}.$$

I also define aggregate short-term debt α as the mass of firms that borrow short-term which is equivalent to the amount of investment funded by short-term contracts since $k^{0S} = 1$ in the short-term contract. Formally,

Definition 4. *Aggregate short-term debt α is*

$$\alpha \equiv \int_0^1 \mathbb{I}(\mathcal{C}(i) = \mathcal{C}^{0S})di.$$

Proposition 7. *The equilibrium mass of firms using short-term contracts α^*, the mass of firms the informed investor produces information about η^* and liquidation costs in the low state γ_l^{0*} borne by firms $i \in \mathcal{I}^0$ are one of the following types depending on the parameter values*

Type 1: $\alpha^* = 1$, $\eta^* = 0$ *and* $\gamma_l^{0*} = 0$

Type 2: $\alpha^* = 1$, $\eta^* > 0$ *and* $\gamma_l^{0*} > 0$

Type 3: $\alpha^* \in (0,1)$, $\eta^* > 0$ *and* $\gamma_l^{0*} > 0$,

where in all equilibrium types a mass $1-\alpha^*$ *of firms choose* $\mathcal{C}^{L*}$.

In the Type 1 equilibrium all firms use short-term contracts and the informed investor does not produce information about any firms which results in a liquidation cost of zero in the asset market. In the Type 2 equilibrium all firms use short-term contracts and a positive mass of investors become informed, where all firms still find it optimal to use short-term contracts because liquidation costs are not too high. Finally, in the Type 3 equilibrium, if all firms chose short-term contracts, liquidation costs would be so high that it would no longer be optimal for any firms to use short-term contracts. When this is the case, a mass of firms less than 1 choose short-term contracts such that firms are indifferent between the short-term contract and the long-term contract that yields the highest profits.

To understand the real consequences of the market equilibrium, I define aggregate investment as the sum of realized investment across firms accounting for i) firms that choose $\mathcal{C}^{0L}$ invest less than 1 and ii) firms that choose $\mathcal{C}^{1L}$ are only financed when the project is good which occurs with probability θ. Formally,

Definition 5. *Aggregate investment* K *is:*

$$K = \begin{cases} \alpha + (1-\alpha)I^{0L} & \text{if } \mathcal{C}^{L*} = \mathcal{C}^{0L} \\ \alpha + (1-\alpha)\theta & \text{otherwise.} \end{cases}$$

Therefore, equilibrium aggregate investment K^* can be characterized in the follow corollary.

Corollary 1. *If the equilibrium is Type 1 or Type 2,* $K^* = 1$, *otherwise* $K^* < 1$.

Hence, if the adverse selection in the asset market is severe enough aggregate investment becomes impaired through a portion of firms resorting to long-term financing.

4.3 The Effect of Uncertainty on Aggregate Short-Term Debt and Investment

In this section I show how an increase in uncertainty can lead to a reduction in aggregate short-term debt and investment. Recall that the only uncertainty in payoffs across project types occurs in the low state and from Proposition 6, the maturity of the short-term contract is decreasing in the probability of the low state, i.e. d_{1l}^{0S} is increasing in π_l. Hence, in the market equilibrium whenever $\alpha^* = 1$ (i.e. Type 1 or Type 2 equilibrium) an increase in π_l leads to an increase in equilibrium aggregate interim payments D^*. In the Type 2 equilibrium, higher aggregate interim payments lead to an increase in the mass of investors that become informed causing liquidation costs to increase. If the probability of the low state becomes large enough the equilibrium can switch from Type 2 to Type 3 in which some firms use long-term contracts, resulting in a drop in aggregate investment and short-term debt. This is summarized in the following proposition.[31]

Proposition 8. *Aggregate investment K^* and short-term debt α^* are decreasing in π_l.*

Although I have only considered exogenous changes in π_l, other changes in parameters that increases the value of information for lenders lead to an increase in d_{1l}^{0S} which in turn increases adverse selection in the asset market.

Proposition 8 can help explain why short-term funding markets periodically become impaired. These episodes are often associated with increases in uncertainty and reduced maturities of short-term debt (e.g. the 2008/2009 financial crisis).

4.4 Welfare

In this section I ask whether firms' financing decisions in the market equilibrium are efficient. I do so by considering a concept of constrained efficiency in which a planner can manipulate the mass of firms using short-term contracts α to maximize welfare, but cannot directly affect the information production decisions of lenders and the informed

[31]This is true even if the NPV of the project $(\pi_h + \pi_l \phi_l)R - 1$ is held constant while π_l varies.

investor. For simplicity, I follow Gromb and Vayanos (2002) by considering an infinitesimal change in α. Total welfare $W(\alpha)$ is the sum of firm and the informed investor's profits

$$W(\alpha) \equiv \alpha V^{0S} + (1-\alpha)V^{L*} + \pi_l \Pi(\eta^*).$$

Differentiating $W(\alpha)$ with respect to α

$$\frac{dW(\alpha)}{d\alpha} = V^{0S} - V^{L*} + \alpha \frac{dV^{0S}}{d\alpha} + \pi_l \frac{d\Pi(\eta^*)}{d\alpha}. \tag{17}$$

The first two terms reflect the difference in profits between firms using short-term contracts and long-term contacts. In the Type 2 equilibrium this is strictly positive, while in the Type 3 equilibrium it equals zero because firms are indifferent between short and long-term contracts. The last two terms reflect the two externalities that individual firms do not take into account when determining their own maturity structures. The third term is the price impact of firms' short-term contracts on asset prices which is negative because the demand curve is downward sloping from (16). Finally, the last term is the impact of firms' short-term contracts on the informed investor's profits, which is positive because shorter aggregate maturities allow the informed investor to buy more assets at a cheap price. The following proposition characterizes the efficiency of the equilibrium.

Proposition 9 (Inefficient Short-Term Debt)**.** *The efficiency of each equilibrium type is as follows*

1. *The Type 1 equilibrium is always constrained efficient*

2. *The planner can raise welfare in the Type 2 equilibrium by reducing α below $\alpha^* = 1$ when demand curve is sufficiently downward sloping*

$$\frac{dp_l^0(\eta^*)}{d\alpha^*} < -\frac{p_l^0(\eta^*)(d_{1l}^{0S} R\eta^*\theta + (V^{0S} - V^{L*} - d_{1l}^{0S}\eta^*\theta)p_l^0(\eta^*))}{d_{1l}^{0S} R\alpha^* \left(\phi_l - \eta^*\theta\right)}.$$

3. *The planner can raise welfare in the Type 3 equilibrium by reducing α below $\alpha^* < 1$*

when the demand curve is sufficiently downward sloping

$$\frac{dp_l^0(\eta^*)}{d\alpha^*} < -\frac{\eta^*\theta(R - p_l^0(\eta^*))p_l^0(\eta^*)}{\alpha^* R\,(\phi_l - \eta^*\theta)},$$

and raise welfare by increasing α above $\alpha^* < 1$ otherwise.

In the Type 1 equilibrium there is no information production at any point and the first-best is achieved $W(\alpha^*) = V^{FB}$. However, the Type 2 and Type 3 equilibrium are inefficient if the demand curve is sufficiently downward sloping. Intuitively, the demand curve slopes downward because shorter aggregate maturities induce information production in the asset market, which is purely wasteful from a social perspective. Hence, the planner would like to avoid this if possible. However, fixing the amount of information the informed investor produces, higher levels of short-term debt also lead to higher profits for the informed investor from more firms facing an adverse selection discount. While individual firms would like to avoid the adverse selection discount, it is irrelevant to the planner because it has no effect on total welfare. The relative magnitude of these two effects determines the efficiency of the Type 2 and Type 3 equilibrium. In the Type 2 equilibrium there can only be too much short-term debt since all firms are using short-term contracts ($\alpha^* = 1$), while in the Type 3 equilibrium there can be too little short-term debt when the demand curve sufficiently flat.

Proposition 9 can rationalize taxes of short-term debt (i.e. repo contracts or margin loans) in good times (Type 2 equilibrium) and subsidizing short-term debt when short-term debt markets become impaired (Type 3 equilibrium). In practice, the latter situation may occur in periods when adverse selection is already severe and the cost of producing information about marginal projects is high or informed investors have already devoted substantial capital to investing in distressed assets.

A caveat to my normative analysis is that I have only considered the inefficiency that may arise from short-term debt through pecuniary externalities in asset markets. There may also be coordination problems that arise between creditors (e.g. He and Xiong (2012) and Brunnermeier and Oehmke (2013)). In addition, when regulating debt maturity and choosing monetary policy, policymakers must distinguish between short-term debt demanded by investors with liquidity needs (e.g. Diamond and Dybvig (1983), Stein (2012) and Diamond (2016)) and short-term debt being used to prevent inefficient information production by lenders. In Stein (2012), the government can reduce the incentives of financial institutions to issue safe securities by issuing them itself. This policy would not have an effect in the context of my model because firms borrow short-term for reasons unrelated to the demand for safe assets.

In practice, regulators can also directly intervene in asset markets. For example if the a regulator committed to buying all assets at $t = 1$ in the low state at R, there would be no incentive for investors to become informed and the first-best would be achieved. However, asset market interventions may have other costs such as moral hazard (e.g. Farhi and Tirole (2012a) and Lee and Neuhann (2017)) or direct costs of intervention. Therefore, I leave the consideration of these types of interventions for future work.

5 Conclusion

In this paper, I propose a new rationale for the widespread use of short-term debt by non-bank financial firms. In particular, I argue that short-term financing allows financial firms to avoid excessive information production by their financiers. This problem may be particularly severe for financial firms that borrow heavily from financial institutions, such as banks, that have expertise in the same types of assets.

Although short-term financing deters information production at origination, it leads to excessive information production when firms liquidate to repay their initial lenders following a negative shock. This delay in information production endogenously raises the cost of short-term financing through information-based fire sales. Moreover, when market conditions deteriorate, short-term funding markets can become impaired, i.e. short-term debt maturities shorten, while the volume of total credit decreases. These implications are consistent with the behavior of numerous short-term debt markets in the 2008/2009 financial crisis.

From a welfare perspective, my analysis rationalizes 1) policymakers' concerns that financial firms' are overly reliant on short-term debt as opposed to detailed credit analysis (Basel Committee on Banking Supervision (1999)) in normal times and 2) short-term debt markets should be supported when they malfunction in financial crises.

Future empirical work could directly test whether shorter debt maturities reduce information production by lenders, while inducing information production in the asset market. In addition, testing how sensitive asset prices are to short-term debt through deferring information production may be useful for policymakers in determining whether or not short-term funding markets should be curbed or supported.

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A Appendix

A.1 Data Description for Figure 1

The hedge fund data is from SEC (2019a) where short-term debt is defined as debt with a maturity under 365 days (Table 48) and Debt/Assets is derived from Borrowing/NAV (Figure 4a). The mortgage REIT data is from Pellerin, Sabol, and Walter (2013a) where short-term debt is defined as repo agreements. The mortgage originator debt maturity data comes from Kim et al. (2018) where they define short-term debt as warehouse loans (typically under a year maturity) and "other forms of short-term". Mortgage originator leverage is defined as secured debt to tangible assets and is taken from a poll of 10 firms by Moody's (Moody's Investor Service, 2016). Industrial firms are from Compustat fiscal year-end 2018 and short-term debt is defined as debt with maturity under one year. I remove any financial firms within the SIC range of 6000-6999 and exclude firms with leverage greater than 1.

A.2 Proofs

Proof of Proposition 1. Denote $\mathcal{C}^{FB} \equiv \{k^{FB}, q_h^{FB}, q_l^{FB}, d_{1h}^{FB}, d_{1l}^{FB}, d_{2h}^{FB}, d_{2l}^{FB}\}$ the optimal benchmark contract. To show $q_h^{FB} = 0$, suppose to the contrary that $q_h^{FB} > 0$. First suppose that $d_{1h}^{FB} = 0$. If the firm reduces q_h^{FB} by any $\epsilon > 0$ where $q_h^{FB} - \epsilon \geq 0$, (4) and (5) would not be violated while the firm's profits (2) would increase because $\gamma_h^0 \geq 0$, which contradicts that $\mathcal{C}^{FB}$ is optimal. Next suppose that $d_{1h}^{FB} > 0$. If the firm reduces q_h^{FB} by any $\epsilon > 0$ where $q_h^{FB} - \epsilon \geq 0$, decreases d_{1h}^{FB} by $\frac{\epsilon}{p_h^0}$ and increase d_{2h}^{FB} by ϵ, (4) and (5) would not be violated and (2) would increase. The same steps can be used to show that $q_l^{FB} = 0$. Since $q_h^{FB} = q_l^{FB} = 0$, (5) implies that $d_{1h}^{FB} = d_{1l}^{FB} = 0$.

To show that $k^{FB} = 1$, suppose to the contrary $k^{FB} < 1$. If the firm increases k^{FB} by any $\epsilon > 0$ where $k^{FB} + \epsilon \leq 1$, increases d_{2h}^{FB} by ϵR and increases d_{2l}^{FB} by $\frac{1-\pi_h R}{\pi_l \phi_l}$, (4) and (5) would not be violated and the firm's profits (2) would increase. Therefore $k^{FB} = 1$. We can rewrite the problem as follows

$$\max_{\mathcal{C}} \sum_z \pi_z \phi_z (R - d_{2h}),$$

$$s.t.$$

$$1 \leq \sum_z \pi_z \phi_z d_{2z}, \tag{A.1}$$

$$d_{2z} \in [0, R] \quad z = h, l. \tag{A.2}$$

Since the firm has all of the bargaining power (A.1) binds with equality. Thus any contract that leads (A.1) to bind and satisfies (A.2) constitutes an optimal benchmark contract and the firm earns profits

$$V^{FB} = (\pi_h + \pi_l \phi_l) R - 1.$$

■

Proof of Lemma 1. From (8) the lender would produce information if offered $\mathcal{C}^{FB}$. The firm's profits would be

$$\theta \left(\sum_z \pi_z (R - d_{2z}) \right). \tag{A.3}$$

Note that the benchmark optimal contract that makes (A.3) largest while satisfying (A.1) is $d_{2h} = R$ and $d_{2l} = \frac{1-\pi_h R}{\pi_l \phi_l}$ which yields

$$\frac{\theta \left(\pi_h R + \pi_l \phi_l R - 1 \right)}{\phi_l}. \tag{A.4}$$

However, (A.4) is strictly less than V^{FB} because $\frac{\theta}{\phi_l} < 1$. ■

Proof of Lemma 2. Denote $\mathcal{C}^{0*} \equiv \{k^{0*}, q_h^{0*}, q_l^{0*}, d_{1h}^{0*}, d_{1l}^{0*}, d_{2h}^{0*}, d_{2l}^{0*}\}$ the optimal contract that deters information acquisition. The same steps from the proof of Proposition 1 can be used to show that $q_h^{0*} = d_{1h}^{0*} = 0$. To show that $d_{1l}^{0*} = q_l^{0*} p_l^0$, suppose to the contrary $q_l^{0*} p_l^0 > d_{1l}^{0*}$. If the firm reduces q_l^{0*} by an $\epsilon > 0$ where $(q_l^{0*} - \epsilon)p_l^0 \geq d_{1l}^{0*}$, (5) would not be violated while the firm's profits (2) would increase because $\gamma_l^0 \geq 0$. Therefore $d_{1l}^{0*} = q_l^{0*} p_l^0$. The problem can then be rewritten as

$$\max_{\mathcal{C}} \pi_h(kR - d_{2h}) + \pi_l \phi_l \left(\left(k - \frac{d_{1l}}{p_l^0} \right) R - d_{2l} \right),$$

$$s.t.$$

$$k \leq 1,$$

$$k \leq \pi_h d_{2h} + \pi_l(d_{1l} + \phi_l d_{2l}), \tag{A.5}$$

$$(1-\theta)(k - \pi_h d_{2h} - \pi_l(d_{1l} + \mu d_{2l})) \leq c, \tag{A.6}$$

$$d_{2h} \leq kR, \tag{A.7}$$

$$d_{2l} \leq \left(k - \frac{d_{1l}}{p_l^0} \right) R. \tag{A.8}$$

Next we can prove the incentive compatibility constraint (A.6) binds. By Lemma 1, (A.6) is violated if the following three conditions are true: i) $d_{1l} = 0$, ii) $k = 1$ and iii) the participation constraint (A.5) binds; hence at least one of the above conditions do not hold. I then prove by contradiction that (A.6) binds in each of these three cases.

Case 1. $d_{1l}^{0*} > 0$

Suppose to the contrary that $d_{1l}^{0*} > 0$ and (A.6) is slack. There exists a small enough $\epsilon > 0$ such that if the firm decreases d_{1l}^{0*} by ϵ and increases d_{2l}^{0*} by $\frac{\epsilon}{\phi_l}$, then (A.5), (A.6) and (A.8) would not be violated. This would reduce q_l^{0*} which causes the firm's profits to increase because $\gamma_l^0 \geq 0$.

Case 2. $k^{0*} < 1$

Suppose to the contrary that $k^{0*} < 1$ and (A.6) is slack. There exists a small enough $\epsilon > 0$ such that if the firm increases k^{0*} by ϵ and increases d_{2h}^{0*} by ϵR and increases d_{2l}^{0*} by $\frac{1-\pi_h R}{\pi_l \phi_l}$, then (A.5), (A.6), (A.7) and (A.8) would not be violated, while the firm's profits would increase.

Case 3. *The participation constraint* (A.5) *is slack*

Suppose to the contrary (A.5) and (A.6) are slack. There exists a small enough $\epsilon > 0$ such that if the firm decreased d_{2h}^{0*}, d_{1l}^{0*}, or d_{2l}^{0*} by ϵ, then (A.5), (A.6), (A.7) and (A.8) would not be violated, while the firm's profits would increase. These three cases imply that the incentive compatibility constraint must bind.

Finally to prove $d_{2h}^{0*} = k^{0*}R$, suppose to the contrary $d_{2h}^{0*} < k^{0*}R$. If the firm increases d_{2h}^{0*} by $\epsilon > 0$ where $d_{2h}^{0*} + \epsilon \leq k^{0*}R$ and decreases d_{2l}^{0*} by $\frac{\epsilon}{\phi_l}$, then (A.5), (A.7) and (A.8) would not be violated and (A.6) would slacken. However, as just shown (A.6) must bind at the optimum, which contradicts $\mathcal{C}^{0*}$ being optimal. ■

Proof of Proposition 2. Following Lemma 2 and ignoring (A.8) for now, the problem can be written as

$$\max_{\mathcal{C}} \pi_l \phi_l \left[\left(k - \frac{d_{1l}}{p_l^0} \right) R - d_{2l} \right],$$

$$s.t.$$

$$k \leq 1, \tag{A.9}$$

$$k(1 - \pi_h R) \leq \pi_l (d_{1l} + \phi_l d_{2l}), \tag{A.10}$$

$$(1 - \theta) \left[k(1 - \pi_h R) - \pi_l (d_{1l} + \mu d_{2l}) \right] = c. \tag{A.11}$$

The Lagrangian is

$$\mathcal{L} = \pi_l \phi_l \left[\left(k - \frac{d_{1l}}{p_l^0} \right) R - d_{2l} \right] - \lambda_1 \big[k(1 - \pi_h R) - \pi_l (d_{1l} + \phi_l d_{2l}) \big] -$$
$$\lambda_2 \big[(1 - \theta) \left(k(1 - \pi_h R) - \pi_l (d_{1l} + \mu d_{2l}) \right) - c \big] - \lambda_3 (k - 1).$$

The Kuhn-Tucker necessary conditions are

$$\mathcal{L}_{d_{1l}} = \frac{\pi_l \left(p_l^0 \left(\lambda_1 + (1-\theta)\lambda_2 \right) - \phi_l R \right)}{p_l^0} \leq 0,$$
$$\mathcal{L}_{d_{2l}} = \pi_l \big[\phi_l \left(1 - \lambda_1 \right) - \mu (1 - \theta) \lambda_2 \big] \leq 0,$$
$$\mathcal{L}_k = \pi_l \phi_l R - (1 - \pi_h R)(\lambda_1 + (1 - \theta)\lambda_2) - \lambda_3 \leq 0,$$
$$\mathcal{L}_{d_{1l}} d_{1l} = 0, \quad \mathcal{L}_{d_{2l}} d_{2l} = 0, \quad \mathcal{L}_k k = 0,$$
$$\lambda_1 \big[k(1 - \pi_h R) - \pi_l (d_{1l} + \phi_l d_{2l}) \big] = 0,$$
$$(1 - \theta) \big[k(1 - \pi_h R) - \pi_l (d_{1l} + \mu d_{2l}) \big] - c = 0,$$
$$\lambda_3 (k - 1) = 0,$$
$$\lambda_1 \geq 0, \quad \lambda_2 > 0, \quad \lambda_3 \geq 0,$$
$$\text{(A.10), (A.11), (A.9)}.$$

There are many potential solutions to the system of equations; however, several can be eliminated immediately upon inspection. After doing so we are left with three potential solutions

$$k = 1, \quad d_{1l} = \frac{1 - \pi_h R - \frac{c\phi_l}{\theta(1-\phi_l)}}{\pi_l}, \quad d_{2l} = \frac{c}{(1-\phi_l)\theta\pi_l}, \tag{A.12}$$
$$\lambda_1 = \frac{\phi_l(p_l^0 - \mu R)}{(1-\mu)\theta p_l^0}, \quad \lambda_2 = \frac{\phi_l(\phi_l R - p_l^0)}{(1-\phi_l)\theta p_l^0}, \quad \lambda_3 = \frac{\phi_l R\left[\pi_l p_l^0 - (1-\pi_h R)\right]}{p_l^0}.$$

$$k = \frac{\phi_l c}{(1-\phi_l)\theta(1-\pi_h R)}, \quad d_{1l} = 0, \quad d_{2l} = \frac{c}{(1-\phi_l)\theta\pi_l}, \tag{A.13}$$
$$\lambda_1 = \frac{\phi_l(1 - \pi_h R - \pi_l \mu R)}{(1-\mu)\theta(1-\pi_h R)}, \quad \lambda_2 = \frac{\phi_l(\pi_h R + \pi_l \phi_l R - 1)}{(1-\phi_l)\theta(1-\pi_h R)}, \quad \lambda_3 = 0.$$

$$k = 1, \quad d_{1l} = 0, \quad d_{2l} = \frac{1 - c - \theta - \pi_h R(1-\theta)}{\mu(1-\theta)\pi_l}, \tag{A.14}$$
$$\lambda_1 = 0, \quad \lambda_2 = \frac{\phi_l}{(1-\theta)\mu}, \quad \lambda_3 = \frac{\phi_l(\pi_h R + \pi_l \mu R - 1)}{\mu}.$$

First, (A.14) can be ruled out because $\lambda_3 < 0$ from Assumption 1.1. In order for (A.12) to be a solution, it must be the case that $\gamma_l^0 \leq 1 - \frac{1-\pi_h R}{\pi_l \phi_l R}$ so that $\lambda_3 \geq 0$. (A.13) is a potential solution because $\lambda_1 > 0$ by Assumption 1.1. However, $\mathcal{L}_{d_{1l}} > 0$, only if $\gamma_l^0 > 1 - \frac{1-\pi_h R}{\pi_l \phi_l R}$. Therefore, if $\gamma_l^0 \leq 1 - \frac{1-\pi_h R}{\pi_l \phi_l R}$ (A.12) is the solution while (A.13) is the solution otherwise. Also, note that (A.8) is not violated in any of the candidate solutions. ■

Proof of Proposition 3. Denote $\mathcal{C}^{1*} \equiv \{k^{1*}, q_h^{1*}, q_l^{1*}, d_{1h}^{1*}, d_{1l}^{1*}, d_{2h}^{1*}, d_{2l}^{1*}\}$ the optimal contract that induces information acquisition. The same steps from the proof of Proposition 1 can be used to show there are no liquidations or payments at $t = 1$ and $k^{1*} = 1$; however, in all cases (11) must remain slack which is always true because of Assumption 2. We can then rewrite the problem as follows

$$\max_{\mathcal{C}} \theta \sum_z \pi_z (R - d_{2z}), \tag{A.15}$$

$$s.t.$$

$$\theta\left(\sum_z \pi_z d_{2z} - 1\right) \geq c, \tag{A.16}$$

$$d_{2z} \in [0, R] \quad z = h, l. \tag{A.17}$$

Since the firm has all of the bargaining power (A.16) binds. Therefore any contract that leads (A.16) to bind and satisfies (A.17) constitutes an optimal contract. The expected profits can be found by plugging the terms of $\mathcal{C}^{1*}$ into (A.15). ■

Proof of Proposition 4. The proof comes immediately from comparing the profits from $\mathcal{C}^{0*}$ and $\mathcal{C}^{1*}$ from Propositions 2 and 3.

■

Proof of Proposition 5. Differentiating V^{0S} with respect to γ_l^0 we have

$$\frac{\frac{c\phi_l}{\theta(1-\phi_l)} + \pi_h R - 1}{(1-\gamma_l^0)^2} < 0.$$

V^{0L} and V^{1L} do not vary with γ_l^0, hence the lower γ_l^0 the more likely $\mathcal{C}^* = \mathcal{C}^{0S}$. ■

Proof of Proposition 6. Differentiating d_{1l}^{0S} with respect to π_l we have

$$\frac{R - 1 + \frac{c\phi_l}{\theta(1-\phi_l)}}{\pi_l^2} > 0.$$

Notice this also true if we define maturity as $\frac{d_{1l}^{0S}}{d_{1l}^{0S}+d_{2l}^{0S}}$

$$\frac{\partial\left(\frac{d_{1l}^{0S}}{d_{1l}^{0S}+d_{2l}^{0S}}\right)}{\partial \pi_l} = \frac{c\theta R}{\left(1-\phi_l\right)\left(c+\theta\left(1-\pi_h R\right)\right)^2} > 0.$$

■

Proof of Lemma 3. See text. ■

Proof of Lemma 4. To see the effect of shorter maturities on the equilibrium number of informed investors we can apply the implicit function theorem

$$\frac{d\eta^*}{dD} = \begin{cases} 0 & \text{if } \Pi(0) < 0 \\ -\frac{\frac{\partial \Pi(\eta^*)}{\partial \eta^*}}{\frac{\Pi(\eta^*)}{\partial D}} = \frac{\theta(1-\phi_l)(1-\eta\theta-\eta\theta(1-\phi_l)\phi_l)\left(1-\eta\theta+\eta\theta\phi_l^2\right)}{\phi_l((1-\eta\theta-\eta\theta(1-\phi_l)\phi_l)^2\kappa''(\eta)-D\theta^2(1-\phi_l))} & \text{if } \Pi(0) \geq 0, \end{cases} \tag{A.18}$$

Focusing on $-\frac{\frac{\partial \Pi(\eta^*)}{\partial \eta^*}}{\frac{\Pi(\eta^*)}{\partial D}}$, the numerator is always positive and the denominator is positive from Assumption 3.2. Hence $\frac{d\eta^*}{dD} \geq 0$ and the inequality is strict when $\Pi(0) > 0$. ■

Proof of Proposition 7. For convenience, define the set of contracts that deter the lender from producing information.

$$\mathcal{C}^0 \equiv \{\mathcal{C} : a = 0\}.$$

Let $V^{0S}(D)$ denote the profits from the short-term contract and $\Pi(\eta, D)$ the informed investor's profits each as a function of the aggregate payments at $t = 1$ in the low state D. I break the proof into three cases.

Case 1. $\Pi\left(0, d_{1l}^{0S}\right) < 0$

If $\alpha = 1$ no investors would find it optimal to become informed $\eta = 0$. Hence, $\eta^* = 0$, $\gamma_l^{0*} = 0$ and $\alpha^* = 1$ (from Proposition 4).

Case 2. $\Pi\left(0, d_{1l}^{0S}\right) \geq 0$ *and* $V^{0S}(d_{1l}^{0S}) \geq V^{L^*}$

Since $\Pi\left(0, d_{1l}^{0S}\right)$, if $\alpha = 1$ then a positive mass of investors $\eta^* > 0$ would find it optimal to become informed resulting in a positive liquidation cost $\gamma_l^{0*} > 0$. However, the resulting profits from the short-term contract $V^{0S}(d_{1l}^{0S})$ are sufficiently high enough such that all firms still find it optimal to choose $\mathcal{C}^{0S}$ by Proposition 4. Hence $\alpha^* = 1$, $\eta^* > 0$, and $\gamma_l^{0*} > 0$.

Case 3. $V^{0S}(d_{1l}^{0S}) < V^{L^*}$

If $\alpha = 1$, the liqudation cost γ_l^0 would be so high that no firms would find it optimal to choose $\mathcal{C}^{0S}$. However, if $\alpha = 0$, then $\gamma_l^0 = 0$ and all firms would find it optimal to choose $\mathcal{C}^{0S}$. Thus, all firms must choose contracts $\mathcal{C}(i)$ such that they are indifferent between $\mathcal{C}(i)$ and the most profitable long-term contract $V(i) = V^{L*}$ for all i.

Lemma A.1. *In Case 3* $V(i) = V^{L*}$ *for all* i.

Proof. Suppose to the contrary there is some contract $\mathcal{C}'$ used in equilibrium in which $V' \neq V^{L*}$. First it can never be the case that $V' < V^{L*}$ by Proposition 4. Now suppose that $V' > V^{L*}$. Since, $\mathcal{C}^{1L} = \mathcal{C}^{1*}$, if $V' > V^{L*}$ then $\mathcal{C}' \in \mathcal{C}^0$. Since $V' > V^{0L}$ it must be that $\mathcal{C}' = \mathcal{C}^{0S}$ by Proposition 2. However, if $V^{0S} > V^{L*}$, then all firms would choose $\mathcal{C}(i) = \mathcal{C}^{0S}$, which is a contradiction because $V^{0S}(d_{1l}^{0S}) < V^{L*}$. Therefore, $V(i) = V^{L*}$ for all i in Case 3. ■

There are two sub-cases within Case 3.

Subcase 1. $\mathcal{C}^{L*} = \mathcal{C}^{1L}$

First note that it cannot be that $\mathcal{C}(i) = \mathcal{C}^{1L}$ for all i because if this were true $\gamma_l^0 = 0$ which would induce all firms to choose $\mathcal{C}^{0S}$. Therefore there must be some contract $\mathcal{C}' \in \mathcal{C}^0$ used in equilibrium with profits V' where from Lemma A.1, $V' = V^{1L}$. From Proposition 2, it must be the case that $\mathcal{C}' = \mathcal{C}^{0S}$. Thus, the only contracts that are used in equilibrium are $\mathcal{C}^{0S}$ and $\mathcal{C}^{1L}$ where α is the fraction of firms that choose $\mathcal{C}^{0S}$. Hence, the following equation characterizes α^*

$$G(\alpha^* d_{1l}^{0S}) = V^{0S}\left(\alpha^* d_{1l}^{0S}\right) - V^{1L} = 0.$$

First note that $\alpha^* \neq 1$ because $V^{0S}(d_{1l}^{0S}) < V^{1L}$. Define $\underline{\alpha}$ as the largest α such that no investors become informed $\eta^* = 0$

$$\underline{\alpha} = \arg\max_{\alpha} \alpha \quad s.t. \quad \eta^* = 0.$$

Since $V^{0S}\left(\underline{\alpha} d_{1l}^{0S}\right) = V^{FB} > V^{1L}$, it must be that $\alpha^* \in (\underline{\alpha}, 1)$. In this region γ_l^0 is strictly increasing in α from (A.18). Hence, $V^{0S}\left(\alpha d_{1l}^{0S}\right)$ is strictly decreasing in α and there exists a unique $\alpha^* \in (0,1)$ such that $G(\alpha^* d_{1l}^{0S}) = 0$.

Subcase 2. $\mathcal{C}^{L*} = \mathcal{C}^{0L}$

From Lemma A.1 $V(i) = V^{0L}$ for all i. It will be useful to establish the following lemma

Lemma A.2. *In Case 3 when* $\mathcal{C}^{L*} = \mathcal{C}^{0L}$, $V^{0S}(D^*) = V^{0L}$.

Proof. Suppose $V^{0S}(D^*) < V^{0L}$ then from Proposition 2 all firms to choose $\mathcal{C}^* = \mathcal{C}^{0L}$. However, if this is the case $\gamma_l^0 = 0$ which is a contradiction. Suppose $V^{0S}(D^*) > V^{0L}$ then from Proposition 2 all firms would choose $\mathcal{C}^* = \mathcal{C}^{0L}$. However, if this is the case $V^{0S}(d_{1l}^{0S}) < V^{0L}$ which is also a contradiction. ■

Lemma A.2 implies that the Lagrange multiplier (λ_3) on the constraint $k \leq 1$ for the candidate solution (A.12) equals zero. Hence, there can potentially be other contracts $\mathcal{C} \in \mathcal{C}^0$ other than $\mathcal{C}^{0S}$ and $\mathcal{C}^{0L}$ used in equilibrium. The following conditions characterize the equilibrium

$$\begin{gathered}
k(i)(1-\pi_h R) = \pi_l \left(d_{1l}(i) + \phi_l d_{2l}(i)\right) \quad \forall i, \\
(1-\theta)\left[k(i)(1-\pi_h R) - \pi_l \left(d_{1l}(i) + \mu d_{2l}(i)\right)\right] = c \quad \forall i, \\
d_{1l}(i) \geq 0 \quad \forall i, \\
V(i; D^*) = V^{0L} \quad \forall i.
\end{gathered}$$

Each firm's participation constraint and incentive compatibility constraint bind and all firms must earn profits equal to the long-term contract with reduced investment given D^*. Further simplifying,

$$\begin{gathered}
d_{2l}(i) = \frac{c}{\theta \pi_l (1-\phi_l)} \quad \forall i, \\
k(i) = \frac{c\phi_l + d_{1l}(i)(1-\phi_l)\theta\pi_l}{(1-\phi_l)\theta(1-\pi_h R)} \quad \forall i, \\
d_{1l}(i) \geq 0 \quad \forall i, \\
V(i; D^*) = V^{0L} \quad \forall i.
\end{gathered} \tag{A.19}$$

Integrating (A.19) over i,

$$K^* = \int_0^1 k(i)di = \frac{c\phi_l + D^*(1-\phi_l)\theta\pi_l}{(1-\phi_l)\theta(1-\pi_h R)}.$$

Since K^* and D^* do not depend on the exact distribution of firms' contracts, I focus on the case where firms choose between $\mathcal{C}^{0S}$ and $\mathcal{C}^{0L}$. Therefore, the following equation characterizes the equilibrium

$$G(\alpha^* d_{1l}^{0S}) = V^{0S}\left(\alpha^* d_{1l}^{0S}\right) - V^{0L} = 0.$$

As in the previous sub-case, $V^{0S}\left(\alpha d_{1l}^{0S}\right)$ is strictly decreasing in α when $\alpha \in [\underline{\alpha}, 1]$. Therefore, there exists a unique $\alpha^* \in (0,1)$ such that $G(\alpha^* d_{1l}^{0S}) = 0$. ∎

Proof of Corollary 1. From Proposition 7 in the Type 1 and 2 equilibria $\alpha^* = 1$. Therefore $K^* = 1$ because $k^{0S} = 1$. In the Type 3 equilibrium $\alpha^* < 1$ which implies $K^* < 1$ because $\theta < 1$ and $k^{0L} < 1$. ∎

Proof of Proposition 8. Recall in the Type 3 equilibrium, α^* solves

$$G(\alpha^* d_{1l}^{0S}) = V^{0S}\left(\alpha^* d_{1l}^{0S}\right) - V^{L*} = 0.$$

Applying the implicit function theorem

$$\frac{d\alpha^*}{d\pi_l} = -\frac{\frac{\partial G}{\partial \pi_l}}{\frac{\partial G}{\partial \eta^*}\frac{d\eta^*}{dD}\frac{\partial D}{\partial \alpha^*}} = -\frac{(-)}{(-)(+)(+)} < 0. \tag{A.20}$$

Differentiating K^* with respect to π_l when $\mathcal{C}^{L*} = \mathcal{C}^{0L}$

$$\left.\frac{dK^*}{d\pi_l}\right|_{\mathcal{C}^{L*}=\mathcal{C}^{0L}} = (1-\alpha^*)\underbrace{\frac{\partial k^{0L}}{\partial \pi_l}}_{(-)} + (1-k^{0L})\underbrace{\frac{d\alpha^*}{d\pi_l}}_{(-)} < 0.$$

and when $\mathcal{C}^{L*} = \mathcal{C}^{1L}$

$$\left.\frac{dK^*}{d\pi_l}\right|_{\mathcal{C}^{L*}=\mathcal{C}^{1L}} = (1-\theta)\underbrace{\frac{d\alpha^*}{d\pi_l}}_{(-)} < 0.$$

Next we need to show that K^* is decreasing in π_l at the point where $V^{0L} = V^{1L}$. First note that $V^{0L} - V^{1L}$ is decreasing in π_l

$$\frac{\partial(V^{0L} - V^{1L})}{\partial \pi_l} = -\frac{c(R-1)R\phi_l^2}{(1-\phi_l)\theta(1-\pi_h R)^2} < 0.$$

This implies that as π_l increases it becomes more likely that $\mathcal{C}^{L*} = \mathcal{C}^{1L}$. Finally we need to show that the realized investment level for $\mathcal{C}^{1L}$ is lower than $\mathcal{C}^{0L}$ when the profits from those contracts are equal i.e. $\theta < k^{0L}$ when $V^{1L} = V^{0L}$

$$k^{0L} - \theta = \frac{c\phi_l}{\theta(1-\phi_l)(1-\pi_h R)} - \theta,$$

which is negative when $V^{1L} = V^{0L}$. Hence, when the equilibrium is Type 3, both K^* and α^* are decreasing in π_l. The last step is to show that as π_l increases the equilibrium moves from Type 1 to Type 2 to Type 3. When the equilibrium is Type 1 the following condition holds

$$\Pi\left(0, d_{1l}^{0S}\right) < 0. \tag{A.21}$$

Since d_{1l}^{0S} is increasing in π_l, an increase in π_l tightens (A.21). When the equilibrium is Type 2, the following conditions are true

$$\Pi\left(0, d_{1l}^{0S}\right) > 0, \tag{A.22}$$

$$V^{0S}\left(d_{1l}^{0S}\right) \geq V^{L*} \tag{A.23}$$

An increase in π_l relaxes (A.22) and from (A.20) tightens (A.23). Therefore, as π_l increases the equilibrium moves from Type 1 to Type 2. When the equilibrium is Type 3, the following condition is true:

$$V^{0S}\left(d_{1l}^{0S}\right) < V^{L*}. \tag{A.24}$$

An increase in π_l relaxes (A.24). Therefore, as π_l increases the equilibrium moves from Type 2 to Type 3. Note that the equilibrium cannot jump from Type 1 to Type 3 from increasing π_l continuously because (A.21) implies (A.23). Summarizing, if an increase in π_l causes the equilibrium to switch types, the new equilibrium type results in a lower K^* and α^*. Together all of these pieces imply that α^* and K^* are decreasing in π_l. ■

Proof of Proposition 9 . In the Type 1 equilibrium, there is no information production by lenders or the informed investor and all firms fully invest $K^* = 1$. Hence the Type 1 equilibrium achieves the first-best: $V^{0S} = V^{FB}$. In the Type 2 equilibrium $\eta^* > 0$ and $\alpha^* = 1$. Since all firms choose the short-term contract there can never be too little short-term financing.

From the terms in (17) first notice that

$$\frac{dV^{0S}}{d\alpha^*} = \frac{d_{1l}^{0S} R\alpha^* \phi_l \frac{dp_l^0(\eta^*)}{d\alpha^*}}{p_l^0(\eta^*)^2}. \tag{A.25}$$

Also notice that

$$\begin{aligned}
\frac{d\Pi(\eta)}{d\alpha^*} =& \frac{d}{d\alpha^*}\int_0^{\eta^*} \theta D\left(\frac{R}{p_l^0(\eta^*)} - 1\right) d\eta - \kappa(\eta^*) \\
=& \left[\theta D\left(\frac{R}{p_l^0(\eta^*)} - 1\right)\right]\frac{d\eta^*}{d\alpha^*}\eta^* + \frac{\partial}{\partial\eta^*}\frac{d\eta^*}{d\alpha^*}\int_0^{\eta^*}\left[\theta D\left(\frac{R}{p_l^0(\eta^*)} - 1\right)\right] d\eta - \kappa(\eta^*) \\
=& \left[\theta D\left(\frac{R}{p_l^0(\eta^*)} - 1\right)\right]\frac{d\eta^*}{d\alpha^*}\eta^* \\
=& \frac{d_{1l}^{0S}\eta^*\theta\left(R\left(p_l^0(\eta^*) - \alpha^*\frac{dp_l^0(\eta^*)}{d\alpha^*}\right) - p_l^0(\eta^*)^2\right)}{p_l^0(\eta^*)^2}
\end{aligned} \tag{A.26}$$

where the third line comes from the fact that $\int_0^{\eta^*}\frac{d}{d\alpha}\left[\theta D\left(\frac{R}{p_l^0(\eta^*)} - 1\right)\right] d\eta - \frac{d}{d\alpha}\kappa(\eta^*) = 0$ at the informed investor's optimal information production choice. Substituting (A.25) and (A.26) into (17) we have

$$\frac{dW(\alpha)}{d\alpha} = V^{0S} - V^{L*} + d_{1l}^{0S}\left(\frac{R\eta^*\theta p_l^0(\eta^*) + R\alpha\left(\phi_l - \eta^*\theta\right)\frac{dp_l^0(\eta^*)}{d\alpha^*}}{p_l^0(\eta^*)^2} - \eta^*\theta\right)$$

Simplifying in terms of $\frac{dp_l^0(\eta^*)}{d\alpha^*}$ we have the following condition for $\frac{dV^{0S}}{d\alpha^*} < 0$ in the Type 2 equilibrium

$$\frac{dp_l^0(\eta^*)}{d\alpha^*} < \frac{p_l^0(\eta^*)(d_{1l}^{0S}R\eta^*\theta + (V^{0S} - V^{L*} - d_{1l}^{0S}\eta^*\theta)p_l^0(\eta^*))}{d_{1l}^{0S}R\alpha^*\left(\phi_l - \eta^*\theta\right)}. \tag{A.27}$$

Hence, whenever the demand curve is sufficiently downward sloping there is too much short-term financing in the Type 2 equilibrium. In the Type 3 equilibrium $\alpha^* < 1$, hence there can potentially be too much or too little short-term financing. At the Type 3 equilibrium point $V^{0S} - V^{L*} = 0$ so (A.27) simplifies to

$$\frac{dp_l^0(\eta^*)}{d\alpha^*} < -\frac{\eta^*\theta(R - p_l^0(\eta^*))p_l^0(\eta^*)}{\alpha^*R\left(\phi_l - \eta^*\theta\right)},$$

Hence whenever the demand curve is sufficiently downward sloping, the planner can raise welfare by reducing the amount of short-term financing. Otherwise, the planner can raise welfare by increasing the amount of short-term financing. ■

B Online Appendix

In the Online Appendix I include various robustness checks and extensions. To avoid overburdensome notation, for each individual section I will refer to $\mathcal{C}^{0*}$, $\mathcal{C}^{1*}$ and $\mathcal{C}^{*}$ as the revised versions of the optimal contract without information acquisition, with information acquisition and overall optimal contract for that particular section. I will be explicit when referring to the specific versions of these contracts in the main text.

B.1 Firm Can Raise Additional Funds at $t = 0$ and Store Funds Across Dates

In the main text I do not allow the firm to raise additional funds beyond k at $t = 0$ or store funds across dates. In this section I show that this is without loss of generality. Consider the following revised definition of a financial contract.

$$\mathcal{C} \equiv \{k, q_z, d_0, d_{1z}, d_{2z}(\tilde{R}), e_0, e_{1z}, e_{2z}(\tilde{R})\}_{z=h,l,\ \tilde{R}=R,0} \tag{B.1}$$

The differences between Definition 1 and (B.1) are i) d_0 which is the funds the firm raises at $t = 0$ which can potentially exceed k and ii) the payment at $t = 2$ $d_{2z}(\tilde{R})$ can be conditioned on the project's success or failure, and iii) e is the firm's consumption that may depend on the state and project output. The revised definition of the contract will only be relevant for the optimal contract without information acquisition $\mathcal{C}^{0*}$. For the optimal contract with information production $\mathcal{C}^{1*}$ as long as the firm captures the full surplus and the lender acquires information its profits will always be $V^{1*} = \theta(R-1) - c$. The timing of the firm's consumption is irrelevant because the firm is risk-neutral and there is no discounting. Hence, it is without loss of generality to assume the firm stores any excess funds raised at $t = 0$ to $t = 1$. The firm's problem can be written as

$$\max_{\mathcal{C}} d_0 - k + \sum_z \pi_z \Big[q_z p_z^0 - d_{1z} + \phi_z \left[(k - q_z) R - d_{2z}(R) \right] - (1 - \phi_z) d_{2z}(0) \Big],$$

$$s.t.$$

$$\begin{aligned}
& k \le d_0, \quad k \le 1, \\
& d_0 \le \pi_h (d_{1h} + d_{2h}) + \pi_l \left[d_{1l} + \phi_l d_{2l}(R) + (1 - \phi_l) d_{2l}(0) \right], \\
& (1 - \theta) \left(d_0 - \pi_h (d_{1h} + d_{2h}) - \pi_l \left[d_{1l} + p d_{2l}(R) + (1 - p) d_{2l}(0) \right] \right) \le c, \\
& q_z \in [0, k], \quad d_{1z} \le q_z p_z^0 + d_0 - k \quad z = h, l, \\
& d_{2h}(R) \le d_0 - k + q_h p_h^0 - d_{1h} + (k - q_h) R, \\
& d_{2l}(\tilde{R}) \le d_0 - k + q_l p_l^0 - d_{1l} + (k - q_l) \tilde{R} \quad \tilde{R} = R, 0, \\
& p_z^0 = (1 - \gamma_z^0) \phi_z R, \quad z = h, l.
\end{aligned} \tag{B.2}$$

Using the same steps from Proposition 1 we can show $q_h^{0*} = 0$. Since there is no difference in the lender's expected payments or the firm's profits if the lender receives payments in the high state at $t = 1$ or $t = 2$ it is w.l.o.g to set $d_h^{0*} = 0$. In addition, using the same steps from Lemma 2 we can show the incentive compatibility constraint (B.2) binds and $d_{2h}^{0*} = k^{0*}(R-1) + d_0^{0*}$. Define δ_1 as the firm's cash at the beginning of $t = 1$

$$\delta_1 \equiv d_0 - k,$$

and δ_{2z} as the firm's cash at the beginning of $t = 2$:

$$\delta_{2z} \equiv d_0 - k + q_z p_z^0 - d_{1z} \quad z = h, l.$$

We can then rewrite the problem as follows

$$\max_{\mathcal{C}} \pi_l \Big[\phi_l \left[\delta_{2l} + (k - q_l)\, R - d_{2l}(R)\right] + (1-\phi_l)\left[\delta_{2l} - d_{2l}(0)\right]\Big], \tag{B.3}$$

$$s.t.$$

$$k \le d_0, \quad k \le 1,$$

$$d_0 \le \pi_h(\delta_1 + kR) + \pi_l\left[d_{1l} + \phi_l d_{2l}(R) + (1-\phi_l) d_{2l}(0)\right], \tag{B.4}$$

$$(1-\theta)\left(d_0 - \pi_h(\delta_1 + kR) - \pi_l\left[d_{1l} + \mu d_{2l}(R) + (1-\mu) d_{2l}(0)\right]\right) = c, \tag{B.5}$$

$$q_l \in [0, k], \quad d_{1l} \le q_l p_l^0 + \delta_1$$

$$d_{2l}(\tilde{R}) \le \delta_{2l} + (k - q_l)\,\tilde{R} \quad \tilde{R} = R, 0,$$

$$p_z^0 = (1-\gamma_z^0)\phi_z R, \quad z = h, l.$$

It will be useful to establish the following lemma.

Lemma B.1. $d_{2l}(0)^{0*} = \delta_{2l}^{0*}$

Proof. Suppose to the contrary $d_{2l}(0)^{0*} < \delta_{2l}^{0*}$. First consider the case in which $d_{2l}^{0*}(R) > 0$. If the firm increases $d_{2l}(0)^{0*}$ by $\epsilon > 0$ where $d_{2l}(0)^{0*} + \epsilon \le \delta_{2l}^{0*}$ and reduces $d_{2l}^{0*}(R)$ by $\left(\frac{1-\phi_l}{\phi_l}\right)\epsilon$, (B.4) would not be violated while (B.5) would slacken which contradicts $\mathcal{C}^{0*}$ being optimal. Next consider the case in which $d_{2l}^{0*}(R) = 0$. Since $\pi_h R < 1$, it must be that $q_l^{0*} > 0$ in order for (B.4) to not be violated. To see this, suppose that $q_l^{0*} = 0$, and insert the largest value of $d_{2l}(0)^{0*} = d_0 - k - d_{1l}$ into (B.4) and we have

$$k(1 - \pi_h R) - \pi_l \phi_l (d_0 - k - d_{1l}) \le 0 \tag{B.6}$$

Inserting the largest possible value of $d_{1l}^{0*} = d_0 - k$ into (B.6) we have

$$k(1 - \pi_h R) \le 0$$

Which is violated so long as $k > 0$. Hence $q_l^{0*} > 0$. The firm can then reduce q_l^{0*} by ϵ and no constraints are violated while the firm's profits (B.3) increase since $\gamma_l^0 \geq 0$. ■

Once again rewriting the problem following Lemma B.1

$$\max_{\mathcal{C}} \pi_l \phi_l \left[\delta_{2l} + (k - q_l) R - d_{2l}(R)\right],$$
$$s.t.$$
$$k \leq d_0, \quad k \leq 1,$$
$$d_0 \leq \pi_h(\delta_1 + kR) + \pi_l \left[d_{1l} + \phi_l d_{2l}(R) + (1 - \phi_l)\delta_{2l}\right], \tag{B.7}$$
$$(1 - \theta)\left(d_0 - \pi_h(\delta_1 + kR) - \pi_l \left[d_{1l} + \mu d_{2l}(R) + (1 - \mu)\delta_{2l}\right]\right) = c, \tag{B.8}$$
$$q_l \in [0, k], \quad d_{1l} \leq q_l p_l^0 + \delta_1$$
$$d_{2l}(R) \leq \delta_{2l} + (k - q_l) R,$$
$$p_l^0 = (1 - \gamma_l^0)\phi_l R.$$

Expanding (B.7) and (B.8),

$$d_0 \leq \pi_h(\delta_1 + kR) + \pi_l \left[\phi_l(d_{1l} + d_{2l}(R)) + (1 - \phi_l) q_l p_l^0\right],$$
$$(1 - \theta)\left(d_0 - \pi_h(\delta_1 + kR) - \pi_l \left[\mu(d_{1l} + d_{2l}(R)) + (1 - \mu) q_l p_l^0\right]\right) = c.$$

Upon inspection, we can see the lender's incentives to acquire information and the firm's profits are invariant between d_{1l} and $d_{2l}(R)$, i.e. storing funds from $t = 1$ to $t = 2$. Hence, it is without loss of generality to set $\delta_{2l}^{0*} = 0$ and rewrite the problem as

$$\max_{\mathcal{C}} \pi_l \phi_l \left[\delta_1 + (k - q_l) R - d_{2l}(R)\right],$$
$$s.t.$$
$$k \leq d_0, \quad k \leq 1,$$
$$d_0 \leq \pi_h(\delta_1 + kR) + \pi_l \left[d_{1l} + \phi_l d_{2l}(R)\right],$$
$$(1 - \theta)\left(d_0 - \pi_h(\delta_1 + kR) - \pi_l \left[d_{1l} + \mu d_{2l}(R)\right]\right) = c,$$
$$q_l \in [0, k], \quad d_{1l} \leq q_l p_l^0 + \delta_1, \quad d_{2l}(R) \leq (k - q_l) R,$$
$$p_l^0 = (1 - \gamma_l^0)\phi_l R.$$

We can use the same steps from Lemma 2 to show that $d_{1l}^{0*} = q_l^{0*} p_l^0 + \delta_1^{0*}$. The problem can be written as

$$\max_{\mathcal{C}} \pi_l \phi_l \left[(k - q_l) R - d_{2l}(R) \right],$$

$$s.t.$$

$$k \leq 1,$$

$$k \leq \pi_h k R + \pi_l \left(q_l p_l^0 + \phi_l d_{2l}(R) \right),$$

$$(1-\theta) \left(k - \pi_h k R - \pi_l (q_l p_l^0 + \mu d_{2l}(R)) \right) = c,$$

$$q_l \in [0, k], \quad d_{2l}(R) \leq (k - q_l) R,$$

$$p_l^0 = (1 - \gamma_l^0) \phi_l R,$$

where d_0 simply drops out. Hence, it is without loss of generality that the firm only raises k initially and does not store funds across periods.

B.2 Firm Knows Project Type and Lender Cannot Acquire Information

In this section, I analyze the case in which the firm knows υ and the lender cannot acquire information. This is useful to show that exogenous asymmetric information alone will not lead to firms' using short-term financing.

Because the firm knows its project type, its contract offer may be a signal about its type. First note that there can never be a separating equilibrium because the bad project is NPV negative. Depending on off-equilibrium beliefs, there can be a multiplicity of equilibria. To narrow down the potential equilibria, I apply undefeated equilibrium refinement from Mailath, Okuno-Fujiwara, and Postlewaite (1993).

This refinement allows the firm with the good project to choose a contract that yields the highest profits subject to being mimicked by the firm with the bad project. The problem can be written as

$$\max_{\mathcal{C}} \sum_z \pi_z \left(q_z p_z^0 - d_{1z} + (k - q_z) R - d_{2z} \right)$$

$$s.t.$$

$$k \leq 1,$$

$$k \leq \sum_z \pi_z (d_{1z} + \phi_z d_{2z}), \tag{B.9}$$

$$q_z \in [0, k], \quad d_{1z} \leq q_z p_z^0, \quad d_{2z} \leq (k - q_z) R \quad z = h, l,$$

$$p_z^0 = (1 - \gamma_z) \phi_z R, \quad z = h, l.$$

The following lemma immediately follows.

Lemma B.2. *In the optimal contract in which the firm knows its project type and the lender cannot acquire information,*

i) $q_h^* = q_l^* = 0$

ii) $d_{1h}^* = d_{1l}^* = 0$

iii) $k^* = 1$

iv) $d_{2h}^* = R$.

Proof. i) and ii) follow from the same steps as Proposition 1. Suppose $k^* < 1$. If we increase k^* by ϵ and increase d_{2h}^* by ϵR and increase d_{2l}^* by $\frac{\epsilon(1-\pi_h R)}{\pi_l \phi_l}$ (B.9) is not violated and the objective increase which is a contradiction. Suppose that $d_{2h}^* < R$. If we increase d_{2h}^* by ϵ and decrease d_{2l}^* by $\frac{\pi_h \epsilon}{\pi_l \phi_l}$ (B.9) is not violated and the objective increase which is a contradiction. ■

After Lemma B.2, the problem reduces to

$$\max_{\mathcal{C}} \pi_l (R - d_{2l})$$

$$s.t.$$

$$(1 - \pi_h R) \leq \pi_l \phi_l d_{2l}. \tag{B.10}$$

Since the firm has all of the bargaining power (B.10) binds and the optimal contract is

$$\mathcal{C}^* \equiv \{k^*, q_h^*, q_l^*, d_{1h}^*, d_{1l}^*, d_{2h}^*, d_{2l}^*\} = \left\{1, 0, 0, 0, 0, R, \frac{1 - \pi_h R}{\pi_l \phi_l}\right\}.$$

B.3 Firm Knows Project Type and Lender Can Acquire Information

In this section, I analyze the case in which the firm knows υ and the lender has the same information acquisition technology as in the baseline model. I apply the same undefeated equilibrium refinement from Mailath, Okuno-Fujiwara, and Postlewaite (1993). Therefore, the firm with the good project chooses the contract that maximizes its profits subject to pooling with the firm with the bad project. Note that because the lender can acquire information, the lender may be able to distinguish the types after the contract offer. Similarly, when the firm knows its type the optimal contract without information production coincides with the optimal contract from the main text $\mathcal{C}^{1*} = \mathcal{C}^{1L}$. Since from Lemma 1, the lender will acquire information if the firm offers a contract in which $k = 1$

and $q_l = d_{1l} = 0$, the firm with the good project's profits from $\mathcal{C}^{1L}$ is

$$R - 1 - c. \tag{B.11}$$

For simplicity, assume information acquisition is contractible. As in the benchmark case there is no value to liquidations; therefore, the lender's break-even condition is

$$k \leq \sum_z \pi_z \phi_z d_{2z}. \tag{B.12}$$

To minimize pooling costs, the firm with the good project chooses $d_{2h} = kR$ and (B.12) binds. Therefore, the firm with the good project's profits are

$$\pi_l k \left(R - \frac{1 - \pi_h R}{\pi_l \phi_l} \right),$$

which is strictly less than (B.11). Hence, the firm with the the good project wants to induce the lender to acquire information to avoid the pooling cost with the firm with the bad project. This result is similar to Fulghieri and Lukin (2001). Therefore, the optimal contract is $\mathcal{C}^* = \mathcal{C}^{1L}$.

B.4 Both Firm and Lender Can Acquire Information

In this section I analyze the case in which the firm can also incur c to learn υ. Before the firm offers the lender a contract, the firm decides whether to acquire information or not. If the firm produces information the choice of producing information becomes immediately public, while υ is revealed at the end of $t = 0$. I assume the firm's information production choice becomes public to avoid the problem of the firm discovering it has a bad project then attempting to pool with a firm that does not produce information. The rest of the timing is exactly the same as in the baseline model in Section 2.

From Section B.3, the optimal contract conditional on the firm knowing its project type is $\mathcal{C}^{1L}$. If the firm acquires information then offers $\mathcal{C}^{1L}$, the firm with the good project's expected profits will be $V^{1L} - c$ which is strictly less than V^{1L}, hence the firm would not acquire information. Summarizing,

Proposition B.1. *If the firm has access to the same information technology as the lender at the beginning of $t = 0$, it does not acquire information and the optimal contract is the same as in the main text.*

B.5 Firm Receives Exogenous Information

In the baseline model, the firm and lender begin symmetrically uninformed; however in practice, it seems plausible firms have some form of information advantage over their lenders. In this section I show that if the firm receives an exogenous noisy signal regarding its project type the optimal contract may still deter information production. Suppose that prior to offering the lender a contract the firm receives a signal $s \in \{G, B\}$ regarding υ. Specifically, $s = G$ with probability $\frac{1}{2}$ and $Pr(\upsilon = g|s = G) = \theta + \epsilon$ and $Pr(\upsilon = b|s = B) = \theta - \epsilon$ otherwise where $\epsilon \leq \max\{\theta, 1-\theta\}$. The change in probability need not be symmetric, but this simplification makes the unconditional probability of the project succeeding the same as in the baseline model (i.e. $Pr(\upsilon = g|s = G)Pr(s = G) + Pr(\upsilon = g|s = B)Pr(s = B) = \theta$). The firm's signal is private information and the lender has access to the same information acquisition technology in the baseline model. Once again, I use the undefeated equilibrium refinement from Mailath, Okuno-Fujiwara, and Postlewaite (1993) so the problem amounts to the firm that receives the good signal $s = G$ maximizing its profits subject to pooling with the firm that receives the bad signal $s = B$. Define

$$\phi_h(G) \equiv 1, \quad \phi_l(G) \equiv \theta + \epsilon + (1 - \theta - \epsilon)\mu.$$

Then the firm that receives signal $s = G$ faces the following problem to deter information production

$$\max_{\mathcal{C}} \sum_z \pi_z \left[q_z p_z^0 - d_{1z} + \phi_z(G) \left((k - q_z) R - d_{2z} \right) \right]$$

$$s.t.$$

$$k \leq 1,$$

$$k \leq \sum_z \pi_z (d_{1z} + \phi_z d_{2z}),$$

$$(1 - \theta) \left[k - \pi_h (d_{1h} + d_{2h}) - \pi_l (d_{1l} + \mu d_{2l}) \right] \leq c,$$

$$q_z \in [0, k], \quad d_{1z} \leq q_z p_z^0, \quad d_{2z} \leq (k - q_z) R \quad z = h, l,$$

$$p_z^0 = (1 - \gamma_z) \phi_z R, \quad z = h, l.$$

Proposition B.2. *When the firm receives an exogenous private signal regarding the project type, the optimal contract that deters information production takes the form $\mathcal{C}^{0L}$ or $\mathcal{C}^{0S}$ depending on parameters.*

The steps are the same as in the main text so I omit them. For the problem that induces information acquisition the firm that receives the good signal solves the following problem

$$\max_{\mathcal{C}}(\theta + \epsilon) \sum_z \pi_z \left(q_z p_z^1 - d_{1z} + (k - q_z)R - d_{2z} \right)$$
$$s.t.$$
$$k \leq 1,$$
$$c \leq \theta \left(\sum_z \pi_z (d_{1z} + d_{2z}) - k \right),$$
$$c \leq (1-\theta) \left[k - \pi_h (d_{1h} + d_{2h}) - \pi_l (d_{1l} + \mu d_{2l}) \right],$$
$$q_z \in [0, k], \quad d_{1z} \leq q_z p_z^1, \quad d_{2z} \leq (k - q_z) R \quad z = h, l,$$
$$p_z^1 = (1 - \gamma_z^1) R \quad z = h, l.$$

The following proposition immediately follows

Proposition B.3. *When the firm receives an exogenous private signal regarding the project type, the optimal contract that induces information production takes the form* $\mathcal{C}^{1L}$.

The firm that receives the good signal's expected profits from the three classes of contracts are

$$V^{0L}(G) = k^{0L}(\pi_h R + \pi_l \phi_l(G) R - 1),$$
$$V^{0S}(G) = \pi_l \phi_l(G) \left(R - d_{2l}^{0S} - \frac{d_{1l}^{0S}}{(1 - \gamma_l^0)\phi_l} \right),$$
$$V^{1L}(G) = (\theta + \epsilon)(R - 1) - c.$$

Both $V^{1L}(G) - V^{0S}(G)$ and $V^{1L}(G) - V^{0S}(G)$ are increasing in ϵ. Hence, when the firm begins with private information, it is more likely the optimal contract induces information production. However, there are still parameter ranges in which the optimal contract is short-term (e.g. when ϵ and γ_l^0 are small).

B.6 NPV Positive Bad Project

In this section, I characterize the optimal contract when the bad project is NPV positive. Specifically,

$$(\pi_h + \pi_l \mu) R > 1. \tag{B.13}$$

Condition (B.13) implies that $\underline{c} < 0$, therefore I impose the additional assumption that $c > 0$, i.e. $c \in (0, \bar{c})$. To keep the problem interesting, I also impose the following condition

$$\pi_h R < 1 \tag{B.14}$$

Condition (B.14) ensures the lender cannot breakeven by only receiving payments in the high state where there is no uncertainty across project types. The firm's problem for the optimal contract without information acquisition $\mathcal{C}^{0*}$ remains the same. However, if we inspect the potential solutions from Proposition (2), note that now (A.13) can be ruled out because of (B.13) and (A.14) is the solution when $\gamma_l^0 \geq \frac{1-\pi_h R}{\pi_l \phi_l R}$ and (A.12), $\mathcal{C}^{0S}$, is the solution otherwise.

The optimal contract that induces information acquisition $\mathcal{C}^{1*}$ can differ from the case in which the bad project was NPV negative because the firm can offer a menu to induce the lender to accept different terms depending on υ. I use superscripts to refer to the contract terms intended for the specific project type. To keep notation manageable, I suppress the references to the optimality of the contract throughout the proofs. For instance if I state $q_l^b = 0$ in a Lemma, this refers to the value of q_l^b at the optimum unless otherwise stated. The firm's problem that induces information acquisition is

$$\max_{k^\upsilon, d_{2z}^\upsilon} \theta \left[\pi_h((k^g - q_h^g)R - d_{2h}^g) + \pi_l((k^g - q_l^g)R - d_{2l}^g)\right] +$$
$$(1-\theta)\left[\pi_h((k^b - q_h^b)R - d_{2h}^b) + \pi_l\mu((k^b - q_l^b)R - d_{2l}^b)\right],$$
$$s.t.$$
$$k^\upsilon \in [0,1] \quad \upsilon = g, b,$$
$$c \leq \theta\Big(\sum_z \pi_z(d_{1z}^g + d_{2z}^g) - k^g\Big) +$$
$$(1-\theta)\left(\pi_h(d_{1h}^b + d_{2h}^b) + \pi_l(d_{1l}^b + \mu d_{2l}^b) - k^b\right), \tag{B.15}$$
$$k^g \leq \sum_z \pi_z(d_{1z}^g + d_{2z}^g), \tag{B.16}$$
$$k^b \leq \pi_h(d_{1h}^b + d_{2h}^b) + \pi_l(d_{1l}^b + \mu d_{2l}^b), \tag{B.17}$$
$$\sum_z \pi_z(d_{1z}^b + d_{2z}^b) - k^b \leq \sum_z \pi_z(d_{1z}^g + d_{2z}^g) - k^g, \tag{B.18}$$
$$\pi_h(d_{1h}^g + d_{2h}^g) + \pi_l(d_{1l}^g + \mu d_{2l}^g) - k^g \leq \pi_h(d_{1h}^b + d_{2h}^b) + \pi_l(d_{1l}^b + \mu d_{2l}^b) - k^b, \tag{B.19}$$
$$q_z^\upsilon \in [0, k^\upsilon], \quad d_{1z}^\upsilon \leq q_z^\upsilon(1-\gamma_z^1)\mathbb{E}[\tilde{R}|\upsilon, z], \quad d_{2z}^\upsilon \leq k^\upsilon R \quad z = h, l, \quad \upsilon = g, b,$$

where (B.15) is the lender's ex-ante participation constraint, (B.16) and (B.17) are the lender's participation constraints conditional on discovering the project is good (bad) and (B.18) says if the firm discovers the project is good it must be incentive compatible to accept the terms for the good project and vice versa for (B.19).

Lemma B.3. $q_h^{\upsilon} = d_{1h}^{\upsilon} = 0, \quad \upsilon = g, b.$

Proof. The proof is the same regardless of υ. Suppose that $q_h^{\upsilon} > 0$ for any $\upsilon \in \{g, b\}$. First suppose that $d_{1h}^{\upsilon} = 0$, then the first can reduce q_h^{υ} by ϵ and no constraints are violated and the firm's profits increase because $\gamma_h^1 \geq 0$. Next suppose $d_{1h}^{\upsilon} > 0$, the firm can decrease q_h^{υ} by ϵ, decrease d_{1h}^{υ} by $\frac{\epsilon}{(1-\gamma_h^1)\mathbb{E}[\tilde{R}|\upsilon,z=h]}$ and increase d_{2h}^{υ} by $\frac{\epsilon}{(1-\gamma_h^1)\mathbb{E}[\tilde{R}|\upsilon,z=h]}$ and none of the constraints are affected and the firm's profits increase because $\gamma_h^1 \geq 0$. Hence, $q_h^{\upsilon} = 0$ and thereby $d_{1h}^{\upsilon} = 0$ for all υ. ■

To simplify the proof I make the following claim which I confirm is true at the conclusion of the proof

Claim B.1. (B.19) *is slack.*

I then establish the following lemma.

Lemma B.4. $q_l^{\upsilon} = d_{1l}^{\upsilon} = 0 \quad \upsilon = g, b.$

Proof. The same steps from Lemma B.3 can be taken to show that $q_l^g = d_{1l}^g = 0$. Next, suppose that $q_l^b > 0$. There are two cases to consider. First suppose that $d_{1l}^b = 0$, then the first can reduce q_l^b by ϵ and no constraints are violated and the firm's profits increase because $\gamma_l^1 \geq 0$. Next suppose $d_{1l}^b > 0$, the firm can decrease q_l^b by ϵ, decrease d_{1l}^b by $\frac{\epsilon}{(1-\gamma_l^1)\mathbb{E}[\tilde{R}|\upsilon=b,z=l]}$ and increase d_{2l}^b by $\frac{\epsilon}{\mu(1-\gamma_l^1)\mathbb{E}[\tilde{R}|\upsilon,z=l]}$ and (B.18) is relaxed while none of the other constraints are affected and the firm's profits increase because $\gamma_l^1 \geq 0$. ■

Hence, the contract is long-term and we can rewrite the problem as

$$\max_{k^{\upsilon}, d_{2z}^{\upsilon}} \theta\left[\pi_h(k^g R - d_{2h}^g) + \pi_l(k^g R - d_{2l}^g)\right] +$$
$$(1-\theta)\left[\pi_h(k^b R - d_{2h}^b) + \pi_l \mu(k^b R - d_{2l}^b)\right],$$
$$s.t.$$
$$k^{\upsilon} \in [0,1] \quad \upsilon = g, b,$$
$$c \leq \theta(\pi_h d_{2h}^g + \pi_l d_{2l}^g - k^g) + (1-\theta)(\pi_h d_{2h}^b + \pi_l \mu d_{2l}^b - k^b),$$
$$k^g \leq \pi_h d_{2h}^g + \pi_l d_{2l}^g,$$
$$k^b \leq \pi_h d_{2h}^b + \pi_l \mu d_{2l}^b,$$
$$\pi_h d_{2h}^b + \pi_l d_{2l}^b - k^b \leq \pi_h d_{2h}^g + \pi_l d_{2l}^g - k^g,$$
$$d_{2z}^{\upsilon} \leq k^{\upsilon} R \quad z = h, l, \quad \upsilon = g, b.$$

Lemma B.5. (B.16) *is slack and* $k^g = 1$

Proof. Suppose (B.16) binds, then we can replace $k^g = \pi_h d^g_{2h} + \pi_l d^g_{2l}$ into (B.18) which simplifies to $k^b \geq \pi_h d^b_{2h} + \pi_l d^b_{2l}$; however, this violates (B.17). Suppose $k^g < 1$, then we can increase k^g by ϵ such that $k^g + \epsilon \leq 1$ and increase d^g_{2h} by $\pi_h \epsilon$ and d^g_{2l} by $\pi_l \epsilon$ and (B.18) and (B.15) are not violated and the firm's profits increase. ■

Lemma B.6. (B.15) *is slack if* $k^b = 1$

Proof. Suppose to the contrary that (B.15) binds if $k^b = 1$, then we can rewrite (B.18) as

$$\frac{\pi_h d^b_{2h} + \pi_l \phi_l d^b_{2l} - 1 - c}{\theta} \leq 0. \tag{B.20}$$

For (B.20) to hold, we need $\pi_h d^b_{2h} + \pi_l \phi_l d^b_{2l}$ to be sufficiently small while not violating (B.16) and $d^b_{2z} \leq R$ for all $z \in \{h, l\}$. It easily shown that the LHS of (B.20) is smallest when (B.16) binds and $d^g_{2h} = R$; however, even when this is the case (B.20) is violated. ■

Lemma B.7. (B.18) *binds.*

Proof. Suppose to the contrary (B.18) is slack. First consider the case in which $k^b < 1$, we can increase k^b by ϵ and increase d^b_{2h} by ϵ and d^b_{2l} by $\frac{\epsilon}{\mu}$ such that remains (B.18) is not violated while (B.15) remains unchanged and the firm's profits increase. Now consider the case in which $k^b = 1$. From Lemma B.6, (B.15) is slack. Hence we can decrease d^g_{2h} by a small enough ϵ such that (B.15), (B.16) and (B.18) remain slack while increasing the firm's profits. ■

Lemma B.8. (B.17) *binds*

Proof. Suppose to the contrary that (B.17) is slack. First consider the case in which $k^b = 1$. When this is the case (B.15) is slack from Lemma B.6. Hence we can decrease d^b_{2l} (note $d^b_{2l} > 0$ because otherwise (B.17) would be violated) by a small enough ϵ such that (B.15) is not violated, (B.18) would not be violated and the firm's profits would increase. Now consider the case in which $k^b < 1$ if we increase k^b by ϵ and increase d^g_{2l} or d^g_{2h} by $\epsilon \frac{\theta \pi_h}{(1-\theta)\mu}$ such that (B.17) remains slack, then (B.15) remains unchanged and (B.18) slackens while the firm's profits increase. ■

Lemma B.9. $d^b_{2h} = k^b R$

Proof. Suppose to the contrary that $d^b_{2h} < k^b R$, then we can increase d^b_{2h} by ϵ and decrease d^b_{2l} by $\frac{\pi_h \epsilon}{\pi_l \mu}$ (d^b_{2l} must be positive because otherwise (B.15) is violated) such that (B.15) and (B.17) remain unchanged; however, (B.18) slackens which leads to a contradiction. ■

Hence from we can rewrite the problem as

$$\max_{k^b, d^g_{2h}, d^g_{2l}, d^b_{2l},} \theta\left[\pi_h(R-d^g_{2h})+\pi_l(R-d^g_{2l})\right]+(1-\theta)\pi_l\mu\left(k^bR-d^b_{2l}\right), \tag{B.21}$$

$$s.t.$$

$$k^b \leq 1 \tag{B.22}$$

$$c \leq \theta(\pi_h d^g_{2h}+\pi_l d^g_{2l}-1)+(1-\theta)(\pi_h k^b R+\pi_l\mu d^b_{2l}-k^b), \tag{B.23}$$

$$k^b = \pi_h k^b R+\pi_l\mu d^b_{2l},$$

$$\pi_h k^b R+\pi_l d^b_{2l}, -k^b = \pi_h d^g_{2h}+\pi_l d^g_{2l}-1, \tag{B.24}$$

$$d^g_{2z} \leq k^g R \quad z=h,l.$$

Notice that (B.21), (B.23), (B.24) depend on the expected payments from the good project $\pi_h d^g_{2h}+\pi_l d^g_{2l}$, but not the relative values of d^g_{2h} and d^g_{2l}. Hence, we can set $d^g_{2h}=R$ (which will ensure Claim B.1 holds). The Lagrangian is

$$\begin{gathered}\mathcal{L}=\theta\left[\pi_h(R-d^g_{2h})+\pi_l(R-d^g_{2l})\right]+(1-\theta)\pi_l\mu\left(k^bR-d^b_{2l}\right)-\lambda_1(k^b-1)-\\ \lambda_2\left[c-\theta(\pi_h d^g_{2h}+\pi_l d^g_{2l}-1)-(1-\theta)(\pi_l\mu d^b_{2l}-k^b(1-\pi_h R))\right]-\\ \lambda_3(k^b(1-\pi_hR)-\pi_l\mu d^b_{2l})-\lambda_4\left(k^b\left(\pi_hR+\frac{1-\pi_hR}{\mu}-1\right)-\pi_h d^g_{2h}-\pi_l R+1\right)-\\ \lambda_5(d^g_{2l}-R)-\lambda_6(d^b_{2l}-k^bR).\end{gathered}$$

The Kuhn-Tucker necessary conditions are

$$\begin{gathered}\mathcal{L}_{k^b}=\pi_l(1-\theta)\mu R-\lambda_1-(1-\pi_hR)\left((1-\theta)\lambda_2+\lambda_3-\lambda_4\right)+\lambda_6R\leq 0,\\ \mathcal{L}_{d^b_{2l}}=\pi_l\left[(1-\theta)\mu\left(\lambda_2-1\right)+\mu\lambda_3-\lambda_4\right]-\lambda_6\leq 0,\\ \mathcal{L}_{d^g_{2l}}=\pi_l\left(\theta\left(\lambda_2-1\right)+\lambda_4\right)-\lambda_5\leq 0,\\ \mathcal{L}_{k^b}k^b=0,\quad \mathcal{L}_{d^b_{2l}}d^b_{2l}=0,\quad \mathcal{L}_{d^g_{2l}}d^g_{2l}=0,\\ \lambda_1(k^b-1)=0,\\ \lambda_2\left[c-\theta(\pi_h d^g_{2h}+\pi_l d^g_{2l}-1)-(1-\theta)(\pi_l\mu d^b_{2l}-(1-\pi_hR)k^b)\right]=0,\\ k^b(1-\pi_hR)-\pi_l\mu d^b_{2l}=0,\\ \pi_h k^b(R-d^g_{2h})+k^b\left(\frac{1-\pi_hR}{\mu}-1\right)-\pi_lR+1=0,\\ \lambda_1\geq 0,\quad \lambda_2\geq 0,\quad \lambda_3>0,\quad \lambda_4>0,\quad \lambda_5\geq 0,\quad \lambda_6\geq 0,\\ \text{(B.22)},\text{(B.23)}.\end{gathered}$$

There are two potential solutions

$$k^b = \frac{c\mu}{\theta(1-\mu)(1-\pi_h R)}, \quad d_{2l}^g = \frac{c+\theta(1-\pi_h R)}{\theta\pi_l}, \quad d_{2l}^b = \frac{c}{\theta\pi_l(1-\mu)}, \tag{B.25}$$
$$\lambda_1 = 0, \quad \lambda_2 = \frac{(\mu+\theta(1-2\mu))(1-\pi_h R) - R(1-\theta)\mu^2\pi_l}{\theta(1-\mu)(1-\pi_h R)},$$
$$\lambda_3 = \frac{(1-\theta)\phi_l(\pi_h R + \pi_l\mu R - 1)}{\theta(1-\mu)(1-\pi_h R)}, \quad \lambda_4 = \frac{(1-\theta)\mu(\pi_h R + \pi_l \mu R - 1)}{(1-\mu)(1-\pi_h R)},$$
$$\lambda_5 = 0, \quad \lambda_6 = 0,$$

and,

$$k^b = 1, \quad d_{2l}^g = \frac{c+\theta(1-\pi_h R)}{\theta\pi_l}, \quad d_{2l}^b = \frac{c}{\theta\pi_l(1-\mu)}, \tag{B.26}$$
$$\lambda_1 = \pi_l(1-\theta)\mu R - \frac{(\mu+\theta(1-2\mu))(1-\pi_h R)}{\mu}, \quad \lambda_2 = 0,$$
$$\lambda_3 = 1+\theta\left(\frac{1}{\mu}-1\right), \quad \lambda_4 = \theta, \quad \lambda_5 = 0, \quad \lambda_6 = 0,$$

where, (B.25) is the solution when $(\mu+\theta(1-2\mu))(1-\pi_h R) - R(1-\theta)\mu^2\pi_l \geq 0$ and (B.26) is the solution otherwise. We can also now confirm Claim B.1. When (B.25) is the solution (B.19) reduces to

$$\mu\left(1+\frac{c}{\theta}\right) + \pi_h(1-\mu)R - 1 \leq 0,$$

which holds. When (B.26) is the solution, the LHS of (B.19) reduces to 0, hence (B.19) holds. The respective profits for (B.25) and (B.26) are

$$\theta(R-1) - c + \frac{c(1-\theta)\mu(\pi_h R + \pi_l\mu R - 1)}{\theta(1-\mu)(1-\pi_h R)}, \tag{B.27}$$
$$\frac{\phi_l(\pi_h R + \mu\pi_l R - 1)}{\mu}.$$

Notice that (B.27) is strictly greater than V^{1L}. Hence, the optimal contract with information acquisition is either (B.25) or (B.26). To find $\mathcal{C}^*$ we can simply compare the profits from the optimal contract with information acquisition and that without information acquisition.

Intuitively, the firm is able to finance the project regardless of its type; however, there is still a welfare loss relative to the first-best because the lender produces information. Hence, for γ_l^0 sufficiently close to 0 the optimal contract is short-term $\mathcal{C}^* = \mathcal{C}^{0S}$.

B.7 Non-Zero Project Payoff in the Case of Failure

Because the project yields 0 in the case of failure, it is not possible to distinguish between equity and debt for payments at $t = 2$. In this section I show that state-contingent debt is the optimal contract when the project yields a positive payoff in the case of failure. Suppose that $\tilde{R} = r < 1$ when the project fails. To analyze the interesting case I revise Assumption 1 as follows

Assumption B.1. *The bad project is NPV negative:*

$$\pi_h R + \pi_l(\mu R + (1-\mu)r) < 1,$$

while the ex-ante, average project is NPV positive:

$$\pi_h R + \pi_l(\phi_l R + (1-\phi_l)r) > 1,$$

and Assumption 2 as follows,

Assumption B.2. $c \in (\underline{c}, \bar{c})$, *where*

$$\underline{c} \equiv (1-\theta)(1-\pi_l\left((1-\mu)r + \mu R\right) - \pi_h R),$$

and

$$\bar{c} \equiv \frac{\theta(1-\phi_l)(1-\pi_h R - \pi_l r)}{\phi_l}.$$

Let $d_{2z}(r)$ denote the promised payment from the firm to the lender if the project fails in state z. Then consider the revised definition of a financial contract

$$\mathcal{C} = \{k, q_h, q_l, d_{1h}, d_{1l}, d_{2h}, d_{2h}(r), d_{2l}, d_{2l}(r)\}$$

To find the optimal contract to induce the lender to not acquire information the firm solves

$$\max_{\mathcal{C}} \sum_z \pi_z \Big(q_z p_z^0 - d_{1z} + \phi_z \left[(k - q_z) R - d_{2z} \right] + (1-\phi_z) \left[(k-q_z) r - d_{2z}(r) \right] \Big)$$

$$s.t.$$

$$k \leq 1,$$

$$k \leq \sum_z \pi_z \left(d_{1z} + \phi_z d_{2z} + (1-\phi_z) d_{2z}(r) \right),$$

$$(1-\theta) \left[k - \pi_h (d_{1h} + d_{2h}) - \pi_l (d_{1l} + \mu d_{2l} + (1-\mu) d_{2l}(r)) \right] \leq c,$$

$$q_z \in [0, k], \quad d_{1z} \leq q_z p_z^0, \quad d_{2z} \leq (k - q_z) R, \quad d_{2z}(r) \leq (k - q_z) r \quad z = h, l,$$

$$p_z^0 = (1 - \gamma_z^0)(\phi_z R + (1-\phi_z) r) \quad z = h, l.$$

The project never fails in the high state so we can ignore $d_{2h}(r)$. Using the same arguments from Proposition 1 and Lemma 2, $q_h^{0*} = d_h^{0*} = 0$, $d_{2h}^{0*} = k^{0*} R$, the incentive compatibility constraint binds and $d_{1l}^{0*} = q_l^{0*} p_l^0$. We can rewrite the problem as follows

$$\max_{\mathcal{C}} \pi_l \Big(q_l p_l^0 - d_{1l} + \phi_l \left[(k - q_l) R - d_{2l} \right] + (1-\phi_l) \left[(k-q_l) r - d_{2l}(r) \right] \Big),$$

$$s.t.$$

$$k \leq 1,$$

$$k(1 - \pi_h R) \leq \pi_l (d_{1l} + \phi_l d_{2l} + (1-\phi_l) d_{2l}(r)), \tag{B.28}$$

$$(1-\theta) \left[k(1-\pi_h R) - \pi_l (d_{1l} + \mu d_{2l} + (1-\mu) d_{2l}(r)) \right] = c, \tag{B.29}$$

$$d_{2l} \leq \left(k - \frac{d_{1l}}{p_l^0} \right) R, \tag{B.30}$$

$$d_{2l}(r) \leq \left(k - \frac{d_{1l}}{p_l^0} \right) r, \tag{B.31}$$

$$p_l^0 = (1-\gamma_l^0)(\phi_l R + (1-\phi_l) r).$$

We can then show that (B.31) binds implying the optimal contract is debt.

Lemma B.10. *In the optimal contract* (B.31) *binds*

Proof. Suppose to the contrary (B.31) is slack. If the firm increases $d_{2l}^{0*}(r)$ by any $\epsilon > 0$ where $d_{2l}^{0*}(r) + \epsilon \leq \left(k^{0*} - \frac{d_{1l}^{0*}}{p_l^0} \right) r$ and decreases d_{2l}^{0*} by $\frac{(1-\mu)\epsilon}{\phi_l}$, then (B.28) and (B.30) would not be violated while (B.29) would slacken. However, because (B.29) binds at the optimum this is a contradiction. ■

Lemma B.10 implies that payments at $t = 2$ are equivalent to debt because all of the cash flows from the project in the case of failure are paid to the lender. I omit the remaining steps to find the optimal contract that induces the lender to not acquire, however it follows from Proposition 2.

B.8 Auction for Market Equilibrium Mechanism

In the main text I assume that the informed investor can make unobservable offers to firms to buy their assets before the firms sell to a pool of uninformed investors. In this section I show how a second-price auction yields the same price as the mechanism in the main text.

The matching process works exactly as in Section 4; however, the informed investor simply learn project types and do not enter a bilateral bargaining game with the firm whose project they learn. Instead, each firm sells $q_l(i)$ units of good in an auction after the low state has been realized. Uninformed investors do not observe if they are bidding against the informed investor which leads to the winner's curse. Uninformed investors are symmetric and have no private information so I can restrict focus to symmetric bidding strategies among the uninformed. Let $b^U(i)$ denote each uninformed investors per unit bid for firm i's project. Let $b^I(i)$ denote the informed investor's bid. If $b^I(i) \geq b^U(i)$ the informed investor wins the auction and pays $b^U(i)q_l(i)$ for the $q_l(i)$ units of the project and vice versa if $b^I(i) < b^U(i)$. For simplicity I assume if an uninformed investor wins the auction there is a random tiebreaker so that one uninformed investor pays $b^U(i)q_l(i)$ for $q_l(i)$ units of the project. If the informed investor does not match with firm i, I assume they bid zero $b^I(i) = 0$. Hence the uninformed problem for firm i's asset is

$$\max_{b^U(i)} \mathbb{E}[(\tilde{R} - b^U(i))q_l(i)|b^I(i) < b^U(i)].$$

When $i \in \mathcal{I}^1$ all investors know firm i is good quality. Therefore, investors bid $b^U(i) = b^I(i) = R$.

Henceforth I restrict focus to firm bidding strategies for firms $i \in \mathcal{I}^0$. When $i \in \mathcal{I}^0$ firm i's project type is not publicly known. The uninformed never bid $b^U(i) < \mu R$ because even if the project is bad with certainty its expected payoff is μR. In addition, $b^U(i) > \mu R$ for all i. Suppose to the contrary that $b^U(i) = \mu R$ for some $i \in \mathcal{I}^0$. Then, the informed investor's best response would be to bid $b^I(i) = \mu R$ and win the good. However, with probability $1-\eta$ there is no informed investor bidding. Therefore, an uninformed investor could always bid ϵ more than μR and earn positive profits. Hence, $b^U(i) > \mu R$ for all i.

The uninformed investor also always bids $b^U(i) < R$. Suppose to the contrary $b^U(i) = R$, then the informed investor would bid $b^I(i) = R$ when $\upsilon(i) = g$ and win the asset and bid $b^I(i) = \mu R$ when the asset is bad and lose the bid. Therefore, the uninformed would earn negative profits by bidding $b^U(i) = R$. Since $b^U(i) \in (\mu R, R)$ the informed bidder bids its valuation and earns profits $R - b^U(i)$ when $\upsilon(i) = g$ and loses the bid otherwise. Hence, the uninformed optimal bid b^* must satisfy:

$$(1-\theta)(\mu R - b^*) + \theta(1-\eta)(\phi_l R - b^*) = 0.$$

Solving for b^*

$$b^* = \left(1 - \frac{\eta\theta(1-\phi_l)}{(1-\eta\theta)\phi_l}\right)\phi_l R. \tag{B.32}$$

Notice that the winning bid in each auction (B.32) is the same as the price in the main text (13). Therefore, the solution is identical to the bargaining process in Section 4 of the main text.