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Uncertain Booms and Fragility

Michael Junho Lee
University of Pennsylvania, michaeljunholee@gmail.com

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Abstract

I develop a framework of the build-up and outbreak of financial crises in an asymmetric information setting. In equilibrium, two distinct economic states arise endogenously: normal times – periods of modest investment, and booms – periods of expansionary investment. Normal times occur when the intermediary sector realizes moderate investment opportunities. Booms occur when the intermediary sector realizes many investment opportunities, but also occur when it realizes very few opportunities. As a result, investors face greater uncertainty in booms. During a boom, subsequent arrival of negative information about an intermediary asset results in large downward shifts in investors' confidence about the underlying quality of long-term assets. A crisis of confidence ensues. Investors collectively force costly early liquidation of the intermediated assets and move capital to safe assets, in a flight-to-quality episode.

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Supervisor of Dissertation

Bilge Yilmaz, Wharton Private Equity Professor, Professor of Finance

Graduate Group Chairperson

Eric Bradlow, K.P. Chao Professor, Professor of Marketing, Statistics, and Education

Dissertation Committee

Richard Kihlstrom, Ervin Miller-Arthur M. Freedman Professor of Finance and Economics

Doron Levit, Assistant Professor of Finance

Dedicated to my parents.

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ABSTRACT

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Michael Junho Lee

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I develop a framework of the build-up and outbreak of financial crises in an asymmetric information setting. In equilibrium, two distinct economic states arise endogenously: *normal times* – periods of modest investment, and *booms* – periods of expansionary investment. Normal times occur when the intermediary sector realizes moderate investment opportunities. Booms occur when the intermediary sector realizes many investment opportunities, but also occur when it realizes very few opportunities. As a result, investors face greater uncertainty in booms. During a boom, subsequent arrival of negative information about an intermediary asset results in large downward shifts in investors' confidence about the underlying quality of long-term assets. A *crisis of confidence* ensues. Investors collectively force costly early liquidation of the intermediated assets and move capital to safe assets, in a flight-to-quality episode.

TABLE OF CONTENTS

CHAPTER 1 : INTRODUCTION

The accumulated history of crises reveals three remarkably predictable stages of a crisis: (1) the *run-up* – an investment boom fueled by credit expansion; (2) the *trigger* – a "small" negative shock concerning the quality of asset markets; and (3) the *outbreak* – widespread capital flight, during which large amounts of investment capital flock from intermediary assets to safe assets.[1] Existing theories of financial fragility and crises commonly view the build-up and trigger as consequences of external aggregate fluctuations. As a result, the literature predominantly focuses on how the fragile capital structure of financial intermediaries amplifies and propagates negative real shocks.[2] This runs counter to mounting evidence that the intermediary sector plays a central role in both the build-up and subsequent fragility of the financial system.[3]

I develop a model that provides a cohesive framework that weaves together the run-up, trigger, and outbreak of a financial crisis. The intermediary sector strategically chooses the quantity of capital to raise from investors and determines the allocation of capital to long-term investment opportunities in the economy. I show that when the intermediary sector is better informed about the set of long-term investment opportunities, two distinct economic states endogenously arise: *normal times* – periods of modest investment and financial stability; and *booms* – periods of expansionary investment that may degenerate into a financial crisis following negative public information about an intermediary asset.

In the model, the financial intermediary sector has exclusive access to a technology that enables it to identify and assess the quality of long-term investment opportunities. Equipped with superior information, the intermediary sector can provide profitable intermediation services to investors, who own capital, but cannot evaluate the quality of the investment opportunities themselves. The intermediary sector chooses the quantity of capital to raise from

[1] Calomiris and Gorton (1991) explores the common denominators of financial crises based on historical data. Reinhart and Rogoff (2008; 2013) highlight the persistence in the occurrence and development of financial crises.

[2] For an overview, see Allen et al. (2009).

[3] See Kindleberger and Aliber (2011), Reinhart and Rogoff (2009), and Schularick and Taylor (2012).

investors, who compete to invest through the intermediary sector. However, as investors cannot verify the nature of the investment opportunities, they potentially face uncertainty about the underlying quality of intermediated assets. Consequently, the intermediary sector's demand for capital acts as an important source of information to investors, who make their investment decisions based on their beliefs.

Two fundamental forces determine the intermediary sector's demand for capital – the *growth* motive and the *risk-taking* motive. The growth motive exists purely through the intermediary sector's access to profitable investments. When financial intermediaries observe a high level of good investment opportunities, large amounts of capital can be productively deployed to produce long-term assets. By expanding their operational size, in the form of leverage, financial intermediaries can allocate capital to productive investment opportunities and increase profits. On the other hand, the risk-taking motive arises under asymmetric information. When endowed with few productive investment opportunities, the intermediary sector has a strong incentive to raise large amounts of capital to invest in inefficiently risky assets, as long as it can obtain funding from uninformed investors. Because intermediaries can always find a bad investment opportunity to invest in, a moral hazard problem arises. This moral hazard problem increases as the intermediary sector realizes fewer opportunities.

In equilibrium, two investment states endogenously arise, depending on the nature of the intermediary sector's investment opportunities. *Normal times* occur when the intermediary sector realizes a *moderate* level of productive investment opportunities. An intermediary sector of moderate type does not have strong growth or risk-taking motives, which weakens its incentives to raise larger amounts of capital from investors. By raising a modest amount of capital, the intermediary sector with moderate investment opportunities focuses on producing good long-term assets. In turn, investors infer from the modest capital demand that the financial sector realized moderate investment opportunities. As a result, the intermediary sector avoids an adverse selection cost of capital.

In contrast, *booms* occur when the intermediary sector realizes either *high* or *low* levels of productive investment opportunities. High capital demand is chosen by the intermediary sector of high and low type, for polar reasons. With high investment opportunities, the intermediary sector is strongly motivated by growth, as more borrowing enables the intermediary sector to allocate capital to highly profitable investment opportunities. The intermediary sector finds it optimal to raise large quantities of capital, even if an adverse selection premium is associated with the cost of capital. In a low realization, the risk-taking motive dominates. The intermediary sector with few investment opportunities maximizes profits by producing inefficient assets using funds obtained from investors, who cannot discern whether the intermediary sector has high or low investment opportunities. As a result, upon observing high capital demand, investors form *polarized* beliefs, under which the underlying intermediary assets are believed to be either highly productive or inefficiently risky. Investors face heightened uncertainty in booms. This concentration of uncertainty brings rise to a development of booms that are fragile to fluctuations in investors' confidence.

Amidst ex-ante uncertainty, public information plays an integral role in informing investors about the underlying quality of assets produced by the intermediary sector. As such, in a boom, subsequent revelation of information can dramatically influence investors' confidence about the value of their exposures to the intermediated assets. When investors are provided with a liquidation option, the intermediary sector becomes fragile to investors' beliefs, in the form of liquidity risk.[4] In particular, negative information about the quality of an intermediary asset can depress investors' confidence about the quality of the intermediated assets. A *crisis of confidence* ensues. Investors draw down capital, effectively forcing early liquidation on intermediaries' assets, and migrate to safe assets. This explains why banking crises appear to be triggered by negative news.[5]

I show that the asymmetric information problem ties together empirical features of financial crises.[6] Prior to a crisis, intermediaries accumulate historically high levels of leverage, or

[4]See Diamond (1991; 1993).

[5]See Calomiris and Gorton (1991) and Demirgüç-Kunt and Detragiache (1997).

[6]Other studies analyze how asymmetric information affects asset securitization (DeMarzo (2005)), precautionary savings (Lucas and McDonald (1992)), fund transparency (Gervais and Strobl (2012)), financing

what is often ex-post described as "excessive leverage."[7] This paper provides an information-based argument that links high leverage to crises.[8] In the model, the borrowing capacity of the intermediary sector is determined endogenously by investors' beliefs. As such, the sustainability of intermediary leverage crucially depends on the stability of investors' beliefs. I show that investors' beliefs are especially sensitive to information during periods of high leverage, due to the propensity for the intermediary sector to take inefficient risks during high investment periods. As a result, crises necessarily erupt from times of high intermediary leverage, when negative information about the quality of intermediary assets shocks investors' confidence and triggers capital flight. Recent studies also find that banking crises often grow out of credit booms, or periods of large expansions in credit.[9] The model causally links episodes of expansive credit creation to fragility, consistent with empirical evidence that shows abnormally high credit creation prior to crises.[10]

A crisis, presented in this paper, originates from the *asset* side of the financial sector. Uncertainty endogenously builds up in booms, during which the financial intermediary sector intermediates large quantities of capital.[11] Negative information about the quality of an intermediary asset precipitates investors' fears about intermediary insolvency.[12] Investors' lack of confidence manifests into illiquidity, which afflicts the financial intermediary sector, regardless of whether the underlying assets produced were actually good or bad. Importantly, the fragility of investors' beliefs in booms stands in striking contrast to the muted response to negative information in normal times, during which information has little effect on investors' beliefs. This is distinct from theories of banking crises that focus on the *liability* side of the financial sector. Notably, in Diamond and Dybvig (1983), fragility stems

structure (Stein (2005)), debt maturity (Diamond (1991)), and monetary policy transmission (Stein (1998)).

[7] Adrian and Shin (2010) documents a sharp increase in banking sector leverage in the recent crisis.

[8] Studies have shown how highly levered intermediaries can become vulnerable when adverse economic shocks affect their net worths, and hence their borrowing capacities. For example, see He and Krishnamurthy (2012; 2013), Brunnermeier and Sannikov (2014), and Gertler and Karadi (2011).

[9] See Berger and Bouwman (2010).

[10] Schularick and Taylor (2012) finds that credit growth strongly predicts crises.

[11] Philippon (2015) finds that historically, periods of high financial sector contribution to GDP in the US are primarily driven by increases in the quantity of intermediated assets. The two peaks correspond to the two most severe financial crises – the Great Depression and recent financial crisis.

[12] See Chari and Jagannathan (1988) and Jacklin and Bhattacharya (1988).

from coordination failure between investors.[13]

In the model, financial fragility is an endogenous and inefficient outcome. My view contrasts with existing theories that argue for the optimality of fragility as a commitment device (Diamond and Rajan (2001)) or fragility as a side effect of the optimal use of debt (Dang et al. (2015)). In these theories, fragility is a necessary feature of a functional financial system. Instead, I view fragility as a detrimental consequence of the strategic interaction between investors and the intermediary sector resulting from information asymmetry, which naturally arises from the specialized nature of financial intermediation and a lax regulatory environment.

These results have important policy implications. Specifically, the discrepancy in the positive view of fragility results in a sharp divergence in the optimal policy. When fragility is optimal, policy discussions circle around the role of ex-post liquidity provisions to the intermediary sector or financial markets.[14] However, under the view that a financial crisis begins at the build-up of an investment boom, these policies are not only ineffective, but can be detrimental. Instead, ex-ante policy, in the form of regulation, is necessary to improve efficiency. One effective policy I propose is the use of retained earnings as capital buffers. Inside equity has an ex-ante regulatory effect – the intermediary sector can credibly commit to increasing borrowing only when there are many productive investment opportunities. This alleviates the asymmetric information problem between investors and the intermediary sector, and actually *improves* the allocative efficiency of intermediation.

A broad objective of the paper is to demonstrate a mechanism through which economic fluctuations originate from the financial intermediary sector. In the model, the intermediary sector determines both the quantity and the quality of the allocation of capital to investment opportunities. The strategic incentives for the intermediary sector to provide capital to the real sector, and its propensity to misallocate capital may directly impact the business

[13] See also Postlewaite and Vives (1987), Rochet and Vives (2004), and Goldstein and Pauzner (2005).
[14] For example, see Allen and Gale (1998).

cycle. I view the intermediary sector as not only amplifying (Kiyotaki and Moore (1997), Bernanke et al. (1999)) and propagating shocks, as commonly viewed by the literature, but as an essential segment of the economy that originates fluctuations through its strategic behavior and interaction with investors.[15]

This view provides a lens to study the transmission mechanism of monetary policy. I show that monetary policy, through its effect on the risk-free interest rate, can potentially contribute to fragility.[16] In particular, I show that even when the interest rate policy is perfectly anticipated, it can contribute to financial instability by lowering the relative cost of adverse selection and increasing investors' propensity to trigger early liquidation of intermediary assets.[17] Furthermore, I argue that when the underlying cause of fragility is rooted in asymmetric information between investors and the intermediary sector, stimulative monetary policy can be highly ineffective in revitalizing the economy. This provides an explanation for why monetary policy might be ineffective in improving credit conditions through the banking sector during a financial crisis.

In Chapter 2, I present the model. Chapter 3 contains preliminary results and analysis of a benchmark case with symmetric information. In Chapter 4, I analyze the main model with asymmetric information. In Chapter 5, I outline the foundations of a confidence-based crisis. In Chapter 6, I consider policy implications. In Chapter 7, I conclude.

[15]This expands on the view that adverse shocks originating from the financial sector can have real effects, as in Jermann and Quadrini (2012). Also, see Borio (2014).

[16]Dell'Ariccia et al. (2014) studies how low real interest rate policies may increase bank leverage and risk-taking.

[17]Allen and Gale (2000) shows how unanticipated shocks to credit policies can have a destabilizing effect.

CHAPTER 2 : A MODEL OF FINANCIAL INTERMEDIATION

Agents. The model has three periods, $t = 0, 1, 2$. There are two types of risk-neutral agents, a measure of competitive investors and one representative intermediary. Investors have deep pockets and the intermediary has zero wealth. The intermediary is privately informed about its type θ, which can be high (H), moderate (M), or low (L) such that:

$$\theta = \begin{cases} H & \text{w.p. } \pi_H \\ M & \text{w.p. } \pi_M \\ L & \text{w.p. } \pi_L \end{cases} \tag{2.1}$$

where $\pi_\theta \in (0, 1)$ and $\sum_\theta \pi_\theta = 1$.

Assets. The representative intermediary has access to a set of long-term investment opportunities. Long-term assets each cost 1 to produce and pay off after two periods. There are two types of long-term assets: good assets $(i = g)$, which pay R with certainty, and bad assets $(i = b)$, which pay R with probability $\alpha \in (0, 1)$. Bad assets are assumed to be perfectly correlated.[1] Good assets have positive returns, while bad assets have negative expected returns. This is captured by the assumption:

$$\alpha R < 1 < R. \tag{2.2}$$

The representative intermediary's type determines its set of investment opportunities.[2]

[1]For instance, bad assets may be exposed to systematic risk that is not fully diversifiable. What is important is that bad assets are partially correlated. High correlation would also be endogenously chosen by the intermediary if it could produce bad assets with any correlation structure.

[2]I offer two broad interpretations of the intermediary's investment opportunities. One view is that any marginal asset produced beyond the maximum quantity of good assets K_θ requires overt risk-taking by the intermediary. The second view is that beyond a certain level of investment K_θ, the intermediary may face limitations in correctly assessing or mitigating risks. Whatever the underlying reason, the key is that investors are uninformed about the nature of the intermediary's opportunities or ability, about which the intermediary sector is privately informed about. I discuss this in greater detail in Chapter 5.

Specifically, an intermediary of type θ has access to K_θ good assets, which is given by:

$$K_\theta = \begin{cases} K & \text{if } \theta = H \\ \gamma K & \text{if } \theta = M \\ 0 & \text{if } \theta = L, \end{cases} \tag{2.3}$$

where $K > 0$ and $\gamma \in (0,1)$. In addition, the intermediary has access to an unbounded amount of bad assets. Investors cannot verify whether a long-term asset is good or bad, and can invest in a short-term risk free asset with return 1 that lasts one period.

Intermediation. To produce k assets, the intermediary must raise k capital from investors. The intermediary of type θ chooses capital demand $k(\theta) \geq 0$. Upon observing capital demand k, investors fund the intermediary's portfolio of assets using a debt contract with an early liquidation option. The debt contract specifies an interest rate $r(k)$ due at $t = 2$, and provides the investor with an option to force early liquidation at $t = 1$. If the option is exercised, the entire proceeds from early liquidation is paid to the investor.[3] If the intermediary fails to pay the required payment $r(k)$ per contract at $t = 2$, the realized returns of the intermediary's pool of long-term assets are distributed to existing investors, proportionally to their initial investments. Investors competitively bid using interest rates $r(k)$, such that, in equilibrium, investors break even in expectation. As such, while the early liquidation value is determined by the amount at which the intermediary can liquidate long-term assets, the funding rate $r(k)$ is determined by investors, who competitively bid until the expected return on debt is equal to the risk free return 1.

After raising $k(\theta)$ capital from investors, an intermediary of type θ selects a portfolio $\mathbf{k}(\theta)$ of long-term assets that specifies a quantity of good and bad assets, subject to its investment

[3] In this setting, investors are contractually entitled to the exact full early liquidation value. This shuts down problems arising from coordination problems between investors à la Diamond and Dybvig (1983).

opportunity set:

$$\mathbf{k}(\theta) = (k_g(\theta), k_b(\theta)) \in \{(q_g, q_b)|\, q_g \in [0, K_\theta] \text{ and } q_b + q_g = k\}, \tag{2.4}$$

where $k_g(\theta)$ and $k_b(\theta)$ are the amounts of good and bad assets produced by an intermediary of type θ.

Public Information and Early Liquidation. At $t = 1$, a public information signal arrives that reveals good (G) or bad (B) information regarding the assets produced by the representative intermediary. The likelihood of good or bad information is endogenously determined by the composition of the intermediary's portfolio. Specifically, a noisy signal y arrives about the quality of a long-term asset that is randomly drawn with equal probabilities, where:

$$Prob(y = G|i = g) = Prob(y = B|i = b) = \rho, \tag{2.5}$$

given an asset of quality i for signal precision $\rho \in [\frac{1}{2}, 1)$. For example, when the intermediary produces a portfolio of (k_g, k_b) assets, the probability that $y = G$ or $y = B$ are given by:

$$y = \begin{cases} G & \text{w.p. } \rho \cdot \frac{k_g}{k} + (1-\rho) \cdot \frac{k_b}{k} \\ B & \text{w.p. } (1-\rho) \cdot \frac{k_g}{k} + \rho \cdot \frac{k_b}{k}. \end{cases} \tag{2.6}$$

Hence, the likelihood that a bad signal $y = B$ arrives at $t = 1$ increases when the intermediary produces a portfolio with lower average quality, and likewise, the likelihood that a good signal $y = G$ arrives at $t = 1$ increases when the intermediary produces a porfolio of higher average quality.

After observing the public signal y, investors face an option to force early but costly liquidation. Let an investor's liquidation decision be denoted $l(k, y) \in \{1, 0\}$, where $l = 1$ when an investor decides to exercise early liquidation, and $l = 0$ if he decides to maintain investments. If $l = 1$, an investor receives the full early liquidation value of $\underline{\mathrm{R}}$ per unit of risky assets, where $\underline{\mathrm{R}} < 1$.

Agents' Objectives. The representative intermediary and investors maximize their expected payoff at $t = 2$. Let the total $t = 2$ cashflow of a θ type intermediary's portfolio be denoted $\tilde{R}(\mathbf{k}(\theta))$. The $t = 2$ payoff of an investor's unit debt contract, denoted D_2, is given by:

$$D_2(\mathbf{k}(\theta), r(k)) = \min\left\{r(k), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}. \tag{2.7}$$

The expected payoff of the debt contract is the minimum between the promised return on debt $r(k)$, and the fractional payoff of the intermediary's portfolio, $\frac{1}{k}\tilde{R}(\mathbf{k}(\theta))$. Importantly, the interest rate $r(k)$, which is competitively determined at $t = 0$, depends on the investors' equilibrium liquidation strategies, since the decision to liquidate affects investors' bidding strategies for the funding rate. Let $r_0(k)$ denote the competitive funding rate given capital demand k and conditional on the investor's liquidation decision being $l(k, y) = 0$ for $y = G, B$. The equilibrium interest rate $r(k)$ is equal to $r_0(k)$ if and only if conditional on the public information signal y for $y = G, B$, maintaining investments (i.e. $l(k, y) = 0$) maximizes the the investor's conditional expected profits at $t = 1$. An individual investor's liquidation decision l conditional on k and y is chosen to maximize $t = 1$ expected profits:

$$\max_{l\in\{0,1\}} l \cdot \underline{R} + (1 - l) \cdot \mathbb{E}\left[D_2(\mathbf{k}(\theta), r_0(k))\middle|\, k, y\right]. \tag{2.8}$$

When the condition for $l(k, y) = 0$ is violated for any y, an investor chooses $l(k, y) = 1$ for some y. Note that investors share the same information set at $t = 0$ and $t = 1$, and each investor obtains the full early liquidation value $\underline{R}$ if they choose to force liquidation, independent of other investors' liquidation decisions. As a result, while each investor independently decides on whether to force early liquidation, the liquidation decision is identical across all investors, conditional on k and y. This directly implies that either all or none of the intermediary's assets are liquidated. This setting is intended to abstract from strategic interactions that may arise due to asymmetric information between investors, as in Chari and Jagannathan (1988), or strategic complementaries that arise due to coordination problems between investors, as in Diamond and Dybvig (1983).

In the model, a liquidation event is a *collective* decision based on investors' beliefs and all available public information at $t = 1$. The equilibrium interest rate for the debt contract must also be identical. Given investors' beliefs, denoted $\mathcal{B}(k)$, the equilibrium funding rate $r(k)$ for capital demand k is determined competitively at $t = 0$ such that in equilibrium:

$$\mathbb{E}\left[\sum_{y' \in \{G,B\}} Prob(y = y'|k) \max\left\{E\left[D_2(\mathbf{k}(\theta), r(k))|k, y'\right], \underline{R}\right\}\right] = 1. \tag{2.9}$$

As stated earlier, the equilibrium funding rate $r(k)$ is determined conditional on investors' liquidation strategies. Investors' bidding strategies reflects the change in the expected terminal payoff of the debt contract when they anticipate exercising their liquidation option in some possible future state at $t = 1$.

A representative intermediary of type θ chooses capital demand $k(\theta)$ and portfolio $\mathbf{k}(\theta)$ that maximizes its expected profits:

$$\max_{\mathbf{k}(\theta)} \sum_{y' \in \{G,B\}} Prob(y = y'|\mathbf{k}(\theta)) \cdot (1 - l(k, y')) \cdot \mathbb{E}\left[\tilde{R}(\mathbf{k}(\theta)) - k(\theta) D_2(\mathbf{k}(\theta), r(k))\right]$$

$$\text{s.t. } k(\theta) \geq 0$$
$$k_g(\theta) \in [0, K_\theta]$$

The intermediary must take into consideration three main aspects that affect its expected profits. First, the intermediary's demand for capital $k(\theta)$ and portfolio decision $\mathbf{k}(\theta)$ directly affect the total surplus from intermediation $\tilde{R}(\mathbf{k}(\theta))$. Second, the intermediary's portfolio decision $\mathbf{k}(\theta)$ determines the nature of the public information signal y, and in particular, the likelihood that good or bad information arrives. Third, the intermediary's demand for capital $k(\theta)$ affects investors' beliefs, which in turn affect investors' equilibrium liquidation strategies $l(k,\cdot)$ and the equilibrium funding rate $r(k)$.

Timeline. The events of the model go as follows:

$t=0$ The representative intermediary privately learns its type θ, and raises $k(\theta)$ capital from investors, who finance the intermediary through a debt contract with a liquidation option. Given $k(\theta)$, the intermediary produces a portfolio $\mathbf{k}(\theta)$ of long-term assets;

$t=1$ Public information signal y arrives. Investors decide on $l \in \{1,0\}$. If investors choose $l=1$, the intermediary is forced to liquidate assets;

$t=2$ Existing assets pay out.

I restrict the analysis to pure strategies. The solution concept used is Perfect Bayesian Equilibrium. An equilibrium consists of the intermediary's capital demand $k^*(\theta)$ and production decision $\mathbf{k}^*(\theta)$ for $\theta \in \{H,M,L\}$, and investors' early liquidation strategies $l^*(k,y)$, equilibrium funding rate $r^*(k)$, and investors' beliefs $\mathcal{B}(k)$. The formal definition can be found in Appendix A.1.

CHAPTER 3 : PRELIMINARY ANALYSIS

In this section, I provide some general properties and then analyze the model when investors are informed about the intermediary's realization θ. This will serve as a benchmark for the main framework. All proofs can be found in the Appendix.

3.1. Asset Production and Investment

First, note that investors will fund an intermediary that demands k capital only if given their beliefs $\mathcal{B}(k)$, their participation condition is satisfied:

Condition 1. *Given investors' beliefs $\mathcal{B}(k)$, investors' participation condition for capital demand k is satisfied if:*

$$\mathbb{E}\left[\sum_{y'\in\{G,B\}} Prob(y=y'|k)\max\left\{E\left[D_2(\mathbf{k}(\theta),R)|k,y'\right],\underline{R}\right\}\right]\geq 1. \tag{3.1}$$

Equivalently, investors find it individually rational to participate as long as conditional on investors' beliefs $\mathcal{B}(k)$, the competitively determined funding rate satisfies $r(k)\leq R$. In other words, an investor provides capital to the intermediary only when given his beliefs, the expected payoff of the intermediary's assets are sufficiently great such that investor can break even. Henceforth, Condition 1 is said to be satisfied if given investors' equilibrium beliefs, all equilibrium production choices $k^*(\theta)$ satisfy investors' participation condition, which is necessary for any intermediation to occur in equilibrium.

The intermediary's portfolio decision has the following general property:

Lemma 1. *The intermediary prefers to produce a good asset to a bad asset.*

Generally, an intermediary has an incentive to select a good asset over a bad asset conditional on a good asset being accessible. Good and bad assets both cost 1 to produce and differ only in the likelihood of terminal payoff R. As a result, the intermediary can always weakly increase its surplus by producing a good asset in place of a bad asset. This setting effectively shuts down agency problems sprouting from asset substitution or hidden effort. Henceforth, I assume that investors' beliefs about the production decision $\mathbf{k}(\theta)$ of an intermediary of type θ reflect the intermediary's general preference outlined in Lemma 1.[1]

3.2. Benchmark: Symmetric Information

To contrast with the main setting, I describe the equilibrium outcomes under symmetric information. Consider when investors cannot directly observe the quality of the long-term assets, but learn the true realization of the intermediary's type θ. The symmetric information equilibrium is characterized below:

Proposition 1. *Under symmetric information about θ, the first-best outcome is achievable: the intermediary of type θ raises K_θ capital, and produces a portfolio comprised of K_θ good assets and no bad assets. Furthermore, investors never exercise early liquidation.*

When investors are symmetrically informed about the investment opportunities of the intermediary, investment capital and the number of good investment opportunities of intermediary sector form a *positive monotonic relation.* When the intermediary realizes more productive investment opportunities, it is able to obtain, and finds it incentive compatible to obtain, greater amounts of capital from investors. I refer to this as the ***growth* motive** of intermediary investment. An intermediary with more investment opportunities has an intrinsically greater level of efficient production. The profit-maximizing behavior of an intermediary motivated by growth coincides with the efficient allocation of capital to productive long-term investments.

Note that the intermediary does not undertake any inefficient risk-taking in the form of producing bad assets. Two factors make risk-taking undesirable. First, the seniority of debt contracts naturally protects investors from inefficient risk-taking at a local level. To see this, consider an intermediary deciding whether to marginally produce a bad asset by borrowing more from investors, and suppose that investors provide the marginal funding

[1] This rules out equilibria where investors' beliefs are such that the intermediary will always produce bad assets and the intermediary is indifferent between a strategy of producing good assets and bad assets.

with a debt contract with terms that would be offered if they believed all assets to be funded were good. Due to the seniority of debt, the intermediary, at the benefit of realizing a greater payoff with probability α when the bad assets pay off, needs to pay investors a greater portion of the surplus from good assets with probability $1-\alpha$, when the bad assets do not pay off. As long as the total payoff from the good assets cover the total cost of funding, investors' payoffs are unaffected by risk-taking.[2] In this way, the intermediary's good assets provide "skin-in-the-game." The intermediary, who must absorb the entire cost of risk-taking with the payoff from its good assets, is better off producing only good assets. While a debt contract renders local risk-taking undesirable, an intermediary may increase its profits by ramping up borrowing and taking sufficiently great risks. However, under symmetric information, since investors can infer that the intermediary plans to produce beyond its capacity, investors will demand a higher interest rate that reflects any anticipated inefficient production of assets.

The growth motive of intermediation captures the positive relation between financial development and economic growth. In times when the set of productive investment opportunities expands (i.e. higher realization of θ), intermediaries have a natural incentive to facilitate greater capital allocation. For instance, financial intermediaries may respond to innovations and opportunities in the real economy and accelerate the capital allocation to long-term projects.[3] Innovations in contracts, market structure, and screening technology can also expand the intermediary sectors' efficiency and result in a larger set of feasible investment opportunities. Real or financial, a positive shock in θ can culminate into greater financial intermediation and long-term investments that contribute to growth.[4]

Overall, under symmetric information about the intermediary's type, the first-best efficient outcome is obtained. This benchmark will serve to highlight the effect and impact of the key friction: asymmetric information about the intermediary's investment opportunities.

[2] Hence, the unit payoff of the debt claim is unchanged for local deviations of production.
[3] See Greenwood and Jovanovic (1990).
[4] See King and Levine (1993).

CHAPTER 4 : INTERMEDIATION UNDER ASYMMETRIC INFORMATION

When the intermediary's investment opportunities are not directly observable, investors must base their investment decisions on their beliefs and all available information. As a result, when the financial intermediary sector is better informed about its pool of investment opportunities, the intermediary demand for capital becomes an important source of information to investors. The intermediary sector's financing decision incorporates investors' perception about its underlying investment opportunities.

4.1. Uncertainty in Booms

To isolate the intuition regarding the effect of asymmetric information on the equilibrium levels of capital investment, I first suppress the $t = 1$ arrival of public information y by considering when $\rho = \frac{1}{2}$. This corresponds to the case where no material public information about the representative intermediary's assets arrives until long-term assets mature.

The first main result is that under asymmetric information, *greater capital investment is necessarily accompanied by greater uncertainty.* Specifically, two investment states endogenously arise: normal times and booms.[1] In normal times, the intermediary sector makes modest capital investment, and investors face no uncertainty about the underlying investment opportunities. In booms, the intermediary sector makes expansionary capital investment, and investors face high uncertainty about the nature of the investment opportunities.

This dichotomy between normal times and booms results from the equilibrium financing strategies of each type of the representative intermediary. I show that normal times are when the intermediary realizes moderate investment opportunities ($\theta = M$), while booms arise when the intermediary is either a high or low type ($\theta = H$ or $\theta = L$). I call this a (K_1, K_2) equilibrium:

Theorem 1 (Uncertain Booms)**.** *Let $\rho = \frac{1}{2}$. There exists an equilibrium in which for some*

[1] These are "states" in the sense that they are the observable aggregate outcomes, endogenously determined from a latent, unobservable state θ.

K_1, K_2*:*

1. *an intermediary of type* M *obtains* K_1 *capital;*

2. *an intermediary of type* H *or* L *obtains* K_2 *capital;*

where $K_2 > K_M \geq K_1 > 0$ *if and only if* $R > \hat{R}$ *for threshold* $\hat{R} = \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}$.

In addition to the growth motive described in Chapter 3, asymmetric information brings rise to another economic force that affects intermediary investment: the ***risk-taking*** **motive**. An intermediary with fewer productive investment opportunities has a stronger incentive to increase its scale of production, primarily by inefficiently taking greater risks, as long as it can mask its private information by pooling with a higher type. This moral hazard problem increases as the intermediary realizes fewer investment opportunities.

The risk-taking motive embodies a deleterious effect of a specialized intermediary sector. Specialization breeds private information, which creates temptations to profit at the expense of uninformed investors. Incentives to take inefficient risks are rooted in profit maximizing behavior – the agency conflict is primarily between insiders and outsiders. In this regard, equity holders, who are positioned to monitor more effectively, may not have strong incentives to do so.[2] This reinforces the sustainability of asymmetric information.

In equilibrium, the intermediary sector raises high amounts of capital K_2 when it realizes high or low investment opportunities, for antithetical reasons. A high type intermediary is principally motivated by growth. A high type raises large amounts of capital in order to exploit the abundance of good investment opportunities. This comes at the cost of paying an adverse selection premium to investors. For a low type intermediary, risk-taking dominates. A low type maximizes profits by intermediating large quantities of capital, and taking inefficient risks that are borne by investors, thereby capitalizing on private information.

In contrast, for a moderate type intermediary, neither the growth motive nor risk-taking

[2]I discuss the policy implications in Chapter 6.

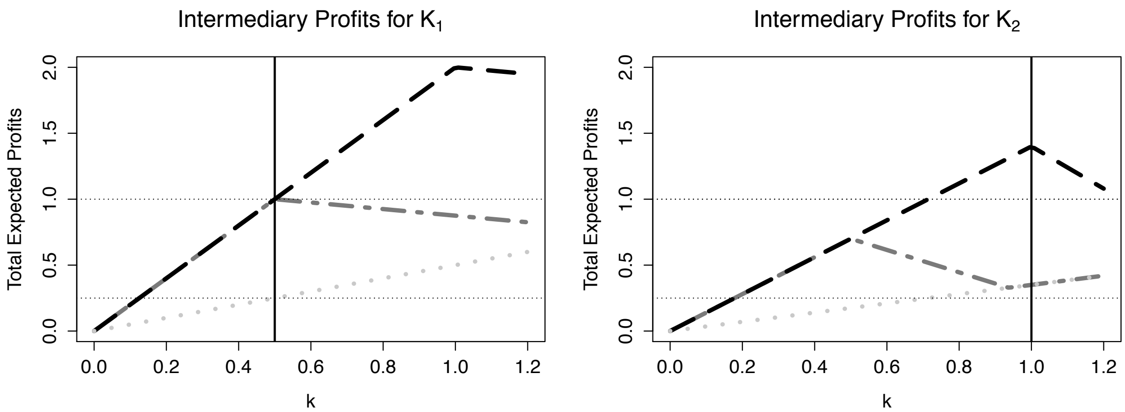

Figure 1: Panel 1 and Panel 2 are the expected profits (and profits from deviation) of the high (**black** dashed curve), moderate (**dark gray** dash-dotted curve), and low type (**light gray** dotted curve) for $k = K_1$ and $k = K_2$, respectively, given investors' beliefs in a (K_1, K_2) equilibrium with $\rho = \frac{1}{2}$. The equilibrium production levels are shown in bold vertical lines, given by $K_1 = K_M$ and $K_2 = K_H$. The parameters are $K = 1$, $R = 3$, $\alpha = \frac{1}{4}$, $\pi_H = \pi_M = \pi_L = \frac{1}{3}$, and $\gamma = \frac{1}{2}$.

motive are strong enough to warrant high capital demand. Instead, profits are maximized when it raises modest amounts of capital K_1 devoted to producing good long-term assets. By doing so, a moderate type can convey its private information through its demand for capital, and avoid an explicit adverse selection cost of capital.

Figure 1 illustrates how the growth and risk-taking motives impact each type of the representative intermediary, and ultimately lead to the (K_1, K_2) equilibrium structure. Panels 1 and 2 graph the profit curves of each type given the equilibrium (or deviating) strategies for K_1 and K_2, respectively. The bold vertical lines in Panel 1 and 2 represent the equilibrium investment levels (K_1, K_2). Accordingly, Panel 1 maps the hypothetical payoff curves of each type for various values of K_1 conditional on investors' beliefs that $\theta = M$. Note in Panel 1, the total expected equilibrium profits of the moderate type, shown in **dark gray**, increase up to K_M, which in this equilibrium also equals to K_1. In comparison, the moderate type's expected profits from deviating to K_2, shown in Panel 2, are globally inferior to that achieved at K_1 in Panel 1. This is attributable to two factors. First, for $k = K_2$, the adverse selection premium on the cost of capital lowers the intermediary's share of the returns from intermediary assets, which can be seen by the dampened slopes of profit curves for all types in Panel 2 compared to those in Panel 1. Second, the moderate type's total expected profits actually decrease as it produces beyond K_M. This is due to the counteraction between the risk-taking and growth motives. A moderate type, by producing bad assets, actually sacrifices the surplus from good assets in order to finance bad assets. Since risk-taking entails investing in negative return assets, this diminishes total profits of the moderate type up to any production level at which the payoff of the good assets cover the intermediary's debt obligations. Note, for sufficiently large k, the moderate type's profit curve intersects and coincides with the low type's profit curve, shown in **light gray**. At this point, the moderate type's profit curve begins to increase, as the risk-taking motive dominates.

The high type's equilibrium profits in Panel 2, represented in **black**, are maximized at K_H, which in this equilibrium is equal to K_2. As with the moderate type, any production greater than K_H decreases its payoff. Importantly, even though its profits are reduced due to the higher cost of capital, they are greater than what it could obtain by deviating to K_1. The availability of many productive investment opportunities incentivizes the high type to pursue greater intermediation, even if it must yield a greater share of the surplus to investors. On the contrary, the low type's profit curve in Panel 2 exhibits no kink. As the low type is primarily motivated by risk-taking, profits are determined solely by the level of intermediation, and not by concerns regarding the quality of its assets. This results in profits monotonically increasing with respect to k over the entire region of the graph. As such, while the high type has a strict preference to produce at levels nearest to K, the low type strictly prefers producing more than K assets.

In a setting of asymmetric information, investment capital and the type of the intermediary form a *non-monotonic* relation. Furthermore, in a (K_1, K_2) equilibrium, asymmetric information is partially resolved at the financing stage, but only when demand for capital is low ($k^* = K_1$). All residual information asymmetry is concentrated in the high investment state K_2, bringing rise to *uncertain booms*. In addition, in an investment boom, investors' beliefs are polarized – their beliefs about the intermediary's type upon observing $k^* = K_2$ are:

$$\theta = \begin{cases} H & \text{with probability } \frac{\pi_H}{\pi_H + \pi_L} \\ L & \text{with probability } \frac{\pi_L}{\pi_H + \pi_L}. \end{cases} \tag{4.1}$$

Put differently, investors rationally form beliefs that high investment states are either when the intermediary sector has many or few investment opportunities. This directly implies that investors face high uncertainty about the underlying quality of the intermediary's assets during booms. In contrast, investors face no uncertainty about asset quality in normal times.

Reconsider the benchmark case described earlier. Under symmetric information, an intermediary of low type was not able to obtain funding from investors; an intermediary of moderate type raised a moderate level of capital; an intermediary of high type raised a high level of capital. As a result, the intermediary sector perfectly facilitated the allocation of capital, and investors faced *no* ex-ante uncertainty for any equilibrium investment level.

Surprisingly, the existence of a (K_1, K_2) equilibrium when $\rho = \frac{1}{2}$ hinges *only* on equilibrium investment levels satisfying investors' individual rationality.[3] For K_1, Condition 1 always holds, since there exists an equilibrium where $K_1 \leq \gamma K$, and $R > 1$. For K_2, Condition 1 holds as long as adverse selection is not prohibitively severe:

$$\frac{\pi_H \left(\frac{k_g(H)}{K_2} + \mathbb{1}_{\{k_g(H) < K_2\}} \cdot \frac{k_b(H)}{K_2} \cdot \alpha \right) + \pi_L \alpha}{\pi_H + \pi_L} R \geq 1. \tag{4.2}$$

A general property of asymmetric information models with signaling is the multiplicity of equilibria. The (K_1, K_2) equilibrium is uniquely the only class of equilibria in which any information is transmitted to investors through the its capital demand that is not trivial in the following sense:

[3] In fact, the (K_1, K_2) equilibrium structure extends to a wide set of contracts, including short-term debt and equity.

Proposition 2. *Any informative equilibrium that is not a (K_1, K_2) equilibrium is always strictly Pareto-dominated by an uninformative equilibrium.*

The nonexistence of a nontrivial separating equilibrium is a direct corollary of Proposition 1.[4] Since the low type cannot obtain any funding from investors under full separation, a low type has an incentive to choose a production level that would be chosen by either a moderate or high type, as long as pooling with a moderate or high type yields profits greater than zero. Incidentally, the low type can achieve expected profits greater than zero whenever a high or moderate type can do so, given any production level.[5]

At glance, the fact that no other nontrivial partial separation can exist is somewhat surprising. A reasonable candidate equilibrium would be one in which the low and moderate types pool and the high type separates. The key is to understand each type's incentives to increase the scale of asset production. For a high type, increasing the scale of investment is beneficial to maximize its asset production capacity to the efficient level. On the contrary, a low type has strong incentives to take excessive risk – increasing scale is purely to take advantage of its private information. As such, the low type has a stronger bias toward increasing scale than either the moderate or the high type. The candidate equilibrium would require there exist a set of production choices for which the low type prefers to pool with the moderate type. This would only be the case if the moderate type's pool entailed higher production levels. However, a high type has a stronger bias toward higher production due to its greater efficient capacity. This prevents the existence of such a case.

To understand the equilibrium relation between the pair (K_1, K_2) to model primitives, I characterize the constrained efficient (K_1, K_2) equilibrium:

Proposition 3. *Let $\rho = \frac{1}{2}$ and $R > \hat{R}$. The constrained efficient (K_1, K_2) equilibrium is:*

[4]There is a knife-edge case where the high type intermediary produces sufficiently many bad assets such that $r(k(H)) = R$. This ensures that the intermediary never makes positive profits. Only in this case is the intermediary of low type indifferent between producing no assets and some assets. This extreme case is strictly dominated by an uninformative equilibrium, where all types choose to produce ϵ assets, for arbitrarily small ϵ.

[5]More generally, fully separating equilibria are always strictly-dominated for sufficiently small K_L.

1. $(\hat{\gamma}K, K)$ *if* $\gamma > \hat{\gamma}$*;*

2. $(\gamma K, K)$ *if* $\gamma \in (\alpha\hat{\gamma}, \hat{\gamma})$*;*

3. $\left(\gamma K, \frac{\gamma}{\alpha\hat{\gamma}}K\right)$ *if* $\gamma < \alpha\hat{\gamma}$*;*

for threshold $\hat{\gamma} = \frac{R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}}{R-1}$.

In general, all efficient (K_1, K_2) equilibria are characterized by the following properties:

$$K_1 \leq \gamma K \tag{4.3}$$

$$\gamma K < K_2 \leq K \tag{4.4}$$

This reveals that relative to the first-best outcome outlined in Proposition 1, underproduction can occur, whether it is in normal times, when $K_1 < K_M$, or in booms, when $K_2 < K_H$. At the same time, overproduction is always committed by the intermediary with low investment opportunities. Asymmetric information results in a *dual inefficiency problem*, in which efficiency losses result from *both* under- and overproduction.

The nature of underproduction depends on the severity of adverse selection, as observed through $\hat{\gamma}$. When adverse selection is high, for example, due to a high likelihood of a low type relative to high type π_L/π_H, a moderate type must produce less than K_M in equilibrium. While a moderate type intermediary does not incur an explicit adverse selection cost of funding, it does incur an *implicit* adverse selection cost required to credibly signal to investors its private information. When adverse selection is low, the diminished cost of risk-taking to the moderate type creates a temptation to overproduce. In this case, the high type underproduces.

In equilibrium, normal times and booms exhibit a dramatic difference in uncertainty. This uncertainty is reflected in the discrepancy in expected returns and variance in the payoff of intermediary assets between normal times and booms. Risk-taking incentives of the intermediary sector naturally lower the expected value of intermediary assets during booms (i.e. $\mathbb{E}[\frac{1}{K_1}\tilde{R}(K_1)] > \mathbb{E}[\frac{1}{K_2}\tilde{R}(K_2)]$), and also contribute to greater variance in the payoff of intermediary assets (i.e. $VAR[\frac{1}{K_1}\tilde{R}(K_1)] < VAR[\frac{1}{K_2}\tilde{R}(K_2)]$).

4.2. Fragility in Booms

In this section, I analyze the main setting in which after investors fund the intermediary's assets at $t = 0$, an informative signal about an intermediary's asset arrives, which corresponds to when $\rho > \frac{1}{2}$.

4.2.1. The Fragility of Investors' Beliefs and Costly Early Liquidation

Subsequent arrivals of information can play a vital role in shaping investors' confidence about their investments made at $t = 0$. In particular, investors' beliefs about the payoff likelihood of the debt claim may change following the arrival of public signal y at $t = 1$. A useful variable is the "investment recovery rate," or the expected fraction of the promised return that an investor can retrieve at $t = 2$, conditional on investors always maintaining investments, i.e. when $l(k, y) = 0$ for $y = G, B$:

Definition 1. *The investment recovery rate $\omega(\mathbf{k}(\theta))$ is given by:*

$$\omega(\mathbf{k}(\theta)) = \begin{cases} 1 & \text{if } k_g(\theta) \geq k(\theta) \cdot \frac{r_0(k)}{R} \\ \alpha + (1-\alpha) \cdot \frac{k_g(\theta) R}{k(\theta) r_0(k)} & \text{if } 0 \leq k_g(\theta) < k(\theta) \frac{r_0(k)}{R} \end{cases} \tag{4.5}$$

The investment recovery rate ω is equal to 1 when investors' debt always pays off at $t = 2$. When the payoff from the good assets produced by the intermediary do not cover the debt payments, the investment recovery rate drops below 1. When negative information arrives, investors may revise downward their beliefs about the soundness of the intermediary's investments. Specifically, when investors face uncertainty about $\mathbf{k}(\theta)$, signal y can affect investors' beliefs about $\omega(\mathbf{k}(\theta))$ at $t = 1$. Importantly, the magnitude of the downward shift in investors' beliefs following public information depends on the informational content that signal y provides, *above and beyond what is already known by investors.* The extent to which investors' beliefs are fragile depends on the influence that negative information has on the formation of investors' beliefs. I formally define a notion of belief *fragility*:

Definition 2. *Given investors' beliefs $\mathcal{B}(k)$ conditional on k, the* **fragility** *of beliefs, denoted $F(k)$, is the change in investors' beliefs about the investment recovery rate following a negative signal $y = B$ about an intermediary asset, i.e.*

$$F(k) = \frac{\mathbb{E}[\omega(\mathbf{k}(\theta))|k]}{\mathbb{E}[\omega(\mathbf{k}(\theta))|k, y = B]}. \tag{4.6}$$

Intuitively, fragility $F(\cdot)$ measures the *sensitivity* of investors' beliefs to information shocks, controlling for investors' beliefs at the financing stage, i.e. after observing capital demand k. As such, it captures the extent to which investors' beliefs about the value of their debt claims can drop when a negative signal about an intermediary asset arrives.

The fragility of investors' beliefs is endogenously determined by the intermediary's equilibrium strategies. Investors form interim beliefs at $t = 0$ based on the intermediary's capital demand $k^*(\theta)$. The informativeness of the public information signal y that arrives at $t = 1$ is endogenously determined by the intermediary's production decision $\mathbf{k}^*(\theta)$. Investors' beliefs become fragile when public information signal y, which compounds information about the composition of the intermediary's assets, highly complements investors' interim beliefs, which are formed based on the intermediary's capital demand.

This fragility of investors' beliefs is closely tied to investors' decision to trigger early liquidation of the intermediary assets. Recall,the debt contract provides investors with an option to exercise early liquidation. Investors select $l \in \{1, 0\}$ after observing public signal y. As shown in Proposition 1, when investors face no uncertainty about the intermediary's type θ, they never choose early liquidation. The option to liquidate is only relevant when asymmetric information remains unresolved after the funding stage.

Suppose that investors provide the intermediary with capital k which satisfies Condition 1 but remain uncertain about the underlying type θ. At $t = 1$, public information y arrives.

Since investors are not perfectly informed about the quality of the intermediary's assets, investors rationally update their beliefs. Clearly:

Lemma 2. *Liquidation never follows good information, i.e. when $y = G$.*

Following good information, investors' posterior beliefs reflect an upward revision in their confidence about the quality of the intermediary assets. However, a negative signal $y = B$ can prompt a downward revision in the perceived value of intermediary sector's assets. This fluctuation in investor confidence results in intermediary's assets becoming subject to potential early liquidation. In general, it is optimal to exercise the liquidation option when beliefs are sufficiently fragile:

Lemma 3. *For sufficiently large belief fragility $F(k)$, investors trigger early liquidation following a negative signal, i.e.*

$$l(k, B) = 1 \text{ if and only if } F(k)^{-1} < \underline{R} \tag{4.7}$$

In other words, only when investors' beliefs are sufficiently fragile (i.e. large $F(k)$), do investors exercise their option to force liquidation. In the context of the model, a collective liquidation event results from sufficiently large drops in investors' confidence about the quality of intermediary assets. This resembles a *flight-to-quality* episode, which refers to the phenomena where investors abruptly move their capital from certain financial markets to safe assets due to concerns about the quality of assets.

The structure of the (K_1, K_2) equilibrium foreshadows when the intermediary sector becomes vulnerable to fluctuations in investors' beliefs. Investors face uncertainty about the underlying quality of the intermediary assets exclusively in booms ($k^* = K_2$). This directly implies that investors' beliefs are fragile only in booms, i.e.

$$F(K_2) > F(K_1) = 0. \tag{4.8}$$

4.2.2. Liquidity Risk in the Intermediary Sector

Consider when investors' beliefs are sufficiently fragile such that the condition specified in Lemma 3 holds for some investment level k'. When the aggregate production level is k', a bad signal (i.e. $y = B$) about an intermediary asset triggers investors to force early liquidation. Since liquidation is conditioned on the production level k' and the arrival of negative public signal, an intermediary of *any* type is subject to liquidity risk. Consequently, the likelihood of early liquidation is taken into account by the intermediary when deciding on the level of production. In other words, the intermediary *anticipates* liquidity risk, which manifests from the mismatch between funding maturity and asset maturity.

The likelihood of a liquidation event, which occurs when negative information arrives, is endogenously determined by the quality of the intermediary's portfolio. The probability of negative information arriving for an intermediary with portfolio (k'_g, k'_b), where $k'_g + k'_b = k'$, is given by:

$$\frac{k'_g}{k'}(1-\rho) + \frac{k'_b}{k'}\rho. \tag{4.9}$$

Producing bad assets increases the likelihood of bad information arriving at $t = 1$, which directly increases the risk of early liquidation. Furthermore, when the intermediary's investment opportunity set is restrictive such that $k' > K_\theta$, the intermediary's type reflects the liquidity risk associated with producing k' assets.

As a result, liquidity risk is greatest for a low type intermediary who cannot produce any good assets and is subject to a higher probability of bad information breaking out. The nature of this risk is detailed in Diamond (1991), who outlines how short-term maturity might be selected by risky firms even though it poses greater risk of liquidation. Here, the intermediary faces a tradeoff between choosing greater production that may carry liquidity risk, or lowering operational scale and avoiding liquidity risk.

4.2.3. A Crisis of Confidence

While liquidity risk dampens the gains from risk-taking, it does not generally thwart the production of bad assets. The (K_1, K_2) equilibrium identified in Theorem 1 extends to the main setting. Importantly, investors trigger early liquidation *exclusively* in booms for sufficiently fragile investors' beliefs. I refer to a (K_1, K_2) equilibrium in which liquidation occurs on the equilibrium path as a fragile (K_1, K_2) equilibrium:

Theorem 2 (Crisis of Confidence)**.** *Suppose $\rho \leq \max\{\check{\rho}, \hat{\rho}\}$ and $R > \hat{R}$ for thresholds $\check{\rho}$, $\hat{\rho}$, and $\hat{R}$. There exists a (K_1, K_2) equilibrium in which for some K_1, K_2:*

1. *an intermediary of type M obtains K_1 capital;*

2. *an intermediary of type H or L obtains K_2 capital;*

where $K_2 > K_1 > 0$. Furthermore, if $\check{\rho} < \hat{\rho}$. then, for any $\rho \in (\check{\rho}, \hat{\rho})$,

1. *when $k^* = K_2$, investors exercise early liquidation following $y = B$;*

2. *when $k^* = K_1$, investors never exercise early liquidation.*

Intuitively, the existence of a fragile (K_1, K_2) equilibrium depends on two broad aspects. First, investors' beliefs must be sufficiently fragile such that in equilibrium, investors find it privately optimal to force early liquidation. As the fragility of investors' beliefs monotonically increases in ρ, when $\rho > \check{\rho}$ for some threshold $\check{\rho}$, investors trigger liquidation following negative information in booms. In parallel, the interim signal must still be noisy enough that the low type finds it profitable to undertake the risk of liquidation ($\rho < \hat{\rho}$). When the separating mechanism between the moderate type and the low and high type described in Section 4.1 dominates the intermediary sector's concerns about liquidity risk, there exists a set of intermediate values of ρ such that in equilibrium, investors trigger early liquidation in booms. This corresponds to when the moderate type is "moderate" ($\gamma \ll 1$), or when risk-taking is costly (α small).

Theorem 2 summarizes the second main result. In a fragile (K_1, K_2) equilibrium, investors' beliefs are fragile to public information only in booms, where uncertainty about the quality of the assets is concentrated. The arrival of negative information about an intermediary asset leads to an abrupt shift in investors' confidence about the quality of the intermediary's assets. Severe pessimism about the outlook of the intermediary's assets results in a *crisis of confidence*. Endowed with an early liquidation option, investors force liquidation and move their capital to safe assets.

In a boom, investors form polarized beliefs about the underlying type of the intermediary, creating conditions particularly conducive to large fluctuations in confidence. Furthermore, each type produces starkly different portfolios of assets – while a high type predominantly produces good long-term assets, a low type produces only bad assets. As a result, even learning about the quality of a single intermediary asset can heavily influence investors' perception toward all of the intermediary's assets.

In this way, intermediaries are fragile to a "small" negative information shock during investment booms fueled by debt with a liquidation option. Fragility endogenously arises from the intermediary sector's financing and production decisions. Importantly, the liquidation event is rationally anticipated by the representative intermediary, who takes a calculated risk, and investors, who are prepared to exit from their exposures to intermediary assets following the revelation of negative information.

In a fragile (K_1, K_2) equilibrium, early liquidation is not necessarily ex-post efficient. Investors, who privately determine whether to force early liquidation, do not internalize potential deadweight losses incurred in the process of liquidation. As a result, liquidation can occur in booms even when the ex-post expected value of intermediary assets is greater than the liquidation value, i.e. when

$$\underline{R} < \frac{1}{K_2}\,\mathbb{E}\left[\tilde{R}(k(\theta), k_g(\theta))\,\middle|\, K_2, y = B\right]. \tag{4.10}$$

This is a consequence of a wedge that can exist between the expected value of the investors' debt claim at $t = 1$, and the expected value of the intermediary assets:

$$\mathbb{E}\left[D_2(\mathbf{k}(\theta), r_0(k)) \middle| k = K_2, y = B\right] < \mathbb{E}\left[\frac{1}{K_2}\tilde{R}(\mathbf{k}(\theta)) \middle| K_2, y = B\right], \tag{4.11}$$

which holds since $r_0(K_2) < R$. When the value of early liquidation is lower than the perceived value of the underlying assets, Pareto improvements can be made through renegotiation. This is no longer the case when the early liquidation value exceeds the expected value of intermediary assets. In general, when $\underline{R} > \alpha R$, while it is socially optimal to liquidate the assets of a low type intermediary, it is greatly inefficient to liquidate the assets of a high type intermediary, who by choosing $k^* = K_2$, also risks the possibility of early liquidation.

4.2.4. The "Calm Before the Storm"

In order to evaluate the effect of liquidity risk on the funding cost $r(k)$, I compare the outcomes of the fragile (K_1, K_2) equilibrium to that of a (K_1, K_2) equilibrium without liquidity risk (i.e. when $\rho = \frac{1}{2}$).[6]

In a fragile (K_1, K_2) equilibrium, during a boom, investors are prepared to force liquidation when negative public information arrives. Investors value the option to exit as it curtails the losses associated with funding a low type intermediary. This flexibility is priced into the cost of debt. Perfectly competitive investors, endowed with an early liquidation option, bid down the funding cost more aggressively. For clarity, let this funding rate be denoted $r^{liq}(k)$. In equilibrium, this has the effect of *decreasing* the cost of capital relative to the case without liquidation, denoted $r^{noliq}(k)$. In other words, prior to the onset of a crisis, we may observe a lower cost of capital – a *"calm before the storm"* effect:

Proposition 4. *When early liquidation is anticipated in the realization of negative public information, the ex-ante funding rate drops relative to the rate without early liquidation,*

[6] Alternatively, the equilibrium without liquidity risk corresponds to the case in which investors finance the representative intermediary with long-term debt without a liquidation option.

i.e.

$$r^{liq}(k) < r^{noliq}(k) \tag{4.12}$$

According to the model, a flight-to-quality episode is preceded by a period of lower-than-usual funding rates. From an econometrician's standpoint, this investor behavior, which results from investors rationally taking into account the positive value of the liquidation option that only arises with incomplete information, would be observationally equivalent to return-chasing. Not only would it appear ex-post that these investors took on more risk than desired, since the econometrician observes market-wide early liquidation, but also left money on the table, since the competitive interest rate appears remarkably lower than what would be expected from the apparent level of risk intolerance.

4.2.5. The Ex-Ante Cost of Liquidity Risk

The anticipation of liquidity risk can considerably impact the intermediary's ex-ante equilibrium investment decision in normal times and booms. As discussed in Section 4.2.2, the likelihood of liquidation is highest for a low type. As a result, under the risk of liquidation, the low type faces a tradeoff between producing many assets and facing liquidity risk. This can further strain the ability of a moderate type to credibly signal its type. One way to see this is to compare the ex-ante equilibrium investment levels between an economy in which liquidity risk arises, to one without liquidity risk.

Figure 2 provides an example that illustrates how liquidity risk may pose an ex-ante cost on the equilibrium investment decision of the intermediary. To differentiate between the two cases, let (K_1^{liq}, K_2^{liq}) denote the equilibrium production with liquidity risk, and let $(K_1^{noliq}, K_2^{noliq})$ denote the corresponding equilibrium production without liquidity risk (i.e. $\rho = \frac{1}{2}$). The top two panels present the intermediary profits of each type for $k = K_1$ and $k = K_2$, respectively, given investors' beliefs in a $(K_1^{noliq}, K_2^{noliq})$ equilibrium with liquidity risk. The bold vertical line on each graph are the equilibrium production levels K_1^{noliq}

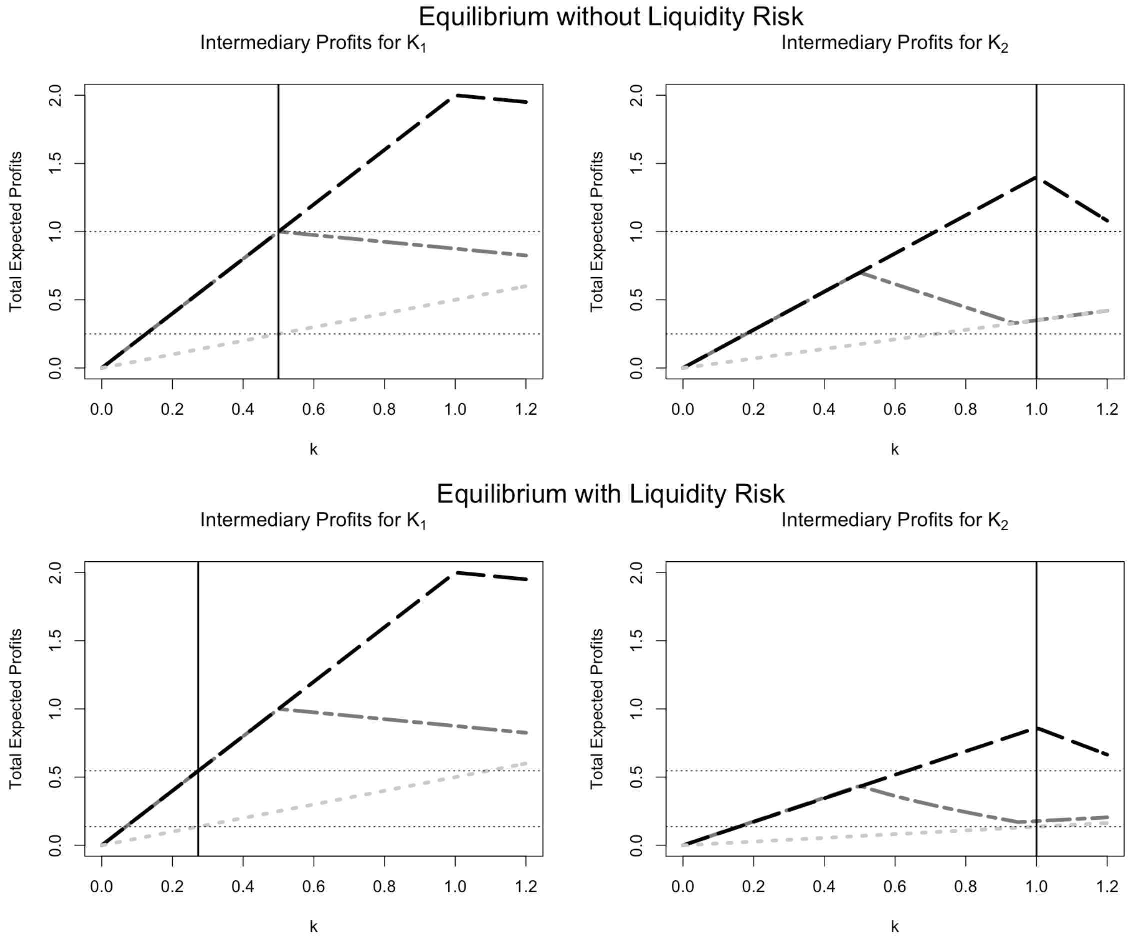

Figure 2: The top two graphs plot the expected profits (and profits from deviation) of the high (**black** dashed curve), moderate (**dark gray** dash-dotted curve), and low type (**light gray** dotted curve) for $k = K_1$ and $k = K_2$, respectively, given investors' beliefs in a (K_1, K_2) equilibrium without liquidity risk ($\rho = \frac{1}{2}$). The bottom two graphs plot the expected profits, given investors' beliefs in a (K_1, K_2) equilibrium with liquidity risk ($\rho = 8/13$). The equilibrium production levels are shown in bold vertical lines. In both equilibria, $K_2 = K$, but $K_1^{liq} < K_1^{noliq} = \gamma K$. The parameters are $K = 1$, $R = 3$, $\alpha = \frac{1}{4}$, $\pi_H = \pi_M = \pi_L = \frac{1}{3}$, $\gamma = \frac{1}{2}$, and $\underline{R} = 7/8$.

and K_2^{noliq}. As explained in Section 4.1, the moderate type maximizes profits at K_1^{noliq}, by producing good assets and avoiding adverse selection costs. The high type maximizes profits at K_2^{noliq}, but pays an adverse selection cost, which is reflected in the slope of its profit curve. The low type also maximizes profits at K_2^{noliq}, primarily by producing bad assets. In this example, $K_1^{noliq} = \gamma K$ and $K_2^{noliq} = K$. In other words, the moderate type and the high type are both able to invest in all the available good assets.

The bottom two graphs present the intermediary profits of each type for $k = K_1$ and $k = K_2$, respectively, given investors' beliefs in a (K_1^{liq}, K_2^{liq}) equilibrium with liquidity risk. As with the economy without liquidity risk, the moderate type maximizes profits at K_1^{liq}, and the high and the low type maximize profits at K_2^{liq}. However, relative to the case without liquidity risk, the intermediary profits in a boom are depressed due to the possibility of forced early liquidation. In particular, the slope of the low type's profits in $k = K_2$ is noticeably lower, due to the higher probability of liquidation. As a result, while $K_2^{liq} = K = K_2^{noliq}$, $K_1^{liq} < \gamma K$. Although an intermediary of moderate type avoids an explicit adverse selection funding cost, it incurs an implicit adverse selection cost through the equilibrium underproduction of long-term assets, that was not required absent liquidity risk.

This shows that in addition to making long-term assets vulnerable to costly liquidation, liquidity risk can potentially *exacerbate* the discrepancy in investment levels between normal times and booms. Funding with short-term capital, a prominent feature of the financial intermediary sector, can directly contribute to greater inefficiencies in the allocation of capital by the intermediary sector. This is reveals an additional potential hazard, when liquidity risk fails to discipline the financial sector and actually contributes to greater instability.[7]

[7]See Calomiris and Kahn (1991) and Diamond and Rajan (2001) for the disciplining effects of short-term debt.

CHAPTER 5 : FOUNDATIONS OF A CONFIDENCE-BASED CRISIS

In this section, I discuss the building blocks of a financial crisis guided by the intuition provided by the model. I categorize them into three main components:

1. Information Asymmetry Between Intermediaries and Investors

The financial sector's investment opportunity set is a function of many factors. Financial intermediaries may encounter limitations in acquiring proficient workers (i.e. labor market), or face difficulty monitoring and correctly aligning the incentives of financial workers (i.e. governance and structure). Financial intermediaries' screening technologies may be subject to limited scalability (i.e. financial technology). The depth of investment opportunities is also determined by real factors, such as the aggregate growth potential of the economy. In particular, the birth of a new industry or technology provides an opening for the financial sector to catalyze economic growth.[1]

All these factors contribute to the accumulation in intermediaries' private information, which naturally arises from specialization and intermediation. While information frictions typically exist in any agency relation, these asymmetries are further amplified by lax regulation, lack of transparency, and complexity that are characteristic of the financial sector.

Ultimately, inefficiencies exist because financial intermediaries, even when confronted with limitations to their scale of productive intermediation, must exercise restraint, at the cost of private profits, to ensure socially beneficial stability. The rational choice results in exposing the economy to catastrophic risks.

2. Investments Funded with Short-Term Capital

As shown in Section 4.2, fragility arises when investors are endowed with a provision of exit. When this flexibility is in the form of debt, long-term assets are at risk of forced early liqui-

[1] Opp (2010; 2014) develops a general equilibrium framework to study the propagation and amplification role of financial intermediaries on real innovations.

dation. Unfortunately, asymmetrically informed intermediaries are drawn to endogenously fund assets using short-term liabilities. Firms may use shorter maturity debt financing to signal quality (Diamond (1991)) or use an open-ended structure to signal ability (Stein (2005)).

The argument applies to both implicit and explicit collateralized borrowing.[2] In essence, investors primarily care about the solvency of financial intermediaries; sound investments ensure that this be the case. Debt seniority offers limited state-contingent control rights, enabling investors to trigger early liquidation whether it is an explicit sell-off (seize and liquidate) or implicit sell-off (rollover risk). In either case, investors' actions hinge on their perception of the value of intermediary assets.

3. Competition for Financial Assets

In the model, rational investors compete to obtain claims on intermediary assets. Frictionless competition results in investors bidding down the return on debt. Consequently, the financial sector extracts the majority of the expected surplus from intermediation. These circumstances impact the behavior of both investors and the financial sector. From the investors' perspective, competition determines the return on intermediary debt, which enhances the relative value of the early liquidation option. As a result, early liquidation can be privately optimal to investors and still be ex-post inefficient. From the intermediary's perspective, the ability to extract the majority of surplus from intermediation attenuates the aversion to taking actions subject to adverse selection.

What contributes to investors' competition for financial assets? In the case of the financial crisis of 2007-2008, one possible source is global imbalances.[3] An influx of foreign capital in search of dollar-denominated assets can result in greater competition for financial assets to preserve wealth. Heated competition led to foreign and domestic investors alike exploring asset classes beyond their expertise. In this way, foreign capital flows can result in capital

[2]See Gorton and Ordoñez (2014).

[3]Bernanke (2005) discusses the "Global Saving Glut".

displacement. Expansionary monetary policy contributes in a similar manner. Treasuries are unique in that while participants may not be perfectly informed, they are likely symmetrically informed. Low interest rates on risk free assets increase the relative benefits of investing in areas subject to information asymmetry. The symmetric informational nature of treasuries also makes them ideal to rebound to when investors become pessimistic. Competition encourages investors to seek exposures in uncharted territories, thereby increasing the insider-outsider conflict between financial intermediaries and investors.[4]

The Destabilizing Role of Monetary Policy

To conceptualize the effects of monetary policy, consider the comparative statics with respect to the risk free return. Let monetary policy be a set of short-term risk free interest rates $(R_{f,0}, R_{f,1})$ effective at the beginning of $t = 0, 1$ respectively, and suppose that the interest rate policy is common knowledge and fully anticipated at $t = 0$. Without loss of generality, consider a (K_1, K_2) equilibrium in which $K_2 = K$. Investors' participation condition is given by:

$$\frac{\pi_H + \pi_L \alpha}{\pi_H + \pi_L} R \geq R_{f,0} \cdot R_{f,1}. \tag{5.1}$$

As before, investors' individually rational constraints are satisfied only if the expected returns on the pooled assets are (weakly) greater than the long-term risk free return. Holding all else constant, a decrease in the long-run risk free return $R_{f,0} \cdot R_{f,1}$ increases the propensity for investors to finance the intermediary sector.

While the funding decision predominantly depends on the expected long-term risk free return, investors' liquidation decisions depend on the *dynamics* of the risk free rate at $t = 0$, when the intermediary sector finances its assets. To see this, reconsider the investors' condition to liquidate at $t = 1$ following $y = B$:

[4] For example, Merrill et al. (2014) shows that demand may also play an important role in the excess production of asset-backed securities prior to the crisis of 2007.

$$\begin{aligned} \underline{R} \cdot R_{f,1} &> \mathbb{E}[D_2(k(\theta), k_g(\theta), y)|k, y] \\ &= \frac{R_{f,0} \cdot R_{f,1} \cdot (\pi_H + \pi_L)}{\pi_H + \pi_L \alpha} \cdot \frac{(1-\rho)\pi_H + \rho \pi_L \alpha}{(1-\rho)\pi_H + \rho \pi_L} \\ \underline{R} &> R_{f,0} \cdot \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \cdot \frac{(1-\rho)\pi_H + \rho \pi_L \alpha}{(1-\rho)\pi_H + \rho \pi_L} \end{aligned}$$

Relative to the main specification, where $R_{f,t} = 1$ for $t = 0, 1$, we see that even if the long-term risk free return is set to $R_{f,0} \cdot R_{f,1} = 1$, the dynamics of the interest rate policy affect investors' rollover decision. Fixing the long-run interest rate $R_{f,0} \cdot R_{f,1}$ constant, as $R_{f,0}$ decreases, investors have a higher propensity to force early liquidation on the intermediary's assets. This follows a simple intuition: the decision to liquidate hinges upon the private value of early liquidation *relative* to the ex-ante risk-free compensation, which determines the competitive rate of return on debt. This suggests that monetary policy can have a destabilizing role *even* when interest rates are fully anticipated.[5] Formally, I show that:

Proposition 5. *Let $R_{f,t}$ be the return on the risk-free asset at the beginning of $t = 0, 1$ that is determined at $t = 0$. Then:*

1. *Lower $R_{f,0} \cdot R_{f,1}$ loosens investors' participation condition;*

2. *Holding $R_{f,0} \cdot R_{f,1}$ constant, lower $R_{f,0}$ increases investors' propensity to force early liquidation.*

To summarize, two nontrivial effects of monetary policy can exist. First, a lower long-term risk free return (i.e. low $R_{f,0} \cdot R_{f,1}$) decreases the relative cost of adverse selection and encourages investors to finance the production of long-term assets that they are uninformed about. Second, even with perfect expectations about the interest rate policy, stimulative policy (i.e. low $R_{f,0}$) can have a destabilizing effect by increasing the private value of liquidation at $t = 1$ following negative information. By influencing the private incentives

[5] It is straightforward to see that an unanticipated monetary shock (i.e. positive shock to $R_{f,1}$) would also contribute to the investors' propensity to trigger early liquidation.

of investors to fund the intermediary sector and to force early liquidation, monetary policy can potentially play a substantive role in amplifying the fragility of the system.

CHAPTER 6 : REGULATING AND MANAGING A CRISIS

In this section, I discuss the policy implications of the model.

6.1. Liquidity Provisions

In the midst of a financial crisis, the central bank or lender of last resort (LLR) must make timely decisions based on available information. A main issue is whether to provide extraordinary liquidity to financial intermediaries. Anticipation of liquidity provisions or asset purchases by the central bank can exacerbate risk taking by the intermediary sector (Farhi and Tirole (2012)). In the context of the model, even without such policy anticipation, the central bank may face difficulties in discerning the ex-post efficient action.

To elaborate, consider any fragile (K_1, K_2) equilibrium, and suppose that during a boom $(k^* = K_2)$, negative information $(y = B)$ arrives about the intermediary assets. This triggers a crisis, whereby investors force early liquidation of the intermediary assets $(l = 1)$. Consider the decision of the central bank to provide emergency capital to the intermediary sector to avoid costly liquidation. This amounts to injecting sufficient capital, such that investors are insured from risks of non-performing intermediary assets. Policymakers may face a *illiquidity v. insolvency* dilemma:

- A liquidation event may occur to either when the intermediary sector realized high or low investment opportunities, as the underlying asymmetric information problem plagues both types. Investors do not know whether the assets are insolvent or illiquid, but liquidation is ex-post profit maximizing.

- When $\underline{R} > \alpha R$, a high type intermediary is illiquid; a low type is insolvent.

- The ex-post optimal policy under complete information is to provide liquidity to the intermediary only if $\theta = H$.[1]

[1] Of course, for reasons beyond the scope of the model, bailouts may be ex-post efficient, even in an insolvency crisis.

- Given all available public information, the central bank can not discern the underlying type of the intermediary.

The optimal policy, which coincides with classical bailout policies advocated by Thornton (1802) and Bagehot (1888), is difficult to implement unless the central bank is capable of assessing the true quality of intermediary assets.[2] This makes ever more relevant the importance for regulators to be informed about the underlying financial assets and be equipped to make impartial judgments on the solvency of financial institutions. Intermingling between regulators and the financial sector, and the constant need for regulators to keep up, presents a clear challenge.[3]

6.2. The Efficacy of Monetary Policy

In an effort to stabilize financial markets and to stimulate the economy, central banks use monetary intervention. I discuss the effectiveness of the liquidity channel of monetary transmission.[4]

In Chapter 5, I discussed how easy monetary policy can amplify the mechanisms described in this paper. I showed that monetary policy could magnify inefficiencies and fragility that can arise due to primitive information frictions.

According to the model, a crisis occurs following sharp reductions in investors' confidence. This prompts an abrupt withdrawal of capital from financial intermediaries and markets. When the root cause of a crisis is investor pessimism, monetary policy can be highly ineffective in terms of transmitting liquidity through open market operations. In order to push investment capital to financial markets, the central bank must push down risk free yields sufficiently low such that investors find intermediary assets, which are marred by distrust and pessimism, attractive. Without intervention, investors' beliefs would rule these out as a viable choice.

[2] Goodhart (1999), regarding the intertwined nature between illiquidity and insolvency, states: " [...] nowadays illiquidity implies at least a *suspicion* of insolvency."

[3] See Bond and Glode (2014).

[4] See Bernanke and Gertler (1995).

Revitalizing investments requires rebuilding investors' confidence in the financial system. In general, lowering yields on safe assets, such as treasuries, simply forces investors to reluctantly consider alternatives, such as intermediary assets, which are regarded with skepticism. Even more so, when markets are built by artificially lowering the return on safe assets create a heavy reliance on central bank support. This was evident in 2013, when markets reacted strongly to public contemplations by the Fed to taper on bond purchases.[5] In view of the model, investors' participation in financial markets could not be self-sustained, as confidence remained very low. Until investments are organically taking place, Fed actions may directly factor into investment decisions and financial stability, putting disproportionate pressure to maintain continued monetary support. This presents a limitation to the cost effectiveness of ex-post monetary policy, and also highlights the importance of using ex-ante regulation to prevent an escalation in systemic risk.

6.3. Leverage and Capital Requirements

A defining feature of financial crises is that intermediaries accumulate historically high levels of leverage, or what is often ex-post described as "excessive leverage." Highly leveraged agents can become vulnerable to fluctuations in economic conditions when liquidity suddenly becomes scarce. As such, one of the main advocated policies is the need for financial regulators to curtail leverage. A common argument against blunt restrictions on leverage is that doing so severely limits financial intermediaries' ability to promote growth. Indeed, absent information frictions, market forces can be sufficient to ensure that the financial sector allocates capital prudently, as shown in Proposition 1. Financial sector leverage itself may not necessarily be inefficient. In the context of the model, inefficiencies of leverage, in the form of debt borrowing, are a *symptom* of asymmetric information. As such, a regulatory constraint on borrowing, while limiting the amount of intermediation, will not prevent inefficiencies. For instance, suppose that the intermediary faces a borrowing constraint $\bar{k}$, such that the intermediary's permissible capital demand k is bounded above by $\bar{k}$. It holds

[5] See Feroli et al. (2014).

generally, that in *any* nontrivial equilibrium:

Proposition 6. *Suppose that the intermediary faces a borrowing constraint* $\bar{k}$. *If* $(\pi_H + \pi_M + \pi_L\alpha)R \geq 1$, *then in any nontrivial equilibrium, the intermediary inefficiently produces bad assets when* $\theta = L$.

In other words, while a borrowing constraint $\bar{k}$ may limit the magnitude of potential inefficient production of assets, it may not alleviate the dual-inefficiency problem described in Section 4.1.

The model presents a case in which investors fund the intermediary sector based on their confidence in the intermediary sector's access to productive investment opportunities. The sustainability of intermediary leverage is predicated on the stability of investors beliefs. As such, precautions must be taken with the build-up of *belief-based* leverage. Markets become vulnerable when financial intermediaries are able to stretch their borrowing capacity based on investors' volatile beliefs. Amidst asymmetric information, observed leverage *does not* imply an efficient outcome disciplined by the usual market forces.

Requiring financial intermediaries to maintain higher capital or equity ratios can help mitigate the situation, but it is not without limitations. First of all, using equity to finance investments under asymmetric information will help reduce fragility as changes in investor confidence does not result in early liquidation of assets. In addition, equity holders may have greater incentives to acquire information, which might mitigate inefficient behavior. Nonetheless, investors will still be subject to the adverse selection problems that lead to the inefficient allocation of capital.

The use of *retained earnings* as a capital buffer is a powerful solution to costliness of equity issuance and the asymmetric information problem.[6] Suppose that in the model, the financial intermediary sector is required to hold capital e at $t = 0$, which it is required to hold in safe assets. I show that for sufficiently large e, separation can be restored between all types:[7]

[6] This policy is also advocated in Admati et al. (2011).

[7] In reality, financial intermediaries have circumvented capital requirements. Thus, for separation to hold,

Proposition 7. *Let e be the level of retained earnings that the intermediary sector holds in the form of capital. For sufficiently large $e > \bar{e}$, first-best is restored.*

Proposition 7 states that sufficient capitalization of the intermediary sector can alleviate the problem of inefficient capital allocation and liquidity risk. This highlights two things. First, because the main source of inefficiency is the misalignment between the intermediary sector's private incentives to intermediate and the public gains from intermediation, the optimal policy entails restoring the discrepancy between the two. Retained earnings, or inside equity, increases the accountability of the intermediary sector to any misinvestment it may undertake. When the gains from risk-taking are outweighed by potential losses in its accumulated earnings, inside equity e can deter the intermediary sector from misallocation of capital.

Second, this underscores an ex-ante regulatory effect of inside equity. Capital buffers are often advocated as a means to improve banks' capacity to absorb liquidity or balance-sheet shocks. By Proposition 7, inside equity is also vital for intermediaries to credibly commit to increasing borrowing *only* when an abundance of good investment opportunities arise.[8] Sufficient capitalization can actually *improve* the intermediary sector's allocative role of resources.

To the extent that moral hazard problems within the financial sectors exist, this also improves the private incentives for equity holders of financial intermediaries to monitor the risk-taking.[9] The appropriate capital requirement remains an empirical question.

6.4. Preventing a Crisis

The direct policy implication is to reduce information asymmetry, or prevent circumstances in which investors with inferior information lend to intermediaries. However there are political frictions that make it difficult to implement. In addition, it could discourage

regulation must take into account implicit leverage beyond the usual legal boundaries.

[8] Other regulatory distortions besides asymmetric information may prevent voluntary accumulation of equity capital, as shown in Admati et al. (2014).

[9] Becht et al. (2011) concludes that shareholders did not actively oppose risk-taking by banks.

financial innovation.

The private solution to the asymmetric information problem is information intermediaries, such as credit rating agencies. These intermediaries normally function to reduce the informational gap between financial intermediaries and investors. Unfortunately, building up to the global financial crisis, they failed to do so; asymmetries became more pronounced, which may have led investors to develop wider priors on the underlying investment opportunities.[10] Malfunctioning of well-defined credit ratings resulted in a breakdown in contract designs, which relied on well defined states to base future contingencies. He et al. (2012) show that mortgage-backed securities produced by issuers more likely to obtain inflated ratings also provided investors with higher yields, suggesting not only the inefficacy of ratings, but also revealing investors' rational behavior of demanding higher returns. Regulation using credit ratings likely worsened their efficacy.[11] From investors' perspectives, the use of shorter term maturities may provide a partial remedy for settings where incomplete contracts pose a serious issue.

If directly reducing information asymmetries is infeasible, policy should focus on barring the financial sector from using privately optimal short-term leverage to take long-term risks. This entails closely monitoring the method and level of leverage in the financial sector. Overall, policy should aim to build a regulatory environment that encourages self-regulation, whether it pertains to the accountability of financial intermediaries, investors, or regulators.

[10] See Kartasheva and Yilmaz (2013).
[11] See Opp et al. (2013).

CHAPTER 7 : CONCLUSION

In this paper, I propose a mechanism that explains crucial features of the development of financial crises. In an economy where the financial intermediary sector plays a vital role in allocating investment capital to long-term investment opportunities, I show that asymmetric information between the financial intermediary sector and investors brings rise to two distinct economic states, *normal times* and *booms*. Profit maximizing behavior of the intermediary sector to intermediate large quantities of capital to promote growth, but also potentially to take large, inefficient risks at the expense of investors leads to an endogenous concentration of uncertainty in booms. Amidst an *uncertain boom*, investors' beliefs exhibit fragility; subsequent arrival of negative public information results in an abrupt loss of confidence in the quality of intermediary assets. A crisis breaks out. Investors force early liquidation on intermediary assets and flee to safe assets, in a flight-to-quality episode. In contrast, during normal times, investors' beliefs are resilient to a negative information signal regarding the quality of intermediary investments. Normal times are quiet.

I derive two main policy implications. First, monetary policy can amplify the fragility of the financial system by lowering investors' aversion to adverse selection, and increasing investors' propensity to force early liquidation. Second, I show that when the primitive source of fragility is misaligned incentives, regulating intermediary equity not only alleviates the build-up of fragility, but can also dramatically improves the efficiency of capital allocation.

There are several avenues for future research. The model can be extended to study the nature of slow recoveries from financial crises, and the optimal policies to restore investors' confidence and economic activity. Another promising direction is to incorporate important aspects that are abstracted from in the current setting. These include the intermediary role of liquidity creation, strategic interactions between financial intermediaries, and the dynamics of asset prices.

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APPENDIX

A.1. Equilibrium Definition

Definition 3. *A Perfect Bayesian Equilibrium is the intermediary's financing decision* $k^*(\theta)$ *and production decision strategies* $\mathbf{k}^*(\theta)$ *for* $\theta \in \{H, M, L\}$*, the investors' early liquidation strategy* $l^*(k, y)$*, the investors' strategy on the funding rate* $r^*(k)$*, and investors' beliefs* $\mathcal{B}(k)$ *such that:*

1. *For* $\theta \in \{H, M, L\}$*,* $k^*(\theta)$ *and* $(k_g^*(\theta), k_b^*(\theta))$ *maximizes the expected profits of the intermediary;*

2. *investors' early liquidation strategy* $l^*(k, y)$ *maximizes conditional expected profits at* $t = 1$*;*

3. *investors' beliefs* $\mathcal{B}(k)$ *are consistent with Bayes' Rule wherever possible;*

4. *investors break even given the funding rate* $r^*(k)$ *specified by the contract.*

A.2. Proofs

Proof of Lemma 1

Proof. I show that the intermediary always weakly prefers to produce a good asset to a bad asset. Consider the production decision of the intermediary with some k capital. First consider when investors offer a funding rate $r(k)$ conditional on some beliefs about (k_g, k_b) such that Condition 1 is satisfied and $k_g \in (0, K_\theta)$, which implies that the intermediary can strictly increase its production of good assets by reducing its production of bad assets. By Lemma 2, investors never exercise early liquidation when $y = G$, which implies that

$l(k, G) = 0$. It holds that for any $\epsilon \in (0, K_\theta - k_g)$,

$$\left(\rho\frac{k_g+\epsilon}{k} + (1-\rho)\frac{k_b-\epsilon}{k}\right)(k\alpha(R - r(k)) + (1-\alpha)\max\{0, (k_g+\epsilon)R - kr(k)\})$$
$$+ (1 - l(k, B))\left((1-\rho)\frac{k_g+\epsilon}{k} + \rho\frac{k_b-\epsilon}{k}\right)(k\alpha(R - r(k)) + (1-\alpha)\max\{0, (k_g+\epsilon)R - kr(k)\})$$
$$\geq \left(\rho\frac{k_g}{k} + (1-\rho)\frac{k_b}{k}\right)(k\alpha(R - r(k)) + (1-\alpha)\max\{0, k_gR - kr(k)\})$$
$$+ (1 - l(k, B))\left((1-\rho)\frac{k_g}{k} + \rho\frac{k_b}{k}\right)(k\alpha(R - r(k)) + (1-\alpha)\max\{0, k_gR - kr(k)\}).$$

This implies that the intermediary can always weakly increase its profits by deviating to produce a good asset in place of a bad asset. Furthermore, the intermediary strictly increases its profits by deviating to producing $k_g + \epsilon$ good assets if $k_gR > kr(k)$ or if $l(k, B) = 0$ and $r(k) < R$.

Next, consider when investors offer a funding rate $r(k)$ conditional on some beliefs about (k_g, k_b) such that Condition 1 is satisfied and $k_g = K_\theta$. Then, for any $\epsilon \in (0, K_\theta)$,

$$\left(\rho\frac{k_g}{k} + (1-\rho)\frac{k_b}{k} + (1 - l(k, B))\left((1-\rho)\frac{k_g}{k} + \rho\frac{k_b}{k}\right)\right)k(R - r(k))$$
$$\geq \left(\rho\frac{k_g-\epsilon}{k} + (1-\rho)\frac{k_b+\epsilon}{k}\right)(k\alpha(R - r(k)) + (1-\alpha)\max\{0, (k_g-\epsilon)R - kr(k)\})$$
$$+ (1 - l(k, B))\left((1-\rho)\frac{k_g-\epsilon}{k} + \rho\frac{k_b+\epsilon}{k}\right)(k\alpha(R - r(k)) + (1-\alpha)\max\{0, (k_g-\epsilon)R - kr(k)\})$$

This implies that the intermediary never finds it optimal to deviate to producing a bad asset in place of a good asset. Altogether, this shows that given a choice, producing a good asset (weakly) dominates producing a bad asset. □

Lemma 4. *Under symmetric information, a low type intermediary cannot obtain funding from investors.*

Proof of Lemma 4

Proof. Since $K_L = 0$, a L-type intermediary can only produce bad assets. Hence, for any asset production level k, the L-type intermediary's portfolio is comprised of only bad assets. For any $k > 0$, a portfolio with k assets produced by a L-type intermediary has expected value of $k\alpha R < k$. Since Condition 1 requires that $r(k) \leq R$, investors do not provide funding for a L-type intermediary for any $k > 0$. □

Lemma 5. *Under symmetric information, the intermediary produces at least K_θ good assets.*

Proof of Lemma 5

Proof. Consider the financing decision of an intermediary of type θ. Following Lemma 1, for any capital demand k made by an intermediary of type θ where $k \leq K_\theta$, investors' beliefs are such that $k_g(\theta) = k$. Furthermore, by increasing production of good assets to K_θ, the intermediary increases expected return by:

$$(K_\theta - k)(R - 1) \geq 0.$$

Hence, the intermediary is strictly better off by producing the maximum level of good assets. □

Lemma 6. *Under symmetric information, the intermediary does not produce any bad assets in equilibrium.*

Proof of Lemma 6

Proof. By Lemma 5, the intermediary choose to produce the maximum level of good assets. Let this amount be some k'. By Lemma 4, a low type intermediary is not able to obtain any funding, since for any $k > 0$, investors' participation condition is not satisfied. Hence, in equilibrium, investors never fund a low type, and a low type trivially produces no bad assets. Consider when $k' > 0$. If the intermediary produces more assets for a total of $k > k'$, $k - k'$ assets must be bad, since no additional good assets are available. Under perfect information, investors know the level of k' and from Lemma 1, they can infer that $k - k'$ additional assets are bad assets. Given this, funding is only obtainable if given k' good assets and $k - k'$ bad assets, Condition 1 is satisfied. Suppose that it holds. The intermediary's profits are:

$$\begin{aligned}\alpha k R + (1-\alpha)k' R - k &= k'(R-1) + (k-k')(\alpha R - 1)\\ &< k'(R-1)\end{aligned}$$

That is, since $\alpha R < 1$, the intermediary is worse off by producing additional bad assets. When Condition 1 is violated, investors do not provide funding to the intermediary. Hence, it is optimal for the intermediary to demand k capital and produce k good assets. □

Proof of Proposition 1

Proof. By Lemma 5, the intermediary always selects $k \geq K_\theta$. By Lemma 6, the intermediary does not produce any bad assets. Since any production $k > K_\theta$ involves producing bad assets, the intermediary selects $k^* = K_\theta$.

Next, consider the investors' liquidation decision given that the intermediary's production decision is $k^* = K_\theta$. Given that the intermediary does not produce any bad assets, $r(k) = 1$, and the intermediary is always able to pay investors the promised return. Since $\underline{R} < 1$, at $t = 1$, liquidation is never optimal. Hence, $l^*(k, y) = 0$ for all $k^* = k$ and $y \in \{G, B\}$. □

Proof of Theorem 1

Proof. Fix $\rho = \frac{1}{2}$. I show that for any $\gamma \in (0,1)$ and $K > 0$, there exists a (K_1, K_2) equilibrium if and only if $R > \hat{R}$, for threshold $\hat{R} = \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}$. I conjecture and verify a candidate (K_1, K_2) equilibrium. Consider a pair (K_1, K_2) such that $K_1 < \gamma K < K_2$ and

$K_1 = K_2 \cdot \frac{R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}}{R-1}$ and consider the following investors' beliefs about θ conditional on k:

$$\theta = \begin{cases} \begin{cases} H & \text{w.p. } \frac{\pi_H}{\pi_H + \pi_L} \\ L & \text{w.p. } \frac{\pi_L}{\pi_H + \pi_L} \end{cases} & \text{if } k = K_2 \\ M & \text{if } k = K_1 \\ L & \text{otherwise.} \end{cases}$$

Given these beliefs, the competitive rate is:

$$r(k) = \begin{cases} \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} & \text{if } K = K_2 \\ 1 & \text{if } K = K_1 \\ \infty & \text{otherwise.} \end{cases}$$

Since $R > \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}$, investors' participation is individually rational for K_1 and K_2. An H-type intermediary finds K_2 incentive compatible if:

$$K_2 \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \right) \geq K_1 \left(R - 1 \right)$$

Since $K_1 = K_2 \cdot \frac{R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}}{R-1}$, this holds. An L-type intermediary finds K_2 incentive compatible if:

$$\alpha K_2 \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \right) \geq \alpha K_1 \left(R - 1 \right)$$

This also holds since $K_1 = K_2 \cdot \frac{R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}}{R-1}$. An M-type intermediary finds K_1 incentive compatible if:

$$K_1 \left(R - 1 \right) \geq \alpha K_2 \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \right) + (1 - \alpha) \max \left\{ 0, \gamma K R - K_2 \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \right\}$$

Substituting in $K_1 = K_2 \cdot \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1}$,

$$\begin{aligned}\left(K_2 \cdot \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1}\right)(R-1) &= K_2\left(R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}\right) \\ &\geq \alpha K_2\left(R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}\right) + (1-\alpha)\max\left\{0, \gamma K R - K_2\frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}\right\}\end{aligned}$$

shows that the M-type intermediary's incentive compatibility condition is satisfied. What remains is to confirm that for any γ and K, there actually exists a pair (K_1, K_2) such that $K_1 < \gamma K < K_2$ and $K_1 = K_2 \cdot \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1}$. This requires that for any $\gamma \in (0,1)$ and $K > 0$, there exists a K_2 such that:

$$K_2 \cdot \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1} < \gamma K < K_2$$

Let $K_2 = K(\gamma + \epsilon)$ for some arbitrarily small $\epsilon > 0$. Then:

$$\begin{aligned}(\gamma+\epsilon) \cdot \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1} &< \gamma < \gamma + \epsilon \\ -\gamma\left(1 - \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1}\right) + \epsilon \cdot \frac{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}}{R-1} &< 0 < \epsilon\end{aligned}$$

Since $\frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha} > 1$, there exists some sufficiently small ϵ such that the above inequality is satisfied. Hence, the desired pair (K_1, K_2) always exists for any γ and K. Together, this verifies that as long as $R > \hat{R}$, a (K_1, K_2) equilibrium always exists. To establish that $R > \hat{R}$ is a necessary condition for the existence of a (K_1, K_2) equilibrium, suppose by contradiction that $R < \hat{R}$ and a (K_1, K_2) equilibrium exists. For any $K_2 \leq K$, the expected value of the intermediary's assets conditional on $k^* = K_2$ is:

$$\begin{aligned}
\frac{1}{K}\left(\frac{\pi_H}{\pi_H+\pi_L}KR + \frac{\pi_L}{\pi_H+\pi_L}K\alpha R\right) &= \frac{\pi_H+\pi_L\alpha}{\pi_H+\pi_L}R \\
&< \frac{\pi_H+\pi_L\alpha}{\pi_H+\pi_L}\cdot\hat{R} \\
&= 1.
\end{aligned}$$

Since this violates investors' participation condition, any (K_1, K_2) equilibrium with $K_2 \leq K$ cannot exist. Note that for any $K_2 > K$, expected value of the intermediary's assets conditional on $k^* = K_2$ is:

$$\begin{aligned}
\frac{1}{K_2}\left(\frac{\left(\frac{K}{K_2}+\alpha\frac{K_2-K}{K_2}\right)\pi_H}{\pi_H+\pi_L}K_2R + \frac{\pi_L}{\pi_H+\pi_L}K_2\alpha R\right) &= \frac{\left(\frac{K}{K_2}+\alpha\frac{K_2-K}{K_2}\right)+\pi_L\alpha}{\pi_H+\pi_L}R \\
&< \frac{\pi_H+\pi_L\alpha}{\pi_H+\pi_L}\hat{R} \\
&= 1.
\end{aligned}$$

Since this also violates investors' participation condition, any (K_1, K_2) equilibrium with $K_2 > K$ cannot exist. Hence, a (K_1, K_2) equilibrium does not exist when $R < \hat{R}$. □

Proof of Proposition 2

Proof. I show that no other equilibrium with partial or full separation between types exists that is nontrivial, in the sense that it is not strictly Pareto-dominated by a pooling equilibrium.

In a fully separating equilibrium, $k^*(\theta') \neq k^*(\theta'')$ for any $\theta' \neq \theta''$, for any $\theta', \theta'' \in \{H, M, L\}$. By Lemma 4, an intermediary can not obtain funding from investors when investors believe that the intermediary is a low type. This necessarily implies that in any fully separating equilibrium, $k^*(L) = 0$. Then, it suffices to show that a nontrivial fully separating equilibrium does not exist if a low type intermediary can make positive profits for any

$k > 0$. Suppose that there exists a separating equilibrium where $k^*(M) \neq k^*(H)$ and $k^*(M), k^*(H) > 0$, and suppose that an intermediary of type $\theta = M, H$ makes positive expected profits from producing $k^*(\theta)$. This necessarily requires that $r(k) < R$. A fully separating equilibrium exists only if for any such $k^*(\theta)$, the low type intermediary can not make positive profits. Note, however, that for any such $k^*(\theta)$, a low type's profits are:

$$\alpha k^*(\theta)(R - r(k)) > 0$$

Hence, for any production level such that a moderate or high type intermediary can make positive profits, the low type can make positive profits by deviating to their production level. This rules out the existence of any nontrivial fully separating equilibrium. There is a knife-edge equilibrium where the intermediary produces sufficiently many bad assets such that $r(k) = R$. This ensures that the intermediary never makes positive profits. Only in this case is the intermediary of low type indifferent between producing no assets and some assets. This case is strictly dominated by an uninformative equilibrium, where all types choose to produce ϵ assets, for arbitrarily small ϵ. I ignore this knife-edge case.

Next, I check that nonexistence of the other possible candidate partial separating equilibria where (i) H and M pool, and L separates; and (ii) M and L pool, and H separates. First, note that the argument for the nonexistence of a fully separating equilibrium holds directly for establishing that there can not exist an equilibrium where the H and M pool, and L separates. It remains to show that there can not exist an equilibrium where the M and L pool, and H separates.

Consider an candidate equilibrium where M and L pool at production level K', and H separates at K''. I show that there does not exist such form of equilibrium in which H is strictly better off choosing K'' over K'.

First, note that for any $k < K_M$, an intermediary of moderate and high type can achieve the same maximum profits under any investors' beliefs. This follows because for any $k < K_M$, as a result of Lemma 1, an intermediary of either type will produce only good assets. Since both produce the same quality portfolio given production k, their profits are identical. Second, note that for any $k > K_M$, a high type intermediary is always able to obtain weakly higher profits than a moderate type intermediary. This is because an intermediary that produces portfolio (k_g, k_b) expects profits:

$$\mathbb{1}_{\{k_b>0\}} \cdot \alpha \max\{kR - kr(k), 0\} + \big(1 - \mathbb{1}_{\{k_b>0\}} \cdot \alpha\big) \max\{k_g R - kr(k), 0\},$$

which (weakly) increase in k_g and (weakly) decrease in k_b. Consider when $K'' < K_H$. Since the H type separates, and only good assets are produced, $r(K'') = 1$. In order for the L type to weakly prefer K' to K'', it must be that $K' > K''$, since it is always true that $r(K') > 1$ for any K'. However, for a moderate type to prefer K' to K'', K' must necessarily be less than K_M. By contradiction, suppose not. For any $K' > K_M$, a moderate type intermediary's expect profit is:

$$\alpha K'(R - r(K')) + (1 - \alpha) \max\{K_M R - K' r(K'), 0\}.$$

When $K_M R > K' r(K')$, the moderate type's profits decrease in K'. When $K_M R < K' r(K')$, the moderate type's profit is:

$$\alpha K'(R - r(K')).$$

The differential with respect to K' is:

$$\alpha(R - r(K')) - K' \frac{\partial r(K')}{\partial K'}$$

which is less than zero, since $\frac{\partial r(K')}{\partial K'} > 0$. Hence, the moderate type intermediary's profit in this candidate equilibrium decreases as $K' > K_M$ increases. There does not exist a K'' is such that a moderate type is indifferent between deviating to K'' and producing the equilibrium level K': if $K'' < K_M$, the high type is strictly better off by deviating to K';

K'' cannot be greater than K_M, since for any $K'' \in (K_M, K'')$,

$$\alpha K''(R-1) + (1-\alpha)\max\{K_M R - K'', 0\} > \alpha K'(R - r(K')) + (1-\alpha)\max\{K_M R - K' r(K'), 0\}.$$

This rules out a the candidate partial separating equilibrium with $K' > K_M$. As such, consider when $K'' \leq K' \leq K_M$. For any K', there exists a sufficiently small K'' such that both a moderate and high type intermediary is indifferent between K' and K'', since there always exists a K'' such that:

$$K''(R-1) = K'(R - r(K')).$$

However, consider a pooling equilibrium in which all types produce K'. Let the equilibrium interest rate in this pooling equilibrium be denoted $r_p(\cdot)$. It holds with loss of generality that:

$$K'(R - r_p(K')) > K'(R - r(K')) = K''(R-1).$$

As such, the partial separating equilibrium described above is Pareto-dominated. Finally, consider when $K'' > K_H$. As before, the L type to weakly prefer K' to K'' only if:

$$\alpha K'(R - r(K')) \leq \alpha K''(R - r(K'')).$$

This requires K'' to be sufficiently high such that $r(K'') \gg r(K')$. Suppose that K'' satisfies $r(K'') \gg r(K')$. In this case, the H type obtains profits:

$$\alpha K''(R - r(K'')) + (1-\alpha)\max\{K_H R - K'' r(K''), 0\}.$$

If $K_H R > K'' r(K'')$, then this equals to:

$$K''(R - r(K'')) - (1-\alpha)(K'' - K_H)R.$$

However, K'' is required to satisfy $K''(R - r(K'')) \leq K'(R - r(K'))$. This implies that

$$\begin{aligned} K''(R - r(K'')) - (1-\alpha)(K'' - K_H)R &\leq K'(R - r(K')) - (1-\alpha)(K'' - K_H)R \\ &\leq K'(R - r(K')) - (1-\alpha)(K' - K_H)R \end{aligned}$$

This rules out any equilibrium with $K' < K''$, since otherwise the H type find it optimal to deviate to K' and obtain $K'(R-r(K'))$. Finally, since a M type strictly prefers to produce less for any $k > K_M$, there can not exist the equilibrium with $K' > K''$. □

Proof of Proposition 3

Proof. Fix $\rho = \frac{1}{2}$. The efficient (K_1, K_2) equilibrium can be identified in two steps. First, I characterize a necessary and sufficient condition for a equilibrium to be the most efficient (K_1, K_2) equilibrium by conjecturing and verifying a criterion. Second, I use this condition to explicitly identify the efficient equilibrium.

I conjecture and verify that the efficient (K_1, K_2) equilibrium is a pair (K_1', K_2') that takes:

1. conditional on $K_2 = K$, take candidate K_1' to be the maximum $k \leq \gamma K$ subject to an H and L-type intermediary's incentive compatibility condition;

2. if the candidate $K_1' = \gamma K$, the maximum $K_2' \in (\gamma K, K]$ subject to an M-type intermediary's incentive compatibility condition; otherwise take $K_2' = K$.

By construction, K_1' satisfies the H and L type intermediary's incentive compatibility condition given $K_2 = K$, and K_2' satisfies the M type intermediary's incentive compatibility condition given K_1'. I verify that this (K_1, K_2) equilibrium is the efficient (K_1, K_2) equilibrium.

First, suppose that $(K_1', K_2') = (\gamma K, K)$. Since $K_M = \gamma K$, for any $K_1'' > \gamma K$, the M-type intermediary produces bad assets. Even if such K_1 satisfies a high and low type intermediary's incentive compatibility condition, since $\alpha R < 1$, K_1'' is strictly dominated by

K_1' – producing K_1' instead of K_1'' yields an ex-ante efficiency gain of:

$$\pi_M(K_1'' - K_1')(1 - \alpha R) > 0.$$

Similarly, $K_H = K$, for any $K_2'' > K$, the H-type intermediary also produces bad assets. Even if K_2'' satisfies a moderate type intermediary's incentive compatibility condition, K_2'' is strictly dominated by K_2'' since producing K_2' instead of K_2'' yields an efficiency gain of:

$$(\pi_H + \pi_L)(K_2'' - K_2')(1 - \alpha R) > 0.$$

For any $K_2'' \in (\gamma K, K)$, the H type intermediary forgoes good investment opportunities. Even if K_2'' satisfies a moderate type intermediary's incentive compatibility condition, K_2'' is strictly dominated by K_2'' since producing K_2' instead of K_2'' yields an efficiency gain of:

$$(K_2' - K_2'')\left((\pi_H + \alpha\pi_L)R - (\pi_H + \pi_L)\right) > 0.$$

Since even if incentive compatibility conditions hold, any deviation away from $(\gamma K, K)$ is ex-ante more inefficient, when $(K_1', K_2') = (\gamma K, K)$, it is the efficient (K_1, K_2) equilibrium.

Next, consider when $(K_1', K_2') = (\gamma K, K_2')$, where $K_2' < K$ is the maximum investment such that the M-type intermediary's incentive compatibility condition is satisfied, conditional on $K_1' = \gamma K$. As argued earlier, the M-type intermediary obtains the highest possible profits when $K_1 = \gamma K$. Hence, when $K_1 = \gamma K$, incentives to deviate from K_1 are the weakest. Given this, K_2' is the largest permissible investment level for the pool for any value of K_1. Since within the interval $(\gamma K, K)$, efficiency increases with investment, any other $K_2 \leq K_2'$ is less efficient.

Finally, consider when $(K_1', K_2') = (K_1', K)$, where $K_1' < \gamma K$ is the maximum investment such that an H and L-type intermediary's incentive compatibility condition is satisfied, conditional on $K_2' = K$. For the H and L type pool, the highest efficiency is obtained when

$K_2 = K$. At $K_2 = K$, the high-type intermediary has the weakest incentives to deviate, since it is the globally most profitable production level in any (K_1, K_2) equilibrium. Since, for any $K_2 \leq K$, both the high and low type have the same preferences, K_1' is the largest permissible investment level for the M-type intermediary for any value of K_2. Since within the interval $(0, \gamma K)$, efficiency increases with investment, any other $K_1 \leq K_1'$ is less efficient.

This verifies that the criterion identifies the ex-ante efficient (K_1, K_2) equilibrium. I use this criterion to identify the efficient equilibrium for the entire interval of $\gamma \in (0,1)$. Using the above criterion, note that conditional on $K_2 = K$, the candidate K_1' must satisfy:

$$\begin{aligned} K_1'(R-1) &\leq K\left(R - r(k)\right) \\ &= K\left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}\right). \end{aligned}$$

Let $\hat{\gamma} \in (0,1)$ be such that:

$$\hat{\gamma} K(R-1) = K\left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}\right).$$

Hence, $K_1' = \min\{\gamma, \hat{\gamma}\}$, where $\hat{\gamma} = \frac{R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}}{R-1}$. Next, suppose that $\gamma < \hat{\gamma}$. The candidate K_2' must satisfy:

$$\gamma K(R-1) \geq \alpha K_2' \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}\right) + (1-\alpha) \max\left\{\gamma K R - K_2' \cdot \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}, 0\right\}.$$

If $\gamma K - K_2' \cdot \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \geq 0$, then:

$$\begin{aligned} \gamma K(R-1) &\geq K_2' \cdot \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}(R-1) \\ &> K_2' \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}\right) - (1-\alpha)\gamma K R. \end{aligned}$$

The inequality holds for $K_2' = K$ when $\gamma K - K_2' \cdot \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \geq 0$. Next, consider when

$\gamma K - K_2' \cdot \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha} \leq 0$. Then the inequality that K_2' must satisfy is:

$$\gamma K(R-1) \geq \alpha K_2' \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}\right).$$

Note that:

$$\alpha\hat{\gamma}K(R-1) = \alpha K \left(R - \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha}\right).$$

Hence, when $\gamma > \alpha\hat{\gamma}$, the inequality is satisfied for $K_2' = K$. When $\gamma < \alpha\hat{\gamma}$, the maximum value of K_2' is given by:

$$\begin{aligned} K_2' &= \frac{\gamma K(R-1)}{R - \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha}} \\ &= \frac{\gamma}{\alpha\hat{\gamma}} K. \end{aligned}$$

Gathering all the cases, I obtain:

1. $(\hat{\gamma}K, K)$ if $\gamma > \hat{\gamma}$;

2. $(\gamma K, K)$ if $\gamma \in (\alpha\hat{\gamma}, \hat{\gamma})$;

3. $\left(\gamma K, \frac{\gamma}{\alpha\hat{\gamma}} K\right)$ if $\gamma < \alpha\hat{\gamma}$.

□

Proof of Lemma 2

Proof. Suppose that investors provide capital k to an intermediary under beliefs such that Condition 1 is satisfied. When the type of the intermediary is certain, investors can infer the quality of the underlying assets. As a result, $r(k)$ is set such that the expected return on debt is 1. Since y provides no new information to investors, liquidation is never optimal, since $\underline{R} < 1$.

Suppose that investors face uncertainty about the type of the intermediary. Without loss of generality, suppose that investors' beliefs conditional on observing k capital demand is:

$$\theta = \begin{cases} H & \text{w.p. } \pi'_H \\ M & \text{w.p. } \pi'_M \\ L & \text{w.p. } \pi'_L \end{cases}$$

for $\pi'_\theta \in (0,1)$ such that $\sum_\theta \pi'_\theta = 1$. Let $(k_g(\theta), k_b(\theta))$, where $k_g(\theta) + k_b(\theta) = k$, represent the portfolio of an intermediary of type θ that produces k assets. Then, given investors' beliefs, the expected value of k_g conditional on $y = G$ is:

$$\sum_\theta k_g(\theta)\pi'_\theta \cdot \frac{\rho\frac{k_g(\theta)}{k} + (1-\rho)\frac{k_b(\theta)}{k}}{\sum_\theta \pi'_\theta\left(\rho\frac{k_g(\theta)}{k} + (1-\rho)\frac{k_b(\theta)}{k}\right)}$$

WLOG, let $k_g(\theta') \geq k_g(\theta'') \geq k_g(\theta''')$, where $\theta', \theta'',' \theta''' \in \{H, M, L\}$ and $\theta' \neq \theta'' \neq \theta'''$. Rewriting the expression:

$$\begin{aligned}
&\sum_\theta k_g(\theta)\pi'_\theta \cdot \frac{\rho\frac{k_g(\theta)}{k} + (1-\rho)\frac{k_b(\theta)}{k}}{\sum_\theta \pi'_\theta\left(\rho\frac{k_g(\theta)}{k} + (1-\rho)\frac{k_b(\theta)}{k}\right)} \\
&= k_g(\theta') \cdot \pi'_{\theta'} \cdot \frac{(2\rho-1)\frac{k_g(\theta')}{k} + (1-\rho)}{\sum_\theta \pi'_\theta\left((2\rho-1)\frac{k_g(\theta)}{k} + (1-\rho)\right)} + k_g(\theta'') \cdot \pi'_{\theta''} \cdot \frac{(2\rho-1)\frac{k_g(\theta'')}{k} + (1-\rho)}{\sum_\theta \pi'_\theta\left((2\rho-1)\frac{k_g(\theta)}{k} + (1-\rho)\right)} \\
&+ k_g(\theta''') \cdot \pi'_{\theta'''} \cdot \frac{(2\rho-1)\frac{k_g(\theta''')}{k} + (1-\rho)}{\sum_\theta \pi'_\theta\left((2\rho-1)\frac{k_g(\theta)}{k} + (1-\rho)\right)} \\
&= k_g(\theta') \cdot \pi'_{\theta'} \cdot \left(1 + \frac{\pi'_{\theta''}(2\rho-1)\frac{k_g(\theta')-k_g(\theta'')}{k} + \pi'_{\theta'''}(2\rho-1)\frac{k_g(\theta')-k_g(\theta''')}{k}}{\sum_\theta \pi'_\theta\left((2\rho-1)\frac{k_g(\theta)}{k} + (1-\rho)\right)}\right) \\
&+ k_g(\theta'') \cdot \pi'_{\theta''} \cdot \left(1 + \frac{\pi'_{\theta'}(2\rho-1)\frac{k_g(\theta'')-k_g(\theta')}{k} + \pi'_{\theta'''}(2\rho-1)\frac{k_g(\theta'')-k_g(\theta''')}{k}}{\sum_\theta \pi'_\theta\left((2\rho-1)\frac{k_g(\theta)}{k} + (1-\rho)\right)}\right) \\
&+ k_g(\theta''') \cdot \pi'_{\theta'''} \cdot \left(1 + \frac{\pi'_{\theta'}(2\rho-1)\frac{k_g(\theta''')-k_g(\theta')}{k} + \pi'_{\theta''}(2\rho-1)\frac{k_g(\theta''')-k_g(\theta'')}{k}}{\sum_\theta \pi'_\theta\left((2\rho-1)\frac{k_g(\theta)}{k} + (1-\rho)\right)}\right)
\end{aligned}$$

The remainder after taking away $\sum_\theta k_g(\theta)\pi'_\theta$ is positive if:

$$
\begin{aligned}
& k_g(\theta') \cdot \pi'_{\theta'} \left(\pi'_{\theta''}(2\rho - 1)\frac{k_g(\theta') - k_g(\theta'')}{k} + \pi'_{\theta'''}(2\rho - 1)\frac{k_g(\theta') - k_g(\theta''')}{k} \right) \\
& + k_g(\theta'') \cdot \pi'_{\theta''} \left(\pi'_{\theta'}(2\rho - 1)\frac{k_g(\theta'') - k_g(\theta')}{k} + \pi'_{\theta'''}(2\rho - 1)\frac{k_g(\theta'') - k_g(\theta''')}{k} \right) \\
& + k_g(\theta''') \cdot \pi'_{\theta'''} \left(\pi'_{\theta'}(2\rho - 1)\frac{k_g(\theta''') - k_g(\theta')}{k} + \pi'_{\theta''}(2\rho - 1)\frac{k_g(\theta''') - k_g(\theta'')}{k} \right) \\
& \propto k_g(\theta') \cdot \pi'_{\theta'} \left(\pi'_{\theta''} \left(k_g(\theta') - k_g(\theta'') \right) + \pi'_{\theta'''} \left(k_g(\theta') - k_g(\theta''') \right) \right) \\
& + k_g(\theta'') \cdot \pi'_{\theta''} \left(\pi'_{\theta'} \left(k_g(\theta'') - k_g(\theta') \right) + \pi'_{\theta'''} \left(k_g(\theta'') - k_g(\theta''') \right) \right) \\
& + k_g(\theta''') \cdot \pi'_{\theta'''} \left(\pi'_{\theta'} \left(k_g(\theta''') - k_g(\theta') \right) + \pi'_{\theta''} \left(k_g(\theta''') - k_g(\theta'') \right) \right) \\
& = \left(k_g(\theta') - k_g(\theta'') \right) \left[k_g(\theta')\pi'_{\theta'}\pi'_{\theta''} - k_g(\theta'')\pi'_{\theta'}\pi'_{\theta''} \right] \\
& + \left(k_g(\theta') - k_g(\theta''') \right) \left[k_g(\theta')\pi'_{\theta'}\pi'_{\theta'''} - k_g(\theta''')\pi'_{\theta'}\pi'_{\theta'''} \right] \\
& + \left(k_g(\theta'') - k_g(\theta''') \right) \left[k_g(\theta'')\pi'_{\theta''}\pi'_{\theta'''} - k_g(\theta''')\pi'_{\theta'}\pi'_{\theta'''} \right] \\
& = \left(k_g(\theta') - k_g(\theta'') \right)^2 \pi'_{\theta'}\pi'_{\theta''} + \left(k_g(\theta') - k_g(\theta''') \right)^2 \pi'_{\theta'}\pi'_{\theta'''} + \left(k_g(\theta'') - k_g(\theta''') \right)^2 \pi'_{\theta''}\pi'_{\theta'''} \\
& > 0
\end{aligned}
$$

Hence, investors' belief about the intermediary's assets improves after $y = G$. Since $r(k)$ is set such that the expected return on debt is 1 given ex-ante beliefs, following $y = G$, the expected return on debt increases. Again, early liquidation is never optimal, since $\underline{R} < 1$. □

Proof of Lemma 3

Proof. Consider the investors' liquidation decision:

$$
l(k, y) = \begin{cases} 0 & \text{if } \mathbb{E}\left[D_2(k(\theta), k_g(\theta), r_0(k)) \middle| \, k, y \right] > \underline{R} \\ 1 & \text{otherwise} \end{cases}.
$$

The expected value of the debt claim conditional on k and y can be reorganized such that:

$$
\begin{aligned}
\mathbb{E}\left[D_2(\mathbf{k}(\theta), r_0(k))|\, k, y\right] &= \mathbb{E}\left[\frac{\sum_\theta \pi_\theta(k)}{\sum_\theta \pi_\theta(k)\cdot\omega(\mathbf{k}(\theta))}|k\right] \\
&\cdot \mathbb{E}\left[\frac{\sum_\theta \left(\frac{k_g(\theta)}{k}(1-\rho)+\frac{k_b(\theta)}{k}\rho\right)\cdot\pi_\theta(k)\cdot\omega(\mathbf{k}(\theta))}{\sum_\theta \left(\frac{k_g(\theta)}{k}(1-\rho)+\frac{k_b(\theta)}{k}\rho\right)\cdot\pi_\theta(k)}|k, y=B\right] \\
&= \left(\frac{\mathbb{E}[\omega(\mathbf{k}(\theta))|k]}{\mathbb{E}[\omega(\mathbf{k}(\theta))|k, y=B]}\right)^{-1} \\
&= F(k)^{-1}
\end{aligned}
$$

Hence, $l(k,y)=1$ is optimal if and only if $F(k)^{-1} < \underline{R}$. □

Proof of Theorem 2

Proof. I show that a (K_1, K_2) equilibrium exists when $\rho < \max\{\hat{\rho}, \check{\rho}\}$ and $R > \hat{R}$, for some thresholds $\hat{\rho}, \check{\rho}$. Furthermore, I show that when $\rho \in [\check{\rho}, \hat{\rho}]$, where $\check{\rho} < \hat{\rho}$ for sufficiently small α, investors force liquidation in equilibrium if and only if $k^* = K_2$ and $y = B$.

I show this in three steps. First, I show that conditional on $l(K_2, B) = 1$, there exists a pair (K_1, K_2) such that the (K_1, K_2) equilibrium structure is incentive compatible for all types of the intermediary for some $\rho \leq \hat{\rho}$. Second, I show that given an incentive compatible pair (K_1, K_2), $l(K_2, B) = 1$ is the equilibrium strategy of investors for $\rho > \check{\rho}$. Lastly, I show that for $\alpha \leq \bar{\alpha}$, thresholds $\check{\rho}$ and $\hat{\rho}$ are such that $\check{\rho} < \hat{\rho}$ and verify that investors' participation condition is satisfied as long as $R > \hat{R}$.

Step 1. Assume that investors' liquidation strategy is $l(K_2, B) = 1$. Note that by Lemma 2, in a (K_1, K_2) equilibrium, it suffices to consider liquidation only when $k^* = K_2$ and

$y = B$. As such $l(k, y) = 0$ if $(k, y) \neq (K_2, B)$. Suppose that investors' beliefs are:

$$\theta = \begin{cases} \begin{cases} H & \text{w.p. } \frac{\pi_H}{\pi_H + \pi_L} \\ L & \text{w.p. } \frac{\pi_L}{\pi_H + \pi_L} \end{cases} & \text{if } k = K_2 \\ M & \text{if } k = K_1 \\ L & \text{otherwise.} \end{cases}$$

Let $\check{\gamma} = (1 - \rho) \cdot \frac{R - r_K}{R - 1}$, where r_K is given by:

$$r_K = \frac{(\pi_H + \pi_L) - ((1 - \rho)\pi_H + \rho\pi_L) \underline{R}}{\rho\pi_H + (1 - \rho)\pi_L \alpha}.$$

There are four potential cases to consider:

(a) $\gamma < \frac{r_K}{R}$ and $\gamma < \check{\gamma}$

(b) $\gamma < \frac{r_K}{R}$ and $\gamma > \check{\gamma}$

(c) $\gamma > \frac{r_K}{R}$ and $\gamma < \check{\gamma}$

(d) $\gamma > \frac{r_K}{R}$ and $\gamma > \check{\gamma}$.

Conditional on investors' beliefs and liquidation strategies specified above, for any K_1 and K_2 such that $K_1 \leq \gamma K \leq K_2$, the competitive rate is:

$$r(k) = \begin{cases} r_2(K_2) & \text{if } k = K_2 \\ 1 & \text{if } k = K_1 \\ \infty & \text{otherwise,} \end{cases}$$

where $r_2(K_2)$ is given by:

$$r_2(K_2) = \begin{cases} r_K & \text{if } K_2 \leq K \\ \frac{(\pi_H+\pi_L)-\left(\left((1-\rho)\frac{K}{K_2}+\rho\frac{K_2-K}{K_2}\right)\pi_H+\rho\pi_L\right)R}{\left(\rho\frac{K}{K_2}+(1-\rho)\frac{K_2-K}{K_2}\right)\pi_H+(1-\rho)\pi_L\alpha} & \text{if } K_2 > K \end{cases}$$

Note that r_K and $r_2(K_2)$ is a function of ρ. Sufficient conditions are identified by first characterizing the conditions on ρ such that a incentive compatible pair (K_1, K_2) exists, conditional on γ obeying one of four cases $(a)-(d)$. I show that for each case, an upper bound on ρ is required. As long as ρ is such that all upper bound conditions on ρ are satisfied for the four possible cases, the existence of an incentive compatible (K_1, K_2) pair is ensured.

case (a)**.** Let $\gamma < \min\left\{\frac{r_K}{R}, \check{\gamma}\right\}$. I show that there exists a threshold $\hat{\rho}_{(a)}$ such that for $\rho < \hat{\rho}_{(a)}$, the pair $(\gamma K, \frac{\gamma}{\check{\gamma}}K)$ is incentive compatible. The low type incentive condition is:

$$\gamma K(R-1) \leq (1-\rho)\frac{\gamma}{\check{\gamma}}K(R-r_K).$$

This holds, since $\check{\gamma} \leq (1-\rho)\frac{R-r_K}{R-1}$ by definition. The high type incentive condition is:

$$\gamma K(R-1) \leq \rho\frac{\gamma}{\check{\gamma}}K(R-r_K),$$

which always holds since $\rho > \frac{1}{2}$. The moderate type incentive condition is:

$$\gamma K(R-1) \geq \left(\rho\frac{\gamma K}{\frac{\gamma}{\check{\gamma}}K} + (1-\rho)\left(1-\frac{\gamma K}{\frac{\gamma}{\check{\gamma}}K}\right)\right)\frac{\gamma}{\check{\gamma}}K\alpha(R-r_K).$$

Organizing the inequality:

$$
\begin{aligned}
\check{\gamma}(R-1) &\geq \left(\rho\check{\gamma} + (1-\rho)\left(1-\check{\gamma}\right)\right)\alpha(R-r_K) \\
\check{\gamma} &\geq \left(\rho\check{\gamma} + (1-\rho)\left(1-\check{\gamma}\right)\right)\alpha\frac{R-r_K}{R-1} \\
1-\rho &\geq \left(\check{\gamma}(2\rho-1) + (1-\rho)\right)\alpha
\end{aligned}
$$

$$
\begin{aligned}
(1-\rho)(1-\alpha) &\geq \check{\gamma}(2\rho-1)\alpha \\
\frac{1-\rho}{2\rho-1}\frac{1-\alpha}{\alpha} &\geq \check{\gamma} \\
\frac{1}{2\rho-1}\frac{1-\alpha}{\alpha} &\geq \frac{R-r_K}{R-1}
\end{aligned}
$$

Since r_K is bounded below by 1, $\frac{R-r_K}{R-1}$ is bounded above by 1. Since $\lim_{\rho\to\frac{1}{2}}\frac{1}{2\rho-1}=\infty$, there exists a threshold $\hat{\rho}_{(a)}$ such that:

$$
\begin{aligned}
\frac{1}{2\hat{\rho}_{(a)}-1}\frac{1-\alpha}{\alpha} &= \frac{R-r_K}{R-1} \\
\hat{\rho}_{(a)} &= \frac{1}{2}\left(\frac{1-\alpha}{\alpha}\frac{R-1}{R-r_K}\right)
\end{aligned}
$$

Hence, for any for any $\gamma < \min\left\{\frac{r_K}{R}, \check{\gamma}\right\}$, there exists an incentive compatible (K_1, K_2) pair for $\rho < \hat{\rho}_{(a)}$.

case (b)**.** Let γ be such that $\check{\gamma} < \gamma < \frac{r_K}{R}$. I show that there exists a threshold $\hat{\rho}_{(b)}$ such that for $\rho < \hat{\rho}_{(b)}$, the pair $(\check{\gamma}K, K)$ is incentive compatible. The low type incentive condition is:

$$\check{\gamma}K(R-1) \leq (1-\rho)K(R-r_K).$$

This holds with equality. The high type incentive condition is:

$$\check{\gamma}K(R-1) \leq \rho K(R-r_K),$$

which always holds since $\rho > \frac{1}{2}$. The moderate type incentive condition is:

$$\check{\gamma}K(R-1) \geq (\rho\gamma + (1-\rho)(1-\gamma))\, K\alpha(R - r_K).$$

Organizing the inequality:

$$\begin{aligned}(1-\rho)K(R-r_K) &\geq (\rho\gamma + (1-\rho)(1-\gamma))\, K\alpha(R - r_K)\\ (1-\rho)(1-\alpha) &\geq (2\rho-1)\alpha\gamma\\ \frac{1-\rho}{2\rho-1}\cdot\frac{1-\alpha}{\alpha} &\geq \gamma\end{aligned}$$

Since $\gamma < \frac{r_K}{R}$, this holds for any $\gamma \in \left(\check{\gamma}, \frac{r_K}{R}\right)$ if $\frac{1-\rho}{\rho}\cdot\frac{1-\alpha}{\alpha} > \frac{r_K}{R}$. Since $\frac{r_K}{R} \leq 1$ and $\lim_{\rho\to\frac{1}{2}} \frac{1-\rho}{2\rho-1} = \infty$, there exists a threshold $\hat{\rho}_{(b)}$ such that:

$$\begin{aligned}(1-\hat{\rho}_{(b)})\cdot\frac{1-\alpha}{\alpha} &= \frac{r_K}{R}(2\hat{\rho}_{(b)}-1)\\ \frac{1-\alpha}{\alpha} + \frac{r_K}{R} &= \left(2\frac{r_K}{R} + \frac{1-\alpha}{\alpha}\right)\hat{\rho}_{(b)}\\ \hat{\rho}_{(b)} &= \frac{\frac{1-\alpha}{\alpha} + \frac{r_K}{R}}{\frac{1-\alpha}{\alpha} + 2\frac{r_K}{R}}\end{aligned}$$

This implies that for any γ where $\check{\gamma} < \gamma < \frac{r_K}{R}$, there exists a incentive compatible pair (K_1, K_2) as long as $\rho < \hat{\rho}_{(b)}$.

case (c)**.** Let γ be such that $\frac{r_K}{R} < \gamma < \check{\gamma}$. I show that the pair $(\gamma K, K)$ is incentive compatible. The low type incentive condition is:

$$\gamma K(R-1) \leq (1-\rho)K(R-r_K),$$

which always holds since $\gamma < \check{\gamma}$. The high type incentive condition is:

$$\gamma K(R-1) \leq \rho K(R-r_K),$$

which always holds since $\rho K(R-r_K) > (1-\rho)K(R-r_K) > \gamma K(R-1)$. The moderate type incentive condition is:

$$\gamma K(R-1) \geq (\rho\gamma + (1-\rho)(1-\gamma))(K(R-r_K) - (1-\alpha)(1-\gamma)KR).$$

Note that the RHS is bounded above by $K(R-r_K) - (1-\alpha)(1-\gamma)KR$. Hence, it suffices to show that:

$$\begin{aligned}
\gamma(R-1) &\geq (R-r_K) - (1-\alpha)(1-\gamma)R \\
r_K - \gamma &\geq (1-(1-\alpha)(1-\gamma)-\gamma)R \\
r_K - \gamma &\geq \alpha(1-\gamma)R \\
\gamma(r_K - 1) &\geq (1-\gamma)(\alpha R - r_K),
\end{aligned}$$

which holds since $r_K > 1$ and $\alpha R < 1$. Hence, the moderate type incentive condition holds.

case (d)**.** Let γ be such that $\gamma > \max\left\{\frac{r_K}{R}, \check{\gamma}\right\}$. I show that for some $K_2 < \frac{KR}{r_2(K_2)}$, a pair (K_1, K_2), where $K_1 \leq \gamma K < K_2$ is incentive compatible as long as $\rho < \hat{\rho}_{(d)}$ for threshold $\hat{\rho}_{(d)}$. The low type incentive condition is:

$$K_1(R-1) \leq (1-\rho)K_2(R - r_2(K_2))$$

Hence, as long as $K_2 \geq \frac{K_1(R-1)}{(1-\rho)(R-r_2(K_2))}$, the low type incentive condition is satisfied. Next, consider the moderate type incentive condition:

$$K_1(R-1) \geq \left(\rho\frac{\gamma K}{K_2} + (1-\rho)\left(1 - \frac{\gamma K}{K_2}\right)\right)(\alpha K_2(R - r_2(K_2)) + (1-\alpha)\max\{\gamma KR - K_2 r_2(K_2), 0\})$$

Next, consider the high type incentive condition:

$$K_1(R-1) \leq \begin{cases} \left(\rho\frac{K}{K_2} + (1-\rho)\left(1-\frac{K}{K_2}\right)\right)(K_2(R-r_2(K_2)) - (1-\alpha)(K_2-K)R) & \text{if } K_2 > K \\ \rho K_2(R - r_K) & \text{if } K_2 \leq K \end{cases}$$

First, since $\rho\frac{\gamma K}{K_2} + (1-\rho)\left(1-\frac{\gamma K}{K_2}\right)$ strictly increases in γ and $\alpha K_2(R - r_2(K_2)) + (1 - \alpha)\max\{\gamma KR - K_2 r_2(K_2), 0\}$ (weakly) increases in γ, for any (K_1', K_2') such that

$$K_1'(R-1) = \left(\rho\frac{\gamma K}{K_2'} + (1-\rho)\left(1-\frac{\gamma K}{K_2'}\right)\right)\left(\alpha K_2'(R-r_2(K_2')) + (1-\alpha)\max\{\gamma KR - K_2' r_2(K_2'), 0\}\right), \tag{A.1}$$

the high type incentive condition always holds, i.e.

$$K_1'(R-1) \leq \left(\rho\frac{K}{K_2'} + (1-\rho)\left(1-\frac{K}{K_2'}\right)\right)\left(\alpha K_2'(R-r_2(K_2')) + (1-\alpha)\max\{KR - K_2' r_2(K_2'), 0\}\right).$$

Hence, it suffices to show that there exists a (K_1, K_2) pair such that $K_1 \leq \gamma K$ and $K_2 \geq \frac{K_1(R-1)}{(1-\rho)(R-r_2(K_2))}$, where Condition $(A.1)$ is satisfied. Note that $r_2(K_2)$ monotonically increases in K_2. Hence, there exists some $K_{2,M}$ such that $K_{2,M} r_2(K_{2,M}) = \gamma KR$. A moderate type's expected profit for $k = K_{2,M}$ is:

$$\begin{aligned}
&\left(\rho\frac{K}{K_{2,M}} + (1-\rho)\left(1-\frac{K}{K_{2,M}}\right)\right)\left(\alpha K_{2,M}(R-r_2(K_{2,M})) + (1-\alpha)\max\{\gamma KR - K_{2,M} r_2(K_{2,M}), 0\}\right)\\
&= \left(\rho\frac{K}{K_{2,M}} + (1-\rho)\left(1-\frac{K}{K_{2,M}}\right)\right)\alpha K_{2,M}(R-r_2(K_{2,M}))\\
&= \left(\rho\frac{K}{K_{2,M}} + (1-\rho)\left(1-\frac{K}{K_{2,M}}\right)\right)\alpha(K_{2,M}-\gamma K)R
\end{aligned}$$

which monotonically increases in ρ. Note that:

$$\begin{aligned}
\left(\rho\frac{K}{K_{2,M}} + (1-\rho)\left(1-\frac{K}{K_{2,M}}\right)\right)\alpha(K_{2,M}-\gamma K)R &< \alpha(K_{2,M}-\gamma K)R\\
&< K_{2,M} - \gamma K\\
&< \gamma K(R-1).
\end{aligned}$$

Separately, let $K_{1,L}(k,\rho)$ for $k \geq K$ be such that:

$$K_{1,L}(k)(R-1) = k(1-\rho)(R-r_2(k))$$

Let $\hat{\rho}_{(d)}$ be such that:

$$1-\hat{\rho}_{(d)} = \left(\hat{\rho}_{(d)}\frac{\gamma K}{K_{2,M}} + (1-\hat{\rho}_{(d)})\left(1-\frac{\gamma K}{K_{2,M}}\right)\right)\alpha$$

Then, for $\rho = \hat{\rho}_{(d)}$, $\gamma K > K_{1,L}(K_{2,M},\rho)$. Consider a pair (K_1, K_2) where $K_1 = \min\{K_{1,L}(K_{2,M},\rho), \gamma K\}$ and $K_2 = K_{2,M}$. Let $\acute{\rho}$ be such that $K_{1,L}(K_{2,M},\acute{\rho}) = \gamma K$. Note that $K_{1,L}(K_{2,M},\rho)$ decreases in $\rho \in (\frac{1}{2}, 1)$. For $\rho \in \left[\max\{\acute{\rho}, \frac{1}{2}\}, \hat{\rho}_{(d)}\right]$,

$$\begin{aligned}
&K_1(R-1) \leq (1-\rho)K_2(R - r_2(K_2))\\
&K_1(R-1) \geq \left(\rho\frac{\gamma K}{K_{2,H}} + (1-\rho)\left(1-\frac{\gamma K}{K_{2,M}}\right)\right)\alpha K_{2,M}(R - r_2(K_2'))\\
&K_1(R-1) < \left(\rho\frac{K}{K_{2,M}} + (1-\rho)\left(1-\frac{K}{K_{2,M}}\right)\right)\left(K_{2,M}(R - r_2(K_2')) - (1-\alpha)(K_{2,M}-K)R\right)
\end{aligned}$$

which correspond to the incentive conditions for the low, moderate, and high type, respectively. Hence, existence of an incentive compatible pair is established for $\rho \in \left[\max\{\acute{\rho}, \frac{1}{2}\}, \hat{\rho}_{(d)}\right]$ when $\rho > \max\left\{\frac{r_K}{R}, \check{\gamma}\right\}$.

Together, to ensure the existence of an incentive compatible pair (K_1, K_2), ρ must be sufficiently low, such that $\rho < \hat{\rho}$, where $\hat{\rho} = \min\{\hat{\rho}_{(a)}, \hat{\rho}_{(b)}, \hat{\rho}_{(d)}\}$.

Step 2. Next, I show that for sufficiently large ρ, investors' optimal liquidation strategy entails $l(K_2, B) = 1$. Since the asset choice of a high type and a low type is constant for any $k \leq K$ and variable (for the high type) over $k > K$, there are two cases to consider:

(i) $K_2 \leq K$

(ii) $K_2 > K$

case (i) First, consider any $K_2 \leq K$. $F(K_2)$ is given by:

$$F(K_2) = \frac{\frac{\pi_H + \pi_L\alpha}{\pi_H + \pi_L}}{\frac{(1-\rho)\pi_H + \rho\pi_L\alpha}{(1-\rho)\pi_H + \rho\pi_L}}.$$

Hence, $l(K_2, B) = 1$ is optimal when:

$$\begin{aligned} F(K_2)^{-1} &< \underline{R} \\ \frac{\pi_H + \pi_L}{\pi_H + \pi_L \alpha} \cdot \frac{(1-\rho)\pi_H + \rho\pi_L\alpha}{(1-\rho)\pi_H + \rho\pi_L} &< \underline{R}, \end{aligned}$$

which holds for $\rho > \check{\rho}_K$, where

$$\check{\rho}_K = \frac{\pi_H((1-\underline{R})\pi_H + (1-\alpha\underline{R})\pi_L)}{\pi_H((1-\underline{R})\pi_H + (1-\alpha\underline{R})\pi_L) + \pi_L((\underline{R}-\alpha)\pi_H + (1-\underline{R})\alpha\pi_L)}.$$

case (ii) When $K_2 > K$. $F(K_2)$ is given by:

$$F(K_2) = \frac{\frac{\pi_H + \pi_L\alpha}{\pi_H + \pi_L}}{\frac{\left((1-\rho)\frac{K}{K_2} + \rho\left(1-\frac{K}{K_2}\right)\right)\pi_H + \rho\pi_L\alpha}{\left((1-\rho)\frac{K}{K_2} + \rho\left(1-\frac{K}{K_2}\right)\right)\pi_H + \rho\pi_L}}.$$

Hence, $l(K_2, B) = 1$ is optimal when:

$$\begin{aligned} F(K_2)^{-1} &< \underline{R} \\ \frac{\pi_H + \pi_L}{\pi_H + \pi_L\alpha} \cdot \frac{\left((1-\rho)\frac{K}{K_2} + \rho\left(1-\frac{K}{K_2}\right)\right)\pi_H + \rho\pi_L\alpha}{\left((1-\rho)\frac{K}{K_2} + \rho\left(1-\frac{K}{K_2}\right)\right)\pi_H + \rho\pi_L} &< \underline{R}, \end{aligned}$$

which holds for $\rho > \check{\rho}(K_2)$, where

$$\check{\rho}(K_2) = \frac{\left(\underline{R}(\pi_H + \pi_L\alpha) - (\pi_H + \pi_L)\right)\frac{K}{K_2}\pi_H}{\left((\pi_H + \pi_L) - \underline{R}(\pi_H + \pi_L\alpha)\right)\left(1 - 2\frac{K}{K_2}\right)\pi_H + \left(\alpha(\pi_H + \pi_L) - \underline{R}(\pi_H + \pi_L\alpha)\right)\pi_L}.$$

Together, a fragile (K_1, K_2) equilibrium requires $\check{\rho}_K < \rho < \hat{\rho}$ if $K_2 \leq K$ and $\check{\rho}(K_2) < \rho < \hat{\rho}$ if $K_2 \geq K$. Let $\check{\rho} = \check{\rho}_K$ if $K_2 \leq K$ and $\check{\rho} = \check{\rho}(K_2)$ if $K_2 \geq K$. I show that for any case identified above, for sufficiently small α, there exists a non-degenerate set of values of ρ such that a fragile (K_1, K_2) equilibrium exists. It suffices to show that for any γ, there exists some $\alpha \in (0,1)$ such that the thresholds on permissible values of ρ are strictly ordered. I show by using a limit argument. Consider the limit case, as $\alpha \to 0$. Then $\hat{\rho}_{(b)}, \hat{\rho}_{(d)} \to 1$

and $\hat{\rho}_{(a)} \to \infty$. Since as $\alpha \to 0$, $\check{\rho} \to \frac{(1-\underline{R})\pi_H+\pi_L}{(1-\underline{R})\pi_H+\pi_L+\pi_L\underline{R}} < 1$, there always exists a sufficiently small $\alpha > 0$ such that $\check{\rho}(K) < \hat{\rho}$. Finally, the investors' participation condition for $K_2 \leq K$ is satisfied for any R such that $R > \frac{\pi_H+\pi_L}{\pi_H+\pi_L\alpha} = \hat{R}$.

Together this establishes that for any γ, for $\rho \leq \min\{\hat{\rho}_{(a)}, \hat{\rho}_{(b)}, \hat{\rho}_{(d)}\}$, there exists a (K_1, K_2) equilibrium. Furthermore, for any $\rho < \check{\rho}$, a (K_1, K_2) equilibrium exists. Since the revelation of information for some noisy signal with precision $\rho > \frac{1}{2}$ is not sufficient to trigger early liquidation $l(K_2, B) = 1$, an equilibrium exists in which no liquidation takes place on the equilibrium path. This corresponds to the set of equilibria described in Theorem 1. Finally, for sufficiently small α, there exists a fragile (K_1, K_2) equilibrium for any $\rho \in (\check{\rho}, \hat{\rho})$. □

Proof of Proposition 4

Proof. Suppose that $\rho \in (\check{\rho}, \hat{\rho})$, such that $l^*(K_2, B) = 1$. This implies that:

$$\mathbb{E}\left[\min\left\{r_0(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = B\right] < \underline{R}$$

Note that $r_0(K_2)$ is such that:

$$\begin{aligned}&P(y = B|k) \cdot \mathbb{E}\left[\min\left\{r_0(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = B\right]\\ &+P(y = G|k) \cdot \mathbb{E}\left[\min\left\{r_0(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = G\right] = 1.\end{aligned}$$

Note also that given $l^*(K_2, B) = 1$, $r(K_2)$ is such that:

$$\begin{aligned}&P(y = B|k) \cdot \underline{R}\\ &+P(y = G|k) \cdot \mathbb{E}\left[\min\left\{r(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = G\right] = 1.\end{aligned}$$

Since $\mathbb{E}\left[\min\left\{r_0(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = B\right] < \underline{R}$,

$$\mathbb{E}\left[\min\left\{r(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = G\right] < \mathbb{E}\left[\min\left\{r_0(K_2), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| y = G\right].$$

This directly implies that $r(K_2) < r_0(K_2)$. $\square$

Proof of Proposition 5

Proof. First consider the generalized form of Condition 1:

$$\mathbb{E}\left[\sum_{y' \in \{G,B\}} Prob(y = y'|k) \max\left\{E\left[D_2(\mathbf{k}(\theta), R)|k, y'\right], \underline{R}\right\}\right] \geq R_{f,0} \cdot R_{f,1}.$$

It follows directly that a decrease $R_{f,0} \cdot R_{f,1}$ generically loosens the above condition. Next, consider the generalized form of investors' liquidation condition:

$$l(k,y) = \begin{cases} 0 & \text{if } \mathbb{E}\left[\min\left\{r_0(k), \frac{1}{k}\tilde{R}(\mathbf{k}(\theta))\right\}\middle| k, y\right] > \underline{R} \cdot R_{f,1} \\ 1 & \text{otherwise} \end{cases}.$$

Without loss of generality, let investors' beliefs, conditional on $k^* = k'$ be:

$$\theta = \begin{cases} H & \text{w.p. } \pi'_H \\ M & \text{w.p. } \pi'_M \\ L & \text{w.p. } \pi'_L \end{cases}$$

for $\pi'_\theta \in (0,1)$ such that $\sum_\theta \pi'_\theta = 1$, and let $\mathbf{k}'(\theta)$ correspond to the asset choices of the intermediary. Then:

$$\begin{aligned} &\mathbb{E}\left[\min\left\{r(k), \frac{1}{k}\tilde{R}(\mathbf{k}'(\theta))\right\}\middle| k, y\right] \\ &= R_{f,0} \cdot R_{f,1} \cdot \underbrace{\frac{\pi'_H + \pi'_M + \pi'_L}{\pi'_H + \pi'_M \cdot \omega(\mathbf{k}'(M)) + \pi'_L \alpha} \cdot \frac{\sum_\theta \left(\frac{k_g(\theta)}{k'}(1-\rho) + \frac{k_b(\theta)}{k'}\rho\right) \cdot \pi'_\theta \cdot \omega(\mathbf{k}'(\theta))}{\sum_\theta \left(\frac{k_g(\theta)}{k'}(1-\rho) + \frac{k_b(\theta)}{k'}\rho\right) \cdot \pi'_\theta}}_{X} \end{aligned}$$

Note that $\omega(\mathbf{k}'(\theta))$ depends only on $R_{f,0} \cdot R_{f,1}$. Hence, holding $R_{f,0} \cdot R_{f,1}$ constant, X remains constant with respect to changes in $R_{f,0}$ or $R_{f,1}$. Investors' liquidation decision for

$k^* = k'$ given $y = B$ is given by:

$$R_{f,0} \cdot R_{f,1} \cdot X < \underline{R} \cdot R_{f,1}$$
$$R_{f,0} \cdot X < \underline{R}$$

This establishes that as $R_{f,0}$ decreases, investors' liquidation condition is more likely to bind. $\square$

Proof of Proposition 6

Proof. I show that for any borrowing constraint $\bar{k}$, any nontrivial equilibrium as defined in Proposition 2 exhibits inefficient investment by the low type. First, suppose that there exists a (K_1, K_2) equilibrium where $K_2 < \bar{k}$. Then the borrowing constraint does not bind. As such, trivially, the low type makes inefficient investments in equilibrium. Next, suppose that $\bar{k}$ is sufficiently low such that $\bar{k}$ is less than the minimum K_2 in the set of (K_1, K_2) equilibria. This implies that the borrowing constraint rules out the existence of a (K_1, K_2) equilibrium. The remaining set of potential nontrivial equilibria is the set of uninformative (pooling) equilibria, in which all types of the intermediary choose some capital investment k^*. Formally, let a pooling equilibrium be characterized by $k^*(\theta) = k^*$ for $\theta \in \{H, M, L\}$ and where investors' beliefs are such that:

$$\theta = \begin{cases} \begin{cases} H & \text{w.p. } \pi_H \\ M & \text{w.p. } \pi_M \\ L & \text{w.p. } \pi_L \end{cases} & \text{if } k = k^* \\ L & \text{otherwise.} \end{cases}$$

where k^* such that Condition 1 is satisfied. It is easily verifiable that incentive conditions of all types hold given investors beliefs, and in equilibrium all types choose capital investment k^*.

Note, when $(\pi_H + \pi_M + \pi_L\alpha)R \geq 1$, Condition 1 is satisfied for any $k^* \leq K_M$. Hence, when $(\pi_H + \pi_M + \pi_L\alpha)R \geq 1$, there exists a pooling equilibrium with equilibrium production $k^* \leq K_M$. Note that in any pooling equilibrium, the low type produces $k^* > 0$ bad assets. Since for any $\bar{k}$ a pooling equilibrium exists, this establishes that when $(\pi_H + \pi_M + \pi_L\alpha)R \geq 1$, a low type always overinvests in equilibrium. □

Proof of Proposition 7

Proof. I show that there exists a threshold $\bar{e}$, such that for any $e > \bar{e}$, an equilibrium with separation exists for any $\gamma \in (0, 1)$ and any set of π_θ. Let $\bar{e} = \alpha K(R-1)$, and suppose that $e = \bar{e}$. I conjecture and verify that a separating equilibrium exists in which $k^*(\theta) = K_\theta$ and investors beliefs are such that:

$$\theta = \begin{cases} H & \text{if } k^* = K_H \\ M & \text{if } k^* = K_M \\ L & \text{otherwise.} \end{cases}$$

Given these beliefs, $r(k)$ is given by:

$$r(k) = \begin{cases} 1 & \text{if } k^* \in \{K_H, K_M\} \\ \infty & \text{otherwise.} \end{cases}$$

Note that for any $k^* \notin \{K_H, K_M\}$, $r(k) = \infty$, and as such profits are 0. Hence, it suffices to show that the intermediary does not have incentive to deviate to a disequilibrium strategy given investors' beliefs, particularly to either K_H if the moderate type, K_M if the high type, and either K_H or K_M if the low type.First consider the high type intermediary. The high type intermediary that chooses $k^* = K_H$ can obtain profits:

$$K(R-1) > \gamma K(R-1)$$

Since profits are (globally) maximized at $k^* = K_H$, a high type intermediary's incentive compatibility condition holds. Next, consider a moderate type intermediary. The moderate type's incentive compatibility holds if:

$$\begin{aligned}\gamma K(R-1)+e &> \alpha K(R-1)+(1-\alpha)\max\{\gamma KR+e-K,0\}\\ \gamma K(R-1) &> (1-\alpha)\max\{\gamma KR+\alpha K(R-1)-K,0\}\end{aligned}$$

If $\gamma KR+\alpha K(R-1)-K<0$, incentive compatibility holds. Suppose that $\gamma KR+\alpha K(R-1)-K>0$, which implies that $\gamma > \frac{1-\alpha(R-1)}{R}$. Then,

$$\begin{aligned}\gamma K(R-1) &> (1-\alpha)\left(\gamma KR+\alpha K(R-1)-K\right)\\ \gamma(\alpha R-1) &> (1-\alpha)(\alpha R-1-\alpha)\\ \gamma &< (1-\alpha)\frac{\alpha R-1-\alpha}{\alpha R-1}\\ &= (1-\alpha)\left(1+\frac{\alpha}{1-\alpha R}\right)\\ &= 1+\frac{\alpha-\alpha^2-\alpha+\alpha^2 R}{1-\alpha R}\\ &= 1+\frac{\alpha^2(R-1)}{1-\alpha R}\end{aligned}$$

Since $\frac{\alpha^2(R-1)}{1-\alpha R}>0$, incentive compatibility holds for any $\gamma\in(0,1)$. Finally, consider the low type's incentive compatibility condition:

$$e > \alpha\gamma K(R-1)+(1-\alpha)\max\{e-\gamma K,0\}$$

for $\gamma\in(0,1]$. Expanding the expression for e:

$$\begin{aligned}\alpha K(R-1) &> \alpha\gamma K(R-1)+(1-\alpha)\max\{\alpha K(R-1)-\gamma K,0\}\\ \alpha(1-\gamma)K(R-1) &> (1-\alpha)\max\{\alpha K(R-1)-\gamma K,0\}\end{aligned}$$

As before, if $\alpha K(R-1) \leq \gamma K$, then the inequality holds, since the RHS becomes 0. Consider the case in which $\alpha K(R-1) > \gamma K$, which implies that $\gamma < \alpha(R-1)$. Then:

$$\begin{aligned}
\alpha(1-\gamma)K(R-1) &> (1-\alpha)(\alpha K(R-1) - \gamma K) \\
\gamma K - \alpha\gamma K(R-1) &> -\alpha K(R-1) + (1-\alpha)\alpha K(R-1) \\
\gamma K(1 - \alpha R + \alpha) &> -\alpha^2 K(R-1) \\
\gamma &> -\frac{\alpha^2(R-1)}{1-\alpha R+\alpha}
\end{aligned}$$

Since $-\frac{\alpha^2(R-1)}{1-\alpha R+\alpha} > 0$, the low type's incentive compatibility condition holds for any $\gamma \in (0,1]$. This verifies that for $e \geq \bar{e}$, a separating equilibrium exists. $\square$