Essays on Macroeconomics and Finance

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ABSTRACT

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This dissertation contains three essays examining the role of informational frictions in financial markets and its aggregate implications. In the first chapter, I study whether securitization can spur financial fragility. I build a model of banking with securitization, where financial intermediaries hold a well-diversified portfolio of asset-backed securities on their balance sheets. On the one hand, securitization diversifies idiosyncratic risk so as to increase the pledgeability of assets in the economy, allowing more profitable investment projects to be financed. On the other hand, individual financial intermediaries do not internalize the benefit of the transparency of the securities they produce, because that benefit is also diversified. Moreover, when financial intermediaries perceive their environment to be safe, they have little incentive to produce more information about the quality of their assets. This leads to an increase in the opaqueness of securitized assets in the economy, causing greater exposure of financial intermediaries to funding and solvency risk. Policy can have a role because of a market failure that induces the securitized-banking system to produce securities that are too opaque making the economy more prone to crises. An efficient macroprudential policy is to impose a flexible capital surcharge on opaque securities.

The second chapter characterizes the optimal interventions to stabilize financial markets in which there is a lemons problem due to asymmetric information. Potential buyers can obtain information about the quality of assets traded in the market to decide whether to buy the assets. A market equilibrium is not necessarily driven by fundamentals, but it can also be driven by agents' beliefs about fundamentals and the corresponding information choices. Multiple self-fulfilling equilibria may arise if the asset price has a large impact on the quality of assets, because a higher asset price increases the likelihood that nonlemons are traded. Large-scale asset purchases are inefficient to correct a market failure, because such purchases crowd out efficient liquidity reallocation in the private sector. In contrast, partial loss insurance, when combined with the credible announcement of an asset price target, implements the efficient allocation as a unique equilibrium. Moreover, the model predicts that direct asset purchases can cause large welfare losses, especially in the mortgage-backed securities markets, and therefore, the partial loss insurance with the credible

announcement is the optimal way to correct the market failure in such securities markets.

The final chapter examines a new propagation mechanism by which the effects of uncertainty shocks amplify in the context of the dynamic stochastic general equilibrium framework. An increase in the cross-sectional dispersion of idiosyncratic returns induces entrepreneurs, who have risk-shifting incentive, to distort the quality of an investment project. This leads lenders to reallocate credit from the high productivity sector, in which the risk-shifting problem is more prevalent, to the low productivity sector, which in turn depresses aggregate economic activities further. Empirical evidence from NBER-CES Manufacturing Industry Database provides support for the model's predictions.

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Chapter 1

Securitization, Stability, and Optimal Regulation

1.1 Introduction

Traditionally, financial innovation has been thought of as providing better risk-sharing opportunities by completing markets and by reducing agency costs and information asymmetries, which ultimately may improve allocative efficiency and economic growth (e.g., Allen and Gale 1994). Furthermore, it has been argued that during the great moderation financial innovation contributed to reduced macroeconomic volatility by smoothing the supply of credit to real sectors through business cycles.[1] Since the financial-market disruptions of 2007-2008, however, new financial products have been at the center of the debate about financial reform among both scholars and practitioners.[2]

I propose an explanation for how the introduction of securitization can contribute to greater financial instability. In particular, I present a model of banking with securitization. Securitizers hold a well-diversified portfolio of securitized assets on their balance sheets, and this serves as collateral against borrowing. My model can explain why, during the run-up to the crisis, banks produced so many risky low-documentation loans, which created a large hidden risk, and it can do so without assuming that they take advantage of superior information over securities investors. Moreover, I explore a way of arranging our financial system that would protect society from potential damages, if any, stemming from the misuse of such securitized products. In particular, while the literature (e.g., Reis 2009a; Korinek 2011; Gertler, Kiyotaki, and Queralto 2012; Stein 2012) contains some explorations of how to resurrect financial stability in the wake of the recent financial crisis, there has been little research into how to regulate the production of information in the context of securitization so as to maintain macroeconomic financial stability. This paper seeks to bridge a gap in the literature by pointing to some optimal regulations that could be easily implemented.

My model has three main ingredients. First, I define securitization as the procedure of pooling projects undertaken by individual banks in order to create asset-backed securities (ABS). Because it diversifies idiosyncratic downside risk of the projects so as to create safe cash-flows, securitization increases the pledgeability of projects, allowing banks to

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[1] See, for instance, Campbell and Hercowitz (2005) and Dynan, Elmendorf, and Sichel (2006). For a counterargument, see Den Haan and Sterk (2011).

[2] The scope and magnitude of the development of new financial instruments in mortgage-related and asset-backed securities has been large over the last three decades. The share of the securities in those markets was 4.4% of U.S. bonds outstanding in 1980, but it then expanded rapidly to 34.5% in 2007 so as to become the largest part of the U.S. bond markets.

borrow more from investors who pursue safety. Despite that benefit, financial innovation comes with a caveat: once projects have been bundled together, banks are forced to trade the pool of projects, not an individual project separately. This captures the idea that, owing to buyers' fear of adverse selection in asset markets, banks cannot selectively dispose of bad projects. Thus while there is a clear benefit to be gained from securitization, there is also a potential cost: When banks need to liquidate assets, good assets are sold along with the bad in a pool.[3]

Second, there is an information friction that generates the solvency risk of projects (credit/default risk). There is adverse selection between banks and projects, and this reflects inherent information imperfections between loan originators and borrowers. As projects can default during economic downturns, each bank must produce costly information (equivalently, screening efforts) to lower the default probability of its projects. Information that each bank produces endogenously determines the solvency risk of its projects, and the aggregation of the solvency risk across banks in the securitization chain defines the quality of ABS: higher quality of ABS implies greater returns in a crisis state of the world. The aggregation of losses in the value of all the ABS produced across securitizers defines tail risk in the economy, in the sense that higher tail risk implies lower aggregate asset returns in the crisis state.

Third, imperfect information about the state of the world, with which the return of ABS is correlated, generates funding risk, as inside investors (primary lenders to securitizers) can run on securitizers before the projects have matured. The key assumption of the paper is that information produced by banks also determines the degree of transparency of ABS: higher transparency implies higher accuracy of a signal indicating the quality of ABS. Given this signal, inside investors are able to learn precisely, but at a cost, about the aggregate state of the world, if they want to do so. The point here is that in some cases the inside investors run on the banks, rather than invest time and resources to evaluate the safety of their investment when it has come into question (Bernanke 2010). In the model, if ABS is more transparent, more inside investors learn about the aggregate state, and thus their funding decisions are better aligned with economic fundamentals, which reduces funding risk. In contrast, opaqueness increases the fraction of imperfectly informed investors, who always refuse to roll over their loans in fear of the safety of their investment. Because this refusal causes securitizers to liquidate valuable assets, they are exposed to funding risk endogenously

[3]Note, however, that I abstract from potential moral hazard problems in the securitization chain. In my model, a securitizer maximizes the collective profits of the banks it is associated with.

even when fundamentals are strong.

My model accounts for a few key aspects of the run-up to the crisis itself. It shows that the interconnectedness among banks, created by securitization, raises the exposure of those banks to funding risk. Even though their assets become safer with the diversification of idiosyncratic risk, their liabilities become more subject to funding risk in response to aggregate risk, particularly when the primary lenders pursue safety. Moreover, as only the *pool* of projects is traded, securitizers may need to liquidate a larger fraction of their portfolio in response to a funding shock. This implies that while securitization increases the pledgeability of assets, it comes at a cost of larger liquidity risk in the crisis state, where liquidity risk is defined as funding risk (the fraction of lenders who withdraw their funds) times the fraction of assets liquidated in the secondary asset market. Nevertheless, I show that there is a strong incentive toward securitization if the probability that better states will occur is sufficiently high to compensate for larger liquidity risk in the crisis state. This is the case when the crisis probability (the tail probability) is small and demand for safe securities is large (large spread between project returns and borrowing rates), as the U.S. financial sector experienced in the last decade (e.g., Reinhart and Rogoff 2008; Rogoff and Obstfeld 2009; Farhi, Caballero, and Gourinchas 2008; Bernanke 2011). These results suggest that during that period greater demand for safety, combined with low perceived downside probability (e.g., the probability that housing prices will decline), provided the ground for the rapid expansion of new financial instruments in the last decade.

The key implication of the model is that securitization can cause a large decline in bank information-production (lending standards), even though it leads to a large solvency risk for their projects. As the economy is perceived to be safer, the banks increase leverage. But greater leverage reduces the benefit of the information gained from quality improvements (lower solvency risk), because it implies that more assets must be liquidated during funding crises; once assets have been sold, their solvency is irrelevant to the banks. Since securitization allows greater leverage, there is room for further reduction in the benefit of information. Importantly, however, when there is no securitization, there are strong counteracting forces: greater leverage increases the benefit of the information derived from transparency improvements (higher accuracy of a signal indicating quality), and higher transparency decreases the funding risk while increasing the trading value of assets in the secondary market.

By contrast, in the case of securitization these offsetting forces can be much weaker. First, as credit risk is shared, transparency can decrease even the trading value of low-quality ABS. Second, securitizers trade among themselves so as to construct a well-diversified portfolio that consists of ABS produced across securitizers, but individual securitizers fail to internalize the impact of the transparency of the ABS they have produced on the transparency of their portfolios. If individual securitizers produce more transparent ABS, their portfolios become more transparent, leading to a lower funding risk. But, because securitization also diversifies the benefit of the transparency of ABS, individual securitizers fail to recognize that benefit. Moreover, information-production with securitization declines faster with a larger spread, as securitizers bet on the boom by taking on leverage, and this leads to a collapse in profits in the bust. As a consequence, a large decline in lending standards leads the financial sector to build up large tail risk and to increase its exposure to liquidity risk, causing more severe crises in the tail event.

I next turn to a normative analysis of the model, asking this question: Are competitive financial markets efficiently arranged to protect themselves from potential risk? In order to determine whether there is a need for policy intervention, one needs to understand how, and under what conditions, private decisions lead to inefficiency at the social level. To address these questions I define constrained efficiency by considering a fictitious planner who faces the same collateral constraint, and has no better knowledge than the private sector.

Moreover, I identify two important sources of the inefficiency that emerges as securitizers fail to fully take into account the social benefits of information production.[4] First, because they are atomistic, securitizers do not internalize the impact of their individual information-production on aggregate information. The increased availability of information leads to increased transparency of financial products, which ultimately results in lower funding risk.

The second source of inefficiency is securitizers' aversion to fire sales; this prevents them from fully internalizing the social costs of the underproduction of information. Securitizers can decrease the net fire-sale losses in downturns by decreasing the quality of ABS, as the lower quality implies lower opportunity costs of fire sales. While imperfect information about the quality of the securities enables the securitizers to transfer plagued assets to other securities investors during a funding crisis, the social planner has no such motive because from her perspective, it is a pure transfer from one agent to another. Consequently, by increasing aggregate information ex ante, the planner can reduce

[4] My model, like the model of a fire-sale externality in the literature, posits a pecuniary externality, for each securitizer does not take into account the general equilibrium effect of asset sales on prices (e.g., Lorenzoni 2008; Stein 2012).

the size of the tail risk as well as the liquidity risk and thereby improve financial stability. This ultimately increases the pledgeability of asset-backed securities, leading to a reallocation of funds from the investors to the banks, which face better investment opportunities. This reallocation leads to a pareto improvement, which is not internalized by the private agents.

I proceed to explore optimal regulation implementable within the current financial system. I show that the policymaker can achieve optimal financial stability by targeting an optimal degree of opaqueness, which can be implemented by imposing a capital surcharge based on the degree of opaqueness of securities. It should be emphasized that policymakers have to control the creation of opaque securities, not of safe securities. Although opaqueness can increase the collateral capacity of securities, as shown in the model, it may camouflage that severe risk, which surges whenever an unfavorable state of the world occurs. Thus what policymakers must do is to control the manufacturing of safety by imposing more costs on the creation of opaque securities. This kind of regulation can be consistent with the creation of safe securities, as long as information about the characteristics of securities is disclosed and their buyers are encouraged to gain a better understanding of their nature. Nonetheless, there does exist an optimal number of opaque securities. The performance of opaque loans has been believed to be on a par with transparent loans unless some bad states occur, while opaqueness cuts down on the transaction costs associated with financial contracts. Moreover, it should be particularly pointed out that if the private sector perceives the likelihood of a tail event to be high, it does not have many incentives to produce opaque securities that involve large hidden risk. Thus time-varying capital surcharges on opaque securities are necessary, to achieve both efficiency and financial stability.

Related literature This paper is related to the literature on securitization and the financial crisis of 2007-2009. Many authors have accrued empirical evidence indicating that securitization led to a decline in lending standards during the run-up to the crisis (Keys, Mukherjee, Seru, and Vig 2009; Keys, Mukherjee, Seru, and Vig 2010; Purnanandam 2011; Jiang, Nelson, and Vytlacil 2014). The "originate-to-distribute" explanation of the crisis emphasizes the misaligned incentives between securities underwriters and investors (e.g., Diamond and Rajan 2009; Akerlof and Shiller 2010). Yet another researcher has pointed out, however, that the private sector has developed mechanisms to make the arrangement incentive-compatible (Gorton 2008). Moreover, there is substantial empirical evidence that is inconsistent with the originate-to-distribute hypothesis: losses from asset-backed securities have remained largely within the entities in the securitization chain (Acharya, Schnabl, and Suarez 2013; Erel, Nadauld, and Stulz 2014), and the performance of unsold loans was even worse than that of the loans sold to investors (Jiang, Nelson, and Vytlacil 2014). Gennaioli, Shleifer, and Vishny (2012, 2013) seek to reconcile those views. They provide a model of shadow banking, where both securitizers and investors are unaware of some possible bad states as a departure from rational expectations. In their model, financial instability arises because securities are over-produced than what would be possible under rational expectations. My paper also provides a model of shadow banking but does so from a different perspective, for here all agents form rational expectations. Many new insights emerge, but most importantly my model can explain a decline in lending standards with securitization, which results in increased financial instability, without having to rely on the assumption that banks (originators, securitizers) take advantage of superior information about their projects over securities investors. Furthermore, my model presents new insights into how we should regulate the growth of securitization activities.

In addition, current policy debates adduce a number of reasons why structured finance products might cause financial-market disruptions: misaligned incentives of underwriters, irrational optimism of financial intermediaries, opaqueness of financial products, and manufacturing tail risk. Of these arguments, only the first two have been developed in the literature.[5] This paper formalizes the third and the fourth arguments.

This paper builds on insights from the extensive literature that studies the general equilibrium effect between financial distress and asset prices, following the seminal contributions of Shleifer and Vishny (1992) and Kiyotaki and Moore (1997). In particular, the "systemic risk" that arises from overborrowing has been a focus of recent studies. In those studies, the excessive use of short-term liabilities leads to pecuniary externalities that work through missing insurance markets (Lorenzoni 2008) or collateral constraints (Korinek 2011; Gertler, Kiyotaki, and Queralto 2012; Stein 2012). The closer one to the model presented here is Stein (2012), where banks create too many short-term liabilities when a short-term borrowing rate is sufficiently low. The need for some form of ex ante regulation has been emphasized in those studies, which basically restrains excessive leverage in the financial sector to mitigate systemic risk. While all of those papers focus only on the liability structure of banks, my model further considers the com-

[5] For optimal security design see, for example, Pennacchi (1988), DeMarzo (2005), and Parlour and Plantin (2008). For the irrational optimism argument, see Gennaioli, Shleifer, and Vishny (2013). See also Acharya, Cooley, and Richardson (2010).

position of the asset side of banks' balance sheets as an endogenous trigger and a cause of a financial crisis. In my model, the funding crises experienced by short-term borrowers and consequent fire sales are symptoms of a financial crisis that may be exacerbated by heavy reliance on short-term liabilities, whereas the nature of banks' assets is critical to triggering funding crises as well as determining the extent of a fire-sale crisis. Consequently, a new dimension of macroprudential policy emerges.

This paper is also related to the literature on debates about the transparency versus the opaqueness of public information. A non-exhaustive list of relevant papers is Morris and Shin (2002), Angeletos and Pavan (2007), Amador and Weill (2010), Pagano and Volpin (2012), and Kurlat and Veldkamp (2013). In the context of a financial market, Kurlat and Veldkamp (2013) argue that transparency is likely to reduce investors' welfare because it decreases the risk of financial assets, precisely the one that investors seek to obtain higher returns. Pagano and Volpin (2012) study a model in which issuers of ABS face sophisticated and unsophisticated investors and can choose between transparency and opaqueness. They found that when the information-acquisition of the sophisticated creates an adverse-selection problem, transparency may be the better option. In my model, both liquidity risk and solvency risk are endogenously determined by banks' choices, and the impact of their information choices on financial stability is analyzed within a more general framework.

1.2 Model

In this section, I present a model of banking with securitization along with a model under financial autarky (no securitization). Section 1.2.1 describes the primitives of the model. Section 1.2.2 introduces securitization into the model. Section 1.2.3-1.2.5 present the optimization problems that the agents in the model face. Section 3-1.2.7 describe the solution of the model. Section 1.2.8 introduces a model of banking under financial autarky as a benchmark economy.

1.2.1 Environment

There is a rectangle of islands, indexed by $j \times i \in [0,1] \times [0,1]$, which define the boundaries of a local asset market as well as the geography of information.[6] In each island, there are a bank and a continuum of inside investors. In addition, there is a continuum of outside investors who operate in the national market. There are three dates, 1, 2, and 3. At the beginning of date 1, each type of agents is endowed with 1, Y^S, and Y^I respectively. They receive no further endowments in the subsequent periods.

State of Nature There are three possible aggregate states S, which I label as high $(S = H)$, middle (M), and low (L), and two island-specific individual states, which I label as good $(s = g)$ and bad $(s = b)$. The high state represents an economic upturn, while the middle and the low states represent economic downturns. The low state, in particular, corresponds to a tail event (or a crisis state). All states are realized at date 2.

The high state (upturn) is realized with probability p, and there is no idiosyncratic risk: $s = g$ with probability 1. In the middle and the low states (downturns), the island-specific individual state becomes matter. The middle state occurs with probability $(1-p)\eta$, in which case $s = g$ with probability $1-\lambda^M_{ji}$ and $s = b$ with probability λ^M_{ji}. Similarly, the state occurs with probability $(1-p)(1-\eta)$, in which state $s = g$ with probability $1-\lambda^L_{ji}$ and $s = b$ with probability λ^L_{ji}, where $\lambda^M_{ji} = c_\lambda \lambda^L_{ji}$ and $c_\lambda < 1$.

Technology Each bank has access to risky long-term investment projects at date 1, each of which costs 1 dollar to undertake. At date 3, each project pays off $\mu(S,s)$, which is state-contingent. In $S = H$ where there is no idiosyncratic risk, it always pays out $\mu(H) = \mu$. In $S = M$ and L where the individual state matters, it pays out $\mu(S,g) = \mu^B$ in the good state, where $\mu^B \leq \mu$. But it collapses to $\mu(S,b) = 0$ in the bad state (equivalently, assets become lemon), which exposes banks to long-term *solvency risk*. The return to the projects is perfectly correlated within an island, but uncorrelated across islands. Assets represent cash flows from projects. No other technology is available to banks.[7]

Each inside investor can invest in a risk-free storage technology that yields a net rate of return 0 with certainty.

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[6] A rectangle of islands is needed to decribe an economic environment in which each securitizer has a limited ability to produce fully diversified ABS. Individual securitizers can construct a fully diversified portfolio only by trading ABS among themselves.

[7] I abstract from bank's cash reserves, but it does not affect qualitative results. See Bolton, Santos, and Scheinkman (2011) for the exposition of this idea.

With no costs, the inside investor can withdraw cash from the storage, or reinvest in it anytime. In addition, an inside investor can lend cash to financial intermediaries (a local bank within her island under financial autarky/securitizers if securitization occurs, which is specified in the next section). It is a source that exposes the inside investors to *the risk of a bank failure* and, in consequence, exposes the banks to short-term *liquidity risk*. The nature of a contract between inside investors and financial intermediaries will be elaborated in Section 1.2.4.

Outside investors are active from the beginning of date 2. They face investment opportunities arriving at date 2, which pays out a fixed rate of return A. Alternatively, they can buy assets from a secondary asset market, which may open at date 2, if banks sell their assets to obtain liquidity. If an outside investor buys an asset from island ji at the price of q_{ji}, the return to the asset at date 3 is given by $\frac{\mu(S,s_i)}{q_{ji}}$.[8]

Preference Banks and outside investors, who invest in risky long-term projects, are risk-neutral. They can consume only at date 3. In contrast, inside investors are infinitely risk-averse in the sense that future consumption levels are valued at the worst state. They can consume both at date 2 and date 3.

Information Agents have imperfect information about the state of the world, but there are two kinds of information available about the underlying states. In the interim period (date 2), either positive $(\overline{S} = P)$ or negative news $(\overline{S} = N)$ arrives, which is informative about the aggregate state. News can be positive with probability p, in which case $S = H$ with probability 1, or can be negative with probability $1 - p$, in which case $S = M$ with probability η or $S = L$ with probability $1 - \eta$; if the negative news is received, there is uncertainty about the realization of the aggregate state in the interim period. This information is symmetric across islands. In addition, in the interim period, agents in each island ji receive either good $(r_{ji} = g)$ or bad news $(r_{ji} = b)$ about the quality of assets in island ji, which is informative about the individual state. This information is symmetric within an island, but asymmetric across islands.

Notice that p and $1 - p$ stand for the probability of a upturn and a downturn respectively. Negative news indicates that the economy is in a downturn. The value of η represents uncertainty about the aggregate state when negative news hits the economy. See Figure A.1 and A.2 for a summary.

[8] Positive net present value projects may not be financed as the outside investors rather try to exploit arbitrage opportunities in the anticipation of asset sales at a fire sale price (Diamond and Rajan 2011).

1.2.2 Securitization

In the light of the recent innovation, as the U.S. financial sector experienced in the last few decades, I define financial innovation as securitization as follows.

Definition 1 *Securitization is the procedure of pooling assets being held by banks across islands to create asset-backed securities (ABS).*

As creating safer securities to be pledged against borrowing, securitization can channel more funds from risk-averse investors who pursue safety into risk-taking banks. In addition, I suppose the following, which may create a potential adverse effect from the perspective of banks, as a consequence of securitization.

Assumption 1 *(No Discretion) Once assets are pooled together, the pool of securitized assets must be sold if they are sold in the secondary asset market.*

Motivation While there is the benefit of securitization, my setting also takes into account the potential cost of securitization with the assumption: as good and bad assets are sold together within the pool, it may lead to larger asset liquidation costs in the secondary asset market. Basically, I consider securitization as an instrument of improving risk-sharing opportunities. Because it diversifies the downside risk of assets to create safe cash flows at date 3, securitization increases the borrowing capacity of banks, allowing them to borrow further to finance new projects. Despite such benefit, securitization comes with a caveat: once projects are bundled together, banks are forced to sell the pool of securitized assets, not an individual asset separately, if they are required to do so. This captures an idea that, because of buyers' fear for adverse selection in the secondary asset market, the banks cannot selectively dispose of bad assets.

A more explicit microfoundation might involve asymmetric information between securitizers and outside investors at date 2—for example, the securitizers get a private signal that gives information advantages over the outside investors. This creates an adverse selection problem for any attempts to pick bad projects to sell, which forces the securitizers to liquidate the pool of securitized assets. In other words, if buyers know that the securitizer has better information about the quality of assets, the buyers will not arrange financial transactions in a way that the securitizer takes advantage of superior information. A natural way to avoid such adverse selection is to force the securitizer to liquidate the pool of entire securitized assets.[9]

Presence of Securitizers Under financial autarky, there are no securitizers who collect loans and produce diversified portfolios. Originators (banks) themselves are assumed not to be able to produce such diversified portfolios, and lenders to originators (inside investors) can only extend credit to the one within their island.

To formalize the idea of securitization, I suppose that there is a continuum of identical securitizers, indexed by $j \in [0,1]$, each of whom operates in islands $j \times i \in j \times [0,1]$.[10] Each securitizer is a syndicator who can dictate how the originators (banks) make decisions on relevant choice variables to maximize the profits of the syndicate.[11] Securitizer j produces ABS_j to diversify the island-specific risk by collecting assets from all the islands $j \times [0,1]$. I introduce further idiosyncratic shock to the return to ABS_j as the source of securitizers' trading motives: with arbitrarily small probability ε, the return to ABS_j collapses to 0.[12] This induces securitizers to trade among themselves to construct a well-diversified portfolio that consists of ABS produced across securitizers. $w_{k,j}$ represents the quantity of ABS_k, which is produced by securitizer k, in securitizer j's portfolio. Lenders (inside investors) can extend credit to the securitizers instead of a local originator with a loan contract (R_2, R_3) as before, in which case their credit is backed by a well-diversified portfolio of each securitizer. Securitization may offer them better opportunities of intertemporal transfer of funds. See Figure A.3, A.4, and A.5 for a summary.

Throughout the paper, I will focus on a parametric case in which the following assumption holds.

Assumption 2 *Securitizers default only in the low state.*[13]

This assumption implies that economic fundamentals are strong enough in the middle state and that securitizers are insolvent only in the low state. But liquidity risk may exist both in the middle and the low state, because of the

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[9]Qualitative results would not be affected to the extent that securitizers have limited discretion over the disposal of assets in the secondary asset market.

[10]Island ji associated with securitizer j is indexed by (j,i). I will omit subscript i when it causes no ambiguity.

[11]I do not further assume any transfer of asset returns among banks at date 3, even if the low state is realized. Regardless of the existence of such transfer, the ex-ante utility of each bank is the same.

[12]In particular, a measure-zero set of ABS produces nothing.

[13]*One possible parameterization is to assume that the fraction that the bank can divert,* ζ, *has a limit such that* $(1-\zeta)(1-\lambda^M)\mu^B - Rd \geq 0$ *and* $(1-\zeta)(1-\lambda^L)\mu^B - Rd \leq 0$, *leading the securitizer to default only in the low state.*

imperfect information about the state of the world when the negative news is received. This assumption is necessary to generate uncertainty regarding R_3 among inside investors.[14] Once the negative news is received, if inside investors knew that the worst state had occurred, it is optimal for them to stop funding for securitizers in the interim period; but an inefficient funding crisis from maturity mismatch can occur even when fundamentals are strong ($S = M$) if inside investors are imperfectly informed about the state of the world.

1.2.3 Banks

There is a continuum of banks, indexed by $j \times i \in [0,1] \times [0,1]$. Island ji is inhabited by bank ji, which is endowed with 1 dollar.[15] Bank ji can borrow d_{ji} dollars from securitizer j in exchange for each project it undertakes, which collateralizes asset-backed securities the securitizer holds in its balance sheet.

Bank's borrowing for each project is subject to the collateral constraint, $d_{ji} \leq D_{ji}^{FI}$ where D_{ji}^{FI} is the function of the model's endogenous variables, which will be specified in Section 1.2.5. Then, the number of projects, N_{ji}, bank ji undertakes is given by

$$N_{ji} = \frac{1}{1 - d_{ji}}, \tag{1.1}$$

and the total amount of borrowing is given by $d_{ji}N_{ji}$.

Information In the first period, securitizer j chooses the amount of information α_j that bank ji produces about its investment projects, where $\frac{1}{2} \leq \alpha_{ji} \leq 1$.[16] I assume that the choice of securitizers/banks is common knowledge as well as the securitizers does not have any informational advantages over investors. The effects of information production of bank ji are two-fold. First, it determines the probability that projects collapse, $\lambda^S(\alpha_{ji})$, where $\lambda^{S\prime}(\alpha_{ji}) < 0$ and $\lambda^{S\prime\prime}(\alpha_{ji}) \geq 0$. It can be interpreted that λ represents the probability that assets become lemons, which perform well

[14] If securitizers do not default both in the middle and the low state, securitizers face no liquidity risk, as inside investors would always roll over debt in the interim period. Also if securitizers default both in the middle and the low state, inside investors would stop funding whenever they receive negative news. In both cases, the existence of the middle state is not necessary, and there is no role in public information available in the interim period, which is the one of the main focus of this paper.

[15] I will omit subscript j when it causes no ambiguity.

[16] Since banks are homogenous ex ante, $\alpha_{ji} = \alpha_j$. Under financial autarky, bank ji itself chooses α_{ji} independently.

in a good time but default in a bad time. The less the bank's screening efforts, which is equivalent to low information production about projects/borrowers' characteristics in the model, the larger the adverse selection/solvency risk in bank's lending activities.

Here I model inadequate information production as the main driving force of larger adverse selection risk, having in mind the financial crisis of 2007-2008. The delinquency rates of less-documented loans was not significantly higher than fully-documented loans until the downturn in the housing market, but the delinquency rates became wide between less- and fully-documented loans as the housing market collapsed.[17][18]

Second, the quantity of information α_{ji} determines the accuracy of a signal, r_{ji}, about the quality of assets, s_{ji}, which is delivered at date 2:

$$\begin{aligned} p(r_{ji}|s_{ji}) &= \alpha_{ji} && \text{if } r_{ji} = s_{ji}, \\ p(r_{ji}|s_{ji}) &= 1-\alpha_{ji} && \text{if } r_{ji} \neq s_{ji}. \end{aligned} \tag{1.2}$$

If more information about projects is produced, agents can better assess the value of projects in their island.[19] This implies that the transparency of an asset is increasing in its quality. Here I assume the symmetric probability of a signal revealing a true state of an island regardless of the aggregate state for simplicity.[20] If information is not produced by bank ji at all, a signal r_{ji} is completely noisy, in which case $\alpha_{ji} = \frac{1}{2}$.[21] If a signal r_{ji} is perfectly revealing about the state of island ji, α_{ji} must be equal to 1. This specific functional form is not essential to results. What is important

[17] Wei Jiang and Vytlacil (2014) find that the risk premium of less-documented loans over fully-documented loans, although the extent of which is very modest. This may reflect the fact that the performance of less-documented loans is comparable to fully-documented loans in normal times, while there exists a reasonably small tail probability of collapse in the performance of less-documented loans.

[18] For the difference of delinquency rates in the subprime mortgage market, see Gerardi, Lehnert, Sherlund, and Willen (2008). For the Alt-A market, see Sengupta (2010). Some other observable characteristics of borrowers related to lending standards such as debt-to-income ratio and loan-to-value ratio may be other factors relevant to the adverse selection risk (e.g., Demyanyk and Van Hemert 2011). However, I abstract those from the determinant of the risk on the following grounds. First, while there are performance differences in subprime and Alt-A loans by cohort year from 2000 to 2007 (e.g., GAO (2009)), we do not see much variation in the level of loan-to-value ratios (LTV), combined loan-to-value ratios (CLTV) or the debt service-to-income (DTI) ratio in this period. (See figure 3 and 4 in GAO (2009)) However, there is considerably larger variation in the percentage of nonprime loans with low documentation (See figure 9 in GAO (2009)). Noticeably, the Alt-A share of the nonprime mortgage market increased from about 15 percent in 2000 to 57 percent in 2007. Second, Gerardi, Lehnert, Sherlund, and Willen (2008) suggest that there is a significant difference of default rates between less- and full documented loans within loans with high CLTV ratios.

[19] Since the island specific state s_i is binary, the agents receive a binary signal r_i as well, which takes either g or b.

[20] This assumption amounts to $p(r|s) = p(r|s,S)$.

[21] The entropy is maximized at $\alpha = \frac{1}{2}$.

is that the accuracy of public signal r should be a monotonically increasing function of the quantity of information produced, α.

This setting can be interpreted in three ways. First, if a securitizer produce high quality ABS (α is high so that λ is small), it would disclose as much information as possible to make ABS transparent for signalling in the primary and the secondary market.[22] Second, if a bank produces low information on projects, which results in high solvency risk, the projects have to go through a more complex procedure to generate safe cash flows. For instance, in order to create more safe securities, securitizers may try to manufacture CDO and CDO^2 out of risky subprime mortgage loans. The complexity of such structured finance products makes investors difficult to penetrate to quality of securities. Third, the increased production of information by the bank at date 1 encourages the development of information infrastructure such as electronic data sources, analytical software, and human capital. As such development makes financial products more transparent, public information about the quality of financial products become more precise at date 2.

Accordingly, I define the cost of information for bank ji as follows:

$$I(N_{ji}, \alpha_{ji}) = N_{ji}\iota(\alpha_{ji})$$

where $\iota(\alpha)$ satisfies $\iota(\frac{1}{2}) = 0$, $\iota' > 0$, and $\iota'' > 0$.[23] $\iota(\alpha_{ji})$ represents the cost of information for each project. ι is convex and increasing in the quantity of information. The total information costs are linear in the number of projects bank ji undertakes.

It is worth noting that I assume that information produced by the bank is shared within the island and the bank's choice is common knowledge; the bank has no information advantage about projects it undertakes over other agents (creditors). I relax this assumption in Section 1.5.3, but there are no qualitative changes to results. Although asymmetric information between banks and creditors may be an important consideration as many authors previously claimed (e.g., Diamond and Rajan 2009; Akerlof and Shiller 2010), as it is called the "originate-to-distribute" explanation of

[22]If ABS a securitizer produced is of the bad quality, it can be optimal to disclose minimum level of information, providing a noisy signal to the market. See also Section 1.3.2.

[23]Instead, we can assume the information cost $\iota(\alpha_i)$ as the mutual information, $\iota(\alpha_i) = E[\log \frac{p(r_i|s_i)}{p(r_i)}]$. However, the specific functional form of information costs are not essential to our results..

the crisis, I abstract this feature from the basic framework on the following grounds. First of all, since securitization began in the 1970s, the private banking system has developed various kinds of instruments to internalize the perverse incentives of agents in the securitization chain in order to eliminate any negative impacts of banks' information advantages about their assets (e.g., the banks are responsible for initial defaults: skin in the game in the originate-to-distribute system), though I here set aside the question of whether the banks kept a proper portion of the risk in their balance sheet before the crisis. Indeed, the securitization chain, from originators to underwriters, is exposed to considerable risks by creating and maintaining securitized products: warehousing of loans and securities before they are sold, mortgage servicing rights and retained interests by originators, retained structured products, and implicit and explicit contractual insurance between the sponsor of the conduits, such as special purpose vehicles (SPVs) and special investment vehicles (SIVs), and investors in the liabilities of such conduits (Gorton 2008).

Second, even if the originators try to conceal information regarding the characteristics of loans they seek to sell, it is unclear that the originators truly have relative informational advantages because the investors have ability to conduct their own research to obtain information. Indeed, empirical evidence indicates that the performance of loans remaining on the bank's balance sheet was worse than the loans sold to investors in terms of delinquency rates (Jiang, Nelson, and Vytlacil 2014). Moreover, while there is some micro evidence that suggests asymmetric information in the prime mortgage backed securities markets (Downing, Jaffee, and Wallace 2009), there is broader evidence against it, which suggests that it may not the main mechanism that caused the financial crisis[24]. Noticeably, it was commercial banks who largely bore the losses of the financial crisis rather than investors in the asset-backed commercial paper (ABCP) that had been the important source of funds in the shadow banking system (Acharya, Schnabl, and Suarez 2013) and the bank's performance during the crisis is negatively correlated with the securitization activity (Erel, Nadauld, and Stulz 2014).[25]

Accordingly, in the model, banks have no discretion to choose which assets back their liabilities; inside investors

[24]Downing, Jaffee, and Wallace (2009) point out that the prepayment risk of loans sold in the prime markets is higher than ones retained. However, Agarwal, Chang, and Yavas (2012) show that such higher prepayment risk was offset by lower default risk. Furthermore, they found no support for adverse selection in the subprime market.

[25]There is also growing empirical evidence that securitization led to the decline in lending standards in the run-up to the crisis (e.g., Keys, Mukherjee, Seru, and Vig 2009; Keys, Mukherjee, Seru, and Vig 2010; Purnanandam 2011; Jiang, Nelson, and Vytlacil 2014). I will show that this empirical evidence is consistent with our results. Lax lending standards do not necessarily imply that banks do not have enough skin in the game.

extend credit to the pool of bank's assets.[26] This structure is in accordance with the practice in the originate-to-distribute system as well as the traditional originate-to-hold system.[27]

1.2.4 Inside Investors

There is a continuum of homogenous inside investors in each island. The endowment of each inside investor, Y^S, is assumed to be sufficiently large to absorb supply of assets by the bank. Given a loan contract (R_2, R_3) offered by a securitizer, an inside investor chooses dN, the amount of lending to each securitizer, and $Y^S - dN$, investment in the storage technology. Each inside investor has linear preferences, but infinitely risk averse with respect to future consumption, which implies that she values consumption levels at the worst state.[28] Her utility function can be written as follows:

$$U_i^I \equiv \min(C_2) + \beta\delta \min(C_3),$$

where C_t denotes consumption at t, $\beta < 1$, $\delta > 1$, $\beta\delta < 1$, and the minimum operator is taken over the states (S, s) given inside investor's information on the underlying state at time t, Ω_t.[29] While infinite risk-aversion is an unusual assumption, it is useful to build a parsimonious model, which captures most insights, as well as it is a simple way to generate demand for safe securities.[30] I relax this assumption in Section 1.5.2, where additional insights emerge.

A securitizer offers a loan contract (R_2, R_3), where R_t is the amount that can be withdrawn at date t, for each unit of loans made at date 1 provided that there have been no previous withdrawals. If an inside investor holds loans until maturity (date 3), it yields a net rate of return R_3 unless the bank defaults. If the bank defaults, it pays out 0 dollars

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[26] See also DeMarzo (2005) for the further theoretical explanation that originators can be better off selling the pool of assets rather than selling them separately in the securitization chain.

[27] Indeed, originators do not have discretion over the choice of loans sold to SPVs. See Gorton and Metrick (2012) for the legal and contractual arrangements of the securitization process.

[28] See also Gennaioli, Shleifer, and Vishny (2012).

[29] $\delta > 1$ represents preferences for safe cash flows. Ω_t represents conditional probability distribution over possible states at time t, $f_t(S, s)$. At $t = 1$, $U_i^I \equiv \min(C_2)$ (securitizers may default, $\min(C_3) = 0$, and no information about the state of the world is available at $t = 1$) . At $t = 2$, $U_i^I = C_2 + \beta\delta \min(C_3)$.

[30] I assume that there are no lenders who are willing to take risk at date 1 in the basic setting. Qualitative results would not be affected if the wealth of risk-taking lenders is not enough to completely absorb demand for loans from securitizers.

instead, which exposes the inside investors to *the risk of a bank failure*.[31] However, an inside investor can claim her cash against the bank to earn R_2 in the interim period, $t = 2$, which is the source that exposes the bank to short-term *liquidity risk*.

Optimal Contract The optimal contract between securitizers and inside investors is characterized by the following lemma.

Lemma 1 *(i) (Optimal Contract) The optimal contract offered by each securitizer is given by* $(R_2, R_3) = (1, R)$, *where* $R \equiv \frac{1}{\beta\delta}$;

(ii) (Date-1 Decisions of Inside Investors) Given the contract, inside investors supply loans up to the collateral constraint of each securitizer.

Notice that, since securitizers can default at $t = 3$, they cannot offer long-term contracts to inside investors. The optimal short-term contract maximizes the profits of a securitizer given the participation constraint of inside investors.[32] Given the risk-free storage technology available to inside investors, $R_2 = 1$ is sufficient to attract inside investors into the loan contract, but the contract must be stipulated in a way that loans are completely riskless between date 1 and 2; if inside investors refuse to roll over debt at $t = 2$, they are guaranteed to be paid back their original investment.[33] Otherwise, infinitely risk-averse inside investors will not extend credit to securitizers at all, flying to the alternative risk-free storage technology.[34] This implies that the inside investors demand collateral against all loans to ensure the safety of their investment in every state at $t = 2$.

In addition, R_3 must be equal or larger than $\frac{1}{\beta\delta}$ to compensate the time discount rate. The abundance of Y^S pins down R_3 at $R \equiv \frac{1}{\beta\delta}$. In the case when a securitizer defaults, he cannot honor the contract and the lenders receive 0. At

[31] It can be generalized to pay out $V(S,s)\psi$, where $V(S,s)$ is the value of assets in (S,s) and ψ represents recovery rates. In the basic setting, I set $\psi = 0$ for simplicity.

[32] The conclusion does not change even if inside investors can offer a loan contract. As their wealth Y^S is sufficiently large, securitizers can always attract them into the contract by offering $(1+\varepsilon, \frac{1}{\beta\delta}+\varepsilon)$, where $\varepsilon > 0$ is arbitrary small.

[33] This setting is meant to capture liquidity risk that stems from maturity mismatch between assets and liabilities, while short-term debt is nearly riskless. Until the financial crisis, bank-sponsored conduits issued asset-backed commercial paper (ABCP) with a maturity of 30 days or less to finance the purchases of longer-term assets with maturities of 3-5 years and hold them to maturity. Holding ABCP was nearly riskless as sponsors use various types of guarantees to provide insurance to outside investors of ABCP. See (Acharya, Schnabl, and Suarez 2013).

[34] Notice that $\min(C_3) = 0$ with information set Ω_1.

$t = 1$, as it is indifferent to invest in the risk-free storage technology, the lenders are willing to supply credit up to the collateral constraint.

Information At $t = 2$, inside investors become exposed to aggregate risk when they receive the negative news ($\overline{S} = N$). Instead of information about the individual state, r_{ji}, the economy needs a device that aggregates dispersed information across islands and securitizers to provide information about the aggregate state. Therefore, I assume that, before they decide whether to roll over debt, inside investors receive a public signal about the aggregate state, ϕ. In particular, ϕ represents the aggregated information of the regional information r_{ji}, $\phi = \phi(\{r_{ji}\}_{ji}, 1-\xi)$, where r_{ji} is distributed according to $p(r_{ji}|s_{ji})$; $1-\xi$ is non-diversifiable noise that represent the costs of aggregating, processing and absorbing large complex data, or it can be thought of as the inaccuracy of credit ratings of complex structured products.

For simplicity, I suppose that the accuracy of ϕ is increasing in the sum of the accuracy of regional signals, $\overline{\alpha}$, where $\overline{\alpha} = \int \alpha_{ji} dj di$. For an expositional purpose, I further suppose that the fraction $\tilde{P}(\overline{\alpha})$ of inside investors become precisely informed about the aggregate state when they receive the additional signal $\overline{\phi} = S$, where $\tilde{P}(\overline{\alpha})' > 0$.[35] $1 - \tilde{P}(\overline{\alpha})$ represents the fraction of inside investors who have imperfect information about the aggregate state. Put differently, if more information is produced by securitizers, it leads to the increased transparency of their portfolio that consists of ABS. Thus more inside investors precisely assess the safety of their loans backed by securitizers' portfolios. A microfoundation involves the decision of each investor to acquire private information on the state of the world at a cost, which is presented in Section 1.5.1.

With her updated information set, Ω_2, each inside investor decides whether to roll over debt until maturity. The following lemma describes the date-2 decision of each type of inside investors.

Lemma 2 *(Date-2 Decision of Inside Investors) (i) Inside investors who become precisely informed about the aggregate state roll over debt only in the middle state;*

(ii) Inside investors who have imperfect information about the aggregate state stop rolling over debt whenever they receive negative news about the aggregate state.

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[35] Inside investor l becomes precisely informed if $\overline{\phi}_l = S$, but not informed if $\overline{\phi}_l = 0$.

The perfect information about the aggregate state eliminates any uncertainty about a securitizer failure, in which case the decision of an inside investor is tied to current economic fundamentals. However, imperfectly informed investors stop funding in the fear of a securitizer failure, which occurs even when current fundamentals are strong. As some investors stop funding securitizers, a certain fraction of ABS being held by securitizers must be sold to the other agents (outside investors) in the secondary asset market to oblige them with liquidity.

1.2.5 Outside Investors

The model of outside investors is similar Stein (2012) with perfect information. There is a continuum of homogenous outside investors, indexed by $l \in [0,1]$, who arrive at date 2 and operate in the national market.[36] They can use their resources Y^I in real investment projects with linear technology A available at date 2, or to absorb financial assets being sold by securitizers (banks under financial autarky), if any, in a competitive secondary asset market.

By Assumption 1, asset-backed securities (ABS) themselves are traded in the secondary market, but the outside investors acknowledge that assets that collateralize ABS are heterogeneous in their quality. In this regard, when ABS from securitizer j is traded, the outside investors observe island-specific information $\{r_{ji}\}_i$, where each r_{ji} is drawn independently from the distribution $p(r_{ji}|s_{ji})$. As outside investors aggregate island-specific information $\{r_{ji}\}_{ji}$, they are able to understand the aggregate state.[37] Given information r_{ji} and S, they form a belief about the quality of each underlying asset, $\bar{f}(s_{ji}|r_{ji},S)$. I suppose that outside investors commit to use $\bar{\alpha} = \int_{ji} \alpha_{ji} d(j,i)$ instead of individual α_{ji} for the formation of conditional probability $\bar{f}(s_{ji}|r_{ji},S)$.

This implies that, while securitizers' information choice affects the distribution of the signal r_j observed by outside investors, individual securitizers cannot manipulate the way that outside investors form the expectation about the quality of asset ji given signal r_{ji}. This setting can be interpreted in two ways. First, late arriving outside investors are

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[36]When there is no confusion, I omit the subscript l.

[37]It allows a parsimonious representation of the model. Instead, however, it can be generalized that the outside investors have imperfect information about the aggregate state, assuming that they cannot perfectly combine the island-specific signals all across islands to infer the aggregate state and are not allowed to learn about the state from an asset price. It preserves most of qualitative results, and in many cases, results are even stronger. See the Appendix for differences.

imperfectly informed about individual α_{ji}, but correctly expect the average $\bar{\alpha}$.[38] If there are losses from the misevaluation of $f(s_{ji}|r_{ji})$ with noisy α_{ji}, outside investors would be able to credibly commit to use $\bar{\alpha}$ in symmetric equilibrium. The second interpretation is that securities buyers use aggregate indexes (e.g., ABX.HE), historical data, and reference data from other sources to obtain more accurate parameters in the calibration of their asset valuation model. Such buyers' efforts to reduce errors in the valuation of opaque securities limit securitizer's ability to increase the valuation of an asset with the bad signal, $f(s=g|r=b)$, by generating a noisier signal. Likewise, if such securitizer's manipulation incurs losses to outside investors, they can credibly threat to use $\bar{\alpha}$ in their expectation formation.[39][40]

Outside investors decide the total funds, M^S, that are used to acquire fire-sold assets and the share of the funds, m_j^S, that are used to purchase ABS sold by securitizer j.[41] Their decisions are based on the evaluation of the profitability of the underlying assets that collateralize ABS. However, when they acquire fire-sold assets, there is the loss of value, which amounts to $\upsilon(M^S)$, where $\upsilon' > 0$ and $\upsilon'' \geq 0$ (Shleifer and Vishny 1992). υ'' governs the magnitude of fire-sale externalities from securitizers issuing additional debt. A larger value of υ'' implies greater inefficiency when assets are being sold at a fire-sale price. If $\upsilon'' = 0$, there is no inefficiency with a notion of constrained inefficiency, which is explored in Section 1.4.

Optimality Conditions In the high state, there are no fire-sold assets, and therefore they invest all of their wealth in new projects, which produce AY^I at date 3.[42] In the other states, they absorb financial assets sold by securitizers to

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[38]This setting does not imply that securitizers have information advantages over outside investors. In symmetric equilibrium, outside investors correctly understand securitizer's choice.

[39]However, outside investors would not be able to credibly commit not to observe $\{r_{ji}\}$ in the valuation of each ABS. This is because the value of each ABS depends not only on the aggregate state, but also on the securitizer-specific idiosyncratic risk (the source of trading motives among securitizers) that affects the distribution of r_{ji}. $\{r_{ji}\}_{ji}$ carries information about the ex-post value of each ABS.

[40]Even if securitizers can fully manipulate its valuation of underlying assets, many of qualitative results still continue to hold, because the impact of α_{ji} on $f(s_{ji}|r_{ji})$ can also be decomposed into transparency and quality components. But there is a difference when the collateral constraint starts to bind ($d = q^b$) under financial autarky. In such a case, banks can generate a noisier signal to increase the worst case individual price, $q^b \approx p(s_{ji}|r_{ji})$, which seems to be implausible to the extent that buyers in a real world would adopt other sources of reference data available to make a better approximation of a fair value.

[41]Equilibrium values of M and m are state dependent. I use the superscript S to denote the aggregate state.

[42]This linear representation of the production function allows me to focus on one parameter υ''. Otherwise, both the concavity of the production function and Y^I matter.

maximize:

$$\max_{M^S,\{m_j^S\}_j} A(Y^I - M^S) + \int_j \int_i \bar{f}(s_{ji} = g|r_{ji}, S)\mu^B di \frac{m_j^S M^S}{\mathbf{q}_j^S} dj - \upsilon(M^S), \tag{1.3}$$

subject to $\int_j m_j^S dj = 1$, where $\mathbf{q}_j^S$ is the price of ABS sold by securitizer j in the state S.[43]

The first order condition with respect to m_j^S implies that there is no arbitrage profit to be made among the securities sold by securitizers: for $j \neq k$,

$$\int_i \bar{f}(s_{ji} = g|r_{ji}, S)di \frac{\mu^B}{\mathbf{q}_j^S} = \int_i \bar{f}(s_{ki} = g|r_{ki}, S)di \frac{\mu^B}{\mathbf{q}_k^S}. \tag{1.4}$$

Then the optimality condition for the supply of the funds M^S (equivalently, the demand for assets) is given by

$$A = \int_i \bar{f}(s_{ji} = g|r_{ji}, S)di \frac{\mu^B}{\mathbf{q}_j^S} - \upsilon'(M^S). \tag{1.5}$$

It implies that the marginal benefit of investment on new projects must be equal to the marginal return from buying existing assets sold by securitizers less the marginal loss of value. If there are more assets being sold, the outside investors may require a lower asset price in the compensation for the loss of value. From this condition, an equilibrium asset price $\mathbf{q}_j^S$ can be derived once equilibrium M^S is determined. Therefore, the price of ABS $\mathbf{q}_j^S$, which is the average value of securitized assets, is given by

$$\mathbf{q}_j^S = \frac{\int_i \bar{f}(s_{ji} = g|r_{ji}, S)\mu^B di}{A + \upsilon'(M^S)}, \tag{1.6}$$

where $F(s_{ji}|S)$ is the distribution of the island-specific state s_{ji} given the aggregate state S.[44] Notice that as the secondary asset market is competitive, each securitizer takes M^S and $\bar{\alpha}$ as given. But each securitizer is aware of the impact of its choice α_j on $\mathbf{q}_j^S$ through the accuracy of r_{ji}, $f(r_{ji}|s_{ji})$.

Notice that, even though I here allow outside investors to be precisely informed about the aggregate state, the

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[43]Remember that if $s_{ji} = b$, asset returns collapse to zero.

[44]Note that $\mathbf{q}_j^S = \frac{\mu^B}{A+\upsilon'(M^S)} \int_{s_{ji}} f_j(r = g|s_{ji}) \bar{f}(s = g|r = g, S) + f_j(r = b|s_{ji}) \bar{f}(s = g|r = b, S) dF(s_{ji}|S)$
$= \frac{\mu^B}{A+\upsilon'(M^S)} \{(\alpha_j(1-\lambda^S(\alpha_j)) + (1-\alpha_j)\lambda^S(\alpha_j)) \bar{f}(s = g|r = g, S) + ((1-a_j)(1-\lambda^S(\alpha_j)) + \alpha_j \lambda^S(\alpha_j)) \bar{f}(s = g|r = b, S)\}$.

extent of their knowledge about the aggregate state, in general, brings only monotonic quantitative adjustments in the prices of ABS, which is not important to qualitative results. What is important to results is that outside investors' asset valuation is based on imprecise signals r_{ji}; as bad assets securitized can be valued positively, the opportunity costs of fire-sales from each securitizer's perspective are even lower if a greater fraction of the underlying assets of a pool is of the bad type. More details are discussed in Section 1.3.2.1 and 1.4.2.2.

One may suppose the case where the secondary asset market breaks down with some probability. If this is the case, buyers in the secondary market can be thought of as government (or taxpayers), in which case $\mathbf{q}_j^S$ may represent the valuation of ABS by the government (for instance, the Troubled Asset Relief Program (TARP) in 2008). Similarly, as long as the government's valuation of ABS is based on imprecise signals, results will not be affected.[45]

1.2.6 Definition of Equilibrium

Since all the agents of each type are homogenous ex ante, I will focus on a symmetric equilibrium, in which all the agents follow identical decision rules. Securitizers' decisions are made at date 1 once and for all before the states are realized. Since all securitizers are infinitesimal, each securitizer takes the price of assets that collateralize ABS, $q^{r,S}$, as given. However, each securitizer continues to be aware of her information choice, α_j, on the price of ABS, $\mathbf{q}_j^S$, as given by equation (1.6).[46] However, she does not internalize the impact of the individual choice α_j on the aggregate information $\overline{\alpha}$, which determines the number of inside investors who stop funding, $1-\tilde{P}(\overline{\alpha})$.

In the interim period, inside and outside investors wish to make choices according to the underlying state of the economy. However, since the state of the world is not perfectly known to them, their decisions must be based upon particular signals, which are potentially informative about the state. Taking all the considerations into account, I define equilibrium as follows.

Definition 2 *(Securitization) A symmetric competitive equilibrium is given by stochastic processes for the signals*

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[45] Another alternative modeling approach might be to reinterpret the wealth of outside investors as cash raised by securitizers in the interim period, which can be used for new investment opportunities in that period or to comply with liquidity demand from the creditor. I do not pursue this complication here, but to the extent that the model can be reinterpreted that κ represents a fraction of assets written off from financial distress and $\mathbf{q}$ as a reference fire sale discount, the qualitative results of the model would not change.

[46] This implies that, as a syndicator, each securitizer imperfectly internalizes its information choice on the asset price.

$p(r|s)$ and $p(\bar{\phi}|\bar{\alpha})$, asset prices $\mathbf{q}_j^S$, aggregate information $\bar{\alpha}$, the tail risk of the economy λ, a financial contract $d,(R_2,R_3)$ between the securitizer and the inside investor, investment and information decisions for the securitizer N_j, α_j, and $\{w_{k,j}\}_k$, and a consumption decision for the inside investor $\{c_2(\bar{\phi}),c_3(\bar{\phi})\}$, and outside investors' demand for assets $D(\mathbf{q}_j^S|\{r_{ji}\}_i,S)$ such that

(i) Securitizers' decision rules maximize expected returns subject to the collateral constraint, taking aggregate information $\bar{\alpha}$ and aggregate asset supply M^S as given.

(ii) Inside investors' decision rules maximize expected consumption given $\bar{\phi}$.

(iii) Outside Investors choose the asset demand to solve the profit maximization problem (1.3).

(iv) The optimal contract maximizes the profits of a securitizer given the participation constraint of inside investors.

(v) The credit market between securitizers and inside investors clears.

(vi) The asset market between securitizers and outside investors clears.

(vii) The aggregate information $\bar{\alpha}$ and the tail risk of the economy λ are consistent with the decision rules of the securitizer: $\bar{\alpha}=\int \alpha_{ji}d(j,i)$ and $\lambda=\int \lambda^L(\alpha_{ji})d(j,i)$.

1.2.7 Equilibrium

In this section, I solve the model and show the existence of equilibrium. I also present the parameterization of the model, which is relevant in the certain sections in the rest of the paper.

1.2.7.1 Solving for Optimal Decision Rules of Securitizers

The problem can be solved using backward induction. Given the optimal contract (Lemma 1-(i)), date-1 loan supply and date-2 liquidity demand by inside investors (Lemma 1-(ii) and Lemma 2), and the demand for assets by outside investors at date 2 (equation (1.5)), it is sufficient to solve for the securitizer's problem.

Date-2 Supply of Assets Each securitizer holds an weighted portfolio of ABS_k, $k\in[0,1]$. But if an inside investor stops rolling over debt in the interim period, securitizer j must liquidate a certain fraction $\tilde{\kappa}_{k,j}^S$ of ABS_k, $k\in[0,1]$, that constitutes its portfolio in the secondary asset market. Notice, also, that if $\tilde{\kappa}_{k,j}^S$ fraction of ABS_k is sold, it is equivalent to liquidating the same fraction $\tilde{\kappa}_{k,j}^S$ of each of underlying assets that collateralize ABS_k regardless of its island-specific state.[47] $\tilde{\kappa}^S_{k,j}$ satisfies the relation that the aggregation over the price of asset-backed securities $\mathbf{q}^S_k$ times the weighted asset supply, $w_{k,j}\tilde{\kappa}^S_{k,j}$, must be equal to the aggregate liquidity demand by inside investors, $\Lambda^S_j d_j N_j$:

$$N_j \int_k \mathbf{q}^S_k w_{k,j} \tilde{\kappa}^S_{k,j} \mathrm{d}k = \Lambda^S d_j N_j = M^S_j, \tag{1.7}$$

where $w_{k,j}$ represents the quantity of ABS_k in securitizer j's portfolio normalized by N_j, and

$$\Lambda^M_j = 1 - \tilde{P}(\overline{\alpha}), \text{ and } \Lambda^L_j = 1, \tag{1.8}$$

by Lemma 2. It implies that the demand for funds M^S_j is equal to debt obligation to the inside investors, $\Lambda^S_j d_j N_j$, and the funds can be obtained by liquidating weighted fraction $w_{k,j}\tilde{\kappa}^S_{k,j}$ of ABS_k at price $\mathbf{q}^S_k$. In equilibrium, the aggregate demand must equal to the aggregate supply:

$$M^S = \int_j M^S_j dj. \tag{1.9}$$

Furthermore, since $\tilde{\kappa}^S_{k,j} \leq 1$, $\Lambda^S_j \leq 1$ and a loan contract must be risk-free between date 1 and 2, the collateral constraint, which is scaled by the number of projects N, is derived from equation (1.7):

$$d_j \leq \min[\int_k \mathbf{q}^S_k w_{k,j} \mathrm{d}k] = \int_k \mathbf{q}^L_k w_{k,j} \mathrm{d}k. \tag{1.10}$$

The weighted price of ABS in the worst state represents the collateral capacity of securitized assets.

Date-1 Borrowing and Information In order to maximize the expected profits of the syndicate, consisting of identical banks, securitizer j chooses $0 \leq d_j \leq 1$, $\frac{1}{2} \leq \alpha_j \leq 1$, $\{w_{k,j}\}_k$, and $\{\tilde{\kappa}^S_{k,j}\}_k$. However, this problem can be simplified for securitizer j to choose d_j and α_j as follows.

[47] Idiosyncratic risk in κ is diversified away, but the aggregate risk cannot be diversified.

Lemma 3 *(Securitization) Given $\overline{\alpha}$ and M^S, each securitizer maximizes:*

$$\Pi^F(d_j,\alpha_j) = \underbrace{N_j\{E[\mu]-Rd_j-\iota(\alpha_j)\}}_{\text{net present value of projects}} - \underbrace{E[L^S(\alpha_j|\overline{\alpha})]d_jN_j}_{\text{net expected losses from fire-sales in the downturn}}, \tag{1.11}$$

subject (1.1), the collateral constraint

$$d_j \leq \mathbf{q}_j^L, \tag{1.12}$$

and

$$E[\mu] = p\mu + (1-p)(\eta(1-\lambda^M(\alpha_j))\mu^B + (1-\eta)\underbrace{(1-\lambda^L(\alpha_j))}_{\text{solvency risk}}\mu^B), \tag{1.13}$$

$$\underbrace{L^S(\alpha_j)\times d_jN_j}_{\text{net losses from fire-sales}} = \underbrace{\Lambda_j^S}_{funding\ risk} \{\underbrace{\mu^B(\alpha_j|S)\overline{\kappa}_j^S N_j}_{foregone\ profits} - \underbrace{Rd_jN_j}_{\text{liabilities due at } t=3}\}, \tag{1.14}$$

where $\mathbf{q}_j^S$ and Λ_j^S are given by (1.6) and (1.8), $\mu^B(\alpha_j|S) = (1-\lambda^M(\alpha_j))\mu^B$ or $(1-\lambda^L(\alpha_j))\mu^B$ for $S=M$, or L, and

$$\overline{\kappa}_j^S = \frac{d_j}{\mathbf{q}_j^S}. \tag{1.15}$$

In the high state, each project yields μ less the borrowing costs, Rd, without uncertainty. In the downturns, however, securitizer's profits are subject to solvency risk as well as funding risk that forces securitizers to liquidate a fraction of their portfolio.[48] The optimal decision rules of the securitizer are implicitly defined by the first order condition for the problem. The asset price $\mathbf{q}_j^S$ satisfies equation (1.5) in equilibrium.

Let us define *liquidity risk* as follows:

$$\kappa_j^S = \Lambda_j^S \overline{\kappa}_j^S,$$

where $\overline{\kappa}_j^S$ is given by (1.15). κ_j^S represents *liquidity risk* each securitizer faces, which is the fraction of inside investors who stop funding, Λ_j^S, times the fraction of assets liquidated for each loan obligation.[49]

[48]Since the trading value of ABS_j at $t=1$ is the function of the trading value in the secondary market at $t=2$, the objective can be written in terms of $\mathbf{q}_j^S$ after substituting the date-1 budget constraint. See the appendix.

[49]With securitization κ depends only on the aggregate state. But, $\kappa^L > \kappa^M$, because not only there is larger liquidity demand from the investors,

1.2.7.2 The Competitive Equilibrium

Before proceeding to the characterization of an equilibrium, it is useful to begin with discussing key tradeoffs in the choice of borrowing d_j and information α_j. First, additional borrowing enables banks to boost profits, exploiting a positive spread in the upturn. However, it increases losses from fire-sales in the state where funding crises occur (increase in $\overline{\kappa}_j^S$). Next, while an additional unit of information is costly and has not any impact on the return in the upturn, it affects securitizers' profits in the downturn by increasing the quality (lower solvency risk $1-\lambda_j^S$) and the transparency (higher accuracy of signal r) of ABS_j. First, the quality improvements increase 1) the rate of the return for each security at $t=3$, $\mu^B(1-\lambda_j^S)$, and 2) the trading value of ABS_j, $\mathbf{q}_j^S$ — the distribution of signal r, which affects $\mathbf{q}_j^S$, is the function of both of the quality and accuracy. Second, the transparency improvements may increase the trading value of ABS_j, $\mathbf{q}_j^S$, as far as a sufficient fraction of the underlying assets of ABS_j is of the good quality.[50] In some cases, however, the direction of the effect can be opposite, and I will further discuss this issue in Section 1.3.2.[51] In addition, greater transparency in the quality of securitizer's portfolio decreases funding risk in the middle state, Λ_j^M, as it aligns lenders' decisions with economic fundamentals. However, since Λ_j^M is the function of $\overline{\alpha}$, this benefit is not internalized. See Figure A.7 for a summary.

The next proposition shows the existence and uniqueness of equilibrium, and I shall focus on a unique stable equilibrium throughout the paper.

Proposition 4 *(Existence and Uniqueness) Suppose $\iota'(\frac{1}{2})$ is small enough. Then, there exists $\overline{I}$ such that if $\frac{d^3}{d\alpha^3}\iota(\alpha)\geq\overline{I}$ for all possible α, there exists a unique equilibrium.*[52]

The condition implies that the rate of change of the acceleration of information costs should be high enough to guarantee a unique equilibrium. Otherwise, there may exist multiple asset prices that are consistent with equilibrium

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but also the price of asset-backed securities is lower, while borrowing dN is fixed at date 1.

[50]Higher $\mathbf{q}_j^S$ reduces the fraction of assets sold during a funding crisis, $\overline{\kappa}^S$.

[51]In some cases, $\frac{\partial \mathbf{q}^L}{\partial \alpha}<0$, in which case there is large solvency risk.

[52]*In the case where $\iota'(\frac{1}{2})$ is not small enough, it can be shown that there exist $\overline{I}$ such that if $\frac{d^2}{d\alpha^2}\iota(\alpha)\geq\overline{I}$, there exists a unique equilibrium.*

conditions. I assume that this condition is satisfied throughout the rest of the paper.

Parameterization In the following sections, I will characterize the positive and normative properties of the model. In the part where an analytical analysis is not straightforward, I will present the result of numerical simulations. In order to do so, there are four functions that need to be specified: $\tilde{P}(\overline{\alpha})$, $\lambda^L(\alpha)$, $\upsilon(M)$, $\iota(\alpha)$. To keep the model simple, I assume that the accuracy of the aggregate signal is linear in $\overline{\alpha}$, $\tilde{P}(\overline{\alpha}) = \overline{\alpha}$, $\tilde{P}_N(\alpha) = \alpha$, and adverse selection risk is convex in α, $\lambda^L(\alpha) = \frac{c_\lambda^{\max} - c_\lambda^{\min}}{\alpha} - (c_\lambda^{\max} - 2c_\lambda^{\min})$ where $\lambda^L(\frac{1}{2}) = c_\lambda^{\max}$, $\lambda^L(1) = c_\lambda^{\min}$. I assume the loss of value is given by $\upsilon(M) = \frac{c_\upsilon}{2}M^2$, where larger c_υ implies greater fire-sale externalities. The cost of information is specified as $\iota(\alpha) = c_I(\alpha - \frac{1}{2})^3$, where $\iota(\frac{1}{2}) = 0$, $\iota'(\frac{1}{2}) = 0$, and c_I controls the marginal cost of information.[53]

In accordance with Assumption 2, I will focus on a case in which c_λ is small enough, i.e., solvency risk in the middle state is not a serious problem. When it is not specified, I set $c_\lambda = 0.03$. In addition, I will use $\eta = 0.6$, $c_\lambda^{\max} = 0.65$, $c_\lambda^{\min} = 0.2$, $A = 1.05$, $c_\upsilon = 0.5$, $R = 1.02$, $\mu^B = 1.02$, and $c_I = 1/8$ whenever I do not set those parameter values separately in the context.

1.2.8 Financial Autarky

This section describes the differences between the models with and without securitization. The model of banking without securitization is used as a benchmark in the next section. The differences can be summarized in three regards: (1) the collateral constraint of each bank (the island-specific asset price instead of the ABS price), (2) information that is relevant to inside investors at $t = 2$ (island specific information $\overline{r}$ instead of aggregated information $\overline{\phi}$), (3) liquidity risk (idiosyncratic state-dependent $\kappa^{r,S}$ instead of the idiosyncratic state-independent κ^S).

1.2.8.1 Banks

(Collateral Constraint) Under financial autarky, there are no securitizers.[54] This implies that each bank must hold projects in its own balance sheet, as well as bank i can borrow only from a local financial market, in which inside

[53] Sufficiently large c_I guarantees a unique equilibrium.

[54] I will omit subscript j when it causes no ambiguity.

investors within island i participate. Inside investors cannot lend to banks outside their island.[55] It alters the collateral constraint, $d_i \leq D_i^{AU}$, where D_i^{AU} will be specified later in this section. Each bank maximizes its profits individually.

1.2.8.2 Inside Investors

(Relevant Information) The fact that the loans from inside investors are backed by the assets of a local bank implies that the island-specific state does matter. The accuracy of information about the individual state, r_i, determines the transparency of assets being held by bank i. Similarly as before, I assume $\tilde{P}_N(\alpha_i)$ is the probability that inside investors within island i become precisely informed about the individual state with an additional exogenous signal $\overline{r}$, where $\tilde{P}_N(\alpha_i)' > 0$. They key difference is that individual banks are aware of the effect of the transparency of their assets with the choice of α_i on local funding risk $\tilde{P}_N(\alpha_i)$.

As the individual state matters, Assumption 2 is modified parallelly in that banks default only in the bad state, and similarly, Lemma 2 is modified in that the informed roll over debt only in the good state and the uninformed always stop rolling over whenever they receive the negative news.

1.2.8.3 Outside Investors

(Trading Value) Under financial autarky, instead of securitizers, banks may sell their assets to outside investors. Similarly as before, the profit maximization of outside investors can be written as:

$$\max_{M^S, \{m_{ji}^S\}_{ji}} A(Y^I - M^S) + \int_{ji} \overline{f}(s_{ji} = g | r_{ji}, S) \mu^B \frac{m_{ji}^S M^S}{q^{r_{ji}, S}} d(j,i) - \upsilon(M^S),$$

and the optimality condition for the supply of the funds M^S is given by

$$A = \frac{\mu^B}{q^{r_{ji}, S}} f(s_{ji} = g | r_{ji}, S) - \upsilon'(M^S). \tag{1.16}$$

[55] This setup captures the idea that inside investors may be limited in diversifying investment risks if there is no risk-sharing technology available, which limits the scope of an intertemporal transfer of their funds.

Therefore, the asset price given signal r, $q^{r,S}$, is given by

$$q^{r,S} = \frac{\overline{f}(s = g|r,S)\mu^B}{A + \upsilon'(M^S)}. \tag{1.17}$$

Notice that, as the secondary asset market is competitive and individual banks take $\overline{\alpha}$ and M^S as given, they take $q^{r,S}$ as given.

1.2.8.4 Equilibrium

The complete definition of equilibrium is provided in Appendix A.

Date-2 Supply of Assets *(Liquidity Risk)* In $S = M$ or L, the supply of assets by bank i, M_i, is determined by the following relationship:

$$M_i = \Lambda_i d_i N_i = q_i \kappa_i N_i, \tag{1.18}$$

where $\Lambda_i = 1 - \tilde{P}_N(\alpha)$, if $s_i = g$, or $\Lambda_i = 1$, if $s_i = b$. Notice that funding risk Λ_i is individual state-dependent. Therefore κ_i is given by:

$$\kappa_i = \Lambda_i \overline{\kappa}_i, \text{ where } \overline{\kappa}_i = \frac{d_i}{q_i}. \tag{1.19}$$

κ_i and $\overline{\kappa}_i$ are individual state-dependent. In equilibrium, the asset market clears:

$$M^S = \int_i M_i di.^{56} \tag{1.20}$$

Since $\kappa_i \leq 1$ and $\Lambda_i \leq 1$, the collateral constraint is given by

$$d_i \leq \min[q^{r_i,S}] = q^{b,L}. \tag{1.21}$$

The collateral capacity of each asset is given by the individual asset price in the worst state.

[56] The distribution of s_i and r_i is aggregate state-dependent.

Date-1 Borrowing and Information Each bank independently maximizes its profits taking the asset price $q^{r,S}$ as given.

Lemma 5 *(Financial Autarky) Given $q^{r,S}$, each bank maximizes:*

$$\Pi^N(d,\alpha) = \underbrace{N\{E[\mu] - Rd - \iota(\alpha)\}}_{\text{net present value of projects}} - \underbrace{E[L^s(\alpha)]dN}_{\text{net expected losses from fire-sales in the downturn}}, \tag{1.22}$$

subject to the collateral constraint (1.21), (1.1), (1.13), and

$$\underbrace{L^s(\alpha) \times dN}_{\text{net losses from fire-sales}} = \underbrace{\Lambda^s}_{funding\ risk} \{\underbrace{\mu^B(s)E_{r|s=g}[\overline{\kappa}^{r,S}]N}_{foregone\ profits} - \underbrace{RdN}_{\text{liabilities due at } t=3}\},$$

where $\overline{\kappa}^{r,S}$ is given by (1.19), $\Lambda^g = 1 - \tilde{P}_N(\alpha)$, $\Lambda^b = 1$, and $\mu^B(s) = \mu^B$ or 0 if $s = g$ or $s = b$.[57]

Summary As previously explained, the differences in the objects can be explained in three regards: the collateral constraint ($\mathbf{q}^L$ versus $q^{b,L}$), information ($\tilde{P}(\overline{\alpha})$ versus $\tilde{P}_N(\alpha)$), and individual state-independent liquidity risk (κ^S versus κ_i). For expositional purposes, suppose that there is no idiosyncratic risk in the middle state, $\lambda^M = 0$. Then the aggregate liquidity risk in $S = M$ in each case is given by $\kappa^M = (1 - \tilde{P}(\overline{\alpha}))\overline{\kappa}^M$ and $E[\kappa_i|S = M] = (1 - \tilde{P}_N(\alpha))E_{r|s=g}[\overline{\kappa}^{r,M}]$.

The difference is more prominent in $S = L$. In particular, securitization can put banks/securitizers under greater liquidity risk. Under financial autarky, the informed inside investors in the good islands keep funding. In contrast, with securitization, every inside investor stops funding securitizers. This implies that even though banks/securitizers' assets become safer by the diversification of idiosyncratic risk with securitization, their liabilities are more vulnerable to funding risk when the solvency of them comes into question. Moreover, κ^L can be even larger than $E_{r|s=g}[\kappa^{r,L}]$ if solvency risk is severe. I will explore those issues in detail in Section 1.3.1.

[57] *The expectation operator is taken with respect to* $F(r|S, s = g)$. $E_{r|s=g}[\overline{\kappa}^{r,S}] = \alpha \frac{d}{q^{g,S}} + (1-a)\frac{d}{q^{b,S}}$.

1.3 Positive Analysis

In this section, I present the positive results of the model, showing the relation between relevant model parameters (particularly tail probability $(1-p)(1-\eta)$, the rate of return in the upside μ, and the marginal cost of information $\iota'(\alpha)$ and endogenous variables in equilibrium (borrowing d, information α, tail risk λ, funding risk $1-\tilde{P}(\overline{\alpha})$), and analyze the effects of securitization on such variables. In doing so, I will answer a few questions that have been the focus of several recent studies: (i) what promotes securitization? (ii) what is the impact of securitization on lending standards? (iii) does securitization increase macroeconomic stability?

1.3.1 What Promotes Securitization?: Greater Liquidity Risk and the Rise of Securitization

Since the Government National Mortgage Association (known as Ginnie Mae) first offered mortgage backed securities (MBS) in 1970 and the subsequent offering of collateralized mortgage obligations (CMO) in 1983 by the Federal Home Loan Mortgage Corporation (known as Freddie Mac), total MBS issuances grew from about $500 million in 1996 to a peak of about $3.2 trillion in 2003. Notably, private-label securities accounted for about 10% of the total in 1996, but they continued to grow until their peak in 2006 to reach 55% of the total. Global CDO outstanding increased from about $4 billion in 1996 to about $355 billion in 2008.[58] The CDO-squared (CDO^2) was first introduced in 1999, and the CDO-squared market grew rapidly between 2002 and 2006.[59] The first synthetic CDO is also issued in 1997, and issuance of synthetic CDOs experienced a jump from $15 billion in 2005 to $61 billion in 2006 (Angelides, Thomas, et al. 2011).

In order to understand the phenomenal increase in the production of structured finance products, one must consider both supply and demand factors affecting structured securities markets. On the supply side, during the 1980s and 1990s, there were significant changes in the U.S. banking system: the deregulation of interest rate ceilings on deposit accounts in 1980, the repeal of branching interstate restrictions in 1994, the rapid growth of the issuance of junk bonds

[58] Global CDO issuance grew from about $68 billion to $520 billion at its peak (Source : Securities Industry and Financial Markets Association). Issuance data prior to 2000 is unavailable.

[59] See also IMF, Global Financial Stability Report Oct 2009.

and commercial paper which compete with bank loans, and the rise of money market mutual funds which compete with bank demand deposits.[60] Competition in the U.S. banking industry increased and the traditional model of banking had become less profitable, which probably encouraged banks to switch to the securitized banking model. Moreover, off-balance sheet financing offered regulatory arbitrage opportunities for financial institutions, because it was cheaper than on-balance sheet financing in that the regulation required lower capital requirements for sponsoring institution's implicit guarantees for the debt of its off-balance sheet vehicle.

On the demand side, there was large growth in the demands for high-grade bonds that can be used as collateral (Gorton and Metrick 2012). For instance, transactions in financial derivative and the repurchase agreement markets and clearing/settlement all need the posting of collateral. Increasing foreign holdings of U.S. Treasury bonds and agency bonds may have caused the shortage of available collateral, which made the creation of high-grade asset-backed securities more attractable.

More importantly, in order to explain a surge of securitization activity in the last decade, one must note that there was the large increase in capital inflows to the United States, which was mainly targeted to safe assets. The U.S. experienced the large and persistent growth of current account deficit particularly after the East Asian Financial Crisis in 1997-1998 (e.g., Reinhart and Rogoff 2008; Rogoff and Obstfeld 2009; Farhi, Caballero, and Gourinchas 2008). In addition to large capital inflows from emerging market economies, which sought safe financial assets (especially U.S. Treasury securities and agency debt) that their financial systems were not able to produce, there were also heavy purchases of U.S. securities that are perceived to be safe including structured financial instruments by European investors; such massive capital inflows were a powerful force that kept long-term interest rates low, including mortgage rates (Bernanke 2005; Bernanke 2007; Bernanke 2011).

In terms of our model, strong demand for safe assets combined with an increase in the convenience yield of securitized assets corresponds to a greater asset return in the high state, μ.[61] The next proposition shows under what conditions securitization may occur.

[60] For further review of the literature, see Gorton and Metrick (2012).

[61] Similar results can be derived for a lower borrowing rate R.

Proposition 6 *(i) There exists μ^* such that for $\mu \geq \mu^*$, the collateral constraint is binding;*

(ii) There exists p^* such that for $p \geq p^*$, net benefit from securitization is greater than 0 *from the perspective of each bank and the bank's profit with securitization is increasing faster in μ than the one under financial autarky:*

$$\frac{\partial \Pi^{SE} - \Pi^{AU}}{\partial \mu} > 0.$$

For such p, the bank's borrowing is greater with securitization.

From the view point of each bank, one important benefit of securitization is that it expands the set of possible contracts over d. If banks face favorable investment opportunities, which correspond to a greater return μ in the model, they may want to engage in as many projects as possible. Proposition 6-(i) implies that there is a natural incentive to innovate to take advantage of such investment opportunities by enlarging the choice set of d.

Although securitization increases the amount of collateral available to banks, however, it does not necessarily imply that banks are incentivized to innovate. Proposition 6-(ii) indicates that the downside risk of an economy should not be large in order to expect that securitization occurs. This is because securitization comes with a cost: greater liquidity risk κ in the low state. There are two reasons why securitization may put banks under greater liquidity risk κ as follows.

Interconnectedness and Greater Funding Risk First of all, the interconnectedness among banks, which is created by securitization, raises the exposure of the banks to funding risk Λ. Notice that, under financial autarky, the aggregate funding risk is given by

$$E[\Lambda_i|S] = 1 - [1 - \lambda^S(\alpha)]\tilde{P}_N(\alpha). \tag{1.23}$$

Under financial autarky, even in the low state, the informed investors in the safe islands keep funding their local banks. In contrast, with securitization, the whole of inside investors stop funding securitizers, as can be seen in expression (1.8). As creditors' decisions become dependent on the aggregate state, securitizers' liabilities are more exposed to funding risk particularly in the low state, even though their assets are considered to be safer with securitization. To understand this point, note that what is important to the funding decision of inside investors is that the return in the worst (crisis) state must be greater than 1. However, securitization decreases (or even eliminate) the number of assets that produce more than 1 in the crisis state. With a scarcity of safe assets in the crisis state, even the informed investors stop funding securitizers: funding crises become global, which were regional under financial autarky.[62] Put differently, if creditors, who pursue safety, recognize that there may be significant risk to some of securitized assets that consist of borrower's portfolio, the location of risk is irrelevant; creditors run on the entire liabilities of borrowers, which are backed by a well diversified portfolio of ABS, in fear of the safety of their loans.

Asset Pooling and Asset Price Moreover, the asset bundling scheme comes with a caveat: if a funding shock hits in the interim period, a fraction of the pool of assets must be liquidated, which corresponds to individual state independent $\bar{\kappa}$ in the model. To examine this, let us decompose risks exist in the model into two types: 1) risk of a signal delivering false information about the quality of assets due to its limited accuracy (information risk), 2) risk of assets becoming lemon (credit/solvency risk). Individual state independent $\bar{\kappa}$ implies that both types of the risk are shared among banks.

To understand this point, suppose there is no credit risk, $\lambda = 0$.[63] Then risk-sharing insures purely against information risk. In this case, using Jensen's inequality, it can be shown that with securitization, a less fraction of assets is liquidated on average. On the other hand, if there is credit risk, $\lambda > 0$, both types of the risks coexist. As in the previous case, within the group of the same quality of assets, insuring against the information risk can decrease the expected fraction of assets being liquidated. However, such benefit is reduced by insuring against the credit risk. This is because, if credit risk λ is larger, more underlying assets receive the bad signal about their quality, which lowers the price of ABS, $\mathbf{q}$. This implies that more assets must be further liquidated, which implies larger $\bar{\kappa}$. Since there is a tension between insuring against the different types of the risks, the benefit of securitization in the upturn may come at the cost of a larger scale of asset liquidation in the downturn if credit risk λ is large.

Rise of Securitization Proposition 6-(ii) describes the condition under which a larger spread spurs securitization.

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[62] The reason for this results is because inside investors are infinitely risk-averse. Notice that their reservation utility is 1, which is still greater than the worst case outcome $\omega(1-\zeta)(1-\lambda)\mu^B$, where ζ is the fraction that securitizers can divert and ω is a recovery rate. Therefore, they stop funding whenever they are imperfectly informed. This result can be overturn if there is a sufficient number of inside investors who are risk-taking. For instance, suppose that before securitization $wR + (1-w)0 < 1$, but after securization $wR + (1-w)\omega(1-\zeta)(1-\lambda)\mu^B > 1$, where w is the weight on the outcome in $S = M$. Then they hold loans until maturity even if they are imperfectly informed.

[63] As far as idiosyncratic risk is sufficiently small in the middle state, the logic here applies.

It says the upside probability p should be sufficiently high, in which case larger profits from taking an additional project with borrowing in the upturn compensate the potentially higher liquidity risk κ in the downturn. And for such a small downside probability, it is also optimal to take on more leverage with securitization from the securitizer's view point, as the securitizer's profits in the upturn are increasing in its leverage. The spread $\mu - R$ affects the securitizer's profits through this leverage channel in the upturn, which implies that for such high upside probability p, a larger spread has a greater impact on the its profits when securitization occurs.[64] Therefore, the securitizers/banks have greater incentives to innovate with higher spread $\mu - R$ if perceived downside risk is small.

Overall, our results suggest that greater demand for safety, which leads to a larger spread, combined with the low perceived downside probability (e.g., the probability that housing prices will decline) provided the ground for the rapid expansion of new financial products in the last decade. In the next section, I will discuss how securitization can affect the amount of information produced by banks.

1.3.2 Securitization and Lending Standards

Lending standards are translated into information α in the current context. In this section, I, first, analyze what are the effects of securitization on information production if it takes place under financial autarky. Next I explore factors that further contribute to a loss of information with securitization, and investigate whether securitization increases volatility in information with some numerical results.

1.3.2.1 Does Securitization Cause a Decline in Lending Standards?

Each of three differences between the models, which are brought by securitization, alters the incentives of banks/securitizers to produce information on their projects. I describe the impact of each of which on information α in this section. Notably, securitizers do not internalize the effect of their information choices α on the aggregate information α. But in order to obtain some intuition, I compare the baseline model with the special case where inside and outside in-

[64]Note that it is a sufficient condition. The sufficient and necessary conditions of p^* for each $\Pi^{FI} \geq \Pi^{NI}$ and $\frac{\partial \Pi^{FI} - \Pi^{NI}}{\partial(\mu - R)} > 0$ can be different depending on the parameters.

vestors have perfect information about the state of the world.[65] But I continue to suppose that λ is still the function of the bank/securitizer's information choice. I will use the superscript *PSE* (perfect information with securitization), *PAU* (perfect information under financial autarky), *SE* (imperfect information with securitization) and *AU* (imperfect information under financial autarky) to denote equilibrium values.

Proposition 7 *(i) (Perfect Information)* $\alpha^{PSE} \geq \alpha^{PAU}$*. If the rate of return in the upside* μ *is sufficiently large, the inequality is strict,* $\alpha^{PSE} > \alpha^{PAU}$.

(ii) (Imperfect Information:Outside investors) Suppose μ *is sufficiently large. If* $-(2\lambda^L(\alpha^{AU})-1)+(2\alpha^{AU}-1)(-\lambda^{L\prime}(\alpha^{AU})) < \bar{c}$*, for* $\bar{c} \geq 0$*, then securitization leads to less information production,* $\alpha^{SE} < \alpha^{AU}$.[66]

Proposition 7-(i) indicates that, if information is perfect, information production α is non-decreasing in securitization. Furthermore, it contrasts results between two cases when the spread $\mu - R$ is sufficiently large. Large returns in the high state induce the securitizers/banks to borrow more to undertake as many projects as it can. In the case of perfect information with securitization, securitizers produce more information to raise the price of ABS in the low state, $\mathbf{q}^L$, to increase the collateral capacities of their assets against borrowing. To see this, note that the collateral constraint in this case is given by $d \leq (1-\lambda^L(\alpha))\bar{f}(s=g|r=g, S=L)$, since $\bar{f}(s=g|r=b, S=L)=0$. Even if information is costly, the sole way to improve the pledgeability of assets for the securitizer is to produce more information α. As more information lowers the fraction of assets of the bad type, there will be more assets that can be sold at a positive price in the interim period, leading to increased collateral capacity. However, Proposition 7-(ii) overturns this result in certain circumstances with the information imperfection. There are several reasons why this is the case, which I describe in the following.

Increased Borrowing Capacity Securitization can reduce the benefit of information from increasing the quality, $1-\lambda_j^L$, of projects. In particular, as $\mu - R$ becomes larger, securitizers increase borrowing, but it reduces the benefit of information from the quality improvements. To understand this point, notice that securitizer's long-term profits in the

[65] If inside investors have perfect information, $\tilde{P}(\alpha) = \tilde{P}_N(\alpha) = 1$. If outside investors have perfect information, $f(s=g|r=g)=1$ and $f(s=g|r=b)=0$.

[66] *In the same way, this proposition can be stated in terms of the tail probability* p *or* η *instead of* $\mu - R$.

low state at $t = 3$ are given by $\mu^B(1-\lambda_j^L)(1-\kappa_j^L)N$, which is the rate of the return times leftover assets; if λ_j^L is lower, the return $\mu^B(1-\lambda_j^L)$ becomes higher, but at the same time, it increases losses from fire-sales, $-\mu^B(1-\lambda_j^L)\kappa_j^L N$. This implies that the marginal benefit of information from the quality improvements can be increasing in securitizer's stakes $1-\kappa_j^L$, and greater borrowing (which implies greater κ_j^L) reduces the marginal benefit as such.

However, with perfect information, securitizer's stakes $1-\kappa_j^L$ do not matter. To see this, the quality improvements also affect securitizer's stakes $1-\kappa_j^L$ by increasing the ABS price $\mathbf{q}_j^S$, where $\mathbf{q}_j^S$ is determined by its quality and transparency. With perfect information, $\mathbf{q}_j^S$ is fully determined by its quality component; any incentives to reduce fire-sale losses with higher λ_j^L are fully offset by a proportional decrease in $\mathbf{q}_j^S$ and a subsequent increase in κ^L.[67] In contrast, under imperfect information, securitizer's stakes $1-\kappa_j^L$ do matter. This is because the ABS price $\mathbf{q}_j^S$ is also affected by the transparency component when buyers have imperfect information. From securitizer j's perspective, a decrease in the quality of projects, $1-\lambda_j^L$, is not fully penalized by a proportional decrease in the price $\mathbf{q}_j^L$.[68] Accordingly, securitizer's stakes become important in its information choice under imperfect information.[69]

Notably, securitizers' stakes, $1-\kappa^L$, can be much smaller than individual bank's stakes, $1-E[\kappa^{r,L}]$, under financial autarky. This is because 1) securitization allows securitizers to take on more debt particularly when $\mu - R$ is large, which leads to larger $\bar{\kappa}^L$, and 2) funding risk with securitization is more severe as can be seen in expression (1.8) and (1.23).[70] Notice that, under financial autarky, since banks' borrowing is limited to $q^{b,L}$, $E[\bar{\kappa}^{r,L}] < 1$.[71] In contrast, with securitization, securitizers can fully pledge up to the price of ABS, $\mathbf{q}^L$. This wipes out the bank's stakes as the collateral constraint becomes binding, $\bar{\kappa}^L = 1$. Reduced stakes in the low state are the sources that decrease the marginal benefit from the quality improvements. The impact of the quality improvements on trading value $\mathbf{q}^S$ is separately explained

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[67] Notice that $\kappa^L = \frac{d}{(1-\lambda^L)\bar{f}(s=g|r=g,S=L)}$.

[68] Even if securitizers can fully manipulate the expectation formation about the quality by the securities buyers, $\bar{f}(s|r)$, as far as the securities buyers have imperfect information about the aggregate state, this result is not affected.

[69] With perfect information $E_{r|S,s=g}[\kappa^{r,S}] = 0$. With imperfect information, both $E_{r|S,s=g}[\kappa^{r,S}]$ and κ^S are not proportional to $1-\lambda^S$.

[70] In fact, if $\tilde{P} = \tilde{P}_N = 1$, banks who are in $s_i = g$ do not need to liquidate their assets at all under financial autarky. Compare $(1-\lambda^L)\mu^B(1-\kappa^L)$ with securitization versus $(1-\lambda^L)(\mu^B - Rd)$ under financial autarky.

[71] Even if $d = q^{b,L}$, $\bar{\kappa}^{g,L} < 1$.

in the following.

Risk-Sharing Securitization can reduce the benefit of information from the transparency improvements. In particular, transparency improvements become less valuable for trading value $\mathbf{q}^S$. This is because information and credit risk (as explained in the previous section) is shared, as the pool of securitized assets must be traded. Contrary to the perfect information case, better information does not necessarily increase $\mathbf{q}^L$ — an increase in $\mathbf{q}^L$ not only improves the collateral capacities, but also decreases $\bar{\kappa}^L$. To fix the idea, suppose that there is no credit risk, $\lambda^S = 0$. Then as information risk is shared, the benefit of information on the accuracy of signal r becomes smaller, leading to $|\frac{\partial E[\bar{\kappa}^{r,S}]}{\partial \alpha}| > |\frac{\partial \bar{\kappa}^S}{\partial \alpha}|_{\lambda=0}$. Next, suppose there is credit risk, $\lambda > 0$. Then, the effect of information on trading value $\mathbf{q}^S$ are two folds: 1) transparency improvements, and 2) quality improvements. The marginal benefit of information from increasing $\mathbf{q}^S$ with transparency improvements for fixed $\lambda > 0$ is given by $\frac{\partial \mathbf{q}^S}{\partial \alpha}_{(transparency)} = -(2\lambda - 1)\bar{f}^S \gtreqless 0$, where $\bar{f}^S = \bar{f}(s = g|r = g, S) - \bar{f}(s = g|r = b, S)$, and thus $|\frac{\partial E[\bar{\kappa}^{r,S}]}{\partial \alpha}| > |\frac{\partial \bar{\kappa}^S}{\partial \alpha}|_{\lambda=0} > |\frac{\partial \bar{\kappa}^S}{\partial \alpha}|_{(transparency)}$. Notice that if credit risk λ is larger, $|\frac{\partial \bar{\kappa}^S}{\partial \alpha}|_{(transparency)}$ is smaller.[72]

The marginal benefit of information from the quality improvements that increase trading value $\mathbf{q}^S$ for fixed accuracy α is given by $\frac{\partial \mathbf{q}^S}{\partial \alpha}_{(quality)} = (2\alpha - 1)(-\lambda')\bar{f}^S > 0$, which makes the sum of the effects ambiguous, $|\frac{\partial \bar{\kappa}^S}{\partial \alpha}|_{(transparency)} \gtreqless |\frac{\partial \bar{\kappa}^S}{\partial \alpha}|$. This is the new marginal benefit of information that emerges with securitization.[73] This is the only source that securitization might increase the marginal benefit of information when the collateral constraint is non-binding.[74] The condition in Proposition 7-(ii) indicates that if the marginal benefit from the quality improvements that increase $\mathbf{q}^S$ is small enough, it is sufficient to say that $\alpha^{SE} < \alpha^{AU}$.

If this condition holds, information tends to be more costly especially when securitizer's profits in $S = H$ are large (e.g., large $\mu - R$ or p); the securitizer wants to initiate as many projects as it can, but transparency leads to reduced liquidity of ABS, resulting in decreased pledgeability of ABS as well as a larger extent of asset liquidation. In such

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[72] If more assets are of the bad quality, more accurate information implies that more assets receive the bad signal $r = b$, which acts as a force to lower $\mathbf{q}^S$.

[73] Under financial autarky, asset price $q^{r,S}$ is determined by a signle signal r. Securitizers recognize that $\mathbf{q}^S_j$ is affected by the distribution of r, which is determined by the quality and the accuracy.

[74] If the collateral constraint is binding, the transparency improvements may relax the collateral constraint when credit risk λ is sufficiently small.

an environment, the agents in the securitization chain have incentives to manufacture safe assets by making securities more opaque, particularly when the quality of projects is low. It is the manufacturing of safety in the sense that, in order to increase the liquidity of the securities, securitizers make it more difficult to penetrate the quality of underlying assets correctly, although many of which potentially turn out to be of the bad quality in the case of the crisis state.

Aggregated Information If inside investors have imperfect information, there is an additional source that securitization leads to a reduction in the benefit of information from the transparency improvements.[75] In particular, securitizers fail to recognize the benefit of the increased transparency of ABS they produce on the funding risk $1-\tilde{P}(\bar{\alpha})$. The quality of securitizer's portfolio becomes transparent with higher $\bar{\alpha}$, but they do not internalize the effect of their individual information α on the aggregate information $\bar{\alpha}$. Higher $\bar{\alpha}$ leads to a greater number of the informed inside investors, which ultimately reduces funding risk when fundamentals are strong. But, since this effect is not internalized by infinitesimal securitizers, they tend to produce the securities that are too opaque.

Notably, this can be a strong force that leads securitizers to produce a large amount of opaque securities, when there are profitable investment opportunities. As securitizers increase borrowing, the marginal benefit of information from the quality improvements $1-\lambda_j^L$ decreases with their reduced stakes $1-\kappa^L$. Under financial autarky, this reduction of the marginal benefit is offset to some extent with an increase in the marginal benefit of information from the transparency improvements. Notice that with greater leverage, a liquidity crisis becomes severe once a bank is hit by a funding shock. But transparency decreases funding risk, and under financial autarky, a local bank is aware that the increased transparency of assets being held leads to reduced funding risk.

In contrast, with securitization, this offsetting effect is non-existent. If securitizer j produces more transparent ABS_j, it increases not only the transparency of its own portfolio, but also the one of others' portfolio, as ABS_j is being equally held across securitizers in the economy. However, securitizer j does not recognize this external benefit, as such benefit is diversified: it keeps only the infinitesimal part of ABS_j and trades the other part in order to hold a well-diversified portfolio.[76] This issue is further explored in Section 1.3.2.3. To summarize, on the one hand,

[75] If inside investors have imperfect information, there is an additional source that reduces information production by securitizers.

[76] Notice that this result has nothing to do with moral hazard or asymmetric information. There are neither unobservable actions nor unobservable characteristics among securitizers. Securitizers trade ABS for diversification, not for a risk transfer.

diversification to create safer securities can be good as more profitable projects can be funded with a greater collateral capacity of the securities. On the other hand, however, it can jeopardize the stability of an economy as it leads to a decrease in the benefit of information from the transparency and quality improvements. As results, securitizers produce asset-backed securities that are too opaque particularly when their investment projects are profitable. Ultimately, it is translated into greater hidden tail and liquidity risk, which I will explore in Section 1.3.3.

1.3.2.2 What Factors Contribute to a Further Decline in Lending Standards?

Once securitization takes place, there may be further changes in lending standards as some parameters, such the tail probability $(1-p)(1-\eta)$ and the spread $\mu - R$ vary over time. The following proposition further explores the relation between such parameters and lending standards.

Proposition 8 *(i) Suppose the collateral constraint is non-binding at α^{SE}. There exists $\bar{\lambda}$ such that if $-\lambda^{L\prime}(\alpha^{SE}) \geq \bar{\lambda}$, then $\frac{\partial \alpha^{SE}}{\partial p} < 0$.*

(ii) Suppose the collateral constraint is binding at α^{SE}. There exists $\bar{c} \geq 0$, such that if $-(2\lambda^{L}(\alpha^{SE})-1)+(2\alpha^{SE}-1)(-\lambda^{L\prime}(\alpha^{SE})) < \bar{c}$, then $\frac{\partial \alpha^{SE}}{\partial p} < 0$.

Proposition 8 implies that lending standards can further decline as securitizers perceive the tail probability $(1-p)(1-\eta)$ to be small.[77] A smaller tail probability initially reduces the marginal benefit of information α as the low state is more unlikely, in which information becomes valuable. Furthermore, as the expected profits of each project rises with a lower downside probability, securitizers increase borrowing d. This feedback effect generates two forces that act in the opposite direction regarding the marginal benefit of information α. On the one hand, an increase in borrowing d decreases the marginal benefit of information α from decreasing the solvency risk λ, because securitizers' stakes shrink in the downturns with larger $\kappa = \frac{d}{\mathbf{q}}$. On the other hand, an increase in d raises the marginal benefit of information α from reducing liquidity risk, κ. The condition in Proposition 8-(i) indicates, however, that if the variation in λ in regard to α is large enough, the former force dominates the other force, leading to a unambiguous decline in information production as securitizers perceive the economy to be safer. Put differently, there is a large

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[77] I adjust p to vary the tail probability $(1-p)(1-\eta)$. This proposition also holds for varying η instead of p.

benefit of information on solvency risk (high $-\lambda^{L\prime}$), but securitizers do not internalize such benefit as their stakes in the low state are wiped out.

Proposition 8-(ii) shows that the same result holds to the case where the constraint is binding. Likewise, as before, there is an initial decrease in the marginal benefit of information α with a smaller tail probability. In this case, however, the feedback effect generates an increase in the marginal benefit of information from relaxing the collateral constraint, because the shadow value of the collateral constraint increases with higher expected profits of a project.[78] But if the condition holds, this increase is modest to allow information production α to decline. In the case of $\bar{c} = 0$, in particular, such marginal benefit even decreases as securitizers seek to manufacture safety by producing opaque securities.

This proposition also holds if p is substituted with $\mu - R$. In general, if such conditions are satisfied, many factors that decrease a tail probability or increase the leverage of shadow banks would lead to reduced information production by shadow banks.

1.3.2.3 Does Securitization Increase Volatility in Lending Standards? : Numerical Results

I further investigate the properties of the equilibrium numerically with the functional forms specified in Section 1.2.7.2. I compute an equilibrium α with and without securitization for the range of $0.8 \leq p \leq 95$, which corresponds to the tail probability, $0.02 \leq (1-p)(1-\eta) \leq 0.06$. Figure A.8 shows the results for two different returns μ, 3.5 and 6.5%.

Increased Volatility Notice that there are larger variations in information α over the tail probability $(1-p)(1-\eta)$. The kink in the left figure is the point where securitizers start to take on debt d, and information α decreases faster from that point compared to the case of financial autarky. To understand this point, notice that, as explained in the previous section, a decrease in the tail probability raises borrowing d, which generates two forces that act in the opposite direction; higher d reduces securitizers' stakes, leading to a decrease in the marginal benefit of information α from the quality improvements; but this decrease can be counteracted as there is an increase in the marginal benefit of information α from the transparency improvements, which may reduce liquidity risk κ. However, with securitization, this counteracting force can be much weaker. Contrary to the case of financial autarky, securitizers do not internalize

[78] However, since borrowing d cannot increase further, there is no change in the marginal benefit of information α from reducing solvency and liquidity risk, λ^L and κ^L.

the effect of their individual transparency, α, of ABS on the aggregate transparency, $\bar{\alpha}$, of their portfolio, which ultimately determines funding risk, Λ. Furthermore, with risk-sharing (individual state-independent $\mathbf{q}$), the transparency becomes less valuable for trading value $\mathbf{q}$ in the secondary asset market.[79] With those weaker counteracting forces, information production decreases faster as the tail probability decreases.

Securitization also amplifies a decline in information α through the interactions between solvency and liquidity risk. To understand this point, suppose that solvency risk λ rises with lower information α. As credit risk λ is shared with securitization, it pushes down the ABS price $\mathbf{q}$, leading to increased liquidity risk κ.[80] This larger liquidity risk κ again reduces securitizer's stakes in the downturns, causing a decrease in the marginal benefit of information from the quality improvements. Therefore, there is a further decline in information α and an increase in solvency risk λ.

The volatility in information production is even higher when the spread $\mu - R$ is larger as can be seen in the right panel of the figure. With a higher spread, securitizers take on more debt as a tail probability becomes lower. It decreases the marginal benefit of information from the quality improvements faster, but it is not offset enough by the counteracting force as in the case under financial autarky. As a result, with a larger spread, securitizers are more likely to bet on the boom with higher leverage, which comes at the cost of reduced profits in the low state. This implies that, in an environment with significant expected investment profits and the perception of a low tail probability, there is much chance that assets turn out to be of the bad type if the crisis state occurs.

Other Observations There are also a few features worth noting in this figure. First of all, in all the cases, information production declines as the tail probability decreases.[81] It implies that the perception of a safe economic environment reduces securitizer's motivation for better information that works only in the downturns, and results in a loss of information, although the bank's behavior is common knowledge among the agents.

Second, in the left panel of the figure, there are the threshold values of the tail probability such that for above the threshold, information with securitization is more or less the same as the ones under financial autarky, or even

[79] See Section 1.3.2.1 for details.

[80] Also, higher λ decreases the marginal benefit of information from the transparency improvements (See Section 1.3.2.1 (Risk-Sharing) for details).

[81] In the right panel of Figure 7, as the collateral constraint starts to bind with securitization, the kink occurs.

better for some values. For a tail probability that is not small enough, taking on leverage comes at a bigger expected liquidation cost in the downturns, and this cost can be even bigger with securitization, as we have seen in Section 1.3.1. This induces securitizers to be less leveraged and produce more information, since their stakes remain high. But, as the tail probability becomes smaller, this effect dissipates; securitizers start to become more leveraged, which eventually leads them to produce less information with securitization.

Discussion Here, we can interpret the tail event as a decline of housing prices. Arguably, many financial market participants before the financial crisis thought the probability of such a tail event was very small as housing prices appreciate. Gorton (2008) argues that the subprime mortgage loans were designed in the way that both borrowers and lenders can benefit in such an environment; banks were effectively in a long position that gains from housing price appreciation, even though banks had to bear a large share of total losses if the tail event were to happen. Many authors show empirical evidence that securitization led to a decline in lending standards during the run-up to the crisis.[82] Our model shows that even without relying on the assumption that there is asymmetric information between borrowers (securitizers) and lenders (inside and outside investors), a large decline in lending standards, nonetheless, emerges when the tail probability is perceived to be small and the spread is large.

1.3.3 Does Securitization Increase the Hidden Risk of an Economy?

This section is a corollary to the previous section. I explore the impact of securitization on tail and funding risks, which are represented by λ and $1-\tilde{P}(\overline{\alpha})$ respectively in the model. Then I relate it to the experience of the financial crisis 2007-2009.

1.3.3.1 Tail Risk and Securitization

The aggregation of the solvency risk λ^L across islands determines the tail risk λ of the economy, in the sense that if the tail event $(S=L)$ occurs, large tail risk implies low returns to ABS. The following corollary shows that the size of the tail risk can be significantly large with securitization, which is corollary to the propositions in the previous section.

[82] See further Keys, Mukherjee, Seru, and Vig (2009), Keys, Mukherjee, Seru, and Vig (2010), Purnanandam (2011), Jiang, Nelson, and Vytlacil (2014).

Corollary 9 *(i) Suppose* $-(2\lambda^L(\alpha^{SE})-10+(2\alpha^{SE}-1)(-\lambda^{L\prime}(\alpha^{SE}))<0$. *If the tail probability* $(1-p)(1-\eta)$ *is sufficiently small, then the tail risk* λ *with securitization is larger,* $\lambda^{SE}>\lambda^{AU}$.
(ii) The tail risk is decreasing in the tail probability if the constraint is non-binding and $-\lambda^{L\prime}(\alpha^{SE})\geq\bar{\lambda}$, *or if the constraint is binding and* $-(2\lambda^L(\alpha^{SE})-1)+(2\alpha^{SE}-1)(-\lambda^{L\prime}(\alpha^{SE}))<0$.

Securitization can expose an economy to even larger tail risk with an abrupt decline of lending information production. Ironically, tail risk builds up potentially when securitizers consider the tail probability small; as far as the tail event is unlikely, securitizers do not care much about the size of the tail risk, but once the tail event is realized, the consequences can be disastrous.

Numerical Results As this is an important source of financial instability, I further explore this issue numerically in the following. In this exercise, I consider the effects of varying p, $0.8\leq p\leq 0.95$, with which the tail probability corresponds to $0.02\leq(1-p)(1-\eta)\leq 0.06$. I show the results for two different returns μ, 3.5% and 6.5%, and two different information costs parameters, $c_I=\frac{1}{12}$, and $\frac{1}{2}$. Here I consider the case in which outside investors do not have information about the aggregate state for an exposition. I also set $c_\lambda^{\max}=0.8$, $c_\lambda^{\min}=0$.

Figure A.9 shows the relation between the tail probability and the equilibrium tail risk. The upper figure represents a case with low information costs ($c_I=\frac{1}{12}$), while the lower figure indicates a case with high information costs ($c_I=\frac{1}{2}$). The kinks in the cases of the higher return ($\mu=1.065$) are where the collateral constraint starts to bind. While the tail risk increases faster with the higher spread in both cases, there is a notable difference between the case of higher and lower information costs. When the spread is high, the tail risk rises further as the tail probability becomes smaller in the lower figure, but the tail risk stabilizes once the collateral constraint binds in the upper figure. This is because there is difference in the marginal benefit of information on the average price, $(1-2\lambda(\alpha^{SE}))+(1-2\alpha^{SE})\lambda'(\alpha^{SE})$, around the kinks; high information costs prevent the banks from maintaining the quality of capital as they take on leverage; as the credit risk of the banks' projects surges, that marginal benefit becomes smaller with higher information costs. If the marginal benefit is sufficiently high at the point where the constraint starts to bind, it pressures the banks to maintain the quality of assets; when they hold better quality of capital, they can improve the pledgeability of assets further by providing more accurate information about it. In contrast, if the marginal benefit is low enough, it cannot force the banks to sustain the quality of assets. It may, even at some point, encourage the banks to manufacture the safety with noisy information when the credit risk of the banks' projects is large. As shown in the figure, securitization may cause the banks to build up large tail risk, especially when the cost of information acquisition is high. It highlights that securitization together with greater macroeconomic stability can cause the build-up of the hidden risk of more severe crises.

1.3.3.2 Funding Risk and Securitization

Next, the possibility of liquidity demand by the inside investors in the interim period is the other channel by which information generates funding/liquidity risk. The imperfect information of the inside investors can cause funding crises even when fundamentals are strong ($S = M$). If they face uncertainty over the state of the world, they reclaim their money from securitizers in the fear of solvency risk, which causes valuable assets to be liquidated.

Section 1.5.1 characterizes under what conditions more inside investors decide to be perfectly informed when they have to pay a cost for precise information about the state of the world. According to the model in the extension, more inside investors are precisely informed in $S = M$ when the quality of securities are transparent rather opaque. This is because the good signal increases the value of the private information; as the good state, only in which the private information is rewarding, is more likely, it encourages them to be precisely informed. This result is in line with Bernanke (2010): "Should the safety of their investments come into question, it is easier and safer to withdraw funds–"run on the bank"–than to invest time and resources to evaluate in detail whether their investment is, in fact, safe. Although subprime mortgages composed only a small part of the portfolios of most structured credit vehicles, cautious lenders pulled back even from those that likely had no exposure to subprime mortgages" (p.3). Cautious investors who value safety would not try to investigate the quality of their investment unless the cost of it is sufficiently small or the value of private information is sufficiently large.

Numerical Results Figure A.10 shows the relationship between the tail probability and the funding risk $1 - \tilde{P}(\overline{\alpha})$.[83] The parameter values are the same as in the previous section. It shows that funding risk in the middle state

[83] Under financial autarky, funding risk is represented by $1 - \tilde{P}_N(\alpha)$.

is more severe when the tail probability is small, especially in the case of securitization. The difference between the models tends to be bigger with higher information costs.

1.3.4 Further Discussion

Although, securitizers are likely to produce little information with securitization, inside investors, who invest in a safe instrument, do not have any incentives to make the securitizers produce more information about assets. In contrast, they are willing to invest in those securities that are manufactured by the securitizers, even if those securities are subject to severe solvency risk in the downturns. In the model, as the inside investors invest in short-term liabilities, they have an option to stop rolling over debt and recoup their investment. This aspect is consistent with the experience of the recent financial crisis in that the loss of investors who participate in asset-backed commercial paper markets (e.g., money market mutual funds) is relatively small compared to commercial banks.

Little production of information leads to large tail risk and increased funding/liquidity risk. funding/liquidity risk in the model, in particular, serves as the propagation mechanism, as even when fundamentals are strong (the middle state), assets may be liquidated, which exacerbates economic outcomes. While banks' mortgage-related losses were relatively modest in the financial crisis of 2007-2009, the scale of the U.S. stock market wealth losses was large (e.g., Brunnermeier 2009; Caballero 2010). I suspect both manufactured tail risk and funding/liquidity risk contributed to an unprecedented scale of the financial crisis.[84] In addition, while I do not incorporate a mechanism into the model here, tail risk or solvency crises can be amplified if it act as a strong deleveraging shock that pushes real interest rates down, leading to a liquidity trap with depressed output (Eggertsson and Krugman 2012).

Furthermore, it is plausible that the information costs of banks were large during the run-up to the financial crisis; once many of prime projects (or borrowers) have their loans, the banks must seek new potentially profitable, but riskier projects in order to expand their balance sheets. As the supply of projects of better quality is depleted, the cost of information may become larger. As information costs for banks' projects were large but there was a good prospect for the return to a project, securitization may have led to the manufacture of the tail risk as well as the increased

[84]If financial markets are segmented, it can be thought of as the realization of tail risk in some markets and asset liquidation in other markets even if the low state had not occurred.

funding/liquidity risk, which caused financial instability.

Nevertheless, some may argue that securitization contributed to reduced macroeconomic volatility in the great moderation by smoothing out the supply of credit to real sectors through business cycles.[85] While I do not incorporate such elements into the model, the results, nonetheless, are not inconsistent with this argument. As far as a spread is low and a tail probability remains high, securitization is unlikely to cause greater macroeconomic instability. It comes into play when demand for safety is large (high spread), the probability that housing prices decline is small (small tail probability), and banks have to lend to subprime borrowers as they exhausted good borrowers (high information costs).

1.4 Welfare and Policy Analysis

In this section, I begin with an analysis of whether there is a market failure that induces the banking system to produce securities that are too opaque. Then I explore optimal regulations that can be implementable in the current financial system. I also discuss the relation of approaches proposed in this paper to other current proposals at the end of the section.

1.4.1 The Social Planner's Problem

In this section, I introduce an efficiency benchmark to answer whether higher welfare could be obtained if the social planner were to make decisions about investment and information in a different way than what the agents do in competitive equilibrium. However, the planner is constrained in two ways; (i) debt must be safe, which implies that the planner faces the same collateral constraint as the banks, (1.12), and (ii) the planner does not have any better information than the private sector, but who has the power to order the banks and the investors to follow particular decision rules regarding information and investment. For an expositional purpose, I define the social planner's objective as the

[85] For instance, see Campbell and Hercowitz (2005) and Dynan, Elmendorf, and Sichel (2006). For counterargument, see Den Haan and Sterk (2011).

equally weighted sum of the expected utility of each type of agents.[86] As can be seen in the following lemma, it turns out to be equivalent to the sum of the total expected production by banks and outside investors and the consumption of inside investors. Therefore, given the planner's optimum, one can find lump-sum transfers, which can lead to a pareto improvement. General cases are provided in the appendix.[87] Taking those considerations account, I define the planner's objective as follows. I rewrite the objective of the bank, (1.11), in a different way for comparison.

Lemma 10 *The social planner chooses d and α to maximize:*

$$\begin{aligned} W(d,\alpha) &= N\{E[\mu]-Rd-\iota(\alpha)\} \\ &\quad +pAY^I+(1-p)\eta[A(Y^I-(1-P^S(\bar{\alpha}))dN)-\upsilon((1-P^S(\bar{\alpha}))dN)+R(1-P^S(\bar{\alpha}))dN] \\ &\quad +(1-p)(1-\eta)[A(Y^I-dN)-\upsilon(dN)+RdN] \end{aligned} \tag{1.24}$$

subject to the collateral constraint (1.12), (1.13), and (1.1).

Comparing objectives (1.24) and (1.11), the first line of these two objectives coincides, while there are differences in the other lines. The first line of each objective represents the net present value of each project less information costs. The second and the third line of the planner's objective express the net expected returns to investment by the outside investors. However, minimizing expected fire-sale losses, which corresponds to the second line of the securitizer's objective, is not a planner's objective as this is a pure transfer between the agents. The complete set of sufficient and necessary conditions for an optimal allocation is provided in the appendix.

I show that a competitive equilibrium is constrained inefficient except in knife-edge non-generic cases.

Proposition 11 *The competitive equilibrium is constrained inefficient.*

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[86]It is equivalent to assume that there is a representative household who collects all the profits from the agents. See the appendix.

[87]While different weights across agents affect the social value of marginal information or debt quantitatively, the qualitative nature of the wedge between the social and the private value of the choice variables is not affected.

1.4.2 Understanding the Sources of Inefficiency

There are many factors that cause divergence between the social and the private benefit of marginal increments in borrowing d and information α. I explain each of which and present some numerical illustrations in this section.

1.4.2.1 Social Value of Marginal Debt

In the model, fire sales create a pecuniary externality, but an individual securitizer does not care about the price effects of its debt choice, which affects every other securitizer's collateral constraint.[88] However, the planner takes into account the impact of additional debt on the asset price $\mathbf{q}^L$, which affects the collateral constraint. The divergence between the social value and private value of marginal debt is given by $S^d \equiv \psi \frac{\partial \mathbf{q}^L}{\partial d} \leq 0$, where ψ is the shadow value of the collateral constraint. Notice that the planner's objective itself does not incorporate any market prices as it is a mere transfer from one agent to others. Therefore, the economy is inefficient through this channel only if the bank's collateral constraint is binding, $\psi > 0$— the existence of pecuniary externalities leads to the violation of the first welfare theorem only if they are operative through prices in constraints that are created by the fact that there is a missing market, say limited pledgeability, not solely through prices in budget constraints (e.g., Lorenzoni 2008; Stein 2012).

Lemma 12 *The social value of marginal debt is smaller than the private value, $S^d < 0$, only if the collateral constraint is binding (e.g., $\mu - R$ is large enough).*

This lemma states that there is the wedge, $S^d < 0$, between the social and the private value of marginal debt d only if the pecuniary externality affects the collateral constraint. If the constraint is non-binding, the social and private marginal value of marginal d coincide. However, if we add another source that the private sector does not internalize, the social value of marginal debt can be lower than the private value even when the collateral constraint is non-binding. Notice that, in the model presented here, the private choice of debt to minimize expected fire-sale losses happens to coincide with the social choice to minimize underinvestment in the interim period via the optimality condition of the

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[88]Since an individual securitizer takes M^S as given, $\mathbf{q}^L$ is not a function of d.

outside investors.[89] However, if, for example, υ is also a function of the aggregate supply of funds, as well as the individual supply of funds, only the social planner internalizes the effect of its choice of debt on the loss of value, υ. Then, the social cost of underinvestment is larger than the private loss from fire sales, leading to $S^d < 0$ even when the collateral constraint is non-binding. Because I mainly focus on information in this paper, however, I do not take into account further sources that may lower S^d.

1.4.2.2 Social Value of Marignal Information

There are four sources that cause divergence between the social and the private benefit of marginal information. First, securitizer's aversion to fire sales leads it to fail to internalize the social costs of underproduction of information. In order to understand this point, notice that expression (1.14) is the function of λ^S, which implies that the securitizer can decrease the fire-sale losses by producing less information— equivalently, the low stakes of the securitizer after asset liquidation causes socially excessive risk-taking. Imperfect information about the quality of assets enables the securitizer to transfer lemons to another agent.[90] However, the planner does not have such motive as it is a pure transfer from one agent to another from her perspective. As a consequence, the social value of marginal information is larger by $E_1^\alpha \equiv (1-p)[\eta(1-\tilde{P}(\overline{\alpha}))(-\lambda^{M\prime}(\alpha))\overline{\kappa}^M + (1-\eta)(-\lambda^{L\prime}(\alpha))\overline{\kappa}^L]\mu^B N \geq 0$. Note that this result can be extended to a more general setting. For example, suppose that securitizers lose κ fraction of their assets from financial distress in the low state, where κ is increasing in solvency risk. To the extent that the securitizer's potential loss κ is not fully adversely affected by its information choice α, it would lead to too little information production.

Second, an individual securitizer does not internalize the impact of its individual information choice α on the aggregate information production $\overline{\alpha}$, which increases the transparency of its portfolio. Information has the aspect of public goods in the model. With higher transparency, a larger number of inside investors is fully informed about the aggregate state. It ultimately leads to the lower funding risk. However, individual securitizers fail to recognize the social benefit of additional information production through this channel, which leads to socially excessive funding

[89] Take derivative the second and the third line of the planner's objective and the second line of the securitizer objective, and compares. See the appendix.

[90] If information is perfect, the securitizers cannot sell the assets of the bad type, and thus this kind of the externality is non-existent.

risk. This factor contributes to the discrepancy of the social and private value by $E_2^{\alpha} \equiv (1-p)\eta \frac{dP^S(\bar{\alpha})}{d\alpha}[A+\upsilon'((1-P^S(\bar{\alpha}))dN)-R]dN \geq 0$.[91]

Third, the securitizer takes into account the effects of marginal information on the fraction transferred κ^S, as information affects κ^S through the price of ABS, $\mathbf{q}^S$. However, such effect is irrelevant to the planner as it is nothing more than a transfer among the agents. It disturbs the private value of information by $E_3^{\alpha} \equiv -(1-p)\{\eta(1-\tilde{P}(\bar{\alpha}))[1-\lambda^M(\alpha)](\frac{1}{\mathbf{q}^M})^2\frac{\partial \mathbf{q}^M}{\partial \alpha}+(1-\eta)[1-\lambda^L(\alpha)](\frac{1}{\mathbf{q}^L})^2\frac{\partial \mathbf{q}^L}{\partial \alpha}\}\mu^B dN$. Notice that if information increases the price of ABS ($\frac{\partial \kappa^S}{\partial \alpha} < 0$), this factor can reduce the wedge between the social and private value of marginal information, caused by the other factors, to some extent. But it is not necessarily the case, since noisy information can also raise the price of ABS when the lemon problem is severe. Thus, the sign of E_3^{α} is ambiguous.

Fourth, an individual securitizer does not internalize the effect of its information choice on the expectation formation process by inside investors, $\bar{f}(r|s,S)$, which affects the collateral constraint, $\mathbf{q}^L$. Since fire sales create a pecuniary externality, when the collateral constraint is binding, it affects the social benefit of marginal α by $E_4^{\alpha} \equiv \psi \frac{\partial \mathbf{q}^L}{\partial \alpha} \geq 0$.

The second source of inefficiency arises from the information imperfection of the inside investors, and the first, third and fourth are due to the information imperfection of the outside investors. If the inside investor's information is perfect, $E_1^{\alpha} = 0$. If the outside investor's information is perfect, the first is precisely offset by the third, $E_1^{\alpha} + E_3^{\alpha} = 0$. Also, $E^4 = 0$, as $\bar{f}(r|s,S)$ becomes independent of α.

Notice that, while pecuniary externalities matter only when the collateral constraint is binding, the other types of externalities are operative all the time. Therefore, it results in a socially inefficient level of information production, leading to a constrained inefficient competitive equilibrium. More specifically, let us define $S^{\alpha} \equiv E_1^{\alpha} + E_2^{\alpha} + E_3^{\alpha} + E_4^{\alpha}$, where S represents the social value $-$ the private value of marginal information. If $E_3^{\alpha} \geq 0$, $S^{\alpha} \geq 0$, but if $E_3^{\alpha} < 0$, the sign of S^{α} is ambiguous. I will use the superscript S (social optimum) and P (private optimum) to denote equilibrium values.

Lemma 13 *(i) There exists $\bar{\lambda}^1$ such that for $-\lambda^{L\prime}(\alpha) > \bar{\lambda}^1$, the social value of marginal information is larger than the private one, $S^a > 0$;*

[91]Notice that $[A+\upsilon'((1-P^S(\alpha))dN)-R]dN$ is the real costs of asset liquidation in the middle state.

(ii) If $-\lambda^{L\prime}(\alpha)$ is sufficiently small, there is a case where the social value of marginal information is smaller than the private one, $S^{\alpha} < 0$.[92]

The first part of the lemma implies that when the marginal benefit of information is large ($-\lambda'(\alpha)$ is large), the amount of information produced in the competitive equilibrium is less than optimal; the private benefit of marginal information to be under-valued relative to the social benefit, $S^{\alpha} < 0$. In this case, a marginal increase in fire-sale losses in the low state from extra unit of information (E_1^{α}) dominates a potential offsetting force (E_3^{α}).

The second part of the lemma explores the opposite case. When the marginal benefit of information is small, information is likely to be overproduced. In this case, the third factor can dominate any other forces; for instance, if the constraint does not bind ($E_4^{\alpha} = 0$, e.g., $\mu - R$ is small), $P^S(\overline{\alpha})'$ is small, the solvency risk, $\lambda^L(\alpha)$, is not too high ($E_3^{\alpha} < 0$ when $\lambda \leq \frac{1}{2}$ and $\lambda^{L\prime}(\alpha)$ is small), and the value of information, $-\lambda^{L\prime}(\alpha)$, is small enough ($E_1^{\alpha} \approx 0$), then the private benefit of marginal information is over-valued relative to the social benefit, $S^{\alpha} < 0$, as E_3^{α} cannot be dominated by the other factors. As a result, too much information is obtained by the private agents as they try to increase the price of fire-sold ABS, which is not considered as valuable by the social planner.

1.4.2.3 Numerical Illustration

This section further illustrates the properties of an optimal and a competitive equilibrium numerically. I present two alternative kinds of economic environments that correspond to the ones in Lemma 13-(i),(ii). First one describes an economy with the large value of information (high $-\lambda'(\alpha)$), where parameter values are picked as follows: $c_I = 1/5$; $\mu = 1.065$. In this example, I use $\tilde{P}(\overline{\alpha}) = 2(\overline{\alpha} - 1/2)$. In this economy, there is a kink where the constraint starts to bind. Figure A.11 compares the private and socially optimal allocation, allowing p to vary between 0.8 and 0.98, thereby causing the tail probability to vary between 0.8% and 8%. As can be seen, $\alpha^S > \alpha^P$ as well as $d^S > d^P$.

Figure A.11 also illustrates the sources that drive a wedge between the private and social marginal benefit of α.[93] While S^{α} remains positive in the range of the tail probability considered here, each factor that contributes to S^{α} shows

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[92]*For instance, if $\mu - R$ and R is sufficiently small, and $\lambda^L(\alpha) \leq \frac{1}{2}$. Then there exists $\overline{\lambda}^2$ such that for $-\lambda^{L\prime}(\alpha) < \overline{\lambda}^2$, the lemma holds.*

[93]Each factor is evaluated at prices that are consistent with planner's equilibrium for expositional simplicity.

some variations over the range. Notice that $E_1^\alpha + E_3^\alpha$ and E_2^α are all decreasing in p, but increasing in d; each of them increases until the constraint starts to bind and then decreases, as d increases fast enough until the constraint starts to bind while p increases. $E_1^\alpha + E_3^\alpha$ is a significant factor in this example with large $-\lambda'$, but E_2^α also can be a more significant factor if the efficiency loss from asset liquidation is larger (larger A or ν') or the marginal value of information from reducing funding risk, $\frac{d\tilde{P}}{d\alpha}$, is larger. E_4^α increases once the constraint binds, as λ' increases. Private agents can also reduce this wedge to some extent, as they may try to increase the price of ABS by producing information (E_3^q), but this effect is not powerful here to offset other factors that create the wedge ($E_1^\alpha + E_3^\alpha$ remains positive). The lower right figure is consistent with Lemma 12. While the private and social marginal benefit of d coincide for the high values of the tail probability, these values diverge further and further from one another as the tail probability decreases. Even though the social benefit of marginal d is non-positive, the socially optimal value of d is still greater than the private optimal value, as can be seen in the upper right figure. This is because the net marginal benefit of d increased with a higher α.[94]

Next one describes an economy with the small value of information, in which there is a small variation of λ along with a variation of α. I pick these parameter values: $c_\lambda^{\max} = 0.40$; $c_\lambda^{\min} = 0.37$; $c_\lambda = 0.5$; $\mu = 1.09$. In this example, I use $\tilde{P}(\overline{\alpha}) = 0.5 + 0.05\overline{\alpha}$. Figure A.12 is analogous to the previous example with the different parameters, but the results are different qualitatively; too much information is obtained in the private optimum, while borrowing is almost identical between the cases. $E_1^\alpha + E_3^\alpha$ can be negative because, with small $-\lambda'$, E_3^α is not dominated by E_1^α. E_2^α remains close enough to 0 with the small $\tilde{P}'(\overline{\alpha})$ over the range of the tail probability. As a result, information can be overproduced in the private optimum, although it may not be quantitatively large. The lower right figure is again consistent with Lemma 12, which is qualitatively similar to the one in the previous example. Notice that even though there is excessive information production in the private optimum, the private and socially optimal value of d are nearly the same. This is because, with a higher α, an increased marginal benefit of d is offset by an increased marginal cost of d, which causes the net marginal benefit to be nearly zero.

[94] α increases both the marginal benefit and cost of d. In this example, the impact of α on the marginal benefit is larger.

1.4.3 Implementation

1.4.3.1 Capital Requirements on Opaque Securities

The analysis thus far shows that the banks produce too little information in a market where there is non-negligible benefit of such activity, thereby exposing the economy to excessively high levels of financial instability. This calls for policymakers to build a more efficient system to head off severe financial crises. To explore feasible policy actions to correct inefficiency, I here define the function $\tilde{o}(\alpha) \equiv 2(1-\alpha)$ as the measure of opaqueness, where $\tilde{o}(\frac{1}{2}) = 1$ and $\tilde{o}(1) = 0$.[95] The policymaker has two targets: the total amount of securities N and the opaqueness of securities, $\tilde{o}(\alpha)$.

A widespread approach to the regulation of financial firms is to impose capital adequacy requirements. I here introduce capital surcharges as policy instruments, which imposes that a minimum fraction of the bank's assets is financed with its own capital: τ^O and τ^N are capital surcharges for the opaqueness and the number of securities respectively. I will show that a restriction of this type of capital surcharges is sufficient to restore constrained efficiency.

Notice that the capital requirements with those capital surcharges must be equal to the bank's initial capital, which is normalized to 1: $(1+\tilde{o}(\alpha)\tau^O + \tau^N - d)N = 1$. The total amount of assets N and the extent of asset liquidation κ^S become $N = \frac{1}{1+\tilde{o}(\alpha)\tau^O+\tau^N-d}$. However, the securitizer's problem can be simplified as the following lemma states.

Lemma 14 *Given capital surcharges τ^O and τ^T on opaque and transparent securities respectively, each securitizer chooses the number of securities N and the share of opaque securities $\tilde{o}$ to maximize:*

$$\begin{aligned} \Pi^F(N,\tilde{o}) &= N\{E[\mu] - Rd - \iota(\alpha)\} - E[L^S(\alpha|\overline{\alpha})]dN \\ &\quad -[p+(1-p)\eta\tilde{P}(\overline{\alpha})](R-1)[\tilde{o}(\alpha)\tau^O + \tau^N]\} \end{aligned} \tag{1.25}$$

subject to the collateral constraint

$$d + [\tilde{o}(\alpha)\tau^O + \tau^N] \leq \mathbf{q}^L,$$

(1.1), (1.13), and (1.14).

[95] Equivalently, one may interpret that $N\tilde{o}(\alpha)$ and $N(1-\tilde{o}(\alpha))$ represent the number of opaque and transparent securities respectively.

Objective (1.25) is equivalent to the objective without capital surcharges, (**??**), except the last line; the weighted average of capital surcharges shows up as increased borrowing costs in the better states. The capital surcharges create the wedge in the collateral constraint as well. As there are two objects that the policymaker targets, capital surcharges on each type of securities are sufficient to ensure that efficient numbers of securities of each type are produced.

Proposition 15 *Given a constrained-efficient allocation, there are capital surcharges τ^O and τ^T such that the corresponding competitive equilibrium is constrained efficient.*

Another question is what the policymaker should do if the private sector has distorted beliefs about the probability distribution of the state, whereas the policymaker has the correct distribution. For instance, from a view point of the policymaker, the private sector may be sometimes too optimistic about future economic outlook, which corresponds to a greater probability of the high state, $p^P > p^S$, where superscripts P and S indicate the private sector and the policymaker respectively. Similar capital surcharges can be used restore constrained efficiency.

Corollary 16 *Suppose the private sector has distorted beliefs about the likelihood of the states of the world (e.g., $p^P \neq p^S$), while the policymaker correctly assign probabilities to the states of the world. There are capital requirements τ^O and τ^N such that the corresponding competitive equilibrium is constrained efficient from the policymaker's perspective.*

As shown thus far, excessive optimism in the financial sector can jeopardize the safety of a society as it tries to create securities that are too many opaque, which involve large hidden risk. Although opaqueness might increase the liquidity of securities in some cases, it may camouflage severe risk that surges once an unfavorable state of the world occurs. In such cases, there is a need to "lean against the optimism" to protect a financial system. However, it should be emphasized that policymakers have to control the creation of opaque securities, not to control the creation of safe securities; not to mention that safe securities are not harmful themselves, if there is insatiable demand for safe securities, it will be unwise to limit the creation of such securities. In that sense, what policymakers must control is the manufacturing of safety by imposing more costs in the creation of opaque securities. This kind of regulation can be consistent with the creation of safe securities; more information about the characteristics of securities should be disclosed, and the buyers of securities should be encouraged to have better understanding about the nature of securities.

Yet, there exists an optimal degree of opaqueness. The performance of opaque loans has been believed to be on a par with transparent loans, unless some bad states occur, while opaqueness saves transaction costs in financial contracts. In particular, if the private sector perceives that the likelihood of the tail event is high, it does not have many incentives to produce many opaque securities, and in such cases, capital charges τ^O must be sufficiently small. Therefore, time-varying flexible capital adequacy requirements are necessary to achieve both efficiency and financial stability.

1.4.3.2 Other Approaches

1.4.3.2.1 Cap and Trade : Quantity Control As an alternative, a policymaker can also consider limiting the quantity of opaqueness (or opaque securities) to improve efficiency. For instance, if complete information about the parameters of the model is available to the policymaker, she can compute the optimal quantities of opaqueness and securities and prohibit the banks from creating those more than desired levels. If there is a lack of information about the parameters, on the other hand, it may be difficult for the policymaker to determine the desired quantities to be produced. In such a case, the policymaker can control the quantity via Cap-and-Trade, which sets a price target of tradable permits to produce opaque securities and varies the quantity of permits until the target price is reached.

In the context of the model, for the quantity of each kind of permits, N_O and N_N respectively, the policymaker sets the target price function $[P^*_O(N_O),\, P^*_N(N_N)]$. Then the policymaker adjusts the quantity $(N_O,\, N_N)$ until the target price equals the market price of permits $[P_O(N_O), P_N(N_N)]$. The following proposition shows that Cap-and-Trade can implement a constrained-efficient allocation even when the policymaker has imperfect knowledge about the underlying parameter of the model.

Proposition 17 *(Cap-and-Trade) There exist the target price* $[P^*_O(N_O),\, P^*_N(N_N)]$ *that are independent of* μ*, and a fixed point,* $(N^*_O,\, N^*_N)$*, such that* $[P_O(N^*_O), P_N(N^*_N)] = [P^*_O(N^*_O), P^*_N(N^*_N)]$*.* $(N^*_O,\, N^*_N)$ *implements a constrained-efficient allocation.*

While Cap-and-Trade may be more difficult to implement in practice, this kind of policy has two advantages over the capital surcharges. First, as shown in the proposition, Cap-and-Trade is particularly useful when the policymaker is incompletely informed of underlying parameters (μ in the model proposed here), as the target price function can be defined in a way that is independent of some underlying parameters. Notice that the optimal capital surcharges depend on the optimal quantity (N_O^*, N_N^*), which demands all the relevant information about the model parameters. However, Cap-and-Trade does not require the policymaker to know the optimal quantity (N_O^*, N_N^*) precisely when she has to pick up the initial quantity of permits. Instead, the observable market price serves as an informative indicator of whether the optimal quantity of permits is chosen.

The second advantage is that Cap-and-Trade may be useful when the bank's collateral constraint is non-binding. Notice that, with the capital surcharges, the extent of the extra marginal costs of creating opaque securities is dependent on the shadow cost of the collateral constraint and the parameters that consist of the last line of objective (1.25). This implies that if the shadow cost of the constraint is small, excessively large capital surcharges may be necessary in some cases, as the capital surcharges do not increase the marginal cost of creating opaque securities far enough. For instance, as shown in the previous section, in the case of a large discrepancy between the optimal and the market quantity of opaqueness without binding constraint— which occurs with a small tail probability, large information costs, and a small spread— the optimal capital surcharge on opaque securities become prohibitively large as R is close to 1. In such a case, the quantity control with Cap-and-Trade may be more effective to curb the creation of opaque securities.

1.4.3.2.2 Pigouvian Taxation Another possible policy instrument involves Pigouvian taxes. In the current context, it corresponds to impose taxes on creating opaqueness and securities, T_O and T_N respectively. With the optimal taxes that are equivalent to the prices of permits at the fixed point, $[T_O^*, T_N^*] = [P_O^*(N_O^*), P_N^*(N_N^*)]$, the policymaker can achieve constrained efficiency. Compared to Cap-and-Trade, the Pigouvian taxation approach has a disadvantage in that it requires full information about the model parameters. Compared to capital surcharges, the Pigouvian taxation allows the direct imposition of the extra cost of creating opaque securities, while extra costs generated by capital surcharges depend on the other model parameters and variables. It implies that the Pigouvian taxation eliminates uncertainty about costs the banks must bear with the government's policy. However, as the optimal taxes vary with the private sector's perception of the state of the world, it may not be effective in practice as the other policy instruments if it is more difficult to adjust tax rates along with an economic environment.

1.4.4 Discussion : Relation to Other Current Proposals

1.4.4.1 Macroprudential Approach

Recently, a macro perspective on financial regulation has brought considerable attention among policymakers and scholars. Broadly speaking, macroprudential instruments can be thought of as tools to minimize macroeconomic costs linked to financial instability (Borio 2003). As macroprudential instruments, among others, I will discuss the shortcomings of systemic capital surcharges and contingent capital, which are relevant in the current context.[96]

1.4.4.1.1 Systemic Capital Surcharges There has been a growing consensus that there is inefficiency in financial markets as financial institutions tend to take on excessive leverage, which eventually leads to large-scale fire sales if a bad state occurs, resulting in a systemic meltdown. In particular, the excessive use of short-term liabilities leads to pecuniary/fire-sale externalities that work through missing insurance markets (Lorenzoni 2008) or collateral constraints (Bianchi 2011; Korinek 2011; Gertler, Kiyotaki, and Queralto 2012; Stein 2012). This literature provided justification for Basel III, which proposes capital surcharges for systemically important financial institutions.[97]

While the existing literature only focuses on the liability structure of borrowers, my model formalizes the idea that the composition of the asset side of borrowers' balance sheet does matter for financial and macroeconomic stability. Those dimensions must be coherently considered for optimal financial regulation. Another strength of this information-based approach may be that it could make the financial system more robust to errors in credit ratings of assets, as capital requirements depend on the opaqueness of securities, independent of ratings given to those securities. Further, there are at least two important pitfalls in the leverage-based capital surcharges, which take into account only the liability structure of financial institutions.

First of all, it is unlikely that the high leverage of financial institutions caused the recent financial crisis. From an empirical standpoint, Lo (2012) disputes the idea that, due to a rule change by the U.S. Securities and Exchange Commission (SEC), shadow banks greatly increased their leverage, leading up to the crisis, and shows that the leverage

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[96] See (IMF) (2011) for other tools.

[97] See on Banking Supervision (BCBS) 2011.

of the shadow banks in 1998 was much higher than in 2006. Moreover, he points out that, although many commentators blamed the SEC rule change for the root of the crisis, it is a misunderstanding as in fact, it has nothing to do with leverage restrictions.

From a theoretical standpoint, even though excess leverage exacerbates the symptom of a financial crisis through fire-sale externalities, it is not the trigger of a crisis itself. In this regard, in order to trigger a crisis, many papers rely on an exogenous shock, whereas my model explicitly incorporates endogenous mechanisms by which a crisis hits an economy. To see this point, let us decompose the source of inefficiency into two parts: 1) pecuniary/fire-sale externalities during a liquidity crisis and 2) exposure to a severe solvency crisis. In the model, a liquidity crisis in the middle state is driven by the opaqueness of securitized assets. Moreover, the extent of the opaqueness and solvency risk jointly determine the volume of assets that must be liquidated at a fire-sale price[98]; the extent of a liquidity crisis is not simply proportional to the leverage of the bank. See Figure A.13 and A.14. Regarding the second source of inefficiency, a solvency crisis constitutes fundamental risk that cannot be offset, whereas efficiency loss from a liquidity crisis might be mitigated by liquidity injections. Moreover, efficiency loss from a solvency crisis may be amplified if it acts as a strong deleveraging shock that pushes real interest rates down, leading to a liquidity trap with depressed output.[99]

The other pitfall is that strong capital (or liquidity) surcharges on short-term liabilities penalize financial institutions that face more profitable investment opportunities than others. To see this point, let us suppose that bank A's profit for each project in the high state, μ_A, is higher than bank B's profit but otherwise both banks are in the same condition. Then optimal regulation involves lower capital surcharges for bank A's liability structure, but investment profitability may be private information to banks, which regulator may not able to identify. In this case, capital surcharges that are based on leverage generate distortion, which is increasing in the magnitude of surcharges. Moreover, there are questions about whether this approach will be robust to the political influence of the lobby of financial institutions and increasing international competitive pressure. It can be problematic in particular if regulators have to impose

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[98]In the basic framework, only the degree of the opaqueness determines the extent of fire sales in the middle state, setting aside the quantity of debt. See Section 1.5.2 for the contribution of solvency risk to the size of inefficiency generated by fire sales both in the middle and the low state.

[99]I do not incorporate this mechanism into the model. See Eggertsson and Krugman (2012) for the exposition of this idea.

higher capital surcharges in a boom. Regulators may fail to implement higher capital surcharges if bank A is able to successfully lobby the regulators.

In this regard, the information-based capital surcharges can be more robust to different economic conditions. For example, suppose that regulators impose the leverage-based surcharges, say 10%, but suppose that the same efficiency can be achieved by the information-based surcharges, say 15% and 5% on opaque and transparent securities respectively. Then bank A can lower the cost of a project associated with capital surcharges by creating more transparent securities. At 5% capital surcharges, the cross sectional distortion across heterogeneous banks can be lower.

1.4.4.1.2 Contingent Capital One weakness of leverage restrictions with capital surcharges is that it turns out to be costly if a bad state does not occur. One way to address this weakness might be to prearrange financial instruments that increase capital only in a bad state. Such contingent capital instruments include reverse convertibles (Flannery 2005) and capital insurance (Kashyap, Rajan, and Stein 2008). The effects of those instruments can be thought of as government's capital injections during a crisis, but at cost from private investors instead of taxpayers.

However, contingent capital is unlikely to be strongly effective to the extent that private agents' decisions internalize the fact that contingent capital increases pledgeable assets in a bad state. To see this effect in the current model, notice that contingent capital of T relaxes the collateral constraint, $d \leq q^B + T$. Because it increases the borrowing capacity of the banks, the banks will neutralize the effect that contingent capital aims for with more debts, if they face sufficiently profitable investment opportunities.[100]

Moreover, even if the banks cannot pledge contingent capital, contingent capital is able to mitigate only the inefficiency arose from pecuniary/fire-sale externalities. In order to correct excessive exposure to a solvency risk, it must be supplemented with another policy.

1.4.4.2 Other Dodd-Frank Proposed Rules

1.4.4.2.1 Information Disclosure As improvements to the regulation of asset-backed securities, Section 942 of the Dodd-Frank Act requires ABS issuers to make additional disclosures of loan-level data. It allows investors to assess

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[100] Korinek (2011) derives a similar result from a different context.

the specific assets underlying asset-backed securities, but forces securitizers to expend money and time gathering and disclosing information. While this policy makes ABS markets more transparent, two points worth noting. First, transparency is superior than opaqueness in markets in which there is sufficient variation in credit risk λ along with information α. Second, a penalty on opaqueness should be time-varying. More penalties should be imposed when private agents are optimistic about the state of the world. Therefore, more flexible policy instruments are needed as supplements for optimal regulation.

1.4.4.2.2 Retention Requirement Section 941 of the Dodd Frank Act specifies risk retention standards to which securitizers must follow. A securitizer must keep at least 5% of the credit risk for an asset-backed security unless the security is collateralized entirely by qualified residential mortgages (QRMs). The definition of QRMs includes an analysis of, among others, the borrower's ability to repay. The act also prohibits securitizers from hedging the credit risk they are required to retain with a few exceptions. The primary purpose of risk retention as a regulatory tool is to promote sound underwriting standards.

There are two points worth noting to understand to what extent retention requirements contribute to increased financial stability. First, as is the case in the other rules, the rules do not allow percentage of retained interests to vary over time. The rules should be supplemented with another flexible policy instruments.

Second, as can be seen in the model, lending standards can decline nevertheless to levels at which financial industries generate socially excessive risk, even though entire asset-backed securities are being held by securitizers and originators. The provision that forces securitizers to hold some fraction of interests does not necessarily achieve desirable degree of lending standards.

In this sense, what is important is that regulators must prohibit securitizers from pledging retained interests as collateral, resulting in the increased costs of creating opaque securities. Furthermore, such retained interests must be prevented from being sold to other investors during a liquidity crisis. Otherwise, it will allow securitizers to transfer credit risk during a liquidity crisis, leading to deteriorated lending standards ex ante. However, while Dodd-Frank proposed retention rules limit the pledgeability of the retained interests, the rules allow the retained interests to be pledged as collateral with full recourse to the sponsor. Therefore, the rules may not have the intended effects if the securitizers are able to sell those interests during a crisis with some obligations.

1.5 Extensions

In this section, I explore three extensions to the basic framework. I start by providing the microfoundation of the information acquisition of inside investors. Then I explore under what conditions the shadow banking system manufactures Collateral Debt Obligations (CDOs). Next, I relax the assumption of infinitely risk-averse inside investors. Lastly, I study an economic environment in which the bank can offload some of its lemon assets to other investors. Throughout this section, I assume $\lambda^M = 0$ for simplicity.

1.5.1 Microfoundation of the Information Acquisition of Inside Investors

Financial Autarky In the interim period, once the inside investor receives public information about the aggregate state and the island-specific state r_i of her island, she decides whether to acquire additional private information about the state of the world on her own.[101] The cost of private information is given by χ for each asset she is holding, and each island independently draws χ from uniform distribution $F \sim U[0,\bar{u}]$.[102] The information acquisition can be costly, because it will take time and resources to uncover the nature of portfolios. The information cost can also be thought of as the risk that the risk-averse inside investor must bear during the period of collecting and processing information, especially if this task is time-consuming.

Upon acquiring information, she privately learns the current state of the island precisely; as time goes, inside investors are allowed to learn more about the market condition and asset returns at a cost, which were not available when the bank originated in the first place.[103] With or without further private information acquired, she updates her information set, Ω_2, to evaluate the return of her portfolios and decides whether to hold her portfolios until maturity.

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[101] I suppose that inside investors cannot infer the state of the world from any aggregate variables.

[102] Here I assume that χ is stochastic to derive the solution of the model using the first order principle. Increasing the total cost of information in the number of assets holding is to capture an idea that it may be more difficult to figure out the correlation between the returns of portfolios and economic conditions as the size of portfolios becomes larger.

[103] For creditors' information advantage over banks, see Jiang, Nelson, and Vytlacil (2014).

If she cancels her loans, some fraction of assets being held by the bank must be sold to the other agents (outside investors) in a secondary asset market to pay back to the inside investors.

Securitization As inside investors exposed only to the aggregate state, they must have a device that aggregates dispersed information across islands to learn about the aggregate state. Therefore, I assume that, before they decide whether to roll over debt, inside investors receive common public information about fundamentals, ϕ, where ϕ is the aggregated information of the regional signals across islands:

$$\phi = \phi(\{r_i\}_i, 1-\xi),$$

where r is distributed according to $p(r|s)$ and $1-\xi$ is non-diversifiable noise that represent the costs of aggregating, processing and absorbing large complex data, or it can be thought of as the inaccuracy of credit ratings of complex structured products. While the signal ϕ is informative about the state of the world, ξ should be defined in a way that does not allow the inside investors to be perfectly informed about an underlying state from observing a public signal.

Here I assume the simple functional form of ϕ, but attempt to minimize the loss of generality; the public signal ϕ delivers incorrect information about the aggregate state with probability $1-\xi(\overline{\alpha})$ where $\xi'(\overline{\alpha}) > 0$, $\xi(\frac{1}{2}) = \frac{1}{2}$ and $\overline{\alpha} = \int \alpha_{ji} d(j,i)$[104]:

$$\begin{aligned} p(\phi|S) &= \xi(\overline{\alpha}) && \text{if } \phi = S, \\ p(\phi|S) &= 1-\xi(\overline{\alpha}) && \text{if } \phi \neq S. \end{aligned} \tag{1.26}$$

It is analogous to expression (1.2). This functional form reflects an idea that the accuracy of a public signal at date 2 is increasing in the aggregate production of information at date 1.[105] This implies that if more information were produced, more agents would receive correct information about fundamentals, as well as it improves the accuracy of a signal itself.[106]

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[104] $f(S|\phi) = f(\phi|S)\frac{f(S)}{f(\phi)}$ and $f(\phi) = \sum_s f(s) f(\phi|s)$. Observe $f(\phi=1) = \eta\xi + (1-\eta)(1-\xi)$ and $f(\phi=0) = \eta(1-\xi) + (1-\eta)\xi$. Note that with $\xi = \frac{1}{2}$, $f(S|\phi) = f(S) = \eta$, i.e., the signal ϕ is not informative at all.

[105] If $\xi(\alpha) = \alpha$, expression (1.26) corresponds to expression 1.2, except that α is aggregated information here.

[106] This means that uncertainty about the aggregate state given ϕ, as measured by Shannon entropy, decreases as α increases.

The inside investor updates her prior distribution of S given public information ϕ, then decides whether to acquire further private information about the state. If she acquires further information, she privately learns the current aggregate state precisely, which amounts to knowing the correlation between the returns of portfolios and the macroeconomic factor (negative news).

Some may question why $\xi(\alpha)$ should be necessarily increasing in α. It may be true that if the information processing capacity of the economy is constrained, the volume of information might play a limited role in producing more precise information about the state of the world. While such information processing capacity may be limited in a very short run, however, the increased availability of information generally promotes the development of information infrastructure such as electronic data sources that can be easily accessed when seeking particular information, analytical software that utilizes better data sources, and human capital capable of exploiting such knowledge and tools[107]; the information processing capacity of the economy is endogenous in the sense that it builds up in accord with the demand for such abilities. In terms of our model, it can be interpreted that the increased production of information at date 1 encourages the building of such information infrastructure, resulting in the increased transparency of asset-backed securities. It subsequently leads to the increased accuracy of public information available at date 2.[108]

1.5.1.1 Solution

If the positive news about the aggregate state arrives in the interim period, inside investors do not need to acquire extra information. However, the arrival of the negative news generates uncertainty about fundamentals, in which case they need to decide whether it is desirable to acquire additional information about the state before making further financial decisions.

Lemma 18 *The inside investor acquires information if and only if the net value of information is greater than zero:*

[107] Even though AAA-rated asset-backed securities were regarded as information insensitive debt instruments, there existed spreads within the class of the AAA-rated securities (e.g., Gorton and Metrick 2012). It suggests that informed investors were possibly able to take an advantage of arbitrage opportunities.

[108] Another possible way to model this interpretation is to assume that the cost of information acquisition is likely to be low if more information is available: the mean ι is decreasing in α. For instance, if banks did not gather enough relevant information about the characteristics of borrowers ex ante, analysts must depend on other indirect variables for the evaluation of assets, which can increase the cost of information but decrease the reliability of the evaluation about the riskiness of borrowers. The qualitative results are similar in both specifications.

with securitization,

$$\chi \leq f(S=M|\phi)(R-1),$$

or without securitization,

$$\chi \leq f(s=1|r)(R-1).$$

From the bank's perspective ex ante at date 1, the inside investor acquires information with probability z: with securitization,

$$z_{\phi} = F(f(S=M|\phi)(R-1)), \tag{1.27}$$

or without securitization,

$$z_r = F(f(s=1|r)(R-1)). \tag{1.28}$$

Therefore, the fraction of the informed investors is given by $\tilde{P}(\overline{\alpha}) = [f(\phi=M|S=M)z_M + f(\phi=L|S=M)z_L]$ and $\tilde{P}_N(\alpha) = [f(r=g|s=g)z_g + f(r=b|s=g)z_b]$ respectively, and it is increasing in information.[109] More information implies that more inside investors receive a good signal in the middle state, and given the good signal, more of them obtain private information.

What is important in their decisions is that, as they have the option to terminate the contract to recoup her investment throughout the interim period, the value of private information should be large enough to justify its cost χ. The value of private information depends on the prior distribution of the state of the world, and such prior distribution is shaped by public information and its accuracy about the quality of securities. It would be interesting to note that the value of private information given the good public signal ($\phi = 1$) increases as public information becomes more precise. Because private information turns out to be valuable only if they find that the middle state has occurred, private information tends to be more valuable if the middle state is more likely to have occurred from the ex-ante perspective of the inside investor.

[109]For general distribution functions, sufficient conditions for $\tilde{P}(\alpha) > 0$ are 1) sufficient uncertainty (η is close enough to $\frac{1}{2}$), and 2) $F(\chi)'' < c_x$ (no irregular spikes).

In other words, the good public information with higher accuracy shapes the inside investor's belief about the state to be more optimistic. This encourages her to take the additional step of the private information acquisition at her own costs, in order to see whether it does make sense for her to maintain her portfolios until maturity. Under imperfect information, more accurate public information can sustain such a positive prospect, and thus it makes private information more valuable. In this regard, as the accuracy of the public information can be improved by banks information production when projects are undertaken, information produced by the banks has the aspect of public goods.

1.5.1.2 Social Value of Private Information

Notice that the inside investors can fail to recognize the social benefit of private information. While the value of each project in the middle state from the planner's view point is μ^B, the inside investor only receive R for each unit deposited; unless $\mu^B = R$, $P^S(\overline{\alpha}) \neq \tilde{P}(\overline{\alpha})$, where $P^S(\overline{\alpha}) = [f(\phi = M|S = M)z^S_M + f(\phi = L|S = M)z^S_L]$ and $z^S_\phi = F[f(S = M|\phi)(\mu^B - 1)]$. The larger $\mu^B - R$, the larger discrepancy between the social value and the private value of information obtained by the inside investors, which leads to socially excessive frequency of asset liquidation.

In practice, policymakers may consider credit policies to enhance liquidity in the shadow banking system in the face of a liquidity crisis; for example, Primary Dealer Credit Facility (PDCF) in the repo market or the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF) and the Commercial Paper Funding Facility (CPFF) in the commercial paper market.

1.5.2 Heterogeneous Preferences

The assumption of infinitely risk-averse inside investors can be generalized as follows to incorporate heterogeneous risk preference profile among them. In this section, I suppose the model with the microfoundation of the information acquisition of inside investors. Suppose that there is a continuum of inside investors, indexed by risk preference profile $i \in [0,1]$. i and $1-i$ indicates the weight on returns in the middle and the low state respectively.

$$E_B[U(C_3)] = iRdN + (1-i)\psi(1-\zeta)(1-\lambda(\overline{\alpha}))\mu^B N,$$

where E_B is the conditional expectation operator given the bad news, ψ is a recovery rate, ζ is a fraction that a securitizer can divert, and $\lambda(\overline{\alpha}) = \int_j \lambda(\alpha_j) dj$.[110] For instance, infinitely risk averse investors correspond to the case of $i = 0$, who value only the worst case cash flows, $E[U(C_3)] = \psi(1-\zeta)(1-\lambda(\overline{\alpha}))\mu^B$.

For appropriate parameter values, as they have the option to stop rolling over debt, it can be shown that there exists $\overline{\iota}$ such that for $i > \overline{\iota}$ (risk-taking),

$$\max_{C_2, C_3} U_i(C_2) + \beta \delta E_B[U_i(C_3)] > dN,$$

and for $i \leq \overline{\iota}$ (risk-averse),

$$\max_{C_2, C_3} U_i(C_2) + \beta \delta E_B[U_i(C_3)] = dN,$$

where the expectation operator is taken with respect to information set at date 2 without extra information acquisition about the aggregate state. Notice that the outside investors with $i > \overline{\iota}$ do not run on securitizers even if they do not obtain private information about the aggregate state.

In addition, it can be shown that risk-taking investors' value of private information is lower than the others, leading to less frequent information acquisition. Each of risk-taking investors acquires private information given ϕ with probability z^i_ϕ :

$$z^i_\phi = F(f(S = M|\phi)(R-1) - c_i),$$

where $c_i > 0$. This implies that they overall acquire private information with probability $\tilde{P}'(\overline{\alpha}|\mathbf{S})$:

$$\tilde{P}'(\overline{\alpha}|S) = \int_{\overline{\iota}}^{1} [f(\phi = M|S) z^i_{\phi=1} + f(\phi = L|S) z^i_{\phi=0}] di.$$

The risk averse investors with $i \leq \overline{\iota}$ acquire private information with probability $\tilde{P}(\overline{\alpha}|\mathbf{S})$:

$$\tilde{P}(\overline{\alpha}|\mathbf{S}) = \int_{0}^{\overline{\iota}} [f(\phi = M|S) z_{\phi=1} + f(\phi = L|S) z_{\phi=0}] di,$$

[110] In the baseline model, I assume $\psi = 0$ for simplicity. Also, notice that since individual securitizers hold a well-diversified portfolio of ABS, only $\lambda(\alpha)$ matters to the inside investors.

where z_ϕ is given by (1.27).

Notable differences between the two types of investors can be summarized as follows; 1) in the low state, risk-averse investors run regardless of private information, but risk-taking investors do not run as far as they do not acquire private information; 2) in the middle state, risk-averse investors run if they do not acquire private information, but risk-taking investors do not run regardless of private information; 3) risk-taking investors acquire private information less frequently than risk-averse investors.

Lemma 19 *$\bar{\iota}$ is increasing in tail risk $\lambda(\bar{\alpha})$.*

If the tail risk is large, a smaller number of the inside investors will be risk-taking. This implies that, as more investors run on banks in the downturns, more assets must be liquidated during a liquidity crisis. However, because the tail risk depends on the aggregate information production, $\bar{\alpha}$, individual securitizers do not internalize the impact of its choice on the tail risk. This can be another channel by which a market failure occurs.

Interestingly, if the tail risk is sufficiently small, more information may lead to a more frequent liquidity crisis. To see this, suppose that λ is small enough so that there are no risk-averse investors, $\bar{\iota} = 0$. Then, no liquidity crisis occurs in the middle state. In the low state, on the other hand, liquidity crises occur when they obtain private information. Put it differently, if the risk of the economy is small and there are many risk-taking investors, some opaqueness may be necessary for stability.

1.5.3 Asymmetric Information

If securitizers are able to dispose of lemon securities for profits, it can further exacerbate information problems. To fix this idea, suppose that at date 1, a securitizer can offload the amount of $s\lambda^L N$ lemon assets (which become lemon with probability 1 in the low state) on less sophisticated investors who value those assets at q_λ, which is higher than a fair price. This relaxes collateral constraint and lowers the fraction that must be liquidated, κ^L :

$$d \leq \mathbf{q}^L + q_\lambda s\lambda^L,$$

$$\kappa^L = \frac{d - q_\lambda s\lambda^L}{\mathbf{q}^L}, \text{ and } \kappa^M = \frac{(1-\tilde{P}(\bar{\alpha}))d - q_\lambda s\lambda^L}{\mathbf{q}^M}.$$

If q_λ is high enough, κ^S is increasing in α, leading to less incentive to produce information. The objective of a securitizer becomes:

$$\begin{aligned}\Pi^F(d,\alpha) \quad = \quad & N\{\underbrace{p}_{High \text{ state}}[\underbrace{(\mu(1-s\lambda^L(\alpha))-Rd)}_{hold}+q_\lambda s\lambda^L(\alpha)] \\ & +\underbrace{(1-p)\eta}_{Middle \text{ state}}[\underbrace{\mu^B(1-s\lambda^L(\alpha))(1-\kappa^M)}_{\text{leftover assets}}-\underbrace{R(1-\Lambda^M)d}_{\text{unpaid debt}})] \\ & +\underbrace{(1-p)(1-\eta)}_{Low \text{ state}}[1-\lambda^L(\alpha)]\underbrace{\mu^B(1-\kappa^L)}_{leftover \text{ assets}}] \\ & -\iota(a)\}.\end{aligned} \tag{1.29}$$

Notice that if q_λ is sufficiently high, it can be shown that the private value of marginal debt increases and the private value of marginal information decreases unambiguously.

1.6 Concluding Remarks

This paper has provided a model of banking with securitization to understand the positive and normative implications of securitization for financial stability within an equilibrium model of competitive financial markets. I compared the model with and without securitization to show how securitization changes the incentives of financial institutions in ways that can cause financial disruptions. The main conclusions of this paper are as follows. First, the interconnectedness among banks, created by securitization, exposes the financial system to greater liquidity risk in two ways: 1) by creating greater funding risk in response to aggregate risk, particularly when investors are pursuing safety, and 2) increasing the amount of asset liquidation via credit risk sharing. Second, even if securitizers do not have any informational advantages over investors, they can produce asset-backed securities that are too opaque, thereby exposing the financial system to considerable hidden risk. Especially, when securitizers consider a tail probability to be small, they produce more opaque securities. Third, macroprudential policy is essential to correct a market failure that induces the securitized-banking system to produce too little information. Countercyclical capital surcharges on opaque securities can achieve financial stability.

My paper deals with several key aspects of the securitized-banking system, but I do not incorporate real sectors into the model. The interactions between the financial and real sectors are one direction of future research. Another question that needs to be addressed is how capital surcharges can be calibrated for securities having different types of underlying assets. There are many types of loans that constitute asset-backed securities; e.g, credit card receivables, auto loans, and subprime mortgage loans. As different loan markets have different characteristics, optimal regulation would require different capital surcharges. This is another promising direction for future research.

Chapter 2

Adverse Selection, Information Acquisition, and Optimal Interventions in Securities Markets

2.1 Introduction

The U.S. financial crisis of 2008-2009 led the Federal Reserve (FED) to implement a new set of unconventional policies (Reis 2009b). In particular, the Fed conducted large-scale asset purchases of agency mortgage-backed securities (MBS), with the goal of relieving concern that some private sectors may not have access to the credit market. While the effectiveness of the Fed's large-scale asset purchases has been explored in the literature (Cúrdia and Woodford 2011; Krishnamurthy and Vissing-Jorgensen 2011), there has been little research on the efficiency of the Fed's credit policy. This paper seeks to bridge that gap in the literature by exploring various kinds of government interventions that can be conducted in such circumstances, and by evaluating the efficiency of different kinds of policy instruments.

To that end, I build a model that incorporates a financial market in which private securities are traded. I focus particularly on the role a financial sector plays in reallocating resources to their most productive uses (e.g., Rajan and Zingales 1998; Levine and Zervos 1998). In the model, entrepreneurs face heterogeneous investment opportunities upon which they base their borrowing and lending decisions. Being constrained from borrowing, entrepreneurs who face favorable investment opportunities seek to pledge their legacy assets in order to obtain liquidity, whereas entrepreneurs who have poor investment opportunities need to store their perishable liquidity by acquiring legacy assets from an financial market.

In a hypothetically frictionless world, well-functioning financial markets are able to successfully reallocate all resources to the highest value use in all states. Nevertheless, both developed and developing countries have experienced occasional financial crises.

I consider asymmetric information about the quality of legacy assets (Akerlof 1970) to be the main cause of financial friction, in the light of both the recent crisis (Gorton 2009; Duffie 2010) and the historical evidence (Calomiris and Gorton 1991; Mishkin 1991). Some fraction of legacy assets that is traded in a market is useless, and jeopardizes the existence of the financial market. Although each buyer's portfolio can be sufficiently diversified to reduce such risk, the expected fraction of useless legacy assets traded in the market, which represents the aggregate state, is an important factor to consider when making one's financial decision.

I allow entrepreneurs to acquire information about the average quality of the assets as an endogenous response to their imperfect knowledge of the state. If they obtain more information, a signal indicating the state of the economy become more precise, but acquiring more accurate information is costly (Sims 2003; Woodford 2008).

There are good reasons to believe that market participants have imperfect information on this kind of the aggregate state. At the onset of the recent crisis, for instance, financial market participants were not able to agree on prices for legacy assets, and this led to a sudden collapse of the secondary loan markets. However, since 2008, when the Fed started buying up financial assets, its profits, accrued from the spread between the interest rate paid on its reserves and the average return on its bond holdings, have skyrocketed.[1]

I show that changes in the entrepreneurs' prior over possible states can trigger a sudden collapse of the asset market, which is not necessarily associated with economic fundamentals. If the entrepreneurs believe that the quality of the assets traded is likely to be poor, they neither obtain any information nor buy any assets regardless of the current state; the asset market collapses, even in a state where economic fundamentals are strong. Small changes in the objective distribution of the state may cause large consequences if the subjective belief of the private sector reacts excessively to these changes. Likewise, the entrepreneurs' optimistic beliefs about the quality of the assets can lead them to flood the financial market with liquidity, regardless of economic fundamentals. Our model also predicts that if the cost of information acquisition is high, economic outcomes are likely to be determined by the prior expected asset return as opposed to contingent upon current economic fundamentals.

Moreover, there may exist multiple equilibria in the economy with imperfect information, which is not the case in the economy with perfect information. Since all entrepreneurs are infinitesimal, they do not internalize the general equilibrium impact of their information choices on the asset price; they take the future asset price as given. Importantly, what kinds of beliefs about a future asset price that entrepreneurs share in their minds determine which sort of equilibrium will be selected, because different beliefs about the future asset price induce different information choices. In addition, there is the benefit of a high asset price to the quality of the assets traded, because there are marginal investors who sell their high quality assets only if an asset price is sufficiently high. This implies that if entrepreneurs believe that a future asset price is high enough, they choose information in ways that increase demand for assets in the

[1] In 2009, the Fed posted $59 billion, a 50 percent increase over 2008. In 2012, it sent record earnings of $88.9 billion to the Treasury, three times greater than its typical profits.

anticipation of higher returns, which in turn results in a high equilibrium asset price that is consistent with the initial belief. Likewise, if the asset price has a large impact on the quality of assets, there exists another equilibrium in which a low asset price causes deterioration in the quality of the assets traded, which in turn leads to an insufficient supply of liquidity in the financial market.

In order to determine whether there is a need for policy intervention, one needs to understand how, and under what conditions, this private choice results in inefficient decision-making at the social level. In this paper, that issue is addressed by focusing on private information acquisition and the corresponding financial decisions, which are endogenous responses to an economic environment. I define constrained efficiency by considering a fictitious planner who is not allowed to directly transfer liquidity among entrepreneurs, but who can dictate to each entrepreneur how to acquire and use information. Then I analyze the efficacy of government policies, such as large-scale asset purchases and loss insurance. The main result is that the large-scale asset purchases crowd out efficient liquidity reallocation in the private sector and that therefore they cannot induce efficient allocation. In contrast, partial loss insurance with a credible public announcement of the asset price target implements the efficient allocation as the unique equilibrium.

It is simple to state the principle of the efficient intervention that intends to inject liquidity into the private sector: to make private agents trade with each other. Such a principle prevents policymakers neither from providing liquidity to financial institutions that are in urgent need (e.g., TAF) nor from using the size and composition of the central bank's balance sheet combined with forward guidance as an instrument of monetary policy to combat deflation at the zero lower bound (Eggertsson and Woodford 2003). It is rather the central-bank's direct purchases of longer-term private securities such as MBS that should be reassessed. Without incurring any loss of efficiency, partial loss insurance with the asset price target effectively channels liquidity to those who face the best investment opportunities by boosting private demand for those securities, and thereby raising an asset price, which in turn lowers longer-term interest rates.

Moreover, our model predicts that direct asset purchases can cause large welfare losses, especially in the MBS market where the cost of information acquisition is large. Changes in an asset price initiated by direct asset purchases in the MBS market can affect the private sector's information choices in ways that lead to a large reduction in the provision of private liquidity. Instead, loss insurance is the optimal way of correcting a market failure within the private securities markets.

This paper is related to an extensive literature on adverse selection initiated by Akerlof (1970). Recent applications to the financial crisis include **?**, Kurlat (2013) and Malherbe (2013). I build on the contribution of Kurlat (2013), who studies a financial market plagued with asymmetric information as an amplification mechanism by which aggregate shocks propagate. I endogenize information acquisition, and evaluate the efficacy of government interventions in the financial market.

The idea that a sudden change in information production can trigger a large consequence is similar to the one in Ordonez and Gorton (2013), who study the dynamic effects of information production but abstract from the trading motive for assets. I explicitly model such a motive, and this allows us to discuss the welfare implications of allocation of liquidity among agents. Those researchers also suppose that agents have rational expectations about the aggregate state and are allowed to be fully informed about the riskiness of each individual trading partner with some fixed costs, whereas I suppose that agents are allowed to obtain information only about the unknown aggregate state and that the cost of the information is tied to its accuracy.

This paper is also closely related to the literature on government interventions in financial markets that suffer from asymmetric information. Minelli and Modica (2009) focus on optimal policies between a monopolistic bank and borrowers. Reis (2011) considers different sectors in which credit policies to be implemented, and shows that the injection of liquidity into the shadow banking system can be highly effective. Chari, Shourideh, and Zetlin-Jones (2011) argue that asset purchases, which overcome adverse selection problems, must bring negative profits to the government. Philippon and Skreta (2012) and Tirole (2012) study cost-minimizing bank bailouts in the context of the mechanism design framework, when the government bails out first prior to opening an asset market. An important difference is that in my model, borrowing and lending decisions are endogenized with heterogeneous investment productivity, which allows us to analyze from the perspective of a social planner the impact of alternative interventions, such as asset purchases and loss insurance, on the reallocation of liquidity.[2]

[2] In Philippon and Skreta (2012) and Tirole (2012), asset purchases (or direct lending) and debt guarantees have an equivalent impact on welfare.

2.2 Model

The economic environment is close to the one in Kurlat (2013). The key new feature of my model is that agents acquire information endogenously on an unknown state of the economy.

2.2.1 Description of the Economy

There are three dates, $t = 0, 1, 2$. The government can offer various programs at the beginning of period 0. The economy is populated by two groups of agents, entrepreneurs and households. There is a continuum of ex ante identical entrepreneurs of measure unity, indexed by j. Households are of measure h, and they are homogeneous. There is a single perishable consumption good, an apple, and a single factor of production, a tree. Each of the entrepreneurs and the households is born with an endowment equal to one unit of the apple tree at date 0, and receives no further endowment in the subsequent periods. Each of them is risk neutral and consumes only at date 2; the utility from consumption is given by $E[c_2]$, where c_2 denotes consumption at date 2.

Production Technology: Each unit of the apple tree delivers one unit of the apple at date 1. After production, a fraction λ_j of the trees becomes a lemon tree. λ_j is random and is drawn from a distribution $Z'(\lambda_j)$ with finite mean λ. Moreover, λ is also a random variable which is drawn from a distribution $Z(\lambda)$, which is the source of aggregate uncertainty. Only an apple tree that has not become a lemon tree produces one unit of the apple in the subsequent period. Lemon trees produce nothing useful at date 2. All trees vanish at date 2 after production. Aggregate output equals the sum of apples produced from trees, and apples cannot be stored.

Investment: An idiosyncratic investment technology shock A_j is realized among entrepreneurs at date 0, and is constant in the subsequent periods. A_j is $i.i.d.$ across entrepreneurs and is drawn from a distribution $G(A_j)$. Each entrepreneur can turn apples (consumption goods) into apple trees (capital goods), but the opposite is not feasible. Investing i_j, each entrepreneur produces $A_j i_j$ units of the tree, which yields $A_j i_j$ units of the apple in the subsequent period. Households do not have access to such investment technologies.

No Storage Technology, Collateralized Borrowing and Asset Markets: Since agents value their consumption only at date 2, they need to transfer the apples from trees at date 1. Because there is no storage technology, each agent j

needs to either transform his own apples into trees with his investment technology A_j, or exchange his own apples for trees traded in the market.[3] The competitive market for buying and selling trees opens at date 1. Each agent is a price taker.[4] All trees are traded at the same price, p, which is the asset price in terms of units of the apple.[5] Note that each agent has a unit of the apple at the beginning of date 1, which can be used to buy a tree.[6] Each agent chooses how many lemon and apple trees to sell in the market, denoted by d_j^L and d_j^{NL} respectively. Short sales are not allowed and new investment is not pledgeable, $d_j^L \in [0, \lambda_j]$ and $d_j^{NL} \in [0, 1-\lambda_j]$. Each of the agents also decides the amount of assets he wishes to purchase, denoted by $b_j \geq 0$, of which the quality is unknown to buyers. The agent's budget constraint is given by

$$i_j + p \cdot b_j \leq 1 + p \cdot (d_j^{NL} + d_j^L) \tag{2.1}$$

where p is an equilibrium asset price.[7] It implies that the sum of the expenditure on new investment and legacy assets bought in the market must be equal or less than the sum of the endowment and revenue from selling legacy assets, which include apple and lemon trees.

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[3]In Appendix C, I consider a case in which storage technology is given by $0 \leq \beta \leq 1$. (No storage technology corresponds to $\beta = 0$.) If $\beta < A^{\min}$, it can be shown that no one uses such technology; in such a case, without loss of generality, we can assume $\beta = 0$. Even if $\beta > A^{\min}$, it can be shown that higher β exacerbates the inefficiency of liquidity reallocation in the private sector.

[4]In general, there may be cases in which buyers ration credit by offering a higher price if there is any benefit to do so (Stiglitz and Weiss 1981). Our competitive market setting is equivalent to assuming that there is no such benefit; because it is costly to acquire information on borrowers, as well as borrowers can be discouraged to apply for a loan in the first place because of high application costs, which include financial, time and psychological costs (Levenson and Willard 2000; Kon and Storey 2003). If there is credit rationing, all the qualitative results would still hold, but there is a unique equilibrium.

[5]There is no separating equilibrium in our framework. The intuition is that if lemon tree sellers were separated, they have to sell their assets at the price 0, which is strictly lower than the other price. Because the bad type can mimic the good type, the bad type never attempts to sell at the price 0.

[6]Another interpretation is that buyers seek to lend their money to profitable entrepreneurs, and they receive $\frac{1}{p}$ units of assets as collateral in exchange for one unit of the loan. It is equivalent to the repurchase agreement that provides a seller with the funds of p backed by a unit of collateral, together with the agreement to repurchase the asset at the price of one unit of the consumption good from a lender at a later date, although the seller can default on the agreement and it is the case whenever the collateral is lemon.

[7]In this setup, there are no insurance providers against losses from lemons. However, the presence of insurance providers does not affect the nature of our results. Section 2.4.6 considers an environment with private insurance providers.

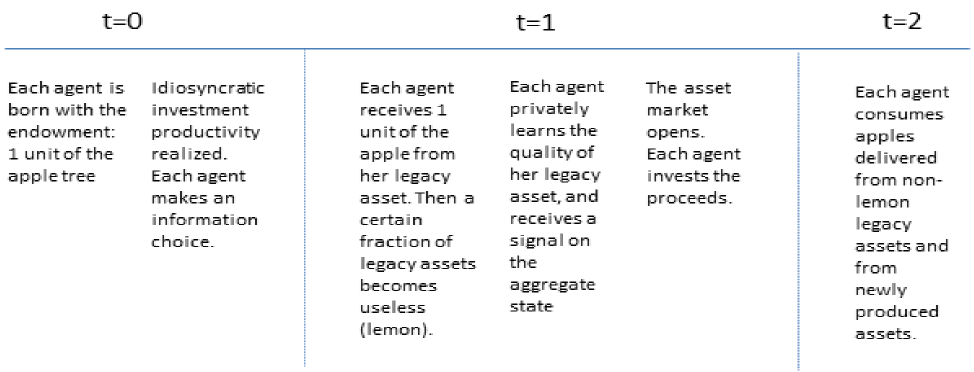

Figure 2.1: Timeline

2.2.2 Information

In period 1, each agent privately identifies lemon trees among the legacy assets he owns. However, information is asymmetric in the sense that the rest of the agents are not aware of the quality of assets that other agents attempt to sell in the market. In the following period, everyone can tell which trees became lemon trees in the previous period because the agents obtain 0 utility from lemons. Furthermore, agents are unaware of the realization of λ_k, $k \neq j$, which is the proportion of lemon trees owned by other agents as well as the total amount of lemon trees existing in the economy, which is equal to $\lambda \equiv \int \lambda_j dj$. Each agent's prior belief over λ is given by a distribution $F(\lambda)$.[8]

Since each entrepreneur's portfolio can be sufficiently diversified, the aggregate state λ is the unique variable about which agents should learn if needed. They can acquire more precise information to have better knowledge on the underlying state, but acquiring more accurate information is costly. The quantity of information is measured as in the information theory of Shannon (1948) and rational inattention literature starting from Sims (2003). Mathematically, collecting more accurate information on the current unknown state reduces the entropy of the agents' posterior over the state space conditional on a signal s, $f_j(\lambda|s)$, relative to the agent's prior, $f(\lambda)$. Moreover, each agent can choose

[8]The distribution $F(\lambda)$ need not necessarily to coincide with the distribution Z; the private sector's prior can be different from the object distribution. A prior over λ_j is omitted, as it is unnecessary for our results.

the set of values of signals he will receive ex ante upon which his decision is based, while signals are random variables of the current state. Then the mutual information, which represents the average quantity of information conveyed by a set of possible signals, is given by

$$\begin{aligned} I(f_j) &\equiv \int_s \bar{f}_j(s) \int_\lambda f_j(\lambda|s) \log f_j(\lambda|s) d\lambda ds - \int_\lambda f(\lambda) \log f(\lambda) d\lambda \\ &= \int_\lambda \int_s f_j(s|\lambda) \log f_j(s|\lambda) ds dF(\lambda) - \int_{s_i} \int_\lambda f_j(s|\lambda) dF(\lambda) \ln[\int_\lambda f_j(s|\lambda) dF(\lambda)] ds \end{aligned} \tag{2.2}$$

where $\bar{f}_j(s)$ is the prior density function of the signal s.[9] Given $\theta > 0$, which is the cost of acquiring an additional unit of information, the cost of information acquisition is given by $\theta \cdot I(f_j)$.

This information choice is made ex ante. Once each agent makes an information choice at date 0, he receives a signal s_j at date 1, which is independent of the signal other agents receive.[10] One interpretation is that a firm needs to hire competent analysts who can effectively learn about unknown economic fundamentals, which is costly, to be more responsive to an uncertain economic environment.

For expositional purposes, agents are assumed not to be allowed to use the current asset price and the individual state λ_j to infer the current economic environment. While it does not affect the qualitative nature of main results, it greatly simplifies the formulation of the problem. Appendix C shows that how the problem can be formulated if agents learn from these observations.[11]

The investment productivity A_j is private information to entrepreneur j. While it is private one, it will be shown in the next section that entrepreneurs do not need to obtain any information about investment opportunities that other agents face.

---

[9]Bayes' theorem was applied in the derivation of equation (2.2).

[10]Given $\{s_j\}$, agents may have heterogeneous posterior beliefs about λ. In reality, people seem to have different opinions on fundamentals even after they acquire information, especially when the cost of information is large. The case in which agents have heterogeneous prior beliefs is beyond the scope of this paper.

[11]By Assumption 3-(2), which is specified in Section 2.3.1.1, it does not matter whether entrepreneurs are allowed to learn about λ from their individual state λ_j or not. In a more general case in which all types of entrepreneurs hold some lemons, in order to allow agents to learn from λ_j, the problem can be formulated in a way that is similar to the case in which an asset price is noisy (Appendix C), as far as λ_j is the same across the same productivity type of entrepreneur so that even though they learn about λ from λ_j, the entrepreneurs of the same type reach homogeneous beliefs about λ. It is straightforward to show that all qualitative results are not affected by the alternative representation of the model.

2.2.3 Definition of Equilibrium

An equilibrium asset price depends on the economy-wide state, which is given by the aggregate amount of lemon trees existing in the economy, λ, as well as the distribution of investment opportunities $G(A_j)$. Given the asset price, each agent wishes to make a choice which depends on the economy-wide state λ, and his own individual states A_j and λ_j. However, since λ is unknown to each agent, his decision should be based upon a particular signal s_j he receives, which may be informative on λ, and the individual states A_j and λ_j. Thus, each agent solves the following problem:

$$\max_{i_j, b_j, d_j^{NL}, d_j^{NL}, f_j(s|\lambda)} \int_\lambda \int_s c_j(s,\lambda) f_j(s|\lambda) ds dF(\lambda) - \theta \cdot I(f_j) \tag{2.3}$$

subject to the budget constraint (3.22) and

$$c_j = 1 \cdot k_j \tag{2.4}$$

$$k_j = [(1 - \lambda_j - d_j^{NL}) + b_j(1 - \lambda^M)] + A_j i_j \tag{2.5}$$

$$0 \leq d_j^{NL} \leq 1 - \lambda_j, 0 \leq d_j^L \leq \lambda_j \tag{2.6}$$

$$0 \leq b_j, 0 \leq i_j \tag{2.7}$$

where the quantity of information $I(f_j)$ is given by (2.2)[12]; λ^M, which is the function of the aggregate state λ, is the proportion of lemon trees traded in the market.

Constraint (2.4) implies that each agent is allowed to consume apples that are produced only at date 2 because of the non-existence of storage technology. Constraint (2.5) states that the total amount of assets available at date 2 to agent j is equal to the sum of nonlemon legacy assets he keeps, $1 - \lambda_j - d_j^{NL}$, and the ones bought in the market $b_j(1 - \lambda^M)$, plus the assets newly produced from his investment, $A_j i_j$. Constraint (2.6) represents the borrowing constraint; since new investment is not pledgeable, each agent can obtain liquidity only to the extent to which he is able to sell his own

[12] I, here, write a model in which agents choose how much information to acquire (θ is exogenous) rather than how to allocate their attention with an upper bound $\bar{I}$ on $I(f_j)$ ($\bar{I}$ is exogenous, but θ corresponds to the Lagrange multiplier for the information constraint). Our specification allows us to derive simple analytical expressions that characterize equilibrium. Note that there is a one-to-one relation between $\bar{I}$ and θ.

legacy assets in the market. Investment and purchases of assets must be nonnegative as indicated by constraint (2.7).

The agents solve for an information choice taking as given common beliefs on the future asset price function, $p^B(\lambda)$. Since all the agents are infinitesimal, they do not internalize the general equilibrium impact of their information choice on the asset price. Taking all the considerations into account, I define equilibrium as follows.

Definition 3 *A competitive equilibrium is given by beliefs on a future asset price* $p^B(\lambda)$*, a realized asset price* $p(\lambda)$*, a market proportion of lemons* $\lambda^M(\lambda)$*, an individual information choice* $f_j(s|\lambda)$ *and individual decision rules* $\{i(s_j,A_j,\lambda_j,p),b(s_j,A_j,\lambda_j,p),d^{NL}(s_j,A_j,\lambda_j,p),d^L(s_j,A_j,\lambda_j,p)\}$ *that jointly satisfy the following conditions:*

(i) Each entrepreneur's information choice $f_j(s|\lambda)$ *maximizes (2.3) given the beliefs on the future asset price and the individual decision rules.*

(ii) The individual decision rules maximize expected consumption subject to constraints (3.22), (2.4), (2.5), (2.6), and (2.7) given the realized asset price.

(iii) The asset market clears: $\int b(s_i,A_i,\lambda_i)di \leq \int [d^L(s_i,A_i,\lambda_i) + d^{NL}(s_i,A_i,\lambda_i)]di.$

(iv) The market proportion of lemons λ^M *is consistent with the individual decision rules*

$$\lambda^M(\lambda) = \frac{\int d^{NL}(s_i,A_i,\lambda_i,p)di}{\int [d^L(s_i,A_i,\lambda_i,p) + d^{NL}(s_i,A_i,\lambda_i,p)]di}.$$

(v) Agents' beliefs on the future asset price are correct: $p^B(\lambda) = p(\lambda)$.

2.3 Equilibrium

To characterize the equilibrium, I will first derive the optimal decision rules and information choice of the entrepreneur. Next, I will show existence and multiplicity of solutions. Then, I will present the relation between various parameters and endogenous variables in equilibrium.

2.3.1 Solving for Optimal Entrepreneur Decision Rules

The problem can be solved using backward induction, starting with deriving the entrepreneurs' decision rules for a given signal. Before proceeding to the characterization of the solution, it is useful to begin with the following observations: (i) Each household becomes a buyer of assets, and (ii) Each entrepreneur always sells his entire lemon assets in the market.

The former observation (i) reflects the fact that, since households possess neither storage technology nor investment technology, buying assets in the market is the sole option they have in order to transfer their apples into the future. At date 2, households enjoy their consumption of apples that they harvest from their own legacy assets from date 0 and from the ones bought in the market at date 1.[13] The latter observation (ii) is a consequence of asymmetric information between sellers and buyers. Selling lemons to other agents is always profitable, as lemons are worthless and buyers have no ability to distinguish lemons from nonlemons.

2.3.1.1 The Period 1 Optimal Choice

With those observations, I start by solving for the period 1 optimal decision rules taking information choices as given. The solution is similar to Lemma 2 of Kurlat (2013). Given an asset price p and a signal s_j, each entrepreneur j decides how many assets they carry into the future by choosing d_j^{NL}, d_j^L, b_j and i_j. The solution to the relevant decision rules are reproduced in the following for completeness.

Proposition 20 *(i) (Seller) An entrepreneur becomes a seller of a nonlemon tree* $(d_j^{NL} + d_j^L = 1$ *and* $b_j = 0)$ *if* $A_j > \frac{1}{p}$; *(ii) (Buyer) An entrepreneur becomes a buyer* $(d_j^{NL} = 0,\ d_j^L = \lambda_j$ *and* $b = \frac{1}{p} + d_j^L)$ *if* $A_j < \frac{1}{p} E[1 - \lambda^M | s_j]$; *(iii) (Keeper) An entrepreneur becomes a keeper* $(d_j^{NL} = b_j = 0$ *and* $d_j^L = \lambda_j)$ *if* $\frac{1}{p} E[1 - \lambda^M | s_j] < A_j < \frac{1}{p}$.

This result is best understood by comparing the return to investment A_j and the return from buying assets $\frac{1-\lambda^M}{p}$ or the opportunity cost from selling nonlemon assets $\frac{1}{p}$. One unit of the apple, which is an endowment at date 1, can be used to produce A_j apple trees, or to buy $\frac{1}{p}$ trees, among which only productive trees produce consumption goods

[13] The presence of households will be useful to ensure that the first order condition of the information choice problem is well defined by ruling out the case in which the asset price is equal to 0.

of $\frac{1-\lambda^M}{p}$ at date 2. As long as the return from buying assets is greater than the return to investment, an entrepreneur supplies the entire liquidity he owns in exchange for assets traded in the market. Similarly, if the return to investment is higher than the cost from selling nonlemon assets, an entrepreneur sells the whole of nonlemon assets to finance his new productive investment project.

The wedge between the return from buying assets and the opportunity cost from selling nonlemon assets emerges if $\lambda^M > 0$. This occurs because of the asymmetric information on the quality of assets between buyers and sellers; each seller knows the quality of assets he sells in the market, while buyers cannot tell nonlemons apart from lemons. This implies that, from a buyer's perspective, each asset traded in the market is risky in the sense that it turns out to be lemons with uncertain probability λ^M. In contrast, from the perspective of a seller of a nonlemon, the asset he sells in the market is risk-free. As a consequence, if entrepreneur j's productivity falls between $\frac{1-\lambda^M}{p}$ and $\frac{1}{p}$, it is neither optimal for the entrepreneur to sell nonlemons nor to buy assets. In such a case, the entrepreneur j keeps his own legacy asset and invests his own liquidity to produce new assets with productivity A_j.

Before proceeding further, I present a simplifying assumption which is useful in the analysis. While deriving the solution to this problem seems to be quite complicated, the problem becomes tractable with the following assumption, without affecting the main qualitative results of our analysis.

Assumption 3 *(1) There are three kinds of investment technology,* A_L, A_H*, and* A_M*;*

(i) A_L *is sufficiently low such that entrepreneurs with* A_L *do not become sellers;*

(ii) A_H *is sufficiently high such that entrepreneurs with* A_H *always become sellers;*

(iii) Entrepreneurs with A_M *are marginal investors in the sense that their decisions depend on an asset price, but* A_M *is high enough such that they do not become buyers.*

(2) Legacy assets owned by only entrepreneurs with A_H *become lemon with probability* λ*.*

The detail of the parameter range that is a consistent with the assumption is provided in Appendix B. The presence of households, which are of measure h, implies that an asset price is always positive, which ensures that Assumption 3 is valid. Much intuition can be obtained with these three types.

The first part of the assumption states that there are three kinds of entrepreneurs. Since A_L is sufficiently low, selling non lemon assets to finance new investment projects is never profitable for entrepreneurs with A_L (low productive entrepreneurs). Therefore the low productive entrepreneurs actively seek to buy productive assets in the market as far as the return to the asset traded is expected to be higher than the return from investing their own resources with A_L. The low productive entrepreneurs represent the group of people who actively search for profitable assets traded in the market. Similarly, since A_H is sufficiently high, the group of entrepreneurs with A_H (high productive entrepreneurs) eager to look for liquidity to finance their promising investment projects. They need to sell one unit of the asset to obtain funds of p.

In between, there are marginal investors with A_M (medium productive entrepreneurs) whose decisions whether to sell or not hinge on the financial decisions of other entrepreneurs; if there are no entrepreneurs who buy assets in the market, the asset price plunges, in which case, the marginal investors do not sell their nonlemons; in contrast, if the asset price is high enough as asset demand reaches its maximum, they sell their nonlemons. Put differently, their financial decisions depend on the return of loans, $\frac{1}{p}$. I shall use, interchangeably, 'marginal investors,' and 'medium productive entrepreneurs.'

The second part of the assumption implies that only high productive entrepreneurs own and sell lemon assets at date 1.[14] This assumption allows us to simplify notation without affecting the substance of the results.

2.3.1.2 The Market Clearing Conditions

Next, I illustrate the determination of the market clearing price function $p(\lambda)$ and the other endogenous aggregate variables, λ^M. Let us denote a fraction of the low productive entrepreneurs who become buyers in the state λ by $\delta(\lambda)$, and a fraction of the marginal investors who become sellers by l_M.

The equilibrium proportion of lemons in the market, λ^M, is consistent with the optimal choice of each entrepreneur, and is given by

$$\lambda^M(\lambda; p(\lambda)) = \frac{\lambda N_H}{N_H + l_M(\lambda; p(\lambda)) N_M}, \tag{2.8}$$

[14] One interpretation is that investors may have better knowledge on the quality of projects and the current state of the economy.

where N_L, N_M and N_H denote the population of the low, medium and high productive entrepreneurs respectively: the total population of entrepreneurs is normalized to 1.[15] The numerator of (2.8) is the aggregate supply of lemons and the denominator is the sum of aggregate supply of lemons and nonlemons.

A market clearing asset price p in each state λ must satisfy

$$\frac{1}{p}[N_L\delta(\lambda)+h] = N_H + l_M N_M. \tag{2.9}$$

The left-hand side of equation (2.9) is the sum of the demand for assets by low productive entrepreneurs and households. The right-hand side is the sum of supply of lemon capital, λN_H, and nonlemon capital, $(1-\lambda)N_H + l_M N_M$ by the medium and high productive entrepreneurs.[16]

Then, $l_M(\lambda; p(\lambda))$ must satisfy the following condition in accord with the optimal decision rules at date 1 (Proposition 20):

$$l_M(\lambda; p(\lambda)) = \begin{cases} 1, & \text{if } p(\lambda) > \frac{1}{A_M}, \\ 0 \leq l_M(\lambda; p(\lambda)) \leq 1, & \text{if } p(\lambda) = \frac{1}{A_M}, \\ 0, & \text{if } p(\lambda) < \frac{1}{A_M}. \end{cases} \tag{2.10}$$

If the asset price is sufficiently high to satisfy $p > \frac{1}{A_M}$, all the marginal investors sell their entire nonlemon assets, whereas if the price is low enough, $p < \frac{1}{A_M}$, they hold their non lemon assets. If $A_M = \frac{1}{p}$, then they are indifferent and l_M is a value that clears the market.

2.3.1.3 The Optimal Information Choice

I next turn to the description of the information acquisition problem at date 0. Assumption 3 ensures that I will be able to focus on a case in which the low productive entrepreneurs acquire information on the underlying state, while the high and medium productive entrepreneurs optimally choose not to obtain any information on the state; Proposition

[15]The shape of l_M depends on a price belief $p^B(\lambda)$ as well as λ. In equilibrium, $p^B(\lambda) = p(\lambda)$.

[16]Note that, $d_i^L = \lambda_i$. Thus, the aggregate amount of lemons in the market, $\int d_i^L(s_i, A_i, \lambda_i, p)di$, is equal to λN_H. With a slight abuse of notation, I will use λ as the aggregate state variable instead of λN_H.

20 indicates that the financial decisions of sellers and keepers do not depend on the unknown state λ $-$ all relevant information that is needed to make optimal decisions for them is common knowledge. In contrast, knowing the current state λ is crucial for the low productive entrepreneurs to decide whether to buy assets or not.[17] Therefore, it suffices to illustrate the optimal information choice problem of the low productive entrepreneurs.

In the proposed framework, each low productive entrepreneur faces the binary choice problem of whether to buy assets or not. The following lemma is useful to simplify the problem further, which is the same as Lemma 1 of Woodford (2008).

Lemma 21 *The optimal structure of the information choice involves either signals that are completely uninformative; or only two possible signals,* $\{0,1\}$, *and a decision rule under which a low productive entrepreneur becomes a buyer if and only if the signal 1 is received.*

This lemma states that low productive entrepreneurs choose to receive either completely uninformative signals or a binary signal, and their decision rule is deterministic upon receiving a signal. Providing that a signal indicates which action is optimal, no more accurate information on the state is needed; finer information does not expand the set of optimal strategies, and it only increases the cost of information. In addition, the decision rule is nonrandom given a signal. If the entrepreneur received the signal s that makes him indifferent between the two actions (i.e., $A_L = \frac{1}{p}\int_{\lambda}[1-\lambda^M(\lambda)]f(s|\lambda)dF(\lambda))$, his decision would be random. In such a case, however, he can decrease information acquisition costs by choosing not to receive such signals without incurring any loss of utility.

Each entrepreneur acquires information privately and independently; none of the entrepreneurs can observe signals received by others. In addition, signals received by entrepreneurs are uncorrelated each other. This is because the objective of the entrepreneur does not directly depend on the decision of others; although others' information choices will affect the realized asset price at date 1, each entrepreneur takes beliefs about the future asset price as given. Therefore the law of large number applies; a fraction of the low productive entrepreneurs who become buyers, $\delta(\lambda)$ $-$ equivalently, the probability of being a buyer in state $\lambda -$ is equal to the conditional probability $f(s|\lambda)$ of receiving

[17] Note that, given price beliefs $p(\lambda)$, λ^M is the function of λ, as l_M is the function of λ. Agents correctly understand the model and therefore, knowing λ^M is equivalent to knowing λ.

the signal 1 in the state λ.[18] Then, the optimal information acquisition problem consists of choosing $\delta(\lambda)$ which maximizes the expected utility taking beliefs on the future asset price $p^B(\lambda)$ and the prior distribution $F(\lambda)$ as given.

$$\max_{\delta(\cdot)} J(\delta) - \theta I(\delta) \tag{2.11}$$

where

$$J(\delta) \equiv \int_\lambda [1 + \frac{1-\lambda^M(\lambda; p^B(\lambda))}{p^B(\lambda)}]\delta(\lambda) + (1+A_L)(1-\delta(\lambda))dF(\lambda); \tag{2.12}$$

$$I(\delta) = \int_\lambda \delta(\lambda)\log\delta(\lambda) + (1-\delta(\lambda))\log(1-\delta(\lambda))dF(\lambda) - \bar{\delta}\log\bar{\delta} - (1-\bar{\delta})\log(1-\bar{\delta}); \tag{2.13}$$

$$\bar{\delta} = \int_\lambda \delta(\lambda)dF(\lambda).$$

Note that $1+\frac{1-\lambda^M}{p}$ is the consumption of an entrepreneur who buys assets at date 2, and $1+A_j$ is the consumption of an entrepreneur with productivity A_j who neither buys nor sells. Then the opportunity costs of being a buyer in the state λ, equivalently the loss function, is given by

$$L(\lambda; p^B(\lambda)) \equiv \frac{1-\lambda^M(\lambda; p^B(\lambda))}{p^B(\lambda)} - A_L,$$

and the solution to (2.11) is equivalent to the one to the following problem:

$$\max_{\delta(\cdot)} \int_\lambda \delta(\lambda)L(\lambda; p^B(\lambda))dF(\lambda) - \theta I(\delta) \tag{2.14}$$

where $p^B(\lambda)$ and $F(\lambda)$ are given as common knowledge.

This problem can be solved using a similar method as shown in Woodford (2008). However, because the shape of the loss function $L(\lambda)$ depends on the beliefs $p^B(\lambda)$, further qualifications are required to have the complete set

[18] Subscript j is omitted since the low productive entrepreneurs are homogeneous at date 0. However, their decision at date 1 may be different if a signal is drawn from a stochastic process.

of necessary and sufficient conditions. I shall focus on an equilibrium in which beliefs about future asset prices are stable.

Proposition 22 *(Sufficient and Necessary Conditions) For each* λ, *let* $\delta^*(\lambda;\overline{\delta})$ *be the highest solution of (2.15) taking* $\overline{\delta}$ *as given:*

$$\frac{1-\lambda^M(\lambda;p(\lambda))}{p(\lambda)} - A_L = \theta[\log\frac{\delta^*(\lambda;\overline{\delta})}{1-\delta^*(\lambda;\delta)} - \log\frac{\overline{\delta}}{1-\delta}] \tag{2.15}$$

where $\lambda^M(\lambda;p(\lambda))$, $p(\lambda)$, *and* $l_M(\lambda;p(\lambda))$ *are consistent with (2.8), (2.9), and (2.10).*[19] *Then the information choice* $\delta^*(\lambda;\overline{\delta}^*)$ *is a stable equilibrium if and only if*

(i) $\overline{\delta}^* = J^*\left(\overline{\delta}^*\right)$ *where* $J^*\left(\overline{\delta}\right) \equiv \int \delta^*(\lambda;\overline{\delta})dF(\lambda)$;

(ii) If $\overline{\delta}^* > 0$, *then there exits* $\varepsilon > 0$ *such that* $J^*(\overline{\delta}) > \overline{\delta}$ *for all* $\overline{\delta} \in (\overline{\delta}^* - \varepsilon, \overline{\delta}^*)$. *If* $\overline{\delta}^* < 1$, *then there exits* $\varepsilon > 0$ *such that* $J^*(\overline{\delta}) < \overline{\delta}$ *for all* $\overline{\delta} \in (\overline{\delta}^*, \overline{\delta}^* + \varepsilon)$.

Equation (2.15) implies that the marginal benefit of being a buyer must be equal to the marginal information acquisition cost which is the product of the cost of acquiring an additional unit of information, θ, and the marginal quantity of information which is needed to become a buyer given $\overline{\delta}$. I suppose that the equilibrium price is given by the highest solution provided $\overline{\delta}$.[20] It implies that, given $\overline{\delta}$, there exists a unique belief about the future price function $p^*(\lambda;\overline{\delta})$ that is consistent with the market clearing condition (2.9). This notation will be useful in the remainder of this paper.

Condition (i) in the proposition states that an equilibrium $\overline{\delta}^*$ is a fixed point, although it does not guarantee that an information choice is optimal. Condition (ii) imposes the optimality of an information choice as well as the stability of beliefs about future asset prices on a fixed point. Because the stability issue arises when there are multiple fixed points, I will revisit this matter in Section 2.3.3.[21]

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[19] *In equilibrium,* $p^B(\lambda) = p(\lambda)$.

[20] Chari, Shourideh, and Zetlin-Jones (2011) and Kurlat (2013) adopt similar assumptions to determine an equilibrium asset price. Doing so, we can eliminate obvious bilateral gains from trade that are not being exploited when they form price expectations given expected liquidity δ. (Note that the highest price $p(\lambda;\overline{\delta})$ corresponds to the highest $\delta^*(\lambda;\overline{\delta})$. By equation (2.15), $\delta^*(\lambda;\overline{\delta})$ is increasing in $\frac{1-\lambda^M(\lambda,p(\lambda))}{p(\lambda)}$. Sellers also gain profits from a higher price.) Furthermore, our multiplicity result in Section 2.3.3 does not rely on this setup.

[21] Also, see the proof in Appendix A.

2.3.2 Existence

In the next two sections, I describe the existence and multiplicity of equilibria. The next proposition shows the existence of equilibria and characterizes the optimal information choice in special cases.

Proposition 23 *(Existence) There exists a fixed point $\overline{\delta}^*$ that satisfies the sufficient and necessary conditions for an equilibrium.*

Let Δ be a set of such equilibria, and E_θ be the θ adjusted expectation operator defined by $E_\theta[\lambda] \equiv Z^{-1}[\int_\lambda Z(\lambda)dF(\lambda)]$, with $Z(\lambda) \equiv \exp(\frac{\lambda}{\theta})$. Then,

(i) $\overline{\delta} = 0 \in \Delta$ if and only if

$$A_L \geq E_\theta[\frac{1-\lambda^M(\lambda; p^*(\lambda; \overline{\delta}=0))}{p^*(\lambda; \overline{\delta}=0)}]; \tag{2.16}$$

(ii) $\overline{\delta} = 1 \in \Delta$ if and only if

$$A_L \leq E_{-\theta}[\frac{1-\lambda^M(\lambda; p^*(\lambda; \overline{\delta}=1))}{p^*(\lambda; \overline{\delta}=1)}]; \tag{2.17}$$

and (iii) $\overline{\delta} \in \Delta$ such that $0 < \overline{\delta} < 1$ if

$$E_{-\theta}[\frac{1-\lambda^M(\lambda; p^*(\lambda; \overline{\delta}=1))}{p^*(\lambda; \delta=1)}] < A_L < E_\theta[\frac{1-\lambda^M(\lambda; p^*(\lambda; \overline{\delta}=0))}{p^*(\lambda; \delta=0)}]. \tag{2.18}$$

There are three important variables to focus on: fixed point $\overline{\delta}$, belief about the asset price $p^*(\lambda; \overline{\delta})$, and information cost adjusted expected returns, $E_\theta[\frac{1-\lambda^M(\lambda;p^*(\lambda;\overline{\delta}=0))}{p^*(\lambda;\overline{\delta}=0)}]$ and $E_{-\theta}[\frac{1-\lambda^M(\lambda;p^*(\lambda;\overline{\delta}=1))}{p^*(\lambda;\overline{\delta}=1)}]$. Those variables will be extensively used to characterize equilibrium in the remainder of the paper.

The first part of the proposition states that the case in which the low productive entrepreneurs become keepers surely $-$ $\overline{\delta} = 0 \Leftrightarrow \delta(\lambda) = 0$ almost surely $-$ is an equilibrium if and only if the returns from being a keeper, A_L, is equal or greater than the θ adjusted expected return from being a buyer taking $p^*(\lambda; \overline{\delta} = 0)$ as given. (Remember that $p^*(\lambda; \overline{\delta} = 0)$ is a unique equilibrium price function given $\overline{\delta} = 0$.) The second part indicates that the case in which the entrepreneurs become buyers surely $-$ $\overline{\delta} = 1 \Leftrightarrow \delta(\lambda) = 1$ almost surely $-$ is an equilibrium if and only if A_L is equal or less than the $-\theta$ adjusted expected returns from buying taking $p^*(\lambda; \overline{\delta} = 1)$ as given. The third part means that if neither buying nor keeping surely is justifiable in terms of the adjusted expected returns, there is an interior solution of $\overline{\delta}$, with which an optimal information choice of $\delta(\lambda)$ depends on λ.

It is worth mentioning that information is obtained if and only if an interior $\overline{\delta}$ is chosen, in which case the probability of the action depends on the state. In contrast, if either of the two polar cases, $\overline{\delta} = 0$ or $\overline{\delta} = 1$, is chosen as an equilibrium outcome, the action of the entrepreneur is independent of the state; in those cases, at date 0, the entrepreneurs predetermine their financial decisions at date 1; no information is obtained, and signals received, if any, are uninformative.

Let us call liquidity that is supplied by the entrepreneurs by private liquidity. Then $\overline{\delta}$ represents the measure of the expected amount of private liquidity available at date 1 from the viewpoint of date 0, and $\delta(\lambda;\overline{\delta})$ the corresponding measure of private liquidity in the state λ. $\overline{\delta} = 0$ describes the situation in which private liquidity reaches its minimum level, as there are no entrepreneurs who buy assets from other entrepreneurs who wish to sell their assets in the market. Similarly, private liquidity reaches its maximum level if $\overline{\delta} = 1$, as the entrepreneurs blindly provide their own liquidity without knowing actual λ.

To gain more intuitions from the expressions, let us consider the following example.

Example 1 *Assume that the prior distribution of λ is normally distributed with mean μ and variance σ^2. Then (2.16) and (2.17) become*

$$A_L \geq \frac{1-\lambda^M(\mu;p^*(\mu;\overline{\delta}=0))}{p^*(\mu;\overline{\delta}=0)} + \frac{1}{2}\frac{\sigma_0^2(\sigma)}{\theta} \tag{2.19}$$

and

$$A_L \leq \frac{1-\lambda^M(\mu;p^*(\mu;\overline{\delta}=1))}{p^*(\mu;\overline{\delta}=1)} - \frac{1}{2}\frac{\sigma_1^2(\sigma)}{\theta} \tag{2.20}$$

where $\frac{1-\lambda^M(\mu;p^*(\mu;\overline{\delta}))}{p^*(\mu;\overline{\delta})}$ is the expected return given $\overline{\delta}$; $\sigma_0^2(\sigma)$ and $\sigma_1^2(\sigma)$ are the variance of the corresponding asset return, both of which are increasing in σ^2. Then,

(i) for sufficiently large $\frac{\sigma^2}{\theta}$, the entrepreneurs do obtain information, i.e., $0 < \overline{\delta} < 0$;

(ii) if $A_L < \frac{1-\lambda^M(\mu;p^*(\mu;\overline{\delta}=1))}{p^*(\mu;\overline{\delta}=1)}$ or $A_L > \frac{1-\lambda^M(\mu;p^*(\mu;\overline{\delta}=0))}{p^*(\mu;\overline{\delta}=0)}$, then, for sufficiently small $\frac{\sigma^2}{\theta}$, there exists an equilibrium in which the entrepreneurs do not obtain any information.

The example shows that what kinds of the conditions are sufficient for the information acquisition. The adjustment terms in inequalities (2.19) and (2.20) indicate that information choices depend on the uncertainty σ^2 and the information cost θ, as well as the expected return in the two polar cases. For large enough $\frac{\sigma^2}{\theta}$, inequalities (2.19) and (2.20) are violated; information is obtained, for gains from obtaining information increase as economic uncertainty rises. In such a case, the entrepreneur's financial decision will be probabilistically tied to the state λ, and the disutility from the cost of information is greater than zero. This implies that the uncertainty σ^2 should not too high relative to information cost θ in order for information not to be acquired.

It is useful to further examine the two polar cases of the information cost parameter θ as described in the following proposition.

Proposition 24 *(i) If θ is arbitrarily close to zero, there exists a unique equilibrium which coincides with an equilibrium with the rational expectation of λ: there exist $\overline{\lambda}^1$ and $\overline{\lambda}^2$ such that $\delta(\lambda) = 1$ for $\lambda < \overline{\lambda}^1$, $\delta(\lambda) = 0$ for $\lambda > \overline{\lambda}^2$, and $0 \leq \delta(\lambda) \leq 1$ for $\overline{\lambda}^1 \leq \lambda \leq \overline{\lambda}^2$; (ii) As θ goes to infinity, $J(\overline{\delta})$ converges to $\overline{\delta}$ for any $0 \leq \overline{\delta} \leq 1$.*

In the absence of information costs, the entrepreneurs receives a precise signal on the current state, which leads them to be perfectly informed on λ and brings a correct decision from their perspective; their decision is deterministic with respect to the state λ unless they are indifferent between the two choices, which occurs for $\overline{\lambda}^1 \leq \lambda \leq \overline{\lambda}^2$.

If θ is arbitrarily large, a signal becomes uninformative on the current state λ as the entrepreneur acquires less and less information; the entropy of the posterior distribution given a signal converges to the one of the prior distribution. As a result, even if $0 < \overline{\delta} < 1$ is chosen as an equilibrium in the limit, it does not necessarily imply that information is obtained. In such a case, their decision is purely random in the sense that they become a buyer with probability $\overline{\delta}$ regardless of the state λ. This occurs because they are indifferent between the two actions, in which case the expected return from each action evaluated using the prior distribution is equalized.[22]

Figure 2.2 shows an example of the shape of the function $J(\overline{\delta})$ for alternative values of θ. As shown in the figure, the vertical shape of the function $J(\overline{\delta})$ converges to the 45-degree line as θ becomes larger. Equilibrium fixed points

[22] It does not necessarily imply that any $0 \leq \overline{\delta} \leq 1$ can be an equilibrium as θ converges to infinity. If $\overline{\delta}$ is an equilibrium, it must still satisfy the conditions in Proposition 22 for arbitrarily large $\theta > 0$.

are marked with arrows. For instance, in the case $\theta = 0.001$, although there are three kinds of fixed points (the two corner points - $\bar{\delta} = 0, 1$ - and the interior one, $0 < \bar{\delta}^I < 1$), only the interior point $\bar{\delta}^I$ is a market equilibrium; the two corner points do not satisfy the condition (ii) in Proposition 22.[23] Note that there is the unique equilibrium price function $p^*(\lambda; \bar{\delta}^I)$ associated with $\bar{\delta}^I$. Once $p^*(\lambda; \bar{\delta}^I)$ is considered to be given as the beliefs about the future price when making an information choice, $\bar{\delta}^I$ is indeed the unique optimal information choice.[24] However, this market equilibrium is not necessarily efficient. I will discuss whether a market equilibrium can be improved upon in Section 2.4.

In this figure, there is no other equilibrium; there are no other beliefs about prices that are consistent with an equilibrium, and thus stability issues do not arise. In general, however, that is not necessarily true. In the next section, I examine the case in which there are multiple equilibria.

2.3.3 Multiplicity

Multiple equilibria would emerge if there are multiple fixed points, $\bar{\delta} = J^*(\bar{\delta})$, which are consistent with the equilibrium conditions.[25] For instance, one observes that in Example 1, if $\frac{1-\lambda^M(\mu; p^*(\mu; \bar{\delta}=0))}{p^*(\mu; \bar{\delta}=0)} < A_L < \frac{1-\lambda^M(\mu; p^*(\mu; \bar{\delta}=1))}{p^*(\mu; \bar{\delta}=1)}$, then, for sufficiently large θ, there are at least the two corner solutions, $\bar{\delta} = 0$ and $\bar{\delta} = 1$.

Corollary 25 *(Multiplicity) There may exist multiple equilibria.*

Figure 2.3 describes a case in which multiple equilibria exist. In this figure, there are two stable equilibria, $\bar{\delta}^1 = 1$ and $0 < \bar{\delta}^2 < 1$, which are indicated by arrows, and one unstable equilibrium, $0 < \bar{\delta}^3 < 1$, which is indicated by dots. One observes that only stable equilibria satisfy the condition (ii) in Proposition 22.[26]

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[23] Those corner points are merely critical points of the objective. For instance, $p^*(\lambda; \bar{\delta} = 1)$ cannot be an equilibrium, because even if $p^*(\lambda; \bar{\delta} = 1)$ is taken as given when making an information choice, the entrepreneur will not choose $\bar{\delta} = 1$, as it is not even a local maximum. For further discussion, see the proof of Proposition 22.

[24] See also Lemma A.1 in Appendix A.

[25] Yang (2013) also shows that multiplicity may arise with the flexible information acquisition mechanism in a different context. In his framework, multiple equilibria may occur with strong coordination motives, as strategic complementarity is the main concern.

[26] Higher $\bar{\delta}$ implies that higher expected private liquidity available at date 1.

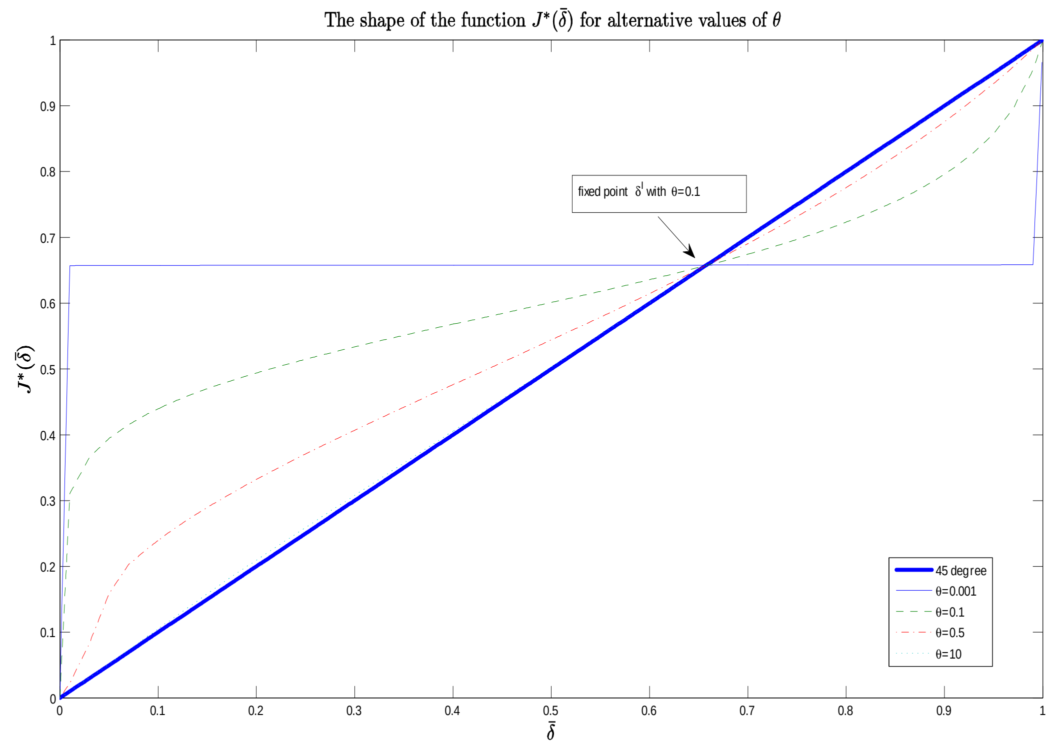

Figure 2.2: The shape of the function $J^*(\overline{\delta})$

Nevertheless, it does not imply that the entrepreneurs are able to choose whatever equilibrium they wish to reach. This figure should be interpreted with caution. When $J^*(\overline{\delta})$ is computed to seek an equilibrium asset price function, one substitutes all those market clearing conditions into equation (2.15) to solve for $\delta^*(\lambda;\overline{\delta})$. In so doing, one associates each $\overline{\delta}$ with a unique corresponding $p^*(\lambda;\overline{\delta})$ ($p^*(\lambda;\overline{\delta})$ is non-decreasing in the expected private liquidity $\overline{\delta}$); the shape of the loss function depends on $p^*(\lambda;\overline{\delta})$ and thereby $\overline{\delta}$ itself.[27] It implies that there may be multiple equilibrium fixed points, each of which is associated with a unique equilibrium belief about the future asset price.[28]

However, when the entrepreneurs choose information, they do not take into account the general equilibrium impact of their information choices on the asset price; as they take the common beliefs $p^B(\lambda)$ as given. As a consequence, one can show that there exists a unique optimal information choice once $p^B(\lambda)$ is taken as given.[29] What kinds of beliefs about future asset prices agents share in their mind determine which equilibrium will be selected, for different beliefs can bring about different information choices.

Note that $\overline{\delta}^3$ can be the unstable equilibrium. However, a small disturbance to the beliefs on the expected liquidity $\overline{\delta}^3$ (equivalently, a disturbance to the belief $p^*(\lambda;\overline{\delta}^3)$) causes further divergence from that point as shown in the figure. This procedure can be interpreted as follows. Suppose a small positive disturbance to the expected liquidity, $\varepsilon > 0$, occurs. This raises the expected asset price among agents to $p^*(\lambda;\overline{\delta}^3+\varepsilon)$, which leads them to choose $\delta^*(\lambda;\overline{\delta}+\varepsilon)$. However, because $\overline{\delta}+\varepsilon < J^*(\overline{\delta}+\varepsilon)$, their beliefs on the expected liquidity need to be revised further upward until it reaches the stable equilibrium $\overline{\delta}^1$. Therefore, I shall focus on an equilibrium in which the stability condition is satisfied.

One natural question is why such multiple equilibria emerge in some cases. To examine this question, let us consider the two stable equilibria, $\overline{\delta}^1 = 1$ and $0 < \overline{\delta}^2 < 1$. In the case $\overline{\delta}^1 = 1$ where the equilibrium price belief is given by the highest one in all possible states, $p^*(\lambda;\overline{\delta}^1) = p^H$, the entrepreneurs anticipate that the high asset price will induce marginal investors to sell their nonlemons in the market, which leads to the improvement of the quality of the

[27] See also Proposition 22 in Appendix A.

[28] In Woodford (2008), there must be a unique equilibrium choice of information. The reason for this difference is that the loss function here is a function of $\overline{\delta}$ as well as λ.

[29] See Lemma A.1 in Appendix A.

assets traded.[30] With the anticipation of the high quality of the assets traded, the low productive entrepreneurs do not obtain any information and become buyers surely. At date 1, the marginal investors do sell in the market facing such a high asset price caused by high demand, which is consistent with the anticipation by the low productive entrepreneurs at date 0. As a result, the equilibrium $\overline{\delta}^1 = 1$ will be indeed realized, in which private liquidity is maximized.

Likewise, in the case that $0 < \overline{\delta}^2 < 1$, the expected asset price, equivalently asset demand, is not high enough in some states to induce some marginal investors to sell; the low productive entrepreneurs anticipate the deterioration of the quality of the assets traded in some states. Compared to the case $\overline{\delta}^1 = 1$, such relatively low expected demand not only decreases the expected asset return, but also increases the dispersion of the return, which increases benefits of information acquisition as shown in Example 1. At date 1, in some states, the marginal investors are discouraged from selling by low asset demand as some entrepreneurs acquire negative information on λ and leave the market; the beliefs $p^*(\lambda;\overline{\delta}^2)$ turn out to be correct.

An important question is whether a policymaker can induce a desirable equilibrium if one equilibrium is more efficient than the others, and what kinds of policy instruments are useful to achieve this goal if that is possible. I will examine this question in Section 2.4.3.

2.3.4 Properties of Equilibrium

This section presents some positive results of the model, showing the relation between relevant model parameters and endogenous variables in equilibrium. The next proposition provides the description of the economy in response to changes in the state variable λ.

Proposition 26 *The price of legacy assets p, the fraction l_M of marginal investors who sell their nonlemons in the market, and private liquidity (equivalently, the probability $\delta(\lambda)$ of becoming a buyer) are non-increasing in the fraction λ of lemons.*

In the state where λ is large, buying trees is unattractive, for the return to a buyer $\frac{1-\lambda^M}{p}$ decreases as more lemons are likely to be sold in the market. The entrepreneurs choose information so as to receive the signal 0 (becomes a

[30] Since the asset price is non-decreasing in demand, $\delta(\lambda)$, the equilibrium asset price is maximized when $\delta(\lambda) = 1$.

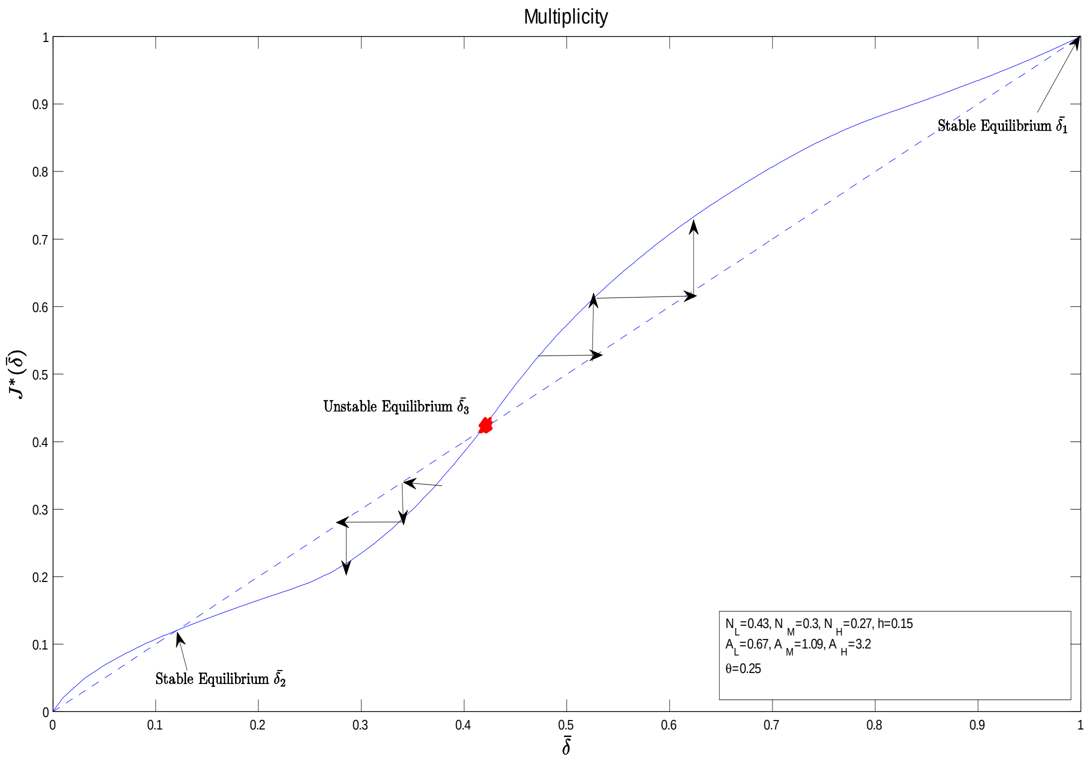

Figure 2.3: Multiplicity

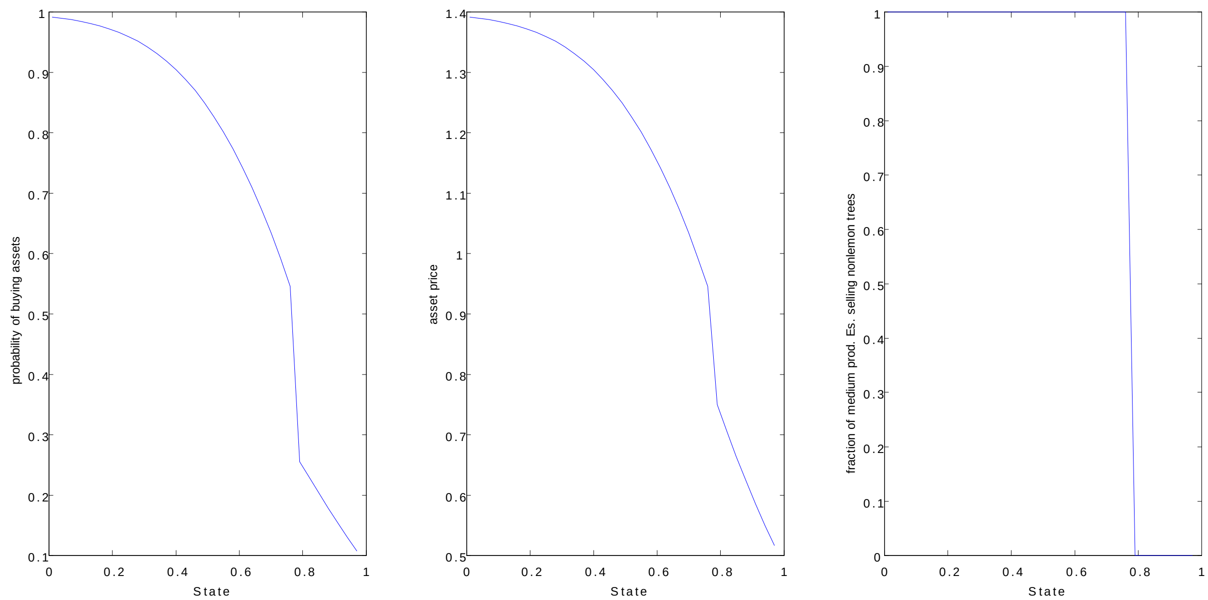

Figure 2.4: Endogenous responses to λ

keeper) with high probability in the state where λ is large. The price of legacy assets decreases as demand falls, but not to the extent that the lower price causes $\frac{1-\lambda^M}{p}$ to be increased. The low asset price is particularly unattractive to the marginal investors and therefore, a smaller number of them sell nonlemons as λ increases. Figure 2.4 plots the equilibrium behavior of the endogenous variables for alternative values of λ. The sensitivity of the endogenous variables to the state λ is especially high around $\lambda = 3/4$, where the return to a keeper becomes larger than the return to a buyer.

Proposition 27 *(Endogenous Productivity) The aggregate investment productivity, which is the ratio of the aggregate new capital produced to the aggregate investment, is increasing in the amount of private market liquidity.*

The aggregate investment productivity is endogenous in our framework. The aggregate investment productivity rises as more liquidity is reallocated from the lower to the higher productive entrepreneurs. Lower λ increases asset demand, which raises the price of legacy assets. The higher productive entrepreneurs receive more liquidity as a return to the provision of the legacy assets. As a result, the low productive entrepreneurs invest less while the high productive entrepreneurs invest more.[31]

In addition, fluctuations in investor sentiment can drive aggregate investment productivity fluctuations in our framework. Note that the subjective prior distribution of λ needs not necessarily to coincide with the objective distribution of λ. If potential buyers of assets believe that a bad state (high λ) is likely to happen with high probability so that condition (2.17) is satisfied, then there will no entrepreneurs who are willing to buy assets in the market. Private market liquidity reaches its minimum level and no capital reallocation among entrepreneurs occurs. As a consequence, the aggregate investment productivity is low.

The next proposition shows how changes in the parameters regarding investment productivity affect available private liquidity in the market.

Proposition 28 *(i) (Investment productivity shock to Marginal investors) Decreases in A_M lead to lower private liquidity for all λ; (ii) (Change in the distribution of Investment productivity) Suppose investment productivity of some high productive entrepreneurs who hold nonlemon assets decreases from A_H to A_M. Then private market liquidity decreases in all states λ.*

As the productivity of the marginal investors decreases, the decisions of the marginal investors become more sensitive to the asset price. They tend to keep nonlemons rather than selling them as the return to investment declines. It deteriorates the quality of assets traded in the market, which reduces the return to a buyer. The low productive entrepreneurs take this effect into account when they choose information. As a result, for all states, they are more likely to stay out of the market. Likewise, suppose that the productivity of some of the high productive entrepreneurs decreases to A_M as in Proposition 28-(ii). There are two effects which reduces the return to a buyer. First, this negatively affects the quality of assets traded in the market as the medium productive entrepreneurs are more likely to stay out of the market depending on the asset price level. Second, as supply of assets decreases, the asset price rises, which further reduces the return to a buyer. Therefore, the provision of private liquidity responds negatively in response to this type of shock.

[31] This is consistent with the empirical evidence presented by Eisfeldt and Rampini (2006). Their main question is why the trading volume of capital is high when the dispersion of the productivity is low.

2.3.5 Application to the MBS markets

Our framework is particularly applicable to the financial markets like the MBS markets, where securitized bonds are traded. There is the obvious possibility of adverse selection in such markets, as it is difficult to observe the quality of a pool of underlying loans that serve as collateral for securities; the cost of information acquisition, θ, is presumably very high in such markets. In contrast, the U.S. treasuries market can be understood as the market where adverse selection is almost non-existent; λ and θ are close to zero.

It is worth noting that there are important differences between those markets regarding the provision of private liquidity in response to exogenous shocks that affect the prior expected asset return. From Example 1, it can be easily seen that, as the cost of information θ converges to zero, information is necessarily obtained, and economic decisions are based upon fundamentals; the prior over λ plays a negligible role in economic outcomes. In contrast, as θ increases, the relative magnitude of the prior expected asset return becomes larger than the augmented term; economic outcomes are likely to be determined by the prior expected asset return rather than they are tied to current economic fundamentals, which leads to the following observation.

Observation 1 *As $\theta \to \infty$, economic outcomes are likely to be untied to fundamentals, but to be determined by prior beliefs.*[32]

Furthermore, notice that an expected asset price plays a crucial role in calculating the prior expected asset returns. It implies that if θ is large, any exogenous shocks that affect an asset price can have significant consequences in information acquisition incentive; financial decisions whether to buy assets or not become more sensitive to an asset price as θ increases.[33] For example, since it can be much more costly to acquire information on the quality of MBS than U.S. treasury bonds, the financial decisions of participants in the MBS markets can be relatively overly reactive to a change in the asset price. This leads to the following observation.

Observation 2 *Relatively small changes in an asset price in the MBS markets can lead to large fluctuations in the*

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[32] *Note that prior beliefs over λ is a key part in evaluating the prior expected asset returns.*

[33] Government interventions can induce a wedge between an asset price and private valuation of the asset. See Section 2.4.

provision of private liquidity.

Investment productivity shocks that deteriorate the quality of underlying assets also cause fluctuations in asset returns.[34] This implies that if the information cost θ is larger, private liquidity provision is more sensitive to the exogenous productivity shocks.

2.4 Policy Analysis

I next turn to the analysis of the normative properties of the model. I will define a notion of constrained efficiency in the context of our framework. Then I will explore the optimal policy interventions when a market outcome is inefficient.

2.4.1 Constrained efficiency

Although agents are ex post heterogeneous, they are identical ex ante. Let us define the welfare objective of a social planner as ex ante expected utility.

$$W = \int_\lambda \int_i c_i(\lambda) di dF(\lambda) \tag{2.21}$$

This welfare objective can be also regarded as a utilitarian aggregator of individual utility.[35]

Because of the linear preferences in consumption, the efficient distribution of consumption is indeterminate. However, maximizing the welfare objective amounts to maximizing the expected aggregate output in our environment. This implies that once the social planner finds a strategy that maximizes aggregate output, she can redistribute the wealth among agents by levying lump-sum taxes, which can lead to a pareto improvement.

A feasible allocation must satisfy the resource constraints.

$$\int_i c_i(\lambda) di \leq 1 + h - \lambda N_H + \int_i A_i i(s_i, A_i, \lambda_i) di - (1+r)D \tag{2.22}$$

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[34] See Proposition 28.

[35] Although this objective does not incorporate information costs, our results are robust to the alternative setup. Efficient allocation and optimal interventions minimize information costs to zero.

$$\int_i i(s_i, A_i, \lambda_i)di \leq 1 + h + D \tag{2.23}$$

Inequality (2.22) represents the aggregate resource constraint. The first part of the righthand side, $1+h-\lambda N_H$, amounts to dividends from the legacy assets. The second part, $\int A_i i_i(s_j, A_j, \lambda_j)di$, represents dividends from the assets newly produced. $D \geq 0$ is liquidity provided by the government at date 1 in addition to private liquidity, $1+h$. Unlike the private sector, the government can pledge future outputs from new investment in the economy to obtain funds from outside capital markets; D is financed by a government deficit at date 1 and is repaid by levying lump-sum taxes at date 2. r is a shadow cost of public funds the government faces at the payback period of a deficit. Inequality (2.23) states that the aggregate investment must be less than the aggregate liquidity available at date 1, which is the sum of private and public liquidity.

If the social planner can tell entrepreneurs apart by investment productivity and collect all existing liquidity available in the economy from the entrepreneurs, it is clear that the planner can improve upon a market equilibrium and achieve the first-best allocation by transfering all liquidity to the most productive entrepreneurs.[36] However, the implementation of this policy is probably infeasible. Investment productivity as well as the type of a tree is private information in our environment. The planner may not have better knowledge than participants in a market transaction. In addition, it seems implausible that the planner can forfeit such a large scale of private property.

Therefore I consider a notion of constrained efficiency where the fictitious planner is constrained in the sense that she is not allowed to directly transfer liquidity among entrepreneurs, because she does not have any better knowledge than the private sector. The fictitious planner can dictate to each entrepreneur how to acquire and use information to the extent that such dictates are consistent with the individual decision rules that are given by Proposition 20, (2.8), (2.9) and (2.10)[37]; the planner must not only satisfy the aggregate resource constraints, but must also respect the optimal private sector decision rules given individual information, s_j, A_j, and λ_j. This implies that the planner should rely on the market mechanism to redistribute liquidity held by entrepreneurs. Once $\delta(\lambda)$ is chosen, the planner lets

[36] Such allocation coincides with the one where information is perfect and borrowing is unconstrained.

[37] The planner may need resources to implement her choice of $\delta(\lambda)$. Since the planner can pledge resources that will be available at date 2, she borrows if needed.

entrepreneurs trade freely in the market, but entrepreneurs' actions are consistent with the planner's choice of $\delta(\lambda)$ as well as their optimal decision rules given the private information. This notion of constrained efficiency serves to identify the best way of obtaining and using information if entrepreneurs were to internalize the impact of their information choice on the others' utility, while their decisions are solely based on their own information.

Definition 4 *(Constrained efficient allocation) An efficient allocation is a collection of an information choice $\delta(\lambda)$, an asset price $p(\lambda)$, consumption $c(\lambda)$, investment $i(s,A,\lambda)$, and public liquidity D that maximizes (2.21) subject to the resource constraints (2.22) and (2.23), and the private sector behavior that is given by Proposition 20, (2.8), (2.9) and (2.10).*

The government buys assets from the market, if any, at the same price as the private sector does. An equilibrium asset price with government assets purchases is given by $p = \frac{\int_i b(s_i,A_i,\lambda_i)di+h+D}{\int d_i^{NL}(s_i,A_i,\lambda_i)di+\int d_i^{L}(s_i,A_i,\lambda_i)di}$. The numerator is liquidity provision by the private and public sector. The denominator is the total asset supply, which is the sum of nonlemons and lemons.

In general, an optimal choice of public liquidity D depends on production technology and investment productivity A_j. I will focus on the parametric case in which the optimal public liquidity, D, is equal to 0.[38] This setting is without loss of generality, because in another parameteric case in which the optimal D is greater than 0, one can show that the efficient allocation in such a case is an affine transformation of the efficient allocation in which the optimal D equals 0.

The main question is whether the fictitious planner can improve upon the market allocation by commanding a different information choice while respecting all budget, resource constraints, and letting entrepreneurs trade freely in the asset market.

[38]For example, one can assume that production capacity is constrained in that the average productivity is less than the cost of public funds, $1+r$ if the scale of investment is larger than some threshold. The assumption on entrepreneurs' production capacity that is consistent with the above case, along with general cases, is provided in Appendix B.

Proposition 29 *(Constrained efficient allocation) The efficient allocation is unique and is given by*

$$\delta(\lambda) = 1 \text{ almost surely}, \tag{2.24}$$

$$i(s, A_j, \lambda_j) = \begin{cases} 0 & \text{for all } A_j = A_L, \\ 1 + p^*(\lambda; \overline{\delta} = 1) \equiv 1 + p^{\max} & \text{for all } A_j = A_H, A_M. \end{cases} \tag{2.25}$$

Only the marginal investors and high productive entrepreneurs invest, which implies that the entire liquidity held by the low productive entrepreneurs is transferred to the more productive entrepreneurs. The expected aggregate investment and consumption are given by

$$I = [A_M N_M + A_H N_H](1 + p^{\max}) \tag{2.26}$$

$$W = \int_\lambda 1 - \lambda N_H + [A_M N_M + A_H N_H](1 + p^{\max}) dF(\lambda). \tag{2.27}$$

Note that if allocation is efficient, there are no keepers in the economy: entrepreneurs either sell or buy without any information acquisition.[39] This principle is also stated in Ordonez and Gorton (2013): "Opacity can dominate transparency and the economy can enjoy a blissful ignorance." The following proposition shows whether a market equilibrium allocation of the economy with the different degree of information opacity is constrained efficient.

Proposition 30 *(i) (Asymmetric information, but perfect information on the aggregate state) Suppose that the quality of each asset traded in the market is unknown but the aggregate state λ is common knowledge among agents. A market outcome may be constrained inefficient.*

(ii) (Asymmetric information, but perfect information on the aggregate state with appropriate subsidies) There exists a transaction subsidy π such that a market outcome is constrained efficient.

(iii) (Asymmetric information, and imperfect information on the aggregate state) A market outcome may be constrained inefficient.

In the case (i), a market equilibrium is inefficient in the state in which $A_L > \frac{1-\lambda^M(\lambda;p)}{p}$ as the low productive

[39] The constrained efficient allocation coincides with the second best allocation in which the only friction is that the planner cannot observe the types A_H and A_M : only individual decision rules of those types are binding.

entrepreneurs become keepers, $\delta(\lambda) = 0$. The case (ii) describes the situation in which the government knows the aggregate state λ and can subsidize buyers of assets by π for each transaction. It can be shown that there exists a subsidy π and a lump sum tax T such that a market outcome is constrained efficient (Kurlat 2013).

However, the main concern in this paper is that buyers have imperfect knowledge on the aggregate state λ and it is costly to obtain information about the unknown state λ, in which case private market liquidity may be inefficiently low. In the case (iii), lemons are traded in the market, as buyers cannot distinguish nonlemons from lemons traded. Since the presence of lemons lowers the return to assets traded, each of the potential buyers may wish to acquire private information on the state λ to make a decision whether to buy assets or not. Some of them would not buy assets if they expect a large fraction of assets traded is lemon given their own private information on the aggregate state. To put it differently, there may exist the low productive entrepreneurs who do not provide their liquidity to the other more productive entrepreneurs. Efficiency is achieved only if the low productive entrepreneurs transfer their liquidity to the more productive entrepreneurs with probability 1 regardless of the state, i.e., $\overline{\delta} = 1$ (full private liquidity equilibrium). This implies that, when there exist multiple equilibria, none of them are efficient other than the full private liquidity equilibrium.

Even though both allocation that is described in the case (i) and the case (iii) can be constrained inefficient, the source of inefficiency is quite different. In the case (i) where agents have rational expectation regarding λ, inefficiency arises only in the states in which λ is sufficiently large. The asset market collapses in such states, as the low productive entrepreneurs rationally expect that buying assets from the market will be unprofitable. In the case (iii), inefficiency is not driven by the underlying state: it is driven by an individual information choice. For instance, even if small enough λ is realized, once acquiring information on the aggregate state λ, there are always some entrepreneurs who obtain incorrect information due to the limited information production capacity. As a result, there is an insufficient amount of liquidity in the market in all states, which is a contrast to the case (i). Efficiency can be achieved only if the low productive entrepreneurs do not obtain any information, and transfer their entire liquidity to the more productive entrepreneurs in all possible states λ.

In the next section, I will discuss what kinds of policies are useful to improve economic welfare if the government does not have better knowledge than the private sector.

2.4.2 Feasible Interventions

The preceding analysis suggests that policies aimed at increasing market liquidity may achieve efficiency. In the recent financial disruption, a set of the targeted asset purchases is particularly aimed at enhancing liquidity in private securities markets (Reis 2009b). Before proceeding to the evaluation of the efficacy of such government interventions, it is worth discussing which kinds of government interventions have this property.

There are a variety of polices that may introduce a wedge between the asset price with government intervention and the underlying private valuations of the asset. Such policies include transaction subsidies, asset purchases and loss insurance. As for transaction subsidies, it is practically difficult to implement because the government must have knowledge on the current state λ in order to determine the appropriate amount of subsidy.[40]

Instead, I will consider more practical instruments such as asset purchases and loss insurance. Asset purchases can be understood as a policy that aims to raise the asset price and thus subsidizes sellers and taxes buyers indirectly. On the contrary, loss insurance subsidizes buyer directly against default risk, and it subsidizes sellers indirectly because the asset price rises as demand increases. Those policies are more realistic from the perspective of informational feasibility, not to mention that those have been adopted by policymakers in the real world.

In the implementation of such instruments, the government is assumed not to have better knowledge than the private sector: the quality of each asset traded as well as the current state λ at date 1 is unknown to the government. However, it becomes common knowledge at date 2, for agents can figure out which assets turn out to be lemon. Investment productivity is private information as well at date 1. However, each entrepreneur's choice made at date 1 reveals his productivity type once the market clears.

To obtain public funds which are needed to implement such policies, I suppose the government can pledge economic resources that will be available only in the future in order to borrow from outside capital markets. Unlike the private sector, the government can exercise its taxation power to pay its debt back; the government is able to borrow without such severe collateral requirements, which are imposed on the private sector.

[40] Also, as Kurlat (2013) noted, the same people can trade the same project several times back and forth and collect the subsidy from each transaction. In order to prevent such a subsidy collecting activity, the government needs to keep tracking of transaction records, and purchases from an original owner need to be solely subsidized, which is a difficult task.

The previous analysis shows that there may exist multiple equilibria with imperfect information on the state λ. In the following section, I will investigate whether the policymaker can induce a desirable equilibrium among multiple equilibria if one of them is more efficient than the others, and what kinds of policy instruments can be used to accomplish this goal.

The reader who is mainly interested in optimal interventions may skip section 2.4.3 without serious loss of continuity. In section 2.4.4, I discuss how policymakers can achieve the constrained efficient allocation.

2.4.3 Can Policymakers Choose a Desirable Equilibrium?

The important question which is investigated in this section is whether a simple public announcement by the policymaker can lead to a desirable equilibrium among multiple equilibria.

More specifically, let us consider the following strategy as a potential way to achieve this goal. At the beginning of date 0, the policymaker uses the model to solve for all possible equilibria given the private sector's prior beliefs over states. Suppose $\bar{\delta}^*$ is the most desirable equilibrium among such equilibria. The policymaker computes the asset price $p(\lambda;\bar{\delta}^*)$ for each state λ, which is an equilibrium asset price if $\bar{\delta}^*$ were chosen by the private sector. Then the policymaker announces that she will intervene in the asset market to implement the asset price target $p(\lambda;\bar{\delta}^*)$, as far as an market equilibrium asset price is not equal to the asset price target. To fulfil her promise, she purchases or sells assets in the market at date 1, if needed, to manipulate the asset price.

The effectiveness of the public announcement depends on its ability to alter the private sector's expectation of the asset price. It is useful to consider two cases separately to address this question: case (i) a set of multiple equilibria involves the efficient equilibrium, $\bar{\delta} = 1$, and case (ii) a set of multiple equilibria does not involve the efficient allocation. I will show that in the case (ii), the public announcement is less likely to be effective than the case (i).

2.4.3.0.1 Case (i): Note that if $\bar{\delta}^* = 1$ were chosen by the private sector, the private sector's financial decision does not depend on the current state λ. This implies that the asset price target $p(\lambda;\bar{\delta}^* = 1)$ is *independent* of the state variable λ, i.e., $p(\lambda;\bar{\delta}^* = 1) = p^{\max}$ for all λ[41]; the policymaker is not required to have knowledge on λ at date 1 to implement the policy $p^{\max}$.[42] If the private sector is convinced that the policymaker will fulfil her promise, this policy changes the private sector's beliefs about the future asset price at date 0; the private sector takes $p^{\max}$ as the future asset price when it makes an information choice. Since this expectation of the asset price is self-fulfilling, the policymaker actually does not need to intervene in the market at date 1; the commitment to the price target p^* improves the social welfare, while it does not incur any costs for the policymaker. Therefore, the public announcement is effective to achieve its goal in this case.

2.4.3.0.2 Case (ii): Note that if $0 < \bar{\delta}^* < 1$ were chosen, the private sector's action depends on λ as information is obtained; the asset price target $p(\lambda;\bar{\delta}^*)$ is *dependent* on λ, i.e., $p(\lambda^1;\bar{\delta}^*) \neq p(\lambda^2;\bar{\delta}^*)$ for some $\lambda^1 \neq \lambda^2$. As a consequence, unless the policymaker has perfect knowledge on the current state, the policymaker cannot precisely achieve the announced target $p(\lambda;\bar{\delta}^*)$ at date 1. Even though the policymaker announces $p(\lambda;\bar{\delta}^*)$ as the target asset price, it would not be credible to the private sector as far as the policymaker has imperfect knowledge on λ; the private sector's expectation of the asset price is unlikely to coincide precisely with the announced target price.

Although such a public announcement is most effective in the case that the asset price target does not require any knowledge on λ, the policymaker may change the private sector's expectation of the asset price regardless in an attempt to induce a better equilibrium. For instance, suppose the policymaker receives a noisy signal s^G on the current state λ, and intervenes with her own estimate on λ, $E[\lambda|s^G]$ where s^G is drawn from the conditional distribution $F(s^G|\lambda)$. Denote the asset price target by $p^T(\lambda)$. Then, the asset price with the intervention in the state λ given s^G is $p(\lambda, s^G) = p^T(E[\lambda|s^G])$. Note that unless the policymaker's estimate is unbiased, the asset price will not match precisely with the announced target price, $p(\lambda, s^G) \neq p^T(\lambda)$.

In such a case, as far as the policymaker's commitment is credible, the private sector takes $p(\lambda, s^G)$, instead of

[41] Even if we generalize Assumption 3-(2) so that legacy assets belong to all types of entrepreneurs become lemon with some probability, $p(\lambda;\bar{\delta}^* = 1)$ can still be independent of λ as long as only more productive investors have a technology that detects lemon assets among their own legacy assets. Otherwise, aggregate asset supply may be dependent on λ, while the aggregate demand remains independent of λ. In such a case, the goal of policymakers can be stated in terms of the target aggregate asset demand.

[42] It is feasible for the government to achieve the asset price target, as government demand induce a wedge between private valuation and actual asset price. In addition, since the asset price target does not require the government to have better knowledge than the private sector has, the government can make a credible announcement in this regard.

$p^T(\lambda)$, as given when making an information choice. Unless $p(\lambda, s^G) \neq p^T(\lambda)$, the private sector's belief $p(\lambda, s^G)$ is not consistent with the initial equilibrium conditions, in which case, the policymaker must intervene at date 1 to restore equilibrium. This incurs some intervention costs, which can be increasing in the estimate bias, $|p(\lambda, s^G) - p^T(\lambda)|$; imprecise knowledge on the current state may incur large intervention costs for the policymaker. Therefore, the public announcement is less likely to be effective if the policymaker has less precise information on the current state. Notice that the volatility of the asset price in each state λ can be increasing in the variance of s^G; the government intervention with the imprecise knowledge on the current state may lead to economic unstability.

2.4.4 Optimal Interventions

In this section, I explore the efficacy of government interventions that can be used to remedy a market failure. I will show that the optimal intervention achieves the constrained social optimum without requiring the government to have any superior wisdom on the current state than the private sector.

The preceding analysis shows that if the efficient equilibrium belongs to a set of multiple equilibria, the credible announcement by the policymaker can induce the efficient equilibrium without incurring any intervention costs. Therefore, in this section I assume that a set of possible market equilibria does not involve the efficient allocation so as to provide scope for government interventions.

First, let us consider the government's strategy of loss insurance as follows. At the beginning of period 0, the government introduces loss insurance to cover lemons that will be traded in the market.[43] Buyers of assets are guaranteed to receive $\kappa^G(\lambda)$ consumption goods at date 2 for each asset they bought in the state λ at date 1. With the loss insurance $\kappa^G(\lambda)$, the buyers are only liable to $\lambda^M(\lambda) - \kappa^G(\lambda)$ fraction of lemons. At date 2, the information on λ becomes common knowledge as each agent figures out which asset turns out to be lemon, and the buyers receive $\kappa^G(\lambda)$ consumption goods for each asset they bought as promised by the government. The cost of the program is financed with lump sum taxes on entrepreneurs at date 2.

[43]The government acts before the private sector obtains information in order to affect the private sector's information choice.

Proposition 31 *(Loss Insurance) Consider the government's strategy of the loss insurance. Suppose* $0 \leq \bar{\delta} < 1$ *is the unique equilibrium before intervention. Then,*

(i) A full insurance policy implements the efficient allocation as the unique equilibrium.

(ii) There exists a partial insurance policy that is consistent with the efficient allocation. However, mutiple equilibria may arise with the partial insurance.

The loss insurance changes the entrepreneur j's consumption in the state λ into $c(\lambda)+b_j\kappa^G(\lambda)$. The loss insurance policy has a direct impact on the quality of assets and raises the asset return initially, which causes higher asset demand. Higher asset demand leads to a higher asset price, which leads the marginal investors to enter the market and sell their nonlemons. This further improves the asset quality traded in the market, which produces a virtuous circle. This policy is robust to whatever prior distribution of λ the private sector has. Even if the private sector has an excessively pessimistic view of the future state, the loss insurance can reshape the prior view of the asset return over possible states by heavily subsidizing in the state where λ is large. It leads the private sector to alter an information choice in ways that discourage information acquisition at all, and all private liquidity is transferred to the more productive entrepreneurs. As a result, the efficient allocation can be achieved with this type of policy.

The full insurance is the one such that with the insurance $\kappa^G(\lambda)$, the return to a buyer is higher than A_L almost surely, $\frac{1-[\lambda^M(\lambda;p)-\kappa^G(\lambda)]}{p} \geq A_L$. Clearly, the full insurance eliminates the impact of imperfect information on information choices, and induces the efficient allocation as the unique equilibrium. The partial insurance is the one such that there exists a non-measure zero set of λ in which $\frac{1-[\lambda^M(\lambda;p)-\kappa^G(\lambda)]}{p} < A_L$. Even though the policy of partial insurance has potential to implement the efficient allocation, it is not necessarily a guarantee of the efficient allocation because a multiplicity of equilibria may arise. However, the following proposition shows that partial credit insurance combined with the credible announcement on the target asset price can implement the efficient allocation as the unique equilibrium.

Proposition 32 *(Optimal Minimum Cost Intervention: Loss Insurance) The loss insurance* $\kappa^G_*(\lambda)$ *that satisfies the following equation*

$$A_L = E_{-\theta}[\frac{1-\{\lambda^M(\lambda;p^*(\lambda;\bar{\delta}=1))-\kappa^G_*(\lambda)\}}{p^*(\lambda;\bar{\delta}=1)}], \tag{2.28}$$

with the credible public announcement of the asset price target $p^*(\lambda;\overline{\delta}=1)$ *implements the efficient allocation as the unique equilibrium.*

Equation (2.28) implies that the larger the cost of information θ, the lower the required insurance coverage that implements the optimal plan. Also, a cost-minimizing insurance policy is designed in a way that reduces the variance of the asset return.[44]

The minimum cost insurance policy that satisfies (2.28) alone does not ensure the efficient allocation, for it may cause a multiplicity of equilibria to arise. To avoid an undesirable equilibrium, it is important to pin down the private sector's beliefs about the future asset price, which the private sector takes as given when it chooses information, to the price that is consistent with the efficient allocation. As the previous analysis in Section 2.4.3 shows, the credible public announcement of the asset price target $p^*(\lambda;\overline{\delta}=1)$, which is backed by the instrument like asset purchases, functions as a credible threat that pins down the private sector's expectations, which are necessary for the efficient allocation. As beliefs are self-fulfilling, this policy implements the efficient allocation as the unique equilibrium, and the government does not actually need to purchase any assets in the market. In this regard, the public announcement is a useful dimension of policy to overcome a multiplicity of equilibria that may emerge with the partial credit insurance.

The next question is whether asset purchases can also implement the optimal plan. Let us consider the government's strategy of non state-contingent asset purchases as follows.[45] At the beginning of date 0, the government promises to purchase D dollars of assets regardless of the state λ at date 1. After the announcement, the private sector makes an information choice. At date 1, D dollars are financed by a government deficit to fulfil its promise. Then, the market clearing condition with the asset purchases becomes

$$\frac{1}{p}\left[N_L\delta(\lambda)+h+D\right]=N_H+l_MN_M.$$

[44] See Example 1. I, here, have stated the general principles of the insurance policy that minimizes the cost of the intervention. Equation (2.28) is the necessary condition for the cost-minimizing insurance policy. A full description of the design of insurance policy is beyond the scope of this study.

[45] This policy is equivalent for the government to post asset price p^G at which the government is willing to buy assets from the private sector, i.e., direct lending. Suppose the government posts the price p^G for a legacy asset. Agents sell their assets to the government only if $p^G > p$ where p is a market price of the asset. Note that, for each price p^G, there is liquidity needed for the government to implement this policy: there is one-to-one correspondence between the policy of direct lending and the policy of asset purchases.

At date 2, the government deficit D is repaid with lump sum taxes and revenues generated by the purchased assets. Note that the implementation of this policy does not require any knowledge about the private information at date 1.

Proposition 33 *(Inefficiency of Non State-Contingent Asset Purchases) Consider the government's strategy of the non state-contingent asset purchases. Suppose* $0 \leq \overline{\delta} < 1$ *is the unique market equilibrium before intervention. Then,*

(i) No policy in this class can implement the efficient allocation.

(ii) If the scale of intervention, D, is large enough, then private liquidity provision is minimized: $\overline{\delta} = 0$ *is the unique equilibrium. In such a case, the government intervention completely crowds out private liquidity reallocation from low to high productive entrepreneurs.*

(iii) Provided that the scale of intervention is $\overline{D}$*, the efficiency loss from liquidity misallocation in the state* λ*,* $\Xi(\lambda;\overline{D})$*, is given by*

$$\Xi(\lambda) = [\delta(\lambda; D=0) - \delta(\lambda; D=\overline{D})]N_L[(1+r) - A_L].$$

The government asset purchases have a direct impact on an asset price, as increased demand with the government purchases basically pushes up an equilibrium asset price. A higher asset price has two opposing effects on the asset return to a buyer. On the one hand, a higher asset price lowers the asset return $\frac{1-\lambda^M(\lambda;p)}{p}$ by decreasing capital gains. On the other hand, a higher asset price may increase the asset return, for it may improve the quality of assets if it induces the marginal investors to enter the market to sell their nonlemons.

Even though the government purchases may increase an equilibrium $\overline{\delta}$ to some extent if a higher asset price has a large impact on the quality of assets, the government cannot achieve the efficient allocation with this type of policy. To see this point, it is important to remember that the low productive entrepreneurs do not acquire information, and become buyers surely, $\overline{\delta} = 1$, only if the $-\theta$ adjusted expected return of being a buyer taking $p^*(\lambda;\overline{\delta}=1)$ as given is sufficiently high, i.e., $A_L \leq E_{-\theta}[\frac{1-\lambda^M(\lambda;p^*(\lambda;\overline{\delta}=1))}{p^*(\lambda;\overline{\delta}=1)}]$ (Proposition 23). Since an asset price higher than $p^*(\lambda;\overline{\delta}=1)$ does not have any impact on λ^M, the $-\theta$ adjusted expected return given $\overline{\delta}=1$ cannot be higher than A_L with the government purchases; the government purchases do not provide any incentive for the private sector to choose $\overline{\delta}=1$, because this policy does not fundamentally change the private sector's view about λ.

Furthermore, the large scale of the intervention causes no private liquidity provision if it sufficiently lowers the θ

adjusted expected return given $p^*(\lambda;\bar{\delta}=0)$, i.e., $A_L \geq E_\theta[\frac{1-\lambda^M(\lambda;p^*(\lambda;\bar{\delta}=0))}{p^*(\lambda;\delta=0)}]$. In such a case, gains from the quality improvement by a higher asset price are dominated by lower capital gains. Therefore, if the private sector has pessimistic prior over λ, this type of policy is unlikely to alter an information choice of the private sector so as to induce more private liquidity provision.

The third part of the proposition shows that the lower bound of efficiency losses is the function of the crowding out effects, $[\delta(\lambda;D=0)-\delta(\lambda;D=\bar{D})]N_L$, the shadow cost of public funds, $1+r$, and the productivity A_L. I will discuss in detail in Section 2.4.5 why the welfare losses from direct asset purchases in the MBS markets are potentially large.

The following example shows the optimal policy within this class of the asset purchases in the special case where a market outcome is given by $\bar{\delta}=0$ (minimum private liquidity).

Example 2 *Suppose $\bar{\delta}=0$ (minimum private liquidity) is the unique market equilibrium.*

(i) For small enough N_M, the optimal asset purchases is given by

$$D = N_L$$

However, $\bar{\delta}=0$ remains the unique equilibrium with the intervention; it does not revive the private liquidity market. The efficiency loss from liquidity misallocation is given by $[A_L-(1+r)]N_L$.

(ii) If an asset price has a large impact on the quality of assets (N_M is large enough), the government is able to revive the market. In such a case, in order to determine the optimal scale of purchases, one needs to assess the marginal benefit of an additional unit of purchase, $\bar{A}$, against the marginal cost of public funds,

$$(1+r)+\int_\lambda \frac{\partial\delta(\lambda;D)}{\partial D}N_L(A_L-\bar{A})dF(\lambda)$$

where $\bar{A}$ is the average productivity of the high and medium productive entrepreneurs; $\delta(\lambda;D)$ is an information choice given D.[46]

[46] *Note that* $\bar{A}=\frac{N_H A_H+N_M A_M}{N_H+N_M}$.

Note that a lack of demand causes losses to both potential sellers and buyers in the model; the productive entrepreneurs are left with an insufficient amount of liquidity to invest with a low asset price as well as they are likely to stay out of the market; buyers may also enjoy gains from higher demand if higher demand encourages a sufficiently large number of marginal investors to sell their high quality assets. The government asset purchases can be understood as a policy that is filling a lack of private demand.

If there are not many marginal investors who stay out of the market in the first place, then a higher price with the government purchases are not able to affect the quality of assets traded significantly. In such a case, the government purchases are not effective if the goal of the policy is to revive the private asset market. Even though, the government can improve welfare by committing to purchase assets at a total cost of N_L, the investors are provided with liquidity by the government, not by the low productive entrepreneurs. As a consequence, while the investment by the more productive entrepreneurs coincides with the constrained efficient allocation, the investment by the low productive entrepreneurs is greater than 0. This is the source of inefficiency as the shadow cost of public funds $1+r$ can be greater than investment productivity A_L.

If an asset price has a large impact on the quality of assets, the government purchases may be able to revive the private market to some extent, although it cannot achieve the optimal allocation.[47] If this is the case, one needs to consider the tradeoff of an additional unit of government purchase to determine the optimal scale of the purchases. It provides an additional unit of liquidity to the more productive entrepreneurs by raising an asset price, which increases welfare by the average productivity of the those entrepreneurs, $\bar{A}$. But this comes at the cost not only of public funds, $1+r$, but also of liquidity misallocation, $\frac{\partial\delta(\lambda;D)}{\partial D}N_L(A_L-\bar{A})$, if the sign of $\frac{\partial\delta(\lambda;D)}{\partial D}$ is negative. $A_L-\bar{A}$ represents the utility loss resulting from the entrepreneurs who are being keepers rather than being buyers. If a higher asset price decreases the asset return, it discourages the entrepreneurs from buying, in which case $\frac{\partial\delta(\lambda;D)}{\partial D}$ is negative. Furthermore, if the goal of the government is just to revive the market, the state-contingent asset purchases policy which targets the asset price to ensure the marginal investors to sell, is more effective in that regard, although such policy cannot implement the efficient allocation as well. Appendix D provides further details.

[47] See Appendix A for further discussion.

2.4.5 Discussion: Should Policymakers Use the Optimal Strategy to Intervene in the MBS markets?

The main role of a financial market in our model is the reallocation of resources among agents. A well-functioning financial market effectively reallocates resources to more productive entrepreneurs, which leads to greater aggregate output and growth. If a financial market breaks down, and if the misallocation from such a market failure causes a large welfare loss, government interventions are justified to the extent to which such interventions are effective in improving upon market equilibrium. The previous analysis indicates that both the direct asset purchases and the loss insurance are useful instruments to some extent in the case of the market failure. I have shown that the cost-minimizing partial loss insurance, combined with the credible announcement of an asset price target, implements the efficient allocation as the unique equilibrium, but the direct asset purchases are less efficient than the loss insurance in that they lead to inefficient uses of private liquidity.

As shown in Proposition 33-(iii), crowding out of private liquidity reallocation caused by direct asset purchases is a source of welfare losses. One natural question is then whether the magnitude of welfare losses from direct asset purchases is large enough, and therefore whether policymakers should adopt the optimal strategy to intervene in the MBS markets. Loss insurance here should be interpreted more broadly. It may cover prepayment risk and liquidity risk as well as credit risk. For instance, if financial institutions hesitate to buy MBS due to liquidity risk, policymakers may offer them liquidity backstop proportional to the size of the MBS holdings of the institution. Also, policymakers may buy Collateralized Mortage Obligation tranches that involve more prepayment risk so that private sectors can buy tranches that involve less prepayment risk with lower costs.

As discussed in Section 2.3.5, our model predicts that inefficiency caused by direct asset purchases can be particularly large in the MBS markets, because the private sector's information choice can be highly sensitive to a change in an asset price if the cost of information acquisition is large; a relatively small increase in an asset price initiated by direct asset purchases can induce a large reduction in private liquidity provision in the MBS markets. This is the pitfall of direct asset purchases, because the scale of asset purchases that is required to fill a gap between demand and supply in the MBS markets can be significantly larger than an policymakers' estimate due to such crowding out effects.

The extent of the resulting inefficiency depends further on the investment productivity of less productive entrepreneurs, A_L, and the shadow cost of public funds, r. I will provide further reasons why the magnitude of such inefficiency is potentially large.

Regarding the former, financial market disruptions, as seen in the financial crisis of 2007-2008, are usually followed by a prolonged period of recession (Reinhart and Rogoff 2009). Arguably, A_L is lower in such a recession compared to that in normal periods. Any policies that discourage resources transfer from lower to higher productive entrepreneurs necessarily lead to inefficient uses of valuable resources, and such losses from the misallocation of resources are particularly large in recession.

Regarding the latter, there are at least three reasons to believe that the shadow cost of public funds r is significantly large. First, the direct asset purchases cause wealth redistribution. As more private assets are held by the government, the asset returns are reaped by the government, not by private agents who are in need of valuable storage technology. This is especially a problem when a good state is realized. If such assets were not in the hand of the government, those resources delivered from the assets would be better used by private agents. Even if the government tries to redistribute those resources to the private sector, it is likely to encounter considerable political controversy as it raises a question about the way in which those transfers ought to be distributed.

Second, it may be difficult to unload large assets from the Fed's balance sheet. It is hard to reach a consensus when to start to use "Exit strategies," for there is a lot of uncertainty about the consequences of such strategies. Among those assets in the Fed's balance sheet, reducing its longer-term mortgage backed securities holdings are particularly difficult, because it is unclear when is optimal to sell those securities to unload; the Fed is subject to unexpected capital losses (Hall and Reis 2013). Moreover, after Chairman Bernanke mentioned in May 2013 that the Fed would begin to cut back on its stimulus program once the economy had improved, speculation over the Fed's future policy became another unnecessary source of financial market instability.

Loss insurance has, in contrast, virtue in this regard. It is easy for the private sector to observe the current default rates. Once it goes back to the one in normal periods, it may not be difficult to reach a consensus between the government and the private sector as to when to undo such policy accommodation. Furthermore, since the government does not hold any assets in its hand, it is unlikely to incur any capital losses to the government when it tries to retreat from such unconventional policy regime.

Third, as the Fed is exposed to many financial institutions by holding private securities, the Fed's independence can be jeopardized (Reis 2013). Many financial institutions that are in financial relations with the Fed may lobby to manipulate the Fed's action in an attempt to obtain private rents that are socially costly, which was not a problem when the Fed dealt with small numbers of heavily regulated financial institutions. In anticipation of such activities, there may be considerable political pressure to control the Fed's action, in which case the ability of the Fed to accomplish its dual mandate will be questioned.

To summarize, it is simple to state the principle of the efficient intervention that intends to inject liquidity in the private sector: to make private agents trade with each other. Such principle prevents policymakers neither from providing liquidity to financial institutions that are in urgent need nor from using the size and the composition of the central-bank's balance sheet combined with forward guidance as an instrument of monetary policy to combat deflation at the zero lower bound (Eggertsson and Woodford 2003). The central-bank is still able to extend liquidity via a set of emergency lending facilities, such as the Term Auction Facility (TAF), the Term Structure Lending Facility (TSLF) and the Primary Dealer Credit Facility. As the terms of those loans are at most three months, by letting them expire, the central bank's effort to inject liquidity is unlikely to have a seriously negative impact on efficiency (Reis 2013). It is rather the central-bank's direct purchases of longer-term private securities like mortgage backed securities that should be reassessed. In addition, the central-bank can rely on forward guidance to fight deflation at the zero lower bound by buying more government bonds than would be required to set the interest rate to zero for an extended period of time, while letting private securities trade among private agents in a private financial market. Such policy not only can satiate the private sector with enough liquidity, but also let the private agent who seeks profitable investment opportunities reap the benefits of valuable financial assets.

2.4.6 Implementation of the Optimal Policy with a Private Insurance Firm

Another interesting question is whether an insurance policy provided by a private insurance firm can lead to the efficient allocation as the unique equilibrium. A private insurance firm is arguably more efficient in providing loss insurance to the private sector than the government, and therefore it is important to establish under what conditions a private insurance firm can implement the efficient allocation on behalf of the government.

Suppose a private insurance firm provides buyers of assets with the protection $\kappa^P(\lambda)$ against lemons in the state λ at the premium τ. The private insurance firm participates only if its profits are greater than 0:

$$\tau - \int \kappa^P(\lambda) dH(\lambda) \geq 0 \tag{2.29}$$

where the distribution $H(\lambda)$ represents the prior of the private insurance firm over possible states λ, which can be different from the entrepreneurs' prior, $F(\lambda)$. This condition represents the participation constraint of the private insurance firm.

This insurance policy changes the return from buying assets into

$$\frac{1-\lambda^M(\lambda;p)+\kappa^P(\lambda)}{p(\lambda)+\tau}.$$

The efficient allocation is achieved only if there exists the protection $\kappa^P(\lambda)$ and the premium τ that satisfy equation (2.29) and

$$A_L \leq E_{-\theta}[\frac{1-\lambda^M(\lambda;p^*(\lambda;\overline{\delta}=1))+\kappa^P(\lambda)}{p^*(\lambda;\overline{\delta}=1)+\tau}]$$

where the $-\theta$ adjusted expectation is taken with respect to the entrepreneur's prior, $F(\lambda)$.

The insurance firm needs to provide a strong protection in the state in which λ is large, and if the entrepreneur believes that such a state will be realized with high probability, but at the same time, the premium τ must remain sufficiently low. The existence of this kind of the policy depends on the prior distributions of both parties over $\lambda, F(\lambda)$ and $H(\lambda)$ in general. Roughly speaking, this kind of insurance is likely to exist if there is sufficient heterogeneity in beliefs over future states between the insurance firm and the potential buyers.[48] If both the insurance firm and the potential buyers are pessimistic about future states, however, there is a comparable rise in the insurance premium τ as compensation for the insurance protection in those states. Subsequently, the insurance policy will not have much

[48]The prior distribution of each agent does not necessarily need to coincide with the objective probability distribution of possible states.

impact on the return to assets, in which case it is difficult to alter an information choice by the private sector. Hence, an insurance policy that implements the socially optimal allocation is unlikely to exist in such a case.

There are two ways for the government to circumvent this difficulty. The first one is to provide an additional insurance protection $\kappa^G(\lambda)$ in such disastrous states on behalf of the insurance firm. Then minimum cost intervention $\kappa^G(\lambda)$ satisfies

$$\tau - \int \kappa^P(\lambda) dH(\lambda) = 0,$$

$$A_L = E_{-\theta}[\frac{1-\lambda^M(\lambda; p^*(\lambda; \bar{\delta}=1)) + \kappa^P(\lambda) + \kappa^G(\lambda)}{p^*(\lambda; \bar{\delta}=1) + \tau}].$$

This policy will be less costly especially when the private sector is overly pessimistic about the economy, but the objective probability of such disastrous states is small.

The second one is to provide a direct subsidy s^τ on the premium τ, which reduces the premium effectively to $\tau - s^\tau$. Notice that raising the contingent tax $\tau^G(\lambda)$ on the return to assets, which imposes some taxes in good states, is helpful to partly cover the intervention cost of s^τ, especially when the pessimism among the private agents is ungrounded. Then the minimum cost intervention $\{s^\tau_*, \tau^G(\lambda)\}$ that implements the efficient allocation satisfies

$$\tau - \int \kappa^P(\lambda) dH(\lambda) = 0,$$

$$A_L = E_{-\theta}[\frac{1-\lambda^M(\lambda; p^*(\lambda; \bar{\delta}=1)) + \kappa^P(\lambda) - \tau^G(\lambda)}{p^*(\lambda; \bar{\delta}=1) + \tau - s^\tau_*}].$$

If beliefs between the insurance firm and entrepreneurs are more pessimistically aligned, then the larger subsidy s^τ_* is needed, while the larger contingent tax $\tau^G(\lambda)$ can be imposed on good states.

In addition, a transaction tax can be imposed to sellers of assets to obtain public funds to implement the policy, if needed. Since the insurance policy increases demand and pushes the price up, which increases the seller's profits, the transaction tax, as far as it is not too large, is still effective in attracting more productive entrepreneurs to sell their nonlemons to invest.

2.5 Concluding Remarks

This paper seeks to assess the efficiency of the government asset purchases program, and characterizes the optimal interventions in private securities markets. My analysis shows that large-scale asset purchases crowd out private liquidity provision, which in turn leads to inefficient uses of private liquidity. Alternatively, loss insurance combined with a credible asset price target achieves the efficient allocation as the unique equilibrium.

Moreover, my model predicts that direct asset purchases can cause serious welfare losses, especially in the MBS market where the cost of information acquisition is large. Increases in an asset price initiated by direct asset purchases in the MBS market can affect the private sector's information choice in ways that lead to a large reduction in the provision of private liquidity. This implies that the strategy proposed in this paper is the optimal way of correcting a market failure within the private securities markets.

One counter-argument would be that the provision of loss insurance by the government can foster moral hazard in lending decisions. It is true that lenders may be tempted to extend credit to risky borrowers if the government provides guarantees against loss without any regulation. Against this objection, direct asset purchases can also induce risk-taking behavior due to the moral hazard among recipients of public funds. Black and Hazelwood (2012) and Duchin and Sosyura (2012) show that risky loans originated more often from banks that received TARP funds than from those that did not.

In addition, in order to prevent the production of too many risky securities, the government may limit the provision of insurance to securities in which a pool of underlying assets satisfies certain underwriting standards. How to, and where to, provide such insurance is one direction for future research.

Chapter 3

Uncertainty, Incentive and Misallocation

3.1 Introduction

Uncertainty increasingly have attracted attention as a potential factor driving business cycle fluctuations. This paper proposes the 'risk shifting' channel by which the effects of uncertainty shocks propagate. Although there is a large corporate finance literature on a risk-shifting problem starting from Jensen and Meckling (1976), existing business-cycle models with financial frictions do not take into account endogenous behavioral responses of entrepreneurs to underlying economic environments.[1] This paper argues that the risk-shifting channel can be crucial in amplifying and propagating business fluctuations through uncertainty shocks.

The framework of the model builds on Bernanke, Gertler, and Gilchrist (1999) (BGG). This paper generalizes the BGG framework and nests it as a special case. The key idea which distinguishes this paper from the early work is that entrepreneurs must pay some costs of exerting effort in order to raise the probability of identifying a better project.[2] Entrepreneurs combine their net worth with loans to invest in a project, which can be either good or bad. A good project is better than a bad project in a sense that the mean return is higher while the variance of the return (uncertainty) is smaller than the other. But identifying a good project is costly to entrepreneurs.[3]

Because of information asymmetry between lenders and entrepreneurs, lenders cannot observe the level of effort entrepreneurs exert as well as a realized idiosyncratic return of a project. The information friction of this type leads entrepreneurs to pursue their hidden benefit which may conflict with lenders' interests. The key trade-off from the perspective of an entrepreneur is between the expected return of a project conditional on solvency and the cost of exerting effort, whereas from the perspective of a lender, only the unconditional expected return does matter. Therefore, as the variance of the return increases, entrepreneurs shift the riskiness of a project in favor of a bad project even though it results in lower unconditional expected profits.

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[1]Some empirical evidence has been addressed to support the risk-shifting hypothesis. For financial firms, see Esty (1997), Gan (2004) and Landier, Sraer, and Thesmar (2011). For nonfinancial firms, see Eisdorfer (2008), Lelarge, Sraer, and Thesmar (2010), Stromberg and Becker (2010).

[2]Alternative interpretation would be the cost of acquiring, absorbing and processing information.

[3]This paper also builds on the insights of Adrian and Shin (2013) by deriving an optimal contract with risk-shifting incentives in the context of general equilibrium. Adrian and Shin (2013) show that the optimal financial contract induces financial intermediaries to conform to the Value-at Risk rule in the partial equilibrium context.

I next presents a two-sector model to examine the effects of an uncertainty shock on business fluctuations. There are two types of entrepreneurs. Only one type of entrepreneurs (small firms) is subject to the risk-shifting problem, while the other (large firms) is not.[4] In response to an uncertainty shock, small firms tend to end up with riskier investment projects, which induces lenders to reallocate loans from small to large firms, which may be called 'flight to quality.' This tightens credit constraints for small firms further. This mechanism, in particular, explains different sectoral responses, which cannot be explained in the reference model without the risk-shfting problem. This type of the financial friction distorts the sectoral loan allocation from high to low productivity sector in response to an uncertainty shock. Loan misallocation caused by the uncertainty shock depresses aggregate economic activity further. In this regard, this paper contributes to a growing literature on uncertainty and business cycle fluctuations (Christiano, Motto, and Rostagno 2007). This paper complements recent papers by identifying the new channel by which higher uncertainty can amplify fluctuations in aggregate activity in the context of a DSGE model.

Furthermore, this paper examines the empirical performance of the theory with the data obtained from Bartelsman, Becker and Gray ("NBER-CES Manufacturing Industry Database," NBER, 2000). As a proxy for the measure of uncertainty, two different level of uncertainty measures are used: the economy-wide uncertainty measure, which is GDP growth volatility, and the industry-wide uncertainty measure, which is adopted from Bloom (2009).[5] As a proxy for firm size, the definition provided by the Small Business Administration (SBA) is applied to classify each industry into size groups. An industry is classified as "small-business dominated" if employment in firms with fewer than 500 employees accounts for at least 60% of industry employment. Likewise, an industry is categorized as "large-business dominated" if employment in firms with fewer than 500 employees is at most 40% of industry employment. The rest of industries are considered as "middle-business industry."

Using these empirical proxies, the empirical investigation finds support for the model's key prediction. Periods are

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[4] In reality, there are certain characteristics which make firms vulnerable to the risk-shifting problem. First, the ownership structure of a firm does matter. If shareholders' and managers' interests are more aligned, such a structure may induce risk-shifting incentives in the managers because of a 'head I win, tail you lose' compensation scheme. Similarly, if a firm is financially depressed, its incentives to gamble for resurrection may increase. In addition, factors such as informational opacity (Berger and Udell 1998), regulation and asset tangibility are relevant in shaping the severity of the risk-shifting problem because such factors increase the degree of informational asymmetry between a lender and a borrower. Arguably, small firms are more associated with those characteristics.

[5] The reason why this industrial measure of uncertainty is adopted for the empirical investigation is that it is constructed using the same manufacturing industry data and thus it may be more relevant measure for our purpose.

divided into the subsamples of high and low uncertainty at both economy-wide and industry levels. During periods of high uncertainty, there is a pattern between firm size and the growth rates. Small firms grow slower than large firms during times of high uncertainty. In contrast, there is no noticeable relation between firm size and the growth rates during times of low uncertainty.[6] In addition, I test the hypothesis whether small businesses generate less value during periods of high uncertainty. The strategy for testing the risk-shifting hypothesis is motivated by Eisdorfer (2008).[7] I also found support for the risk-shifting hypothesis, which suggests that this mechanism may operate at aggregate level.

The rest of the paper is organized as follows. Section 2 introduces the model. Section 3 calibrates and simulates the model. Section 4 addresses some empirical observations from the data and tests the risk-shifting hypothesis. Section 5 concludes.

3.2 Model

Drawing on insights from the literature on asymmetric information and financial factors in business fluctuations (especially Adrian and Shin (2013) and Bernanke, Gertler, and Gilchrist (1999)), a New Keynesian dynamic general equilibrium model that captures the empirical evidence presented in the previous section is developed. The most of the BGG model assumptions on the entrepreneurial sector are adapted for simplicity. One important difference is that an additional dimension of heterogeneity in the distribution of idiosyncratic risk is considered to introduce a moral hazard problem in the standard costly state verification model. The one sector model with the new feature is first developed. Then behavioral heterogeneity among entrepreneurs is allowed to capture the cross-sectional difference in productivity and investment growth as uncertainty increases.

The modeling approach introduced in this section may be interpreted as a way to build a reduced form model

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[6]The model and empirical analysis are also motivated by the literature on the excess sensitivity of small firms. Gertler and Gilchrist (1991) find asymmetric sales growth responses to a monetary shock between small and large firms. Ghosal and Loungani (2000) document the sensitivity of investment by small firms to uncertainty risks. See, for more examples, Kashyap, Lamont, and Stein (1992), Oliner, Rudebusch, Oliner, and Oliner (1994) and Morgan (1998).

[7]He tests the hypothesis that the investment of financially distressed firms generates less value during periods of high uncertainty using 40 years data from CRSP and COMPUSTAT and finds robust evidence that supports the hypothesis of the existence of risk-shifting behavior. What distinguishes our paper is that the difference in patterns between size and productivity growth depending on the degree of uncertainty is addressed, using the different data set which contains private firms which are not publicly traded as well as publicly traded firms.

which is consistent with the rational inattention hypothesis. In other words, an entrepreneur may be inattentive if it is costly to struggle to conduct market research to look for a good project. As a consequence, an entrepreneur is more likely to end up with a bad project if high uncertainty incurs higher information costs. Arguably, this tendency is pronounced among small businesses because a small business tends to have limited human resources to perform high quality market research. This leads entrepreneurs to fail to conduct sufficient market research and causes the high probability of failure rate.

3.2.1 Basic Structure

The model is in line with the New Keynesian DSGE model incorporating a costly state verification problem between lenders and borrowers. The model consists of households, firms, capital producers, entrepreneurs and financial intermediaries. The output produced by firms can be either used as consumption goods by households or as investment goods by capital producers. Capital producers turn investment goods, as well as used capital purchased from entrepreneurs, into new capital. Entrepreneurs purchase new capital using their net worth and funds from the intermediaries, and rent the capital to firms.

Households cannot invest in firms directly, but they can invest indirectly through the intermediaries. The financial intermediaries (lenders) are risk-neutral. They collect savings from households and lend them to entrepreneurs (borrowers). Because a loan market is competitive, the intermediaries earn a zero profit. Accordingly, the optimal contract between lenders and borrowers maximizes borrowers' profit subject to the zero profit condition of lenders, which is equivalent to minimize expected monitoring costs.

There is a large number of risk-neutral entrepreneurs, who invest in firms. Entrepreneurs are homogeneous ex ante. But the nature of firms being invested by entrepreneurs is heterogeneous ex post: each firm can be either a good one (G) or a bad one (B).[8] Entrepreneurs can increase the probability that a firm being invested is good by exerting more efforts. Returns to their investment are subject to both aggregate and idiosyncratic risk. A bad one is inferior in a sense that the expected return is lower while the volatility of the return is higher than a good one. BGG studied the

[8]This implies that each entrepreneur specializes in one type of projects.

case in which an ex-post return to investment is unknown to a lender, unless a lender pays state-verification costs. The key difference in this paper is that there is an additional dimension of information asymmetry: lenders cannot verify whether borrowers have engaged in a good or a bad investment project. Therefore, lenders cannot punish borrowers based on an ex-post outcome of investment projects.

Each entrepreneur draws an idiosyncratic return from one of the following distribution depending on his/her type.

$$\omega^G \sim (1, \sigma^2) \tag{3.1}$$

$$\omega^B \sim (a, (b\sigma)^2) \tag{3.2}$$

where $a < 1$, and $b > 1$.

In general, this assumption on the distributions of idiosyncratic productivity may not be innocuous. For instance, as an aggregate productivity shock makes $(1-a)$ larger, the expected cost of switching to a bad project is getting bigger, and so borrowers incline to engage in a good project in response to a negative productivity shock. Therefore this type of the incentive stabilizes the economy in response to productivity shocks. In contrast, larger b makes a bad project relatively attractive to entrepreneurs since ex post profits in default are not of interest to entrepreneurs. As a result, this kind of the incentive magnifies uncertainty shocks.

The information costs to identify a good project are referred simply as 'effort' since the costs are assumed to be non-pecuniary for simplicity. In order to identify and invest in a good project, an entrepreneur must exert an unobserved and costly effort, e, and the effort only affects the probability, $p(e)$ that the entrepreneur's project turns out to be good. Creditors do not observe both efforts entrepreneurs made and realized idiosyncratic disturbances. Moreover, creditors cannot detect whether investment by each entrepreneur turned out to be good or bad.

Therefore the entrepreneur has an incentive to lie about realized returns and the level of effort they made to identify a good project. This introduces a moral hazard and asymmetric information problem into the model as the interest between entrepreneurs and creditors conflict. As the case in BGG and Carlstrom and Fuerst (1997), the optimal contract is designed to minimize costs stemming from these agency problem and induce truth-telling by entrepreneurs.

And the model allows for one-period contracts between entrepreneurs and creditors assuming anonymity in credit markets as this assumption makes the contract problem much easier not affecting the implication of the model.

For the rest of this section, we describe agents' objectives and constraints.

3.2.2 Entrepreneurs

Entrepreneurs combine their net worth and borrowing to finance their new investment. The way to describe the optimal contract between entrepreneurs and lenders closely follows Adrian and Shin (2013). This paper builds on their work by introducing costly efforts and endogenizing the probability that a project is good in a dynamic framework.

A contract between a lender and an entrepreneur is characterized by the face value of debt, $\bar{D}$, the market value of debt, D, the market value of assets of the entrepreneur, T, and the level of effort, e, the entrepreneur must exert. The market value of debt D is smaller than the face value $\bar{D}$, because entrepreneurs cannot honor their obligation in some states. The difference between T and n is equal to the amount of borrowing.

To motivate intuitions embedded in the contract, it is useful to characterize the value of defaultable debt in terms of option values. Holding defaultable debt with the face value $\bar{D}$ is equivalent to the strategy which combines (i) cash holdings of $\bar{D}$ and (ii) writing a put option on the value of borrower's assets, T, with the exercise price of $\bar{D}$.[9] Let us denote the value of the put option by $o_X(\bar{D}, T, \sigma)$, where X represents the nature of entrepreneur's project which can be either good $(X = G)$ or bad $(X = B)$; and σ denotes underlying volatility. Furthermore, suppose that it satisfies homogeneity of degree 1, i.e., $o_X(\bar{D}, T, \sigma) = T o_X(\bar{d}, 1, \sigma)$, where $\bar{d} = \frac{\bar{D}}{T}$. Define

$$o_X(\bar{d}, \sigma) \equiv o_X(\bar{d}, 1, \sigma), \tag{3.3}$$

which implies that the value of the put option on one dollar's worth of the entrepreneur's asset.

[9] See Merton (1974).

3.2.2.1 Lender's participation constraint

If an entrepreneur borrows D from lenders, the gross expected payoff to the lenders can be written by

$$T[p(e)(\bar{d} - o_G(\bar{d}, \sigma_G)) + (1 - p(e))(\bar{d} - o_B(\bar{d}, \sigma_B))], \tag{3.4}$$

where $p(e)$ denotes the probability that the entrepreneur's project is good. The lenders participate in the loan market only if their expected payoff is greater than their opportunity costs, $D \times R^m$.

$$T[p(e)(\bar{d} - o_G(\bar{d}, \sigma_G)) + (1 - p(e))(\bar{d} - o_B(\bar{d}, \sigma_B))] \geq D \times R^m, \tag{3.5}$$

where R^m is a market return.

Note that in a discrete time case, if $p(e) = 1$, the participation constraint is reduced to the one in BGG, where projects are ex-ante homogeneous. In order to see this, observe the following relation between $\bar{d}$ and $\bar{\omega}$, where $\bar{\omega}$ is defined as the threshold value of the idiosyncratic disturbance where the entrepreneur does not default. Then,

$$\bar{d} = \frac{\bar{D}}{T} = \frac{ZD}{T} = \bar{\omega} R_k, \tag{3.6}$$

where Z is a gross non-default loan rate, D is the associated level of lending, T is the total market value of the entrepreneur asset and R_k is the aggregate equity return. Notice that there is one to one relation between $\bar{d}$ and $\bar{\omega}$. Provided the idiosyncratic disturbance ω is i.i.d. with cdf $F(\omega)$, the spot value of the put option that matures in the next period is given by

$$\begin{aligned} o(\bar{d}, \sigma) &= \int_0^{\bar{\omega}} (\bar{\omega} R_k - \omega R_k) dF(\omega) \\ &= \bar{\omega} R_k F(\bar{\omega}) - R_k \int_0^{\bar{\omega}} \omega dF(\omega). \end{aligned} \tag{3.7}$$

The spot value of the portfolio held by a lender is given by

$$T\{\bar{d}-o(\bar{d},\sigma)\}=T\{R_k[\bar{\omega}(1-F(\bar{\omega}))+\int_0^{\bar{\omega}}\omega dF(\omega)]\}. \tag{3.8}$$

Therefore, if state verification costs are added into the above relation, the participation constraint is equivalent to the one in BGG.

3.2.2.2 Entrepreneur's Incentive Compatibility Condition

The expected net payoff to the entrepreneur is given by the difference between the expected return in investment and the payoff to the lender. Let r_G and r_B denote the expected return of a good project and a bad project respectively. Then the entrepreneur's portfolio consists of the risky asset with net expected payoff $T(r_X-\bar{d})$ and the put option of which the value is given by $To_X(\bar{d},\sigma_X)$. Hence, the entrepreneur's objective function is written by

$$p(e)T(r_G-\bar{d}+o_G(\bar{d},\sigma_G))+(1-p(e))T(r_B-\bar{d}+o_B(\bar{d},\sigma_B))-Tc(e) \tag{3.9}$$

where $c(e)$ is the entrepreneur's non-pecuniary costs of exerting effort.

The level of entrepreneur's effort is not observable by lenders, which is the source of information asymmetry. Therefore, entrepreneurs can pursue their own interests in the choice of the level of effort regardless of the other terms are specified in the contract. Thus the optimal contract must satisfy the following first order condition with respect to the level of effort:

$$p'(e)(r_G-r_B)=p'(e)(o_B(\bar{d},\sigma_B)-o_G(\bar{d},\sigma_G))+c'(e) \tag{3.10}$$

where $p'(e)$ and $c'(e)$ are the first derivatives of $p(e)$ and $c(e)$. While an increase in the share of good projects brings the greater expected payoff, it decreases the put option value and increases the cost of effort. This first order condition requires the difference between two put option values to be small in order to motivate the entrepreneur to exert more effort.

For the rest of the paper, I assume that $p(e)$ is linear and $c(e)$ is quadratic:

$$p(e) = cpb \times e \tag{3.11}$$

$$c(e) = \frac{1}{2}e^2. \tag{3.12}$$

Then the equation above can be rewritten by

$$r_G - r_B = o_B(\bar{d}, \sigma_B) - o_G(\bar{d}, \sigma_G) + \frac{e}{cpb}. \tag{3.13}$$

Then left hand side is the marginal benefit of effort and the right hand side is the marginal cost of effort. As long as the expected return of each project remains the same, $r_G - r_B$ remains constant while both $o_B(\bar{d}, \sigma)$ and $o_G(\bar{d}, \sigma)$ are increasing in σ. For appropriately parameterized values for the mean and the volatility, the difference between two option values, $o_B(\bar{d}, \sigma_B) - o_G(\bar{d}, \sigma_G)$, is increasing in σ. Figure C.1 (in the appendix) is an example with $r_G = 1$ and $r_B = 0.9$. As uncertainty on the underlying asset increases, the option value of holding a bad asset increases more than the one of holding a good asset, and hence the entrepreneur has less incentive to exert effort in identifying a good project.

3.2.2.3 Discrete Time One-Period Optimal Contract

This section derives the optimal contract described so far in the context of a discrete time model. To invest in firms in return for equity, entrepreneurs collect deposits from lenders to combine with their net worth. The flow-of-funds constraint is

$$T_t = q_t S_{t+1} = n_t + d_{t+1}$$

where q_t is the market price of equity; S_{t+1} denotes the volume of equity; n_t denotes the net worth of the entrepreneur; d_{t+1} is the amount of loans. Entrepreneurs can borrow loans conditional on the terms of the contract and the contract stipulates rules entrepreneurs follow.

An idiosyncratic return, which governs the value of underlying assets, is unknown at the time when an entrepreneur and a lender enter into a contract. However, the distribution of the idiosyncratic return is known to both lenders and entrepreneurs. Suppose idiosyncratic returns ω_G and ω_B are distributed log-normally with c.d.f. $G(\omega)$ and $B(\omega)$ respectively:

$$\log\omega_t^G \sim N(-\frac{1}{2}\sigma_t^2, \sigma_t^2) \tag{3.14}$$

$$\log\omega_t^B \sim N(-\frac{1}{2}(b\sigma_t)^2 + \log(r_L), (b\sigma_t)^2) \tag{3.15}$$

where $E(\omega^G) = 1$, $E(\omega^B) = r_L$, and $r_L < 1$.

Similarly as in the previous case, objective (3.9) can be shown to collapse to the one in BGG in the special case where $p(e) = 1$ and $c(e) = 0$. Using relation (3.8), I obtain

$$T(r - \bar{d} + o(\bar{d}, \sigma_G)) = TR^k[\int_0^\infty \omega dF(\omega) - \bar{\omega}(1 - F(\bar{\omega})) - \int_0^{\bar{\omega}} \omega dF(\omega)] \tag{3.16}$$

$$= TR^k \int_{\bar{\omega}}^\infty \omega F(\omega) - \bar{\omega}(1 - F(\bar{\omega})). \tag{3.17}$$

The optimal contract in BGG maximizes the objective (3.16) subject to the participation constraint (3.8) with state verifiaction costs. Likewise, the conventional CSV approach, analyzed by Townsend (1979), is employed in this research, and hence our case nests BGG as a special case. Considering the fact that the payoff in investment depends on the level of effort the entrepreneur exerts, the expected return to investment is expressed as

$$\begin{aligned} &\max_{T_t, \bar{\omega}_{t+1}, e_t} p(e_t)T_t \int_{\bar{\omega}_{t+1}}^\infty R_{t+1}^k \omega_{t+1} dG(\omega_{t+1}) \\ &+(1 - p(e_t))T_t \int_{\bar{\omega}_{t+1}}^\infty R_{t+1}^k \omega_{t+1} dB(\omega_{t+1}) \\ &-\{1 - [p(e_t)G(\bar{\omega}_{t+1}) + (1 - p(e_t))B(\bar{\omega}_{t+1})]\}\bar{\omega}_{t+1}T_t R_{t+1}^k \\ &-\frac{1}{2}e_t^2 T_t. \end{aligned} \tag{3.18}$$

The participation constraint (3.5) in the context of a discrete time model can be written as

$$\begin{aligned} & \{1-[p(e_t)G(\bar{\omega}_{t+1})+(1-p(e_t))B(\bar{\omega}_{t+1})]\}\bar{\omega}_{t+1}T_tR^k_{t+1} \\ & +(1-\mu)T_tR^k_{t+1}[p(e_t)\int_0^{\bar{\omega}_{t+1}}\omega_{t+1}dF(\omega_{t+1}) \\ & +(1-p(e_t))\int_0^{\bar{\omega}_{t+1}}\omega_{t+1}dG(\omega_{t+1})] \\ \geq\ & R^m_{t+1}(T_t-n_t), \end{aligned} \tag{3.19}$$

where μ represents monitoring costs.

Notice that entrepreneurs can choose the level of effort, e_t, to maximize the objective (3.18), regardless of $(T,\bar{\omega}_{t+1})$ specified on the contract, because e_t is not observable by lenders. The revelation principle implies that the contract is incentive compatible only if it satisfies (3.10), which can be expressed as

$$\begin{aligned} & p'(e_t)T_tR^k_{t+1}(\int_{\bar{\omega}_{t+1}}^{\infty}R^k_{t+1}\omega_{t+1}dG(\omega_{t+1})-\int_{\bar{\omega}_{t+1}}^{\infty}R^k_{t+1}\omega_{t+1}dB(\omega_{t+1})) \\ & +p'(e_t)[G(\bar{\omega}_{t+1})-B(\bar{\omega}_{t+1})]\}\bar{\omega}_{t+1}T_tR^k_{t+1} \\ =\ & e_tT_t. \end{aligned} \tag{3.20}$$

Consequently, lenders offer contract $(T,\bar{\omega}_{t+1},e_t)$ which maximize the objective (3.18) subject to both the participation constraint (3.19) and the incentive compatibility condition (3.20).

3.2.2.4 Comparative Statics

This section presents results from the partial equilibrium analysis, showing the relation between the value of various parameters and endogenous financial variables. The partial equilibrium analysis focuses only on the contract between lenders and entrepreneurs, taking the aggregate return to capital, R^k, funding rates from households, R^m, and capital prices, q, as given. Those price variables are also endogenous in the general equilibrium analysis. Specifically, I set $R^k = 1.02$, $R^m = 1.01$, and $q = 1$.

Figure C.2 (in the appendix) plots some financial variables implied by the model as a function of cross-section dispersion of productivity, σ (uncertainty). Note that as uncertainty increases, the bankrupt probability and expected bankruptcy costs rise. Given the level of the leverage of an entrepreneur, lenders need to be compensated for higher bankruptcy costs by raising threshold value $\bar{\omega}_{t+1}$, which corresponds to a credit risk premium. This leads lenders to write a contract with a higher credit risk premium or a lower level of leverage. From the perspective of entrepreneurs, there is a tradeoff between leverage and borrowing rates as greater leverage implies higher borrowing rates. Therefore, a rise in uncertainty reduces the entrepreneur's incentive to take on leverage, as can be seen in the second panel on the first row. Even though this decreases the threshold value $\bar{\omega}_{t+1}$ to some extent, it is not strong enough to decrease credit spreads, as shown in the next panel. However, it might seem surprising to see the effort increases after it reaches its lower bound as uncertainty continues to rise. To see this point, notice that there can be two opposite effects of changing σ on the difference in the option values, $o_B(\bar{d},\sigma_B) - o_G(\bar{d},\sigma_G)$, in which the level of effort is decreasing. On the one hand, $o_B(\bar{d},\sigma_B) - o_G(\bar{d},\sigma_G)$ is increasing in σ. One the other hand, an increase in σ may decrease $\bar{d}$, which lowers $o_B(\bar{d},\sigma_B) - o_G(\bar{d},\sigma_G)$. Therefore, in the partial equilibrium analysis, the relation between uncertainty and effort may be non-monotonic.

However, in general equilibrium in which the capital price is endogenously determined, the level of effort is monotonically decreasing in uncertainty. As a reduction in entrepreneurs' borrowing decreases capital demand, the capital price drops. This leads to a decline in the market value of the entrepreneur's equity. As the market value of the equity wipes out, entrepreneurs end up with higher leverage, which raises $\bar{\omega}_{t+1}$ and $\bar{d}$. Due to the limited liability structure, this leads to an increase in the profit of a riskier project to entrepreneurs conditional on solvency, which induces them to exert less effort. But it raises bankruptcy costs even further and thus, lenders command a higher risk premium. This mechanism amplifies the impact of an uncertainty shock.

Figure C.3 graphs the responses of the selected variables to changes in the mean of idiosyncratic productivity of a bad project. A rise in the mean makes a bad project more attractive as the expected opportunity cost of engaging in a bad project declines. Entrepreneurs exert less effort to identify a good project. As it increases the bankruptcy cost, entrepreneurs become less leveraged. The threshold value $\bar{\omega}_{t+1}$ declines, but not so much to result in a decrease in the credit spread.

Figure C.4 reports the relation between the selected variables and the monitoring costs, μ. Higher μ leads to lower leverage, and in turn lower $\bar{\omega}_{t+1}$. This implies higher expected profits conditional on solvency. Then entrepreneurs exert more effort, and the bankrupt probability declines. The credit spread also declines because $\bar{\omega}_{t+1}$ drops sharply as leverage decreases.

3.2.3 Households

The optimal contract developed in the previous section is embedded within a New Keynesian DSGE model. There is a representative household which makes a decision on consumption, saving and supply of labor. The representative household indirectly lends to entrepreneurs via financial intermediaries. The utility function of the representative household is given by

$$\max_{\{C_{t+i},H_{t+i},B_{t+1+i}\}_{i=0}^{\infty}} E_t \sum_{i=0}^{\infty} \beta^i [\ln(C_{t+i}) - \frac{\psi}{1+\chi} H_{t+i}^{1+\chi}] \tag{3.21}$$

$$s.t\ P_t C_t + B_{t+1} = R_t^m B_t + W_t H_t + \Pi_t \tag{3.22}$$

where E_t is the expectation operator conditional on household information available at time t; B_t denotes deposits; R_t^m denotes the rate of return on deposits; W_t is the nominal wage; C_t denotes consumption; H_t denotes labor supply; P_t is the price level; Π_t is dividends received from the ownership of monopolists and capital producers. The representative household chooses consumption, labor supply and saving to maximize the expected discounted utility (3.21) subject to the budget constraint (3.22).

3.2.4 Capital Producers

There is a representative, competitive capital producer. At period t, the capital producer make new capital using newly produced goods and existing undepreciated capital subject to adjustment costs. The capital producer chooses I_t to solve

$$\max E_t \sum_{i=t}^{\infty} \beta^i \{q_t I_t - [1 + f(\frac{I_i}{I_{i-1}})] I_i\}$$

where $f(\frac{I_i}{I_{i-1}})I_i$ reflects adjustment costs, with $f(1) = f'(1) = 0$ and $f(\frac{I_i}{I_{i-1}})'' > 0$. For simplicity, I assume the quadratic capital adjustment costs:

$$f(\frac{I_t}{I_{t-1}}) = \frac{\phi}{2}(\frac{I_t}{I_{t-1}} - 1)^2.$$

Solving the profit maximization problem of the capital producer, the price of capital q_t is determined as follows:

$$q_t = 1 + f(\frac{I_t}{I_{t-1}}) + \frac{I_t}{I_{t-1}} f'(\frac{I_t}{I_{t-1}}) - E_t \lambda_{t,t+1} (\frac{I_{t+1}}{I_t})^2 f'(\frac{I_{t+1}}{I_t}),$$

where $\lambda_{t,t+1}$ is the stochastic discount factor of the household. Any profits are transferred as a lump-sum payment to the household.

3.2.5 Intermediate Goods Firms

Intermediate output is produced by competitive firms using the constant returns to scale technology with capital and labor inputs.

$$Y_t = A_t K_t^{\alpha} H_t^{1-\alpha} \ , \ 0 < \alpha < 1,$$

where A_t denotes aggregate productivity which is normally distributed. Intermediate goods firms finance their investment by selling their equity to entrepreneurs and promising them to pay back $\omega \times MP_k$ and undepreciated capital, $(1-\delta)\omega K$ in return. Before the realization of an idiosyncratic productivity shock, they choose labor inputs to maximize their expected profits:

$$\max_{H_t} P_t^w (p(e_t) + (1 - p(e_t)) r_L) A_t K_t^{\alpha} H_t^{1-\alpha} - W_t H_t,$$

where P_t^w is the relative price of wholesale goods and $(p(e_t) + (1 - p(e_t)) r_L)$ is the weighted average of idiosyncratic productivity. The demand for household labor equates the expected marginal product of labor with the wage:

$$W_t = P_t^w (p(e_t) + (1 - p(e_t)) r_L)(1 - \alpha) \frac{Y_t}{H_t}.$$ [10]

The expected return to holding a unit of equity from t to $t+1$ by an entrepreneur is given by

$$E_t[(p(e_t)+(1-p(e_t))r_L)R^k_{t+1}],$$

where

$$E_t[R^k_{t+1}] = E_t[\frac{P^w_t \frac{\alpha Y_t}{K_t} + q_{t+1}(1-\delta)}{q_t}].$$

Note that the aggregate return to capital, R^k_{t+1}, is subject to idiosyncratic risk. The supply for capital is obtained by solving the optimal contract problem as described previously. The equilibrium quantity of capital is determined by combining the demand and supply condition. The aggregate law of motion for capital is given by

$$K_{t+1} = I_t + [p(e)+(1-p(e)r_L](1-\delta)K_t.$$

3.2.6 Retailers

There exists a continuum of monopolistic competitive retailers of measure one. Retailers buy output from intermediate goods firms in a competitive market, then differentiate the output they purchase without any costs. Households and capital producers purchase Dixit-Stiglitz aggregates of these retail goods and convert them into consumption and investment goods.

$$Y^f_t = [\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di]^{\frac{\theta}{\theta-1}}, \quad 1 < \theta,$$

where $Y_t(i)$ denotes the time-t output of retail goods i, $i \in (0,1)$, measured in units of wholesale goods. This requires that consumption of each good i satisfies

$$C_t(i) = (\frac{P_t(i)}{P_t})^{-\theta} C_t,$$

and the corresponding price index is given by

$$P_t = [\int_0^1 P_t(i)^{1-\theta} di]^{\frac{1}{1-\theta}}.$$

Since each retailer understands its sales depend upon the relative price they charge to the price aggregate,

$$Y_t(i) = (\frac{P_t(i)}{P_t})^{-\theta} Y_t$$

Calvo-type of sticky prices is adopted to introduce non-monetary neutrality. In each period t, a fraction of retailers, $1-\zeta$, can reoptimize their prices. When the retailers are able to change prices, they optimize their prices to maximize discounted profits over future horizons, taking as given the demand curve and the price of wholesale goods, P_t^w. Profits from the retail sector are distributed to households as a lump-sum payment.

3.2.7 Law of Motion for Net Worth

As long as the realized idiosyncratic productivity is above $\bar{\omega}_{t+1}$ at time period $t+1$, an entrepreneur can retain the rest of the profits after paying the face value of debt. If the realization of idiosyncratic productivity ω_{t+1} is below $\bar{\omega}_{t+1}$, the entrepreneur declares default, in which case the lenders pay verification costs and get residuals.

After the entrepreneur has settled obligation on its debt in period $t+1$, the used capital is sold to capital producers and the net worth of the entrepreneur is determined. To induce stationarity in the law of motion for net worth, the entrepreneur is assumed to exit the economy with probability $1-\gamma$. At the same time, new entrepreneurs are born and enter into the economy, which results in a constant total number of entrepreneurs. Entrepreneurs who exit transfer the constant fraction of their net worth ν to new entrepreneurs in order to get them started, and consume the remaining fraction of their net worth, $1-\nu$. Assuming γ is relatively small, this process induces stationarity and prevents entrepreneurs from accumulating enough net worth.

The law of motion for the aggregate net worth of entrepreneurs, N_{t+1}, is given by

$$N_{t+1} = \gamma W_{t+1} + \nu(1-\gamma)W_{t+1},$$

where

$$
\begin{aligned}
W_{t+1} &= (p(e_t)+(1-p(e_t))r_L)R_t^k T_t - R_t B_t \\
&\quad -\mu T_t R_t^k[p(e_t)\int_0^{\bar{\omega}_t}\omega_t dG(\omega_t)+(1-p(e_t))r_L\int_0^{\bar{\omega}_t}\omega_t dB(\omega_t)].
\end{aligned}
$$

3.2.8 Monetary Policy and Exogenous Process

A simple taylor type monetary policy rule is used to conduct model evaluation exercises. Under this rule, the monetary policy operating target i_t is adjusted according to the following reaction function:

$$\log(i_t/i^*) = \rho^i \log(i_{t-1}/i^*) + \rho^\pi \log(\pi_t/\pi^*) + \varepsilon_t^i,\ \varepsilon_t^i \sim i.i.d.$$

The productivity and dispersion of idiosyncratic productivity obey stationary autoregressive processes as follows.

$$\log A_t = \rho^A \log(A_{t-1}) + \varepsilon_t^A,\ \varepsilon_t^A \sim i.i.d,$$

$$\log(\sigma_t/\sigma) = \rho^\sigma \log(\sigma_{t-1}/\sigma) + \varepsilon_t^\sigma,\ \varepsilon_t^\sigma \sim i.i.d.$$

3.2.9 Resource Constraint

In equilibrium, the aggregate resource constraint must be satisfied. It requires market clearing in both the loan and the labor market. After imposing the equilibrium relations on the household's budget constraint, the resource constraint is given by

$$
\begin{aligned}
& C_t + C_t^e + [1+f(\frac{I_t}{I_{t-1}})]I_t && (3.23)\\
& +\mu T_t R_t^k[p(e_t)\int_0^{\bar{\omega}_{t+1}}\omega_{t+1}dG(\omega_{t+1})+(1-p(e_t))r_L\int_0^{\bar{\omega}_{t+1}}\omega_{t+1}dB(\omega_{t+1})] && (3.24)\\
=\ & (p(e_t)+(1-p(e_t))r_L)Y_t,
\end{aligned}
$$

where $C^e_t = (1-\nu)(1-\gamma)W_{t+1}$.

The term $\mu T_t\{p(e_t)\int_0^{\bar{\omega}_{t+1}} \omega_{t+1} dG(\omega_{t+1}) + (1-p(e_t))r_L \int_0^{\bar{\omega}_{t+1}} \omega_{t+1} dB(\omega_{t+1})\}$ captures the monitoring costs incurred as a result of the default of some entrepreneurs.

3.2.10 Extension to Two Sector Model

It is straightforward to extend the model to include two different groups of entrepreneurs. Depending on which group an entrepreneur belongs to, there is heterogeneity in his ability to distort the quality of investment projects by not exerting sufficient effort. I interpret the group of entrepreneurs, who have risk-shfting incentive, as firms that are opaque, relatively new, and small in size. The other group of entrepreneurs represent transparent, well-established, and large firms.

Two different types of entrepreneurs are involved with the different types of intermediate goods firms. Wholesale firms combine the different kinds of intermediate goods into a single wholesale good via a CES aggregator. The objective of the wholesale firm is given by

$$\max_{Y_t, Y_{1t}, Y_{2t}} P^w_t Y_t - P_{1t}Y_{1t} - P_{2t}Y_{2t},$$

subject to

$$Y_t = (\lambda Y_{1t}^{\frac{\psi-1}{\psi}} + (1-\lambda)Y_{2t}^{\frac{\psi-1}{\psi}})^{\frac{\psi}{\psi-1}},$$

which yields

$$\frac{P_{1t}}{P^w_t} = \lambda(\frac{Y_{1t}}{Y_t})^{\frac{-1}{\psi}},$$

$$\frac{P_{2t}}{P^w_t} = \lambda(\frac{Y_{2t}}{Y_t})^{\frac{-1}{\psi}},$$

where P_{it} denotes the price of intermediate goods i, P^w_t denotes the wholesale goods price, Y_t denotes the production of the wholesale goods, and Y_{it} represents intermediate goods i which is used in the production of Y_t.

Also, there are two types of capital producers who produce sector-specific capital, and hence there are two capital prices and two law of motion for capital. Likewise, labor is sector-specific and households supply a different kind of labor to each sector. Households' objective can be written as

$$\max_{\{C_{t+i},H_{1t+i},H_{2t+i},B_{t+1+i}\}_{i=0}^{\infty}} E_t \sum_{i=0}^{\infty} \beta^i [\ln(C_{t+i}) - \frac{\psi}{1+\chi} H_{1t+i}^{1+\chi} - \frac{\psi}{1+\chi} H_{1t+i}^{1+\chi}], \tag{3.25}$$

$$s.t\ P_t C_t + B_{t+1} = R_t^m B_t + W_{1t} H_{1t} + W_{2t} H_{2t} + \Pi_t.$$

The other features of the model are the same.

3.3 Numerical Analysis

This section presents some numerical experiments designed to illustrate how the business cycle dynamics of the financial accelerator model with moral hazard is different from the standard model. The two-sector model is simulated to analyze the effects of the entrepreneur's incentive on loan misallocation and aggregate productivity. Specifically, it is shown that how the financial system, which is exposed to the moral hazard problem, might propagate the effect of a disturbance to uncertainty risk that might otherwise have a modest effect on the economy.

I provide with the benchmark models for comparisons. Then I turn to the calibration of the model and numerical exercises.

3.3.1 Model Variant

For model comparison purposes, I consider a variant of the baseline model. It is derived from the baseline specification by deactivating the main propagation mechanism that is introduced so far. This variant is referred as 'modified BGG.' The only difference between the models is that the probability function $p(e)$ is now fixed instead of allowing it to respond to changes in the level of effort, i.e., $p(e) = \bar{p}$. Hence the dynamics associated with the incentive problem have been turned off in the modified BGG model. The optimal contract in the modified BGG is written by

$$\begin{aligned}
&\max_{T_t,\bar{\omega}_{t+1}} \bar{p}T_t \int_{\bar{\omega}_{t+1}}^{\infty} R^k_{t+1}\omega_{t+1}dG(\omega_{t+1}) \\
&+(1-\bar{p})T_t \int_{\bar{\omega}_{t+1}}^{\infty} R^k_{t+1}\omega_{t+1}dB(\omega_{t+1}) \\
&-\{1-[\bar{p}G(\bar{\omega}_{t+1})+(1-\bar{p})B(\bar{\omega}_{t+1})]\}\bar{\omega}_{t+1}T_tR^k_{t+1},
\end{aligned} \tag{3.26}$$

subject to the participation constraint

$$\begin{aligned}
&\{1-[\bar{p}G(\bar{\omega}_{t+1})+(1-\bar{p})B(\bar{\omega}_{t+1})]\}\bar{\omega}_{t+1}T_tR^k_{t+1} \\
&+(1-\mu)T_tR^k_{t+1}[\bar{p}\int_0^{\bar{\omega}_{t+1}} \omega_{t+1}dF(\omega_{t+1}) \\
&+(1-\bar{p})\int_0^{\bar{\omega}_{t+1}} \omega_{t+1}dG(\omega_{t+1})] \\
\geq\ & R^m_{t+1}(T_t-n_t).
\end{aligned} \tag{3.27}$$

The other features of the model are the same as the baseline model. The same parameters and the same steady state values are used in the model simulation exercise.

3.3.2 Model Parameterization

There are twenty three parameters that need to be assigned values. Standard values are chosen for preference and technology parameters. These include the discount factor β, the inverse of the Frisch elasticity of labor supply χ, the capital share parameter α, the depreciation rate δ, and the elasticity of the price of capital with respect to the investment ϕ. Fairly reasonable values are chosen as reported in Table 1 in the appendix. In order to calibrate non-standard parameters associated with financial variables, I fix the steady state ratio of good to bad projects roughly around 2, $p(e) = 0.64$, and the agency cost parameter, μ, at 0.12 in keeping with BGG. In addition, there are three target financial variables.

First, a ratio of debt to net worth, $\frac{D}{N}$, is of 0.4 for small firms and 0.6 for large firms respectively. In the cross-section, credit spreads are larger for low leverage firms (Collin-Dufresne, Goldstein, and Martin 2001) and empirical evidence consistently found that leverage is positively related to firm size (Titman and Wessels 1988; Rajan and Zingales 1995; Fama and French 2002). Faulkender and Petersen (2006) and Levin, Natalucci, and Zakrajsek (2004) argue that 0.5 would be reasonable value for average leverage. As there is no clear guidance in regard to the difference in the leverage ratio, I suppose large firms have 50% more debt, and the results are not sensitive even if 25% is chosen instead of 50%.

In BGG, however, small firms with less access to credit have higher leverage ratio. They set leverage ratio of 1.1 for small firms and 0.8 for large firms. But those values may not be consistent with empirical observations. Even if the leverage ratio is countercyclical, it is more likely to be positively correlated with firm size in the cross-section, as consistently reported in the literature.[11] In addition, Faulkender and Petersen (2006) report firms with access to public bond markets, which are likely to be large in firm size, have 35% more debt. Fama and French (2002) and Leary and Roberts (2010) document the leverage ratio is negatively correlated with profitability and growth opportunities, which tend to be associated with small firms.

The second target variable is an annualized business default rate, $F(\bar{\omega})$, which is three percent for small firms and one point five percent for large firms, so that the average is 2.25%. It is comparable to 3% in BGG.

Third, a risk spread, $R^k - R$, is equal to four percent for small firms and one percent for large firms, so that 2.5% on average. BGG suggest a spread of 200 b.p. over the risk-free rate and Levin, Natalucci, and Zakrajsek (2004) find a spread of 227 b.p. for the median firm in their sample over 1997-2003. Our choice is within the reasonable range of spread.

Consistent with these target variables, several parameters associated with the financial contract are calibrated, such as the aggregate return of small and large firms, R_1^k and R_2^k, the volatility of the idiosyncratic risk, σ, the mean of idiosyncratic productivity in bad projects, a, the ratio of volatility between good and bad projects, b, and the coefficient on the probability function, cpb.

Then the fraction of transfer to new entrepreneurs, v, is assumed to be 0.01, and the exit rate of entrepreneurs, γ, is calibrated to induce stationarity of aggregate net worth dynamics, which is virtually technical and does not change

[11] For instance, the leverage of small firms that are depressed could be higher than the one of large firms. But a new entrant, which is small in size, would srtart with low leverage due to limited credit access. This is consistent with our setting and results.

the results qualitatively. See also Table C.1 in the appendix.

3.3.3 Results

This section presents impulse responses, which generate different sectoral responses to business cycle shocks. The risk-shifting channel is important to address the asymmetric impacts of business cycle shocks, which may be called "excess sensitivity" of small firms as reported by Gertler and Gilchrist (1991), Kashyap, Lamont, and Stein (1992), Oliner, Rudebusch, Oliner, and Oliner (1994), Morgan (1998), and Ghosal and Loungani (2000).

In Figure C.5 and C.6, each panel plots the impulse responses to an uncertainty shock in the baseline model and the modified BGG respectively. The solid line corresponds to the small firms and the dotted line corresponds to the large firms. In Figure C.5, in response to an uncertainty shock, investment by the small firms decreases by more than three times as much as the investment of the large firms. The other variables such as sectoral output, asset prices, and credit spread are also differ sharply across the sectors. While the baseline model is able to generate a quantitatively severe impact of an uncertainty shock on the small firms, it is not the case in the modified BGG model in which there is no cost associated with identifying a better project. As shown in Figure C.6, the small firms do not respond to the shock as much as the large firms.

The implications are the same even if we consider a monetary policy shock as shown in Figure C.7 and C.8. Hence incorporating the additional dimension of the incentive problem is crucial to generate the cross-sectional differences in response to the business cycle shocks across the sectors. As an increase in the cross-sectional dispersion of productivity induces entrepreneurs to engage in a risky project, lenders' fear for the risk-shifting problem heightens. This in turn makes lenders reevaluate creditworthiness of the investment, and it leads them to reallocate a greater amount of their loans into large firms, which may be called, "flight to quality." This exacerbates negative business-cycle shocks to an economy by generating the distortion of loan allocation across sectors: more loans are supplied into the sector where the marginal productivity is relatively low.

Figure C.9 and C.10 show the impact of loan reallocation across the sectors. Each panel in Figure C.9 graphs the impulse responses to an uncertainty shock and in Figure C.10 plots the impulse responses to a monetary shock. The solid line corresponds to the baseline model and the dotted line corresponds to the modified BGG. The misallocation of loans across the sectors is clear in the baseline model. As shown in the first and the second panel, ‘Flight to quality’ phenomena channel relatively more credit to the large firms, but their marginal productivity is relatively low. The small firms incline to an inferior project, which further reduces productivity and sectoral and overall output.

3.4 Some Empirical Evidence

In the model, as uncertainty rises, the small firms turn to proejcts that are of low productivity on average. As lenders adjust portfolio compositions in favor of the large firms, it leads to a collapse of investment by the small firms. This section presents some patterns between firm size and growth together with a decomposition of periods by high and low uncertainty, which is consistent with the prediction of the model.

3.4.1 Data

The empirical investigation is conducted using industry data. Annual (1958-1996) SIC four-digit industry, time-series data are obtained from Bartelsman, Becker and Gray ("NBER-CES Manufacturing Industry Database," NBER, 2000).[12] While Compustat firm-level data set is widely used, this industry-level data set has comparative advantage in that it contains data on private firms as well as publicly traded firms. Given that relatively small firms are more likely to be private firms, which are not included in Compustat dataset, it would be appealing to use the industry-level data. After removing industry data that did not have a consistent time series, there are 451 industries in our sample. The data provides time series on new capital spending, value of industry shipments, real capital stock and multi-factor total factor productivity growth, as well as various types of price deflator.

Each industry is classified using the definition provided by the Small Business Administration. As is common in the literature, the number of employees is used to measure size. And an industry is "small-business dominated" only if employment in firms with fewer than 500 employees accounts for at least 60% of industry employment. Following Ghosal and Loungani (2000), this paper classifies an industry as "consistently" small-business dominated if an industry

[12] SIC four-digit industry has been supplanted by the six-digit NAICS code, which is released in 1997. Therefore it may be more reliable to use data from 1958 to 1997. However, since a updated version through 2005 is available at http://www.nber.org/nberces/, the same empirical exercises in this paper were conducted to check robustness of results. The qualitative results remain largely intact.

is classified as small-business dominated over 1990 and 1997. Likewise, an industry is "consistently large-business dominated" only if employment in firms with fewer than 500 employees is at most 40% of industry employment over 1990 and 1997. The other industries are considered as "middle-business industry." The U.S. Census Bureau provides industry structure data (SIC four-digit data) on the size distribution of firms and number of employment. Using this statistics of U.S. Business data, industries are categorized into three groups : Small, Middle and Large.

3.4.2 Productivity Differences by Firm-Size Classes during the Periods of High Uncertainty

In order to test the hypothesis that productivity differences between firms categorized by size during times of uncertainty, the measurement of uncertainty is required. Two different levels of uncertainty measures are considered. As an economy-wide measure, GDP growth volatility is constructed from a GARCH(1,1) specification with log(GDP) regressed on its 4 quarterly lagged. It is calculated using data from BEA NIPA tables (1955-1996).[13] The industry-wide uncertainty measure is also adopted, which is the same as in Bloom (2009), in order to check robustness of results.[14] Specifically, this industry uncertainty measure is the annualized interquartile range of industrial production growth for manufacturing industries which is calculated from Federal Reserve Board's monthly industrial production database. The reason why this industrial measure of uncertainty is chosen for the empirical test is that it is constructed using the same manufacturing industry data source and thus it may be more relevant measure to test the implication of the model. Annual output growth from monthly data is defined as $(x_{i,t+12} - x_{i,t})/(0.5 \times x_{i,t+12} - 0.5 \times x_{i,t})$.[15]

Table I and II present the mean and standard deviation of productivity growth, value added growth and investment growth for three different size industry groups. Results are presented separately for subsamples of low and high expected uncertainty at both economy-wide and industry levels. The median uncertainty is used to divide periods into the subsamples of high and low uncertainty at both economy-wide and industry levels.

There are several patterns which are noticeable in Table I and II. First, within the same size group, productivity

---

[13]It is calculated from 1955 to avoid the impact of the wage and price controls from the Korean War.

[14]Due to the availability of data, this measure is only available from 1973 onwards.

[15]The correlation of these measures and GDP growth is documented in Bloom (2009). The level of uncertainty increases during recessions.

Table 3.1: MEAN(S.D.) OVER 1960-1996 : Economy-Wide Uncertainty Measure

Uncertainty Measure	Forecast Standard Deviation of GDP Growth					
	High Uncertainty			Low Uncertainty		
	Small	Middle	Large	Small	Middle	Large
Productivity Growth	0.00073	0.00373***	0.00637***	0.00679***	0.00586***	0.00890***
(s.d.)	(0.0016)	(0.0011)	(0.0011)	(0.0015)	(0.0011)	(0.0010)
Value Added Growth	-0.00059	0.00484*	0.01502***	0.02020***	0.01593***	0.01915***
(s.d.)	(0.0034)	(0.0027)	(0.0024)	(0.0034)	(0.0026)	(0.0021)
Investment Growth	0.01854	0.02444***	0.03349***	0.02755**	0.02461***	0.03366***
(s.d.)	(0.0119)	(0.0065)	(0.0057)	(0.0114)	(0.0065)	(0.0058)

***,**,* denotes significance at the 1, 5 and 10 percent level

Table 3.2: MEAN(S.D.) OVER 1972-1996 : Industry-Wide Uncertainty Measure

Uncertainty Measure	Annual IQR of Industrial Production Growth					
	High Uncertainty			Low Uncertainty		
	Small	Middle	Large	Small	Middle	Large
Productivity Growth	-0.00169	0.00233	0.00546***	0.00780***	0.00668***	0.00858***
(s.d.)	(0.0022)	(0.0015)	(0.0015)	(0.0018)	(0.0014)	(0.0013)
Value Added Growth	-0.01494***	-0.01039***	-0.00028	0.01861***	0.01459***	0.01742***
(s.d.)	(0.0046)	(0.0038)	(0.0033)	(0.0040)	(0.0033)	(0.0026)
Investment Growth	-0.01307	-0.00667	0.01169*	0.03976***	0.03756***	0.04289***
(s.d.)	(0.0144)	(0.0080)	(0.0071)	(0.0146)	(0.0077)	(0.0069)

***,**,* denotes significance at the 1, 5 and 10 percent level

growth and value added growth are both higher during times of low uncertainty. Second, when uncertainty is high, there is a remarkable pattern between firm size and growth rates. Small-business dominated industries grow slower than large-business dominated industries during times of high uncertainty. This pattern is robust to the three alternative measures of growth, and the two different ways to measure uncertainty. All types of growth rates increase in firm size. In contrast, there is no discernible pattern in the growth rates during periods of low uncertainty.

Table III provides the results of the mean comparison test of the productivity growth and value added growth between small- and large-firm dominated industries. T-statistic and p-value were obtained assuming unequal variances. The number in parentheses is a p-value under the hypothesis that two sample means are equal.

The formal tests establish the pattern observed in Table I and II. The hypothesis that productivity growth or value added growth between small- and large-business dominated industries are the same when uncertainty is high, is

Table 3.3: Two-sample Mean Comparison Test

Uncertainty Measure	Forecast S.D. of GDP Growth		IQR of Industrial Prod. Growth	
	High Uncertainty	Low Uncertainty	High Uncertainty	Low Uncertainty
Productivity Growth(t-stat)	-2.8594***	-1.1964	-2.6941***	-0.3565
(p-value)	(0.0021)	(0.1158)	(0.0036)	(0.3607)
Value Added Growth(t-stat)	-3.7262***	0.2660	-2.5825***	0.2460
(p-value)	(0.0001)	(0.6049)	(0.0049)	(0.5971)
Investment Growth(t-stat)	-1.1358	-0.4777	-1.5444*	-0.1938
(p-value)	(0.1281)	(0.3164)	(0.0614)	(0.4232)

***,**,* denotes significance at the 1, 5 and 10 percent level

strongly rejected at the 1% significance level. While the hypothesis of the same growth rates is strongly rejected during times of high uncertainty, the hypothesis cannot be rejected when uncertainty is low. These tests are robust to two different ways to construct aggregate uncertainty as reported in Table III. While the hypothsis of the same investment growth rates when uncertainty is high is not rejected at the 10% significance level with the economy-wide uncertainty measure, it is rejected with the industry-level measure.

3.4.3 Discussion

The patterns we observed in the previous section raise an interesting question. Why do small firms suffer from the significant lower growth rates during the times of high uncertainty than large firms? Which factors may cause remarkable declines in the growth rates of small firms as uncertainty rises? Several competing theories that are consistent with this observation can be discussed.

First, small firms are more likely to shift the riskiness of their projects. Shareholders can transfer wealth from bondholders by engaging in risky projects. Some empirical evidence is addressed to support the risk-shifting hypothesis (For financial firms, Esty (1997), Gan (2004) and Landier, Sraer, and Thesmar (2011). Regarding nonfinancial firms, Eisdorfer (2008), Lelarge, Sraer, and Thesmar (2010), and Stromberg and Becker (2010). Small firms tend to have more growth opportunities and intangible assets. They are more likely to be credit constrained, opaque and subject to less regulation. Moreover, shareholders' and managers' interests of a small firm are more aligned than larger firms due to the ownership structure. Arguably, these characteristics are correlated with risk-shifting incentive.

Second, as a complement to the first story, if a period of high uncertainty is associated with higher information acquisition and processing costs, it would be difficult for firms with the scarcer resource of human capital to identify a good project. Adequate market research and sophisticated planning must be conducted to survive in a highly competitive market. However, a small business with fewer employees tends to have a scarcer resource of human capital and a small-size research department to manage its business. If the marginal costs of producing information rise faster in a small business in a highly uncertain world, small firms may generate less value during periods of high uncertainty.

However, there may be some objections in regard to the cause of the observation. First, someone might argue that a scarcity of liquidity at high uncertainty periods would cause small firms to liquidate a fraction of their high return projects. If firms engage in long term investment with short term debt, they may need to liquidate some fraction of high-return long term investment in response to a liquidity shock. This may lead firms to suffer from low productivity growth. Indeed, small firms tend to rely more on short-term debt (**?**; **?**).

However, this possibility can be excluded since small firms tend to maintain a significantly larger stock of liquid assets and working capital than large firms to cover their short-term liabilities. Table IV shows that total debt to equity ratio is higher in large firms.[16] Short term debt to equity ratio is higher in small firms while long-term debt to equity ratio is higher in large firms. Yet, even though small firms carry the higher ratio of short term debt, they maintain a significantly larger stock of liquid assets and working capital to cover their short-term liabilities.[17] This is consistent with Diamond and Rajan (2001)'s view in that short-term debt is a sympton of adverse economic environments and the consequence of optimal choices rather than a cause of a crisis. The accumulation of short-term debt reflects the poor creditworthiness of borrowers, and those borrowers hold a greater amount of liquid assets endogenously to minimize liquidity risk.[18]

Next, demand factors may play a role to some extent. If demand for goods and services mainly produced by small-

[16] Since asset values are subject to inflation, it may be justified to collect data over relatively short periods of time

[17] In this context, Levin, Natalucci, and Zakrajsek (2004) also point out that it is reasonable to use the long term debt to equity ratio instead of total debt to equity ratio in their estimation of BGG model. In this regard, when borrowers and lenders make financial contracts, long term debt to equity ratio should be of more concern.

[18] In the context of financial firms, Benmelech and Dvir (2013) test the hypothesis whether the high ratios of short-term debt caused the East Asian financial crisis of 1997-1998. They find even negative relation between short-term debt and the probability of failure.

Table 3.4: Mean over all manufacturing firms from 1987-1995

	Small(less than $25 million)	Large
Debt/Equity	0.67	0.74
Long Term Debt/Equity	0.42	0.60
Short Term Debt/Equity	0.24	0.13
Liquidity Stock/Equity	0.26	0.10
Working Capital/Total Asset	0.32	0.09

Data Source : Quaterly Financial Report for Manufacturing Corporations (QFR) from 1987-1995

business dominated industries is more cyclical, it might prevent small firms from engaging in productivity-enhancing investment. However, to the best of my knowledge, this channel is not very well documented in existing literature. In the following empirical exercise, several instruments are used to try to isolate this industry specific demand effect to some extent.

3.4.4 Empirical Tests

This section conducts a formal test for the risk-shifting hypothesis. In order to control a potential endogeneity caused by unobserved industry specific demand factors, a set of instruments is used which is unlikely driven by industry specific factors. The strategy for testing the hypothesis closely follows Eisdorfer (2008), who test a similar hypothesis over financially distressed firms using CRSP and COMPUSTAT data.

3.4.4.1 Empirical Strategy

The risk-shifting in the model implies that the investment of a small business generates less value during periods of high uncertainty compared to periods of low uncertainty.

As the measurement of firm value, which is a dependent variable in regression, productivity growth is selected as the primary measure, and empirical tests are repeated with value added growth as an alternative measure. Productivity growth is constructed by Bartelsman, Becker and Gray (2000). Value added growth rates of each industry are adjusted to annual inflation rates as NBER-CES Manufacturing Industry Database only provides information on nominal annual value added.

As an independent variable, investment intensity (I/K) is measured by gross industry investment scaled by the beginning-of-period capital stock as Fazzari, Hubbard, and Petersen (1987), Hoshi, Kashyap, and Scharfstein (1991) and Ghosal and Loungani (2000).[19] Lagged industry cash flow scaled by capital stock, (CF/K) is included as a control variable as it may affect the firm's investment policy. In addition, the NBER recession indicator is included to capture potential economy-wide influences. Main findings of this study are not sensitive to the inclusion of them.

The empirical tests consist of the following steps:

1. Parition samples into two periods by the median uncertainty at both economy-wide and industry levels : (a) high uncertainty, and (b) low uncertainty.

2. Construct the dummy variable, which is assigned 1 if an industry is dominated by small businesses or 0 if it is dominated by large businesses by the classification system of the SBA.[20]

3. Regress productivity growth rates or value added growth rates on investment intensity in that year and on an interaction variable between investment intensity and the size dummy variable. A two-stage least squares (2SLS) method is applied with a set of instrument variables to control a potential endogeneity, which is explained in the next section.

All variables are measured in logarithms, and observations are pooled together as the size dummy variable is not time varying. Productivity growth equation is given by

$$G^A_{i,t} = a_i + \beta_1 (I/K)_{i,t} + \beta_2 SIZE_i + \beta_3 (I/K)_{i,t} * (SIZE_i) + \beta_4 (CF/K)_{i,t-1} + \beta_5 RECESSION_t + \varepsilon_{i,t}.$$

3.4.4.1.1 Endogeneity of Investment Since the empirical tests regress changes in productivity (or changes in value added) in a specific year on investment intensity in the same year, they may be affected by a reverse causality relation.

[19]One might question the validity of regressing productivity growth on investment. While intangible investment like R&D outlays is believed to induce higher productivity growth, work in the aggregated growth accounting tradition has been typically skeptical about the causal effect of capital investment on productivity growth. And NBER-CES Manufacturing Industry Database only provides information on investment which includes new machinery and equipment while it does not include expenditures on intangible assets. While there may be controversy over the causality between equipment investment and productivity growth, there is some empirical evidence supporting an idea that equipment investment may have an impact on the cross-countries distribution of growth rates (De Long and Summers 1990; De Long and Summers 1993; Jones 1994).

[20]The sample of middle-business dominated industries is dropped to avoid potential measurement errors in our measure of firm size.

In addition, if demand is more cyclical in small-dominated industries, a latent variable may be potentially correlated with investment and the growth rate. To obtain consistent estimates, a two-stage least squares (2SLS) regression technique is applied with a set of instruments. Investment and the interaction variables are treated as endogenous. A set of instruments includes the growth rate of aggregate net equipment & software investment (data from NIPA table), HP-filtered energy prices and the growth rate of the Federal funds rate, which is adjusted to inflation.[21] These instruments may affect investment decisions of firms, but because these variables operate at the economy-wide level, it is reasonable to argue that those variables are exogenous to each industry.[22]

3.4.4.2 Results

Table V presents results using the economy-wide uncertainty measure which divides samples into subsamples of high and low uncertainty periods. Value added growth as well as productivity growth is used as a dependent variable to check robustness. Table VI shows similar results for industry-level uncertainty measure. The results are not sensitive to the other estimation procedure like GMM method.

Across all results reported in Table V and VI, in periods of low uncertainty, the coefficient of the interaction term is not significant, which implies that firm size does not have a statistical implication in the relation between investment and productivity growth (or value added growth). In periods of high uncertainty, however, the impact of investment on the growth is closely related to firm size. All the regression coefficients of the interactive variable indicate that it is negative and statistically significant, which implies that investment by small-businesses generates less value or less productivity enhancing than large businesses when uncertainty is high. These results are in favor of the results of the model.

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[21]Ghosal and Loungani (2000) also use similar instruments. In order to get rid of upward trend in aggregate demand, the HP filter is applied to annual energy prices using $\lambda = 100$. Alternatively, the growth rate of energy prices may be used instead of the HP filtered energy prices. However, the main results are not sensitive to this alternative instrument.

[22]The correlation (p-value) between investment intensity and aggregate equipment & software investment growth / real interest rate growth / HP-filtered energy prices are 0.0827 (0.0000) / 0.1096 (0.0000) / -0.0198 (0.0105) respectively. Even if the correlation between investment intensity and HP filtered energy prices seems small, they are correlated quite differently in each subsample. From 1960 to 1996, the correlation is –0.0833(0.000) in the subsamples of high uncertainty while 0.0618(0.000) in the subsamples of low uncertainty. It may reflect different demand and supply conditions of energy in each subsample.

Table 3.5: Estimation Results : Economy-wide Uncertainty Measure

	Productivity Growth Rate		Value Added Growth Rate	
	High Uncertainty	Low Uncertainty	High Uncertainty	Low Uncertainty
Intercept	0.0855***	-0.0699	0.5225***	-0.2626**
	(3.00)	(-1.32)	(7.32)	(-2.11)
Investment	0.0335***	-0.0285	0.2059***	-0.1059**
	(2.91)	(-1.39)	(7.12)	(-2.21)
Size Dummy	-0.1424***	0.0345	-0.2453**	0.1110
	(-3.07)	(0.48)	(-2.21)	(0.65)
Investment×Size	-0.0525***	0.0139	-0.0953**	0.0434
	(-3.01)	(0.52)	(-2.28)	(0.68)
Recession Dummy	-0.0302***	-0.0327***	-0.0905***	-0.0878***
	(-9.72)	(-9.45)	(-13.34)	(-10.16)
Lagged Cash Flow	-0.0145***	-0.0085***	-0.0499***	-0.0136***
	(-7.28)	(-5.12)	(-10.49)	(-3.27)
# Observations	4972	4715	4972	4715
Root MSE	0.0644	0.0576	0.1428	0.1372

Note: The dependent variable is at top of each column. The subsamples are divided by the median of the economy-wide uncertainty.
T-statistics are in parentheses based on heteroskedasticity-consistent standard error.
***,**,* denotes significance at the 1, 5 and 10 percent level.

Table 3.6: Estimation Results : Industry-Level Uncertainty Measure

	Productivity Growth Rate		Value Added Growth Rate	
	High Uncertainty	Low Uncertainty	High Uncertainty	Low Uncertainty
Intercept	0.0746**	0.1059	0.5133***	-0.1865
	(2.02)	(0.97)	(5.46)	(-0.78)
Investment	0.0283*	0.0395	0.2027***	-0.0775
	(1.91)	(0.94)	(5.36)	(-0.84)
Size Dummy	-0.1483**	0.0362	-0.2876**	0.0793
	(-2.53)	(0.31)	(-2.03)	(0.31)
Investment×Size	-0.0539**	0.0093	-0.1112**	0.0311
	(-2.44)	(0.22)	(-2.07)	(0.33)
Recession Dummy	-0.0302***	-0.0777***	-0.0975***	-0.3834***
	(-8.28)	(-3.35)	(-11.82)	(-7.09)
Lagged Cash Flow	-0.0165***	-0.0233**	-0.0573***	-0.0030
	(-5.15)	(-2.43)	(-7.62)	(-0.14)
# Observations	3142	3406	3142	3406
Root MSE	0.0683	0.0616	0.1531	0.1366

Note: The dependent variable is at top of each column. The subsamples are divided by the median of the economy-wide uncertainty.
T-statistics are in parentheses based on heteroskedasticity-consistent standard error.
***,**,* denotes significance at the 1, 5 and 10 percent level.

3.5 Conclusions

This paper proposes a financial accelerator model that takes account of the risk-shifting incentive of entrepreneurs. The risk-shifting channel serves as the amplification mechanism for the uncertainty shock. Increases in uncertainty lead entrepreneurs to engage in riskier projects, which shifts risk to lenders. As the lenders reallocate credit from the high productivity sector, in which the risk-shifting problem is more prevalent, to the low productivity sector, it further depresses aggregate economic activities. Some empirical evidence supports the prediction of the model.

It might be in principle possible that variation in the cross-sectional dispersion of productivity is endogeneously driven rather than it is given exogenously. However, this paper does not address the origin of the variation in the dispersion of productivity, and it is beyond the scope of this paper. Another question is whether it would be welfare improving if policymakers can reallocate loans from the low to the high marginal productivity sector where the external financing constraint tends to be more severe. It may not always be the case if the high marginal productivity sector is more vulnerable to the risk-shifting problem. This can be another direction for future research.

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Appendix A

Appendix for Chapter 1

A.1 Proofs

Proof of Lemma 3

The net profits of securitizer j can be written as

$$\begin{aligned}
\Pi^F &= \text{weighted sum of the expected value of ABS}_k - \text{liabilities} - \text{information costs} && \text{(A.1)}\\
&= N_j \int_k w_{k,j}\{p\mu + (1-p)\eta[(1-\lambda^M(\alpha_k))\mu^B(1-\tilde{\kappa}^M_{k,j}) + d^M_k] \\
&\quad +(1-p)(1-\eta)[(1-\lambda^L(\alpha_k))\mu^B(1-\tilde{\kappa}^L_{k,j}) + d^L_k]\}\mathrm{d}k \\
&\quad -N_j d_j\{pR + (1-p)\eta[\Lambda^M + R(1-\Lambda^M)] \\
&\quad +(1-p)(1-\eta)[\Lambda^L + R(1-\Lambda^L)]\} - N\iota(\alpha_j),
\end{aligned}$$

subject to the collateral constraint

$$d_j N_j \leq N_j \int_k w_{k,j}\mathbf{q}^L_k \mathrm{d}k,^1 \qquad \text{(A.2)}$$

[1]Remember that, for a measure zero set of ABS_k, the return of underlying projects collapses to zero. But at $t = 1$, securitizer k is expected to receive that shock with probability ε, where ε is arbitrarily small.

the budget constraint

$$N_j \int_k w_{k,j} Q_k \mathrm{d}k \leq N_j Q_j, \tag{A.3}$$

and

$$\Lambda^S d_j = \int_k w_{k,j} d_k^S \mathrm{d}k,$$

where 1) $w_{k,j}$ represents the quantity of ABS_k in securitizer j's portfolio normalized by N_j, 2) $\tilde{\kappa}_{k,j}^S$ is a fraction of ABS_k being liquidated to obtain d_k^S, and 3) Q_k is the price of ABS_k at $t = 1$.

Securitizer j chooses d_j, α_j, $\{w_{k,j}\}_k$, and $\{\tilde{\kappa}_{k,j}^S\}_k$, and is aware that its information choice affects Q_j. The problem can be solved in two steps. First, I solve for $\{w_{k,j}\}_k$ and then solve for the rest of the choice variables.

The first order condition with respect to $w_{k,j}$ implies that

$$\psi' Q_k - \psi \mathbf{q}_k^S = p\mu + (1-p)\eta[(1-\lambda^M(\alpha_k))\mu^B(1-\tilde{\kappa}_{k,j}^M) + d_k^M] + (1-p)(1-\eta)[(1-\lambda^L(\alpha_k))\mu^B(1-\tilde{\kappa}_{k,j}^L) + d_k^L],$$

where ψ' and ψ are Lagrangian multipliers for the budget and the collateral constraint respectively. Plugging it into the budget constraint (A.3), we obtain

$$\begin{aligned}
& \int_k w_{k,j}\{p\mu + (1-p)\eta[(1-\lambda^M(\alpha_k))\mu^B(1-\tilde{\kappa}_{k,j}^M) + d_k^M] \\
& +(1-p)(1-\eta)[(1-\lambda^L(\alpha_k))\mu^B(1-\tilde{\kappa}_{k,j}^L) + d_k^L]\}\mathrm{d}k \\
\leq\; & p\mu + (1-p)\eta[(1-\lambda^M(\alpha_j))\mu^B(1-\tilde{\kappa}_{j,j}^M) + d_j^M] \\
& +(1-p)(1-\eta)[(1-\lambda^L(\alpha_j))\mu^B(1-\tilde{\kappa}_{j,j}^L) + d_j^L] - \psi(\int_k w_{k,j}\mathbf{q}_k^L \mathrm{d}k - \mathbf{q}_j^L).
\end{aligned}$$

Substituting this into the objective (A.1), the Lagrangian objective function can be written as

$$\begin{aligned}
\Pi^F(d_j, \alpha_j) &= N_j\{p\mu + (1-p)\eta[(1-\lambda^M(\alpha_j))\mu^B(1-\tilde{\kappa}^M_{j,j}) + d^M_j] \\
&\quad +(1-p)(1-\eta)[(1-\lambda^L(\alpha_j))\mu^B(1-\tilde{\kappa}^L_{j,j}) + d^L_j]\} \\
&\quad -N_j d_j\{pR + (1-p)\eta[\Lambda^M + R(1-\Lambda^M)] \\
&\quad +(1-p)(1-\eta)[\Lambda^L + R(1-\Lambda^L)]\} - N\iota(\alpha_j) \\
&\quad -\psi N_j(\int_k w_{k,j}\mathbf{q}^L_k \mathrm{d}k - \mathbf{q}^L_j) + \psi[N_j \int_k w_{k,j}\mathbf{q}^L_k \mathrm{d}k - d_j N_j] \\
&= N_j\{p\mu + (1-p)\eta[(1-\lambda^M(\alpha_j))\mu^B(1-\tilde{\kappa}^M_{j,j})] \\
&\quad +(1-p)(1-\eta)[(1-\lambda^L(\alpha_j))\mu^B(1-\tilde{\kappa}^L_{j,j})]\} \\
&\quad -N_j d_j\{pR + (1-p)\eta[R(1-\Lambda^M)] \\
&\quad +(1-p)(1-\eta)[R(1-\Lambda^L)]\} - N\iota(\alpha_j) \\
&\quad +\psi N_j(\mathbf{q}^L_j - d_j).
\end{aligned}$$

Since there are no arbitrage opportunities in the secondary asset market (equation (1.4)), I focus on a case in which securitizer j chooses to liquidate the equal fraction $\tilde{\kappa}^M_{k,j}$ of ABS_k, $k \in [0,1]$ that constitutes its portfolio (this is indeed true in a symmetric equilibrium). This implies that $d^S_k = \Lambda^S d_j$, and therefore, $\tilde{\kappa}^M_{k,j} = \frac{\Lambda^S d_j}{\mathbf{q}^S_k}$.

Therefore, the objective of each securitizer can be further simplified to the problem in which each securitizer chooses d_j and α_j to maximize

$$\begin{aligned}
\Pi^F(d_j, \alpha_j) &= N_j\{p\mu + (1-p)[\eta(1-\lambda^M(\alpha_j)) + (1-\eta)(1-\lambda^L(\alpha_j))]\mu^B - Rd_j - \iota(\alpha_j)\} \\
&\quad -N_j(1-p)\{\eta[1-\lambda^M(\alpha_j))\mu^B\kappa^M_j - R\Lambda^M d_j] + (1-\eta)[(1-\lambda^L(\alpha_j))\mu^B\kappa^L_j - R\Lambda^L d_j]\} \\
&= N_j\{p\mu + (1-p)[\eta(1-\lambda^M(\alpha_j)) + (1-\eta)(1-\lambda^L(\alpha_j))]\mu^B - Rd_j - \iota(\alpha_j)\} \\
&\quad -N_j(1-p)\{\eta\Lambda^M[(1-\lambda^M(\alpha_j))\mu^B\overline{\kappa}^M_j - Rd_j] + (1-\eta)[(1-\lambda^L(\alpha_j))\mu^B\overline{\kappa}^L_j - Rd_j]\},
\end{aligned}$$

subject to the collateral constraint $d_j \leq \mathbf{q}^L_j$. Consequently, the lemma follows.□

Proof of Lemma 5

The objective of each bank under financial autarky can be expressed as

$$\begin{aligned}
\Pi^N(d,\alpha) &= N\{\underbrace{p}_{High\text{ state}}\underbrace{(\mu - Rd)}_{hold} \\
&+ \underbrace{(1-p)\eta}_{Middle\text{ state}}\underbrace{(1-\lambda^M(\alpha))}_{\text{good state (s=g)}}\left\{\begin{array}{c}\underbrace{\tilde{P}_N(\alpha)}_{\text{prob. that ins. investors do not run}}\underbrace{[\mu^B - Rd]}_{hold}+ \\ \underbrace{[1-\tilde{P}_N(\alpha)]}_{\text{run}}\underbrace{\mu^B\int(1-\kappa^{r,M})dF(r|s=g)}_{liquidation}+Rd-Rd\end{array}\right\} \\
&+(1-p)\eta\lambda^M\{Rd-Rd\} \\
&+ \underbrace{(1-p)(1-\eta)}_{Low\text{ state}}\underbrace{(1-\lambda^L(\alpha))}_{\text{good state (s=g)}}\left\{\begin{array}{c}\underbrace{\tilde{P}_N(\alpha)}_{\text{do not run}}\underbrace{[\mu^B - Rd]}_{hold}+ \\ \underbrace{[1-\tilde{P}_N(\alpha)]}_{\text{run}}\underbrace{\mu^B\int(1-\kappa^{r,L})dF(r|s=g)\}}_{liquidation}\end{array}\right\} \\
&+(1-p)\eta\lambda^M\{Rd-Rd\} \\
&- \underbrace{\iota(a)}_{\text{information costs}} \quad \},
\end{aligned}$$

which can be rewritten as

$$\begin{aligned}
\Pi^N(d,\alpha) &= N\{p\mu + (1-p)\{\eta\mu^B(1-\lambda^M(\alpha)) + (1-\eta)\mu^B(1-\lambda^L(\alpha))\} - Rd - \iota(\alpha)\} \\
&-N(1-p)\{\eta(1-\lambda^M(\alpha))\Lambda^g[\mu^B\int\overline{\kappa}^{r,M}dF(r|s(g)) - Rd] + \eta\lambda^M(\alpha)\Lambda^b(-Rd) \\
&+(1-\eta)(1-\lambda^L(\alpha))\Lambda^g[\mu^B\int\overline{\kappa}^{r,L}dF(r|s(g)) - Rd] + (1-\eta)\lambda^L(\alpha)\Lambda^b(-Rd)\},
\end{aligned}$$

where $\overline{\kappa}^{r,S} = \frac{d}{q^{r,S}}$. Therefore, the lemma follows.

For future references, the first order conditions are given by

$$\begin{aligned}
0 &= p(\mu - R) + (1-p)\eta(1-\lambda^M(\alpha))[\mu^B(1-E(\frac{1-\tilde{P}_N(\alpha)}{q^{r,M}})) - R\tilde{P}_N(\alpha)] \\
&+(1-p)(1-\eta)(1-\lambda^L(\alpha))[\mu^B(1-E(\frac{1-\tilde{P}_N(\alpha)}{q^{r,L}})) - R\tilde{P}_N(\alpha)] \\
&-\iota(a) - \psi(1-d)^2,
\end{aligned} \tag{A.4}$$

$$0 = (1-p)\eta(1-\lambda^M(\alpha))(1-\tilde{P}_N(\alpha))\mu^B(\frac{1}{q^{b,M}} - \frac{1}{q^{g,M}})\frac{d}{1-d} \tag{A.5}$$

$$+(1-p)(1-\eta)(1-\lambda^L(\alpha))(1-P_N(\alpha))\mu^B(\frac{1}{q^{b,L}} - \frac{1}{q^{g,L}})\frac{d}{1-d}$$

$$+(1-p)\eta(-\lambda^{M\prime})\{\mu^B[1-(1-P_N(\alpha))(\alpha\frac{d}{q^{1,M}} + (1-a)\frac{d}{q^{0,M}})] - RP_N(\alpha)d\} \tag{A.6}$$

$$+(1-p)(1-\eta)(-\lambda^{L\prime})\{\mu^B[1-(1-P_N(\alpha))(\alpha\frac{d}{q^{g,L}} + (1-a)\frac{d}{q^{b,L}})] - RP_N(\alpha)d\} - \iota'(\alpha)\frac{1}{1-d}$$

$$+(1-p)\eta(1-\lambda^M(\alpha))[-Rd + \mu^B E_{r|s=g}(\kappa^{r,M})]P_N(\alpha)'\frac{1}{1-d}$$

$$+(1-p)(1-\eta)(1-\lambda^L(\alpha))[-Rd + \mu^B E_{r|s=g}(\kappa^{r,L})]P_N(\alpha)'\frac{1}{1-d},$$

and the slackness condition

$$\psi(d - q^{b,L}) = 0. \tag{A.7}$$

□

Proof of Proposition 23

The first order condition with respect to d is given by

$$\begin{aligned} 0 \quad = \quad & p\mu + (1-p)\{\eta\mu^B(1-\lambda^M(\alpha)) + (1-\eta)\mu^B(1-\lambda^L(\alpha))\} - R \\ & -(1-p)\eta(1-\lambda^M(\alpha))\mu^B(1-\tilde{P}(\overline{\alpha}))[\frac{1}{\mathbf{q}^M} - R] \\ & -(1-p)(1-\eta)(1-\lambda^L(\alpha))\mu^B(\frac{1}{\mathbf{q}^L} - R) \\ & -\iota(a) - \psi(1-d)^2, \end{aligned} \tag{A.8}$$

equivalently

$$\begin{aligned} 0 \quad = \quad & p(\mu - R) + (1-p)\eta[\mu^B(1-\lambda^M(\alpha))(1-\frac{1-\tilde{P}(\overline{\alpha})}{\mathbf{q}^M}) - R\tilde{P}(\overline{\alpha})] \\ & +(1-p)(1-\eta)(1-\lambda^L(\alpha))\mu^B(1-\frac{1}{\mathbf{q}^L}) \\ & -\iota(a) - \psi(1-d)^2. \end{aligned} \tag{A.9}$$

The first order condition with respect to α is given by

$$
\begin{aligned}
0 \quad = \quad & (1-p)\eta(-\lambda^{M\prime})\mu^B + (1-p)(1-\eta)(-\lambda^{L\prime})\mu^B \qquad \text{(A.10)}\\
& -(1-p)\eta(-\lambda^{M\prime})\mu^B \frac{(1-\tilde{P}(\overline{\alpha}))d}{\mathbf{q}^M}\\
& -(1-p)(1-\eta)(-\lambda^{L\prime})\mu^B \frac{d}{\mathbf{q}^L}\\
& +(1-p)\eta\mu^B(1-\lambda^M(\alpha))\frac{C^M(\alpha)\overline{f}^M}{(\mathbf{q}^M)^2}(1-\tilde{P}(\overline{\alpha}))d\\
& +(1-p)(1-\eta)\mu^B(1-\lambda^L(\alpha))\frac{C^L(\alpha)\overline{f}^L}{(\mathbf{q}^L)^2}d\\
& -\iota'(a) + \psi C^L \overline{f}^L(1-d),
\end{aligned}
$$

equivalently

$$
\begin{aligned}
0 \quad = \quad & (1-p)\eta\mu^B(1-\lambda^M(\alpha))\frac{C^M(\alpha)\overline{f}^M}{(\mathbf{q}^M)^2}(1-\tilde{P}(\overline{\alpha}))d \qquad \text{(A.11)}\\
& +(1-p)(1-\eta)\mu^B(1-\lambda^L(\alpha))\frac{C^L(\alpha)\overline{f}^L}{(\mathbf{q}^L)^2}d\\
& +(1-p)\eta(-\lambda^{M\prime})\mu^B(1-\frac{(1-\tilde{P}(\overline{\alpha}))d}{\mathbf{q}^M})\\
& +(1-p)(1-\eta)(-\lambda^{L\prime})\mu^B(1-\frac{d}{\mathbf{q}^L})\\
& -\iota'(a) + \psi C^L \overline{f}^L(1-d),
\end{aligned}
$$

where $C^S(\alpha) = -(2\lambda^S(\alpha)-1) + (2\alpha-1)(-\lambda^{S\prime}(\alpha))$ and $\overline{f}^S = [\overline{f}(s=g|r=g,S) - \overline{f}(s=g|r=b,S)]/(A+\upsilon'(M^S))$.

The slackness condition is given by

$$\psi(\mathbf{q}^L - d) = 0.$$

Choose any $\frac{1}{2} \leq \alpha \leq 1$. Since $\mathbf{q}_j^S = \frac{\mu^B}{A+\upsilon'(M^S)} \int_i \overline{f}(s_{ji} = g|r_{ji}, S)di$, $\mathbf{q}_j^S$ is decreasing in d. There exists a unique $0 < \overline{d} < 1$ that satisfies $d = \mathbf{q}^L$ evaluated at $d = \overline{d}$. Notice that for $d < \overline{d}$, the collateral constraint is non-binding, $\psi = 0$.

Define the right-hand side of equation **(A.8)** as $F^d(d, \alpha, \psi)$ after substituting the asset prices into it. Then

$\frac{\partial F^d(d,\alpha,\psi)}{\partial d} < 0$ for $d < \bar{d}$, and $F^d(d,\alpha,\psi)$ is continuous for $0 < d < \bar{d}$. If $F^d(0,\alpha,\psi) \leq 0$, $d^* = 0$ and $\psi^* = 0$. Suppose $F^d(0,\alpha,\psi) > 0$. If $F^d(\bar{d},\alpha,\psi) < 0$, there exists a unique solution $0 < d^* < \bar{d}$ that solves $F^d(d^*,\alpha,\psi^*) = 0$ given $\psi^* = 0$. Otherwise, $d^* = \bar{d}$, and ψ^* solves $F^d(\bar{d},\alpha,\psi^*) = 0$.

Therefore, we can define the solutions in terms of α, say $d^*(\alpha)$, $\psi^*(\alpha)$, and $\mathbf{q}^{S*}(\alpha)$. Define the right-hand side of equation **(A.10)** as $F^\alpha(\alpha)$ after substituting those solutions into it and ethe equilibrium condition $\bar{\alpha} = \alpha$. Notice that given that $\iota'(\frac{1}{2})$ is sufficiently small, $F^\alpha(\frac{1}{2}) > 0$, since $\bar{f}^S_{|\alpha=\frac{1}{2}} = 0$. Therefore, it is sufficient to say that if $\frac{\partial^2 F^\alpha}{\partial \alpha^2} < 0$, there exists a unique equilibrium α^*. Define $\bar{I} \equiv \max_{\frac{1}{2}\leq\alpha\leq 1} \frac{\partial^2(F^\alpha + \iota'(\alpha))}{\partial \alpha^2}$. Then if $\iota'''(\alpha) > \bar{I}$, $\frac{\partial^2 F^\alpha}{\partial \alpha^2} < 0$. If $F^\alpha(1) < 0$, there exists α^* such that $\frac{1}{2} < \alpha^* < 1$. Otherwise, $\alpha^* = 1$.$\square$

Proof of Proposition 6

(i) Suppose the collateral constraint is never binding for any μ, $\psi = 0$. Then, from the first order condition **(A.8),** it must be that $\iota(\alpha) \longrightarrow \infty$ as α is close to 1, so that for any sufficiently large μ, there exists α that makes the first order condition holds. However, since $\iota(\alpha) \longrightarrow \infty$ implies that $\iota'(\alpha) \longrightarrow \infty$, the other first order condition **(A.10)** cannot be satisfied (other variables are bounded). Therefore, there exists μ^* such that the collateral constraint is binding.

Suppose $\mu = \mu^*$, α^* can be implicitly defined by the collateral constraint as the function of d. Substituting the solution α^* into the right-hand side of **(A.10),** ψ^* can be implicitly defined as the function of d. Define $F^d(d|\mu)$ as the right-hand side of **(A.8),** after substituting α^* and ψ^* into it. The existence of a unique equilibrium implies that $F^d(d|\mu) \geq 0$ for $0 \leq d \leq \mathbf{q}^L$. Since $\frac{\partial F^d(d|\mu)}{\partial \mu} > 0$, $d = \mathbf{q}^L$. The tightness of the collateral constraint is non-decreasing in μ.

(ii) Step 1: Notice that if $p = 1$, $\Pi^{SE} > \Pi^{AU}$. In this case, securitizers can enjoy the same profits as under financial autarky with the same choice, but they do not. They borrow up to the collateral constraint, which will be further explained below.

Step 2: There exist p^1 and p^2 such that for $p \geq p'$ where $p' = \max[p^1, p^2]$, the collateral constraint is binding for both cases, securitization and financial autarky.

To show this, first notice that if p is large enough, the collateral constraint is binding. For instance, suppose that $p = 1$, but the collateral constraint is non-binding, $\psi = 0$. The f.o.c. **(A.10)** implies that $\alpha = \frac{1}{2}$. Then the f.o.c. **(A.8)** cannot be satisfied, which is contradictory. Then, we can choose lowest p above which the collateral constraint is binding for each economy.

Step 3: Note that for $p \geq p'$, $\Pi^{SE}(p)$ and $\Pi^{AU}(p)$ are continuous in p. By the Envelope theorem,

$$\begin{aligned}\Pi^{SE}(p)' &= (\mu - R)\mathbf{q}^{L}, \\ \Pi^{AU}(p)' &= (\mu - R)q^{b,L}.\end{aligned}$$

Step 4: Since $\Pi^{SE}(1) > \Pi^{AU}(p)$ and they are continuous for $p \geq p'$, there exists p''' such that for $p \geq p'''$, $\Pi^{SE}(p) > \Pi^{AU}(p)$. Let $p^* = \max[p', p''']$. Then the proposition follows.□

Proof of Proposition 7

(i) Under financial autarky, $d = 0$. The optimal information production satisfies that the marginal net benefit of information for each project equals 0:

$$(1-p)\mu^{B}[\eta(-\lambda^{M\prime}) + (1-\eta)(-\lambda^{L\prime})]N - N\iota'(\alpha) = 0. \tag{A.12}$$

With securitization, an optimal choice α satisfies

$$(1-p)\mu^{B}[\eta(-\lambda^{M\prime}) + (1-\eta)(-\lambda^{L\prime})]N + \psi(-\lambda' q^{b,L}) - N\iota'(\alpha) = 0.$$

If $\psi = 0$, $\alpha^{PSE} = \alpha^{PAU}$. As proved in Proposition **6,** for large enough μ, $\psi > 0$. Then it is clear that $\alpha^{PSE} > \alpha^{PAU}$.

(ii) Similarly as in the proof of Proposition 23, let us define the solutions to the financial autarky case as $d_A^*(\alpha)$ and $\psi_A^*(\alpha)$, and to the securitization case as $d_S^*(\alpha)$ and $\psi_S^*(\alpha)$. In addition, let $F_A^{\alpha}(\alpha)$ and $F_S^{\alpha}(\alpha)$ be the right-hand side of (A.5) and (A.10) respectively. Then it is sufficient to show that $F_A^{\alpha}(\alpha^{AU}) - F_S^{\alpha}(\alpha^{AU}) > 0$. Given that $P_N(\alpha)' > 0$, $\mu^B E_{r|s=g}(\kappa^{r,L}) > R$ and small enough c_λ, we can safely neglect the third, the fifth, and the sixth line of $F_A^{\alpha}(\alpha)$ and the third line of $F_S^{\alpha}(\alpha)$.

Comparing the fourth lines, as the collateral constraint becomes binding ($d_S^*(\alpha)->\mathbf{q}^L$ as $p->1$), the fourth line of $F_S^\alpha(\alpha)$ goes to 0, but $F_A^\alpha(\alpha)$ is strictly positive. Comparing the first lines, notice that since $\alpha \geq \frac{1}{2}$, for any M^S,

$$\frac{1}{q^{b,M}}-\frac{1}{q^{g,M}}=\frac{q^{g,M}-q^{b,M}}{q^{b,M}q^{g,M}}=\frac{\bar{f}^M}{q^{b,M}q^{g,M}}>\frac{\bar{f}^M}{(\alpha q^{b,M}+(1-\alpha)q^{g,M})^2}\approx\frac{C^M(\alpha)\bar{f}^M}{(\mathbf{q}^M)^2}.$$

Also, notice that the first and the third line of $F_A^\alpha(\alpha)$ is strictly positive. However, the sum of the third and the fifth line of $F_S^\alpha(\alpha)$ can be even negative depending on $C^L(\alpha)$. Therefore, for sufficiently large $\mu-R$, if $C^L(\alpha)\leq\bar{c}$, $F_A^\alpha(\alpha^{AU})-F_S^\alpha(\alpha^{AU})>0.\square$

Proof of Proposition 8

Similarly as in the proof of Proposition 23, let us define the solutions to the securitization case as $d^*(\alpha)$ and $\psi^*(\alpha)$. In addition, let $F^\alpha(\alpha)$ be the right-hand side of (A.10). Given d^* and ψ^*, $F^\alpha(\alpha)$ is decreasing in p, but given a, d^* and ψ^* are non-decreasing in p.

(i) If $\psi^*=0$, an increase in d^* raises the marginal benefit of information from an increase in the trading value (the fourth and the fifth line in (A.10)), but reduces the marginal benefit of information from the quality improvements (the second and the third line in (A.10)). Therefore it is sufficient to show that if $-\lambda^{L\prime}$ is large enough, a reduction in the marginal benefit of information from the quality improvements is larger than an increment in the marginal benefit of information from an increase in the trading value.

Let $q_r^S=\frac{\bar{f}(s=g|r,S)\mu^B}{A+v'(M^S)}$. Then, since

$$\begin{aligned}[1-\lambda^S(\alpha)]\frac{1}{(\mathbf{q}^S)^2}\frac{\partial\mathbf{q}^S}{\partial\alpha}d &= (1-\lambda^L)\frac{[-(2\lambda^S-1)+(2\alpha-1)(-\lambda^{S\prime})](q_g^S-q_b^S)}{((\alpha(1-\lambda^S)+(1-\alpha)\lambda^S)q_g^S+((1-a)(1-\lambda^S)+\alpha\lambda^S)q_b^S)}\frac{d}{\mathbf{q}^S}\\ &= \frac{(1-\lambda^L)(1-2\lambda^S)(q_g^S-q_b^S)}{\mathbf{q}^S}\bar{\kappa}^S+A(-\lambda^{S\prime})\bar{\kappa}^S\\ &= [(1-2\lambda^S)(\bar{f}(s=g|g,S)-\bar{f}(s=g|b,S))+A(-\lambda^{S\prime})]\bar{\kappa}^S.\end{aligned}$$

where $A = \frac{(1-\lambda^S)(2\alpha-1)(q_g^S-q_b^S)}{((\alpha(1-\lambda^S)+(1-\alpha)\lambda^S)q_g^S+((1-a)(1-\lambda^S)+\alpha\lambda^S)q_b^S)}$,

$$\begin{aligned} C &= \int_S \mu^B N[-(-\lambda^{S\prime}(\alpha))\overline{\kappa}^S + (1-\lambda^S(\alpha))\frac{1}{(\mathbf{q}^S)^2}\frac{\partial \mathbf{q}^S}{\partial \alpha}d]\mathrm{dS} \\ &= \int_S \mu^B N\{-(-\lambda^{S\prime}(\alpha))(1-A) + (1-2\lambda^S)\mu^B[\overline{f}(s=g|g,S) - \overline{f}(s=g|b,S)]\}\overline{\kappa}^S \mathrm{dS}. \end{aligned}$$

Notice that $A < 1$. Because, if $A > 1$, then

$$\begin{aligned} (2\alpha-1)(1-\lambda^S)(q_g^S - q_b^S) &> (\alpha(1-\lambda^S)+(1-\alpha)\lambda^S)q_g^S + [1-(\alpha(1-\lambda)+(1-\alpha)\lambda)]q_b^S \Leftrightarrow \\ [(\alpha-1)(1-\lambda^S)-(1-\alpha)\lambda^S](q_g^S-q_b^S) &> q_b^S. \end{aligned}$$

But, since $[(\alpha-1)(1-\lambda^S)-(1-\alpha)\lambda^S] < 0$, it is contradictory.

Therefore, for sufficiently large $\lambda^{L\prime}(\alpha^{SE})$, $C < 0$. This completes the proof.

(ii) If $\psi^* > 0$, $d = \mathbf{q}^L$.

By equation (A.8),

$$\begin{aligned} \psi &= \frac{1}{(1-\mathbf{q}^L)^2}\{p(\mu-R) + (1-p)\eta[\mu^B(1-\lambda^M(\alpha))(1-\frac{1-\tilde{P}(\overline{\alpha})}{\mathbf{q}^M}) - R\tilde{P}(\overline{\alpha})] \\ &\quad +(1-p)(1-\eta)(1-\lambda^L(\alpha))\mu^B(1-\frac{1}{\mathbf{q}^L}) \\ &\quad -\iota(a)\}. \end{aligned}$$

Then,

$$\begin{aligned} \psi C^L\overline{f}^L(1-d) &= \frac{C^L\overline{f}^L}{(1-\mathbf{q}^L)}\{p(\mu-R) + (1-p)\eta[\mu^B(1-\lambda^M(\alpha))(1-\frac{1}{\mathbf{q}^M})(1-\tilde{P}(\overline{\alpha})) \\ &\quad +(\mu^B(1-\lambda^M(\alpha)) - R)\tilde{P}(\overline{\alpha})] \\ &\quad +(1-p)(1-\eta)(1-\lambda^L(\alpha))\mu^B(1-\frac{1}{\mathbf{q}^L}) \\ &\quad -\iota(a)\}. \end{aligned} \tag{A.13}$$

Since $\frac{\partial F^{\alpha}}{\partial \alpha}|_{\alpha^{SE}} < 0$ and

$$\frac{\partial \alpha}{\partial p}|_{\alpha^{SE}} = -\frac{\frac{\partial F^{\alpha}}{\partial p}}{\frac{\partial F^{\alpha}}{\partial \alpha}}|_{\alpha^{SE}},$$

it is sufficient to show that $\frac{\partial F^{\alpha}}{\partial p} < 0$. Plugging expression (A.13) into F^{α},

$$\begin{aligned}
\frac{\partial F^{\alpha}}{\partial p} &= -\eta\mu^{B}(1-\lambda^{M}(\alpha))(1-\tilde{P}(\overline{\alpha}))[\frac{C^{M}\overline{f}^{M}}{\mathbf{q}^{M}}\frac{\mathbf{q}^{L}}{\mathbf{q}^{M}} - [\frac{C^{L}\overline{f}^{L}}{\mathbf{q}^{M}}\frac{1-\mathbf{q}^{M}}{1-\mathbf{q}^{L}}] \\
&\quad -\eta(-\lambda^{M\prime})\mu^{B}(1-\frac{(1-\tilde{P}(\overline{\alpha}))\mathbf{q}^{L}}{\mathbf{q}^{M}}) \\
&\quad +\frac{C^{L}\overline{f}^{L}}{(1-\mathbf{q}^{L})}\{(\mu-R)-\eta((\mu^{B}(1-\lambda^{M}(\alpha))-R)\tilde{P}(\overline{\alpha}).
\end{aligned}$$

Therefore, for small enough $C^{L}|_{\alpha^{SE}}$, $\frac{\partial F^{\alpha}}{\partial p}|_{\alpha^{SE}} < 0$. This completes the proof.□

Proof of Lemma 10

Observe

$$\begin{aligned}
W(d,\alpha) &= U^{B}+U^{I}+U^{O} \\
&= C_{2}^{I}+\beta(\delta C_{3}^{I}+C_{3}^{B}+C_{3}^{O}),
\end{aligned}$$

where

$$\begin{aligned}
U^{I} &= Y^{S}-dN+p[dN]+(1-p)\eta[(1-P(\overline{\alpha}))dN+\beta\delta RP(\overline{\alpha})dN]+(1-p)(1-\eta)[dN] \\
&= Y^{S}-dN+p[dN]+(1-p)\eta[dN]+(1-p)(1-\eta)[dN] \\
&= Y^{S},
\end{aligned}$$

$$
\begin{aligned}
U^O &= \beta p[AY^I] \\
&+\beta(1-p)\eta[A(Y^I-(1-P^S(\overline{\alpha}))dN)+\frac{(1-\lambda^M)\mu^B}{\mathbf{q}^M}(1-P^S(\overline{\alpha}))dN-\upsilon((1-P^S(\overline{\alpha}))dN)] \\
&+\beta(1-p)(1-\eta)[A(Y^I-dN)+\frac{(1-\lambda^L)\mu^B}{\mathbf{q}^L}dN-\upsilon(dN)],
\end{aligned}
$$

and

$$
\begin{aligned}
U^B &= -N\iota(\alpha)+\beta pN[\mu-Rd] \\
&+\beta(1-p)\eta N[(1-\lambda^M)\mu^B(1-\frac{(1-P^S(\overline{\alpha}))d}{\mathbf{q}^M})-RP^S(\overline{\alpha})d] \\
&+\beta(1-p)(1-\eta)N[(1-\lambda^L)\mu^B(1-\frac{d}{\mathbf{q}^L})] \\
&= -N\iota(\alpha)-\beta RdN+\beta pN\mu \\
&+\beta(1-p)\eta N[(1-\lambda^M)\mu^B(1-\frac{(1-P^S(\overline{\alpha}))d}{\mathbf{q}^M})+R(1-P^S(\overline{\alpha}))d] \\
&+\beta(1-p)(1-\eta)N[(1-\lambda^L)\mu^B(1-\frac{d}{\mathbf{q}^L})+Rd]
\end{aligned}
$$

Therefore, disregarding constants, the lemma follows.□

Proof of Lemma 13

Notice that $S^a = E_1^\alpha + E_2^\alpha + E_3^\alpha + E_4^\alpha$ is given by

$$
\begin{aligned}
S^\alpha &= (1-p)[\eta(1-\tilde{P}(\overline{\alpha}))(-\lambda^{M\prime}(\alpha))\overline{\kappa}^M+(1-\eta)(-\lambda^{L\prime}(\alpha))\overline{\kappa}^L]\mu^B N \\
&+(1-p)\eta\frac{dP^S(\overline{\alpha})}{d\overline{\alpha}}[A+\upsilon'((1-P^S(\overline{\alpha}))dN)-R]dN \\
&-(1-p)\{\eta(1-\tilde{P}(\overline{\alpha}))[1-\lambda^M(\alpha)]\frac{1}{(\mathbf{q}^M)^2}\frac{\partial\mathbf{q}^M}{\partial\alpha}+(1-\eta)[1-\lambda^L(\alpha)]\frac{1}{(\mathbf{q}^L)^2}\frac{\partial\mathbf{q}^L}{\partial\alpha}\}\mu^B dN \\
&+\psi\frac{\partial\mathbf{q}^L}{\partial\overline{\alpha}}.
\end{aligned}
$$

Since $E_2^\alpha \geq 0$ and $E_4^\alpha \geq 0$, in order to prove the first part, it is sufficient to show that $E_1^\alpha + E_3^\alpha \geq 0$ for sufficiently large $\bar{\lambda}^1$.

Let $q_r^S = \frac{\bar{f}(s=g|r,S)\mu^B}{A+\upsilon'(M^S)}$. Then, since

$$\begin{aligned}
[1-\lambda^S(\alpha)]\frac{1}{(\mathbf{q}^S)^2}\frac{\partial \mathbf{q}^S}{\partial \alpha}d &= (1-\lambda^L)\frac{[-(2\lambda^S-1)+(2\alpha-1)(-\lambda^{S\prime})](q_g^S-q_b^S)}{((\alpha(1-\lambda^S)+(1-\alpha)\lambda^S)q_g^S+((1-a)(1-\lambda^S)+\alpha\lambda^S)q_b^S)}\frac{d}{\mathbf{q}^S} \\
&= \frac{(1-\lambda^L)(1-2\lambda^S)(q_g^S-q_b^S)}{\mathbf{q}^S}\bar{\kappa}^S + A(-\lambda^{S\prime})\bar{\kappa}^S \\
&= [(1-2\lambda^S)(\bar{f}(s=g|g,S)-\bar{f}(s=g|b,S))+A(-\lambda^{S\prime})]\bar{\kappa}^S.
\end{aligned}$$

where $A = \frac{(1-\lambda^S)(2\alpha-1)(q_g^S-q_b^S)}{((\alpha(1-\lambda^S)+(1-\alpha)\lambda^S)q_g^S+((1-a)(1-\lambda^S)+\alpha\lambda^S)q_b^S)}$,

$$\begin{aligned}
&\mu^B N[(-\lambda^{S\prime}(\alpha))\bar{\kappa}^S-(1-\lambda^S(\alpha))\frac{1}{(\mathbf{q}^S)^2}\frac{\partial \mathbf{q}^S}{\partial \alpha}d] \\
=\ &\mu^B N\{(-\lambda^{S\prime}(\alpha))(1-A)-(1-2\lambda^S)\mu^B[\bar{f}(s=g|g,S)-\bar{f}(s=g|b,S)]\}\bar{\kappa}^S.
\end{aligned} \tag{A.14}$$

Therefore, it is sufficient to show that $A<1$. Suppose $A>1$. Then

$$\begin{aligned}
(2\alpha-1)(1-\lambda^S)(q_g^S-q_b^S) &> (\alpha(1-\lambda^S)+(1-\alpha)\lambda^S)q_g^S+[1-(\alpha(1-\lambda)+(1-\alpha)\lambda)]q_b^S \Leftrightarrow \\
[(\alpha-1)(1-\lambda^S)-(1-\alpha)\lambda^S](q_g^S-q_b^S) &> q_b^S.
\end{aligned}$$

However, since $[(\alpha-1)(1-\lambda^S)-(1-\alpha)\lambda^S]<0$, it is contradictory, and therefore $S^a>0$.

For the second part, suppose $E_2^\alpha = 0$ (e.g., $\frac{dP^S(\bar{\alpha})}{d\bar{\alpha}}=0$), and $E_4^\alpha = 0$ (e.g., the colalteral constraint is non-binding). From expression (A.14), if $\lambda^{S\prime}$ and λ^S are close enough to 0, it follows that $S^a<0$.□

Proof of Lemma 14

With capital surchages τ^O and τ^N, notice that

$$N = \frac{1}{1+\tilde{o}(\alpha_j)\tau^O+\tau^N-d}$$

Then the objective is given by

$$\begin{aligned}\tilde{\Pi}^F(d_j,\alpha_j) &= N_j\{p\mu+(1-p)[\eta(1-\lambda^M(\alpha_j))+(1-\eta)(1-\lambda^L(\alpha_j))]\mu^B-Rd_j-\iota(\alpha_j)+\tilde{o}(\alpha_j)\tau^O+\tau^N\}\\ &-N_j(1-p)\{\eta\Lambda^M[(1-\lambda^M(\alpha_j))\mu^B\overline{\kappa}^M_{,j}-Rd_j-(\tilde{o}(\alpha_j)\tau^O+\tau^N)]\\ &+(1-\eta)[(1-\lambda^L(\alpha_j))\mu^B\overline{\kappa}^L_{,j}-Rd_j-(\tilde{o}(\alpha_j)\tau^O+\tau^N)]\},\end{aligned}$$

where $\overline{\kappa}^S_{,j}=\frac{d-(\tilde{o}(\alpha_j)\tau^O+\tau^N)}{\mathbf{q}^S_j}$.

Define

$$\overline{d_j}=d_j-(\tilde{o}(\alpha_j)\tau^O+\tau^N).$$

Then the collateral constraint becomes

$$\overline{d_j}+[\tilde{o}(\alpha_j)\tau^O+\tau^N]\leq\mathbf{q}^L_j,$$

and

$$\overline{N}=\frac{1}{1-d_j}.$$

Thus, the objective can be expressed as

$$\begin{aligned}\tilde{\Pi}^F(d_j,\alpha_j) &= \overline{N}_j\{p\mu+(1-p)[\eta(1-\lambda^M(\alpha_j))+(1-\eta)(1-\lambda^L(\alpha_j))]\mu^B\\ &-R\overline{d_j}-\iota(\alpha_j)-(R-1)(\tilde{o}(\alpha_j)\tau^O+\tau^N)\}\\ &-\overline{N}_j(1-p)\{\eta\Lambda^M[(1-\lambda^M(\alpha_j))\mu^B\tilde{\kappa}^M_{,j}-R\overline{d_j}-(R-1)(\tilde{o}(\alpha_j)\tau^O+\tau^N)]\\ &+(1-\eta)[(1-\lambda^L(\alpha_j))\mu^B\tilde{\kappa}^L_{,j}-R\overline{d_j}-(R-1)(\tilde{o}(\alpha_j)\tau^O+\tau^N)]\},\\ &= \overline{N}_j\{p\mu+(1-p)[\eta(1-\lambda^M(\alpha_j))+(1-\eta)(1-\lambda^L(\alpha_j))]\mu^B-R\overline{d_j}-\iota(\alpha_j)\}\\ &-\overline{N}_j(1-p)\{\eta\Lambda^M[(1-\lambda^M(\alpha_j))\mu^B\tilde{\kappa}^M_{,j}-R\overline{d_j}]\\ &+(1-\eta)[(1-\lambda^L(\alpha_j))\mu^B\tilde{\kappa}^L_{,j}-R\overline{d_j}\}\\ &-N_j[p+(1-p)\eta\tilde{P}(\overline{\alpha})](R-1)[\tilde{o}(\alpha_j)\tau^O+\tau^N],\end{aligned}$$

where $\tilde{\kappa}^S_{,j} = \frac{\bar{d_j}}{\mathbf{q}^S_j}$. Therefore, the lemma follows.□

Proof of Proposition 15

$$
\begin{aligned}
W(d,\alpha) &= N\{E[\mu] - Rd - \iota(\alpha)\} \\
&+ pAY^I + (1-p)\eta[A(Y^I - (1-P^S(\bar{\alpha}))dN) - \upsilon((1-P^S(\bar{\alpha}))dN) + R(1-P^S(\bar{\alpha}))dN] \\
&+ (1-p)(1-\eta)[A(Y^I - dN) - \upsilon(dN) + RdN]
\end{aligned}
$$

Notice that the first order conditions to the planner's problem is given by

$$
\begin{aligned}
0 &= \frac{1}{(1-d)^2}\{p\mu + (1-p)[\eta(1-\lambda^M(\alpha)) + (1-\eta)(1-\lambda_L(\alpha))]\mu^B - R - \iota(\alpha)\} \\
&+ \frac{1}{(1-d)^2}(1-p)\eta(1-P^S(\bar{\alpha}))[R - A - \upsilon'((1-P^S(\bar{\alpha}))dN)] \\
&+ \frac{1}{(1-d)^2}(1-p)(1-\eta)[R - A - \upsilon'(dN)] \\
&+ \psi(\frac{\partial \mathbf{q}^L}{\partial d} - 1),
\end{aligned}
$$

which is the first order condition with respect to d, and

$$
\begin{aligned}
0 &= N\{(1-p)[\eta(-\lambda^{M\prime}(\alpha)) + (1-\eta)(-\lambda^{L\prime}(\alpha))]\mu^B - \iota'(\alpha)\} \\
&+ (1-p)\eta\frac{dP^S(\bar{\alpha})}{d\bar{\alpha}}[A + \upsilon'((1-P^S(\bar{\alpha}))dN) - R]dN \\
&+ \psi(\frac{\partial \mathbf{q}^L}{\partial \alpha} + \frac{\partial \mathbf{q}^L}{\partial \bar{\alpha}}),
\end{aligned}
$$

which is the first order condition with respect to α.

The differences between the private and the social benefit of marginal debt and marginal information are given by

$$\bar{S^d} = \psi^S(\frac{\partial \mathbf{q}^L}{\partial d} - 1) - \psi^P(-1) + \frac{1}{(1-d^S)^2}[p + (1-p)\eta \tilde{P}(\bar{\alpha})](R-1)[\tilde{o}(\alpha)\tau^O + \tau^N],$$

and

$$\begin{aligned} \bar{S^\alpha} \quad = \quad & (1-p)[\eta(1-\tilde{P}(\bar{\alpha}))(-\lambda^{M\prime}(\alpha))\bar{\kappa}^M + (1-\eta)(-\lambda^{L\prime}(\alpha))\bar{\kappa}^L]\mu^B N \\ & +(1-p)\eta\frac{dP^S(\bar{\alpha})}{d\bar{\alpha}}[A + \upsilon'((1-P^S(\bar{\alpha}))dN) - R]dN \\ & +\psi^S(\frac{\partial \mathbf{q}^L}{\partial \alpha} + \frac{\partial \mathbf{q}^L}{\partial \bar{\alpha}}), \\ & -(1-p)\{\eta(1-\tilde{P}(\bar{\alpha}))[1-\lambda^M(\alpha)]\frac{1}{(\mathbf{q}^M)^2}\frac{\partial \mathbf{q}^M}{\partial \alpha} + (1-\eta)[1-\lambda^L(\alpha)]\frac{1}{(\mathbf{q}^L)^2}\frac{\partial \mathbf{q}^L}{\partial \alpha}\}\mu^B dN \\ & +N_j[p + (1-p)\eta\tilde{P}(\bar{\alpha})](R-1)[\tilde{o}'(\alpha)\tau^O] \\ & -\psi^P[\frac{\partial \mathbf{q}^L}{\partial \alpha} - \tilde{o}'(\alpha)\tau^O], \end{aligned} \tag{A.15}$$

respectively. $\bar{S^d}$ and $\bar{S^a}$ are evaluated at the planner's optimal choice of d and α, but the Lagrangian multiplier of the planner and the private, ψ^S and ψ^P respectively, can be different.

Let us suppose that $\tau^N = -\tilde{o}(\alpha)\tau^O$. Then the private collateral constraint becomes

$$d \leq \mathbf{q}^L,$$

and

$$\bar{S^d} = \psi^S(\frac{\partial \mathbf{q}^L}{\partial d} - 1) - \psi^P(-1).$$

Case 1) At the social optimum (d^S, α^S), the collateral constraint is non-binding, $\psi^S = 0$.

The social optimum can be implemented if and only if $\bar{S^d} = 0$ and $\bar{S^\alpha} = 0$. Let $\psi^P = 0$ and τ^{O*} solve $\bar{S^\alpha} = 0$ given the planner's optimum, $(d^S,\ \alpha^S)$. Then, given capital surcharges (τ^{O*}, τ^{N*}), the private optimum (d^P, α^P) is equivalent to the social optimum.

Case 2) At the social optimum (d^S, α^S), the collateral constraint is binding, $\psi^S > 0$.

Let ψ^P solve the securitizer's first order condition with respect to d given the social optimum. (Notice that $\psi^P \geq \psi^S$.) Then let τ^{O*} solve $\bar{S}^\alpha = 0$ given the social optimum, ψ^S and ψ^P. Then the private optimum (d^P, α^P) solves $d = \mathbf{q}^L$ and the private first order condition with respect to α, and the private optimum is equivalent to the social optimum.□

Proof of Proposition 17

Let the target prices be

$$P_O^* = \frac{\mathrm{d}\Pi}{\mathrm{d}\tilde{o}} = \frac{1}{\tilde{o}'}\frac{\mathrm{d}\Pi}{\mathrm{d}\alpha},$$

$$P_N^* = \frac{\mathrm{d}\Pi}{\mathrm{d}N} = (1-d)^2\frac{\mathrm{d}\Pi}{\mathrm{d}d}$$

In order to obtain the social optimum,

$$\frac{\mathrm{d}\Pi}{\mathrm{d}\alpha} = S^\alpha,$$

$$\frac{\mathrm{d}\Pi}{\mathrm{d}d} = S^d,$$

where $S^\alpha = E_1^\alpha + E_2^\alpha + E_3^\alpha + E_4^\alpha$, and $S^d = E^d$ as defined in Section 1.4.2. The value of Lagrangian multiplier that is associated with the collateral constraint can be obtained by solving the private first order condition with respect to α given N_O and N_N, which is independent of μ. At the social optimum, the target prices are equal to the observed prices, $[P_O(N_O^*), P_N(N_N^*)] = [P_O^*(N_O^*), P_N^*(N_N^*)]$, where (N_O^*, N_N^*) is a fixed point.□

Proof of Lemma 18

If the inside investor does not acquire additional information, the inside investor's utility can be written as,

$$\begin{aligned} \max_{C_2,C_3}[\min(C_2) + \beta\delta\min(C_3)] &= \max[\underbrace{dN}_{\textit{liquidation}\text{ value at date 2}}, \underbrace{0}_{\textit{worst}\text{ case at date 3}}]\} \\ &= dN, \end{aligned} \tag{A.16}$$

where the first equality is derived from Assumption 2.

Notice that Assumption 2 also implies that if the inside investor has perfect information, she holds her portfolio until maturity when $S=M$ ($s=g$ under financial autarky), or liquidates when $S=L$ ($s=b$ under financial autarky).

As the inside investor can observe the underlying state at her own cost χ, her expected utility with information acquisition is that, with securitization,

$$\begin{aligned} f(S &= M|\phi)\max_{C_2,C_3} E[C_2+\beta\delta C_3|\overline{\phi}=M]+f(S=L|\phi)\max_{C_2,C_3} E[C_2+\beta\delta C_3|\overline{\phi}=L] \\ &= [f(S=M|\phi)\beta\delta R+f(S=L|\phi)]dN. \end{aligned} \tag{A.17}$$

or under financial autarky,

$$\begin{aligned} f(s &= g|r)\max_{C_2,C_3} E[C_2+\beta\delta C_3|\overline{r}=g]+f(s=b|r)\max_{C_2,C_3} E[C_2+\beta\delta C_3|\overline{r}=b] \\ &= [f(s=g|r)\beta\delta R+f(s=b|r)]dN. \end{aligned}$$

Notice that the difference between expression A.17 and A.16 represents the value of extra information. Thus, the inside investor acquires information if and only if the net value of information is greater than zero: with securitization,

$$0 \leq [f(S=M|\phi)\beta\delta R+f(S=L|\phi)-\chi]dN-dN,$$

$$\Leftrightarrow \chi \leq f(S=M|\phi)(\beta\delta R-1),$$

or under financial autarky,

$$0 \leq [f(s=g|r)\beta\delta R+f(s=b|r)-\chi]dN-dN,$$

$$\Leftrightarrow \chi \leq f(s=g|r)(\beta\delta R-1).$$

Since $\chi \sim F$, from the securitizer's perspective ex ante at date 1, the inside investor acquires information with probability z: with securitization,

$$z_\phi = F(f(S=M|\phi)(\beta\delta R-1)),$$

or under financial autarky,

$$z_r = F(f(s=g|r)(\beta\delta R - 1)).$$

With information acquisition, $R > \frac{1}{\beta\delta}$. An optimal contract would balance the cost of an increase in R against a decrease in funding risk, but this additional complication does not affect the qualitative results of this paper. Also, Assumption 2 is important in this derivation in that otherwise, it is always optimal for the inside investors to keep loans until maturity (or always stop roll over). This implies that there will be no liquidity crises arised from the liquidity demand from the inside investor (or liquidity crises whenever the negative news arived, i.e., $S = M$ or L). Therefore there no incentives to obtain costly extra information.□

Proof of Lemma 18

Notice that $\bar{\iota}$ solves

$$\beta\delta\{\bar{\iota}RdN + (1-\bar{\iota})\psi(1-\zeta)(1-\lambda(\bar{\alpha}))\mu^B N\} = dN.$$

Since $Rd > \psi(1-\zeta)(1-\lambda(\bar{\alpha}))\mu^B$, $\frac{\partial\bar{\iota}}{\partial\lambda} > 0$.□

Definition 5 *(No Securitization/Financial Autarky) A symmetric competitive equilibrium is given by stochastic processes for the public signals $p(r|s)$ and $p(\bar{r}|\alpha)$, asset prices $q^{r,S}$, a fraction of assets liquidated $\kappa^{r,S}$, the tail risk of the economy λ, a financial contract $d, \{R_2, R_3\}$ between the bank and the inside investor, investment and information decisions for the bank N and α, and a consumption decision for the inside investor $\{c_2(\bar{r}), c_3(\bar{r})\}$, and outside investors' demand for assets $D(q^{r,S}|r,S)$ such that*

(i) Banks' decision rules maximize expected returns subject to the collateral constraint (1.21), taking the asset price $q^{r,S}$ as given.

(ii) Inside investors' decision rules maximize expected consumption given $\bar{r}$.

(iii) Outside investors choose the asset demand to solve the profit maximization problem (1.3).

(iv) The optimal contract maximizes the profits of a bank given the participation constraint of inside investors.

(v) The credit market between the bank and the inside investor clears.

(vi) The asset market clears: $q^{r,S}$ *and* $\kappa^{r,S}$ *satisfy equations (1.19) and (1.9).*

(vii) The tail risk of the economy λ *are consistent with the decision rules of the banks:* $\lambda = \int \lambda^L(\alpha_i)di$.

A.2 Figures

Figure A.1: Preference and Technology

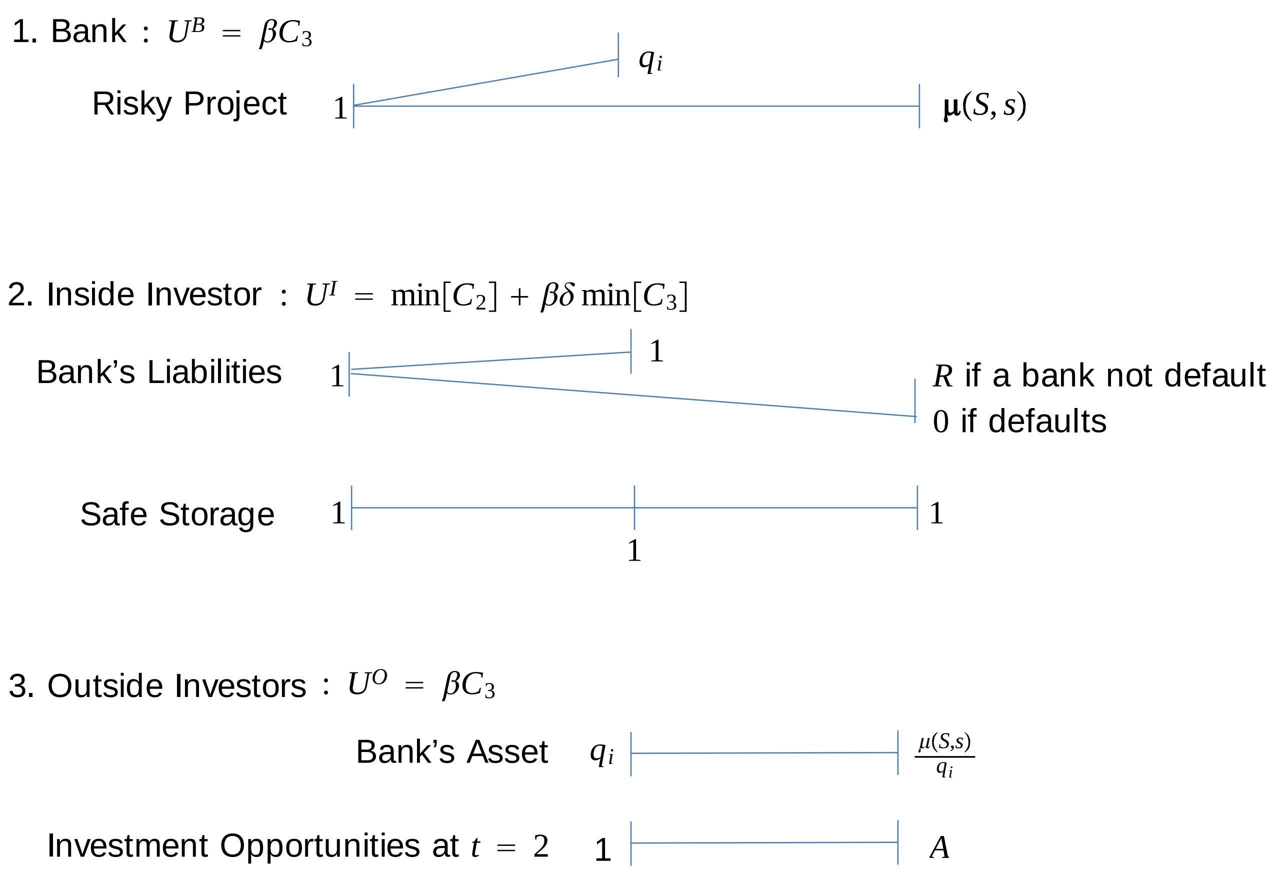


Figure A.2: Economic Environment Each Bank Faces

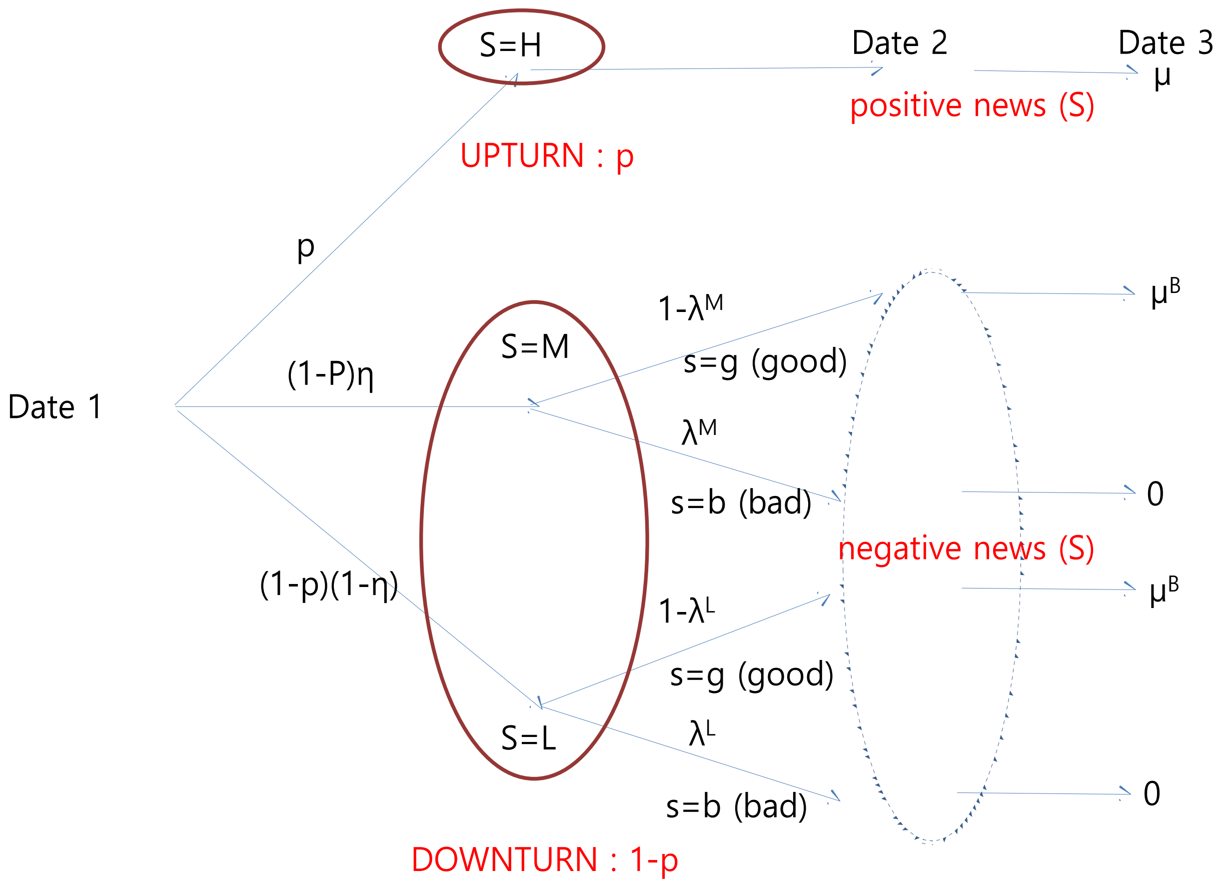


Figure A.3: Financial Autarky

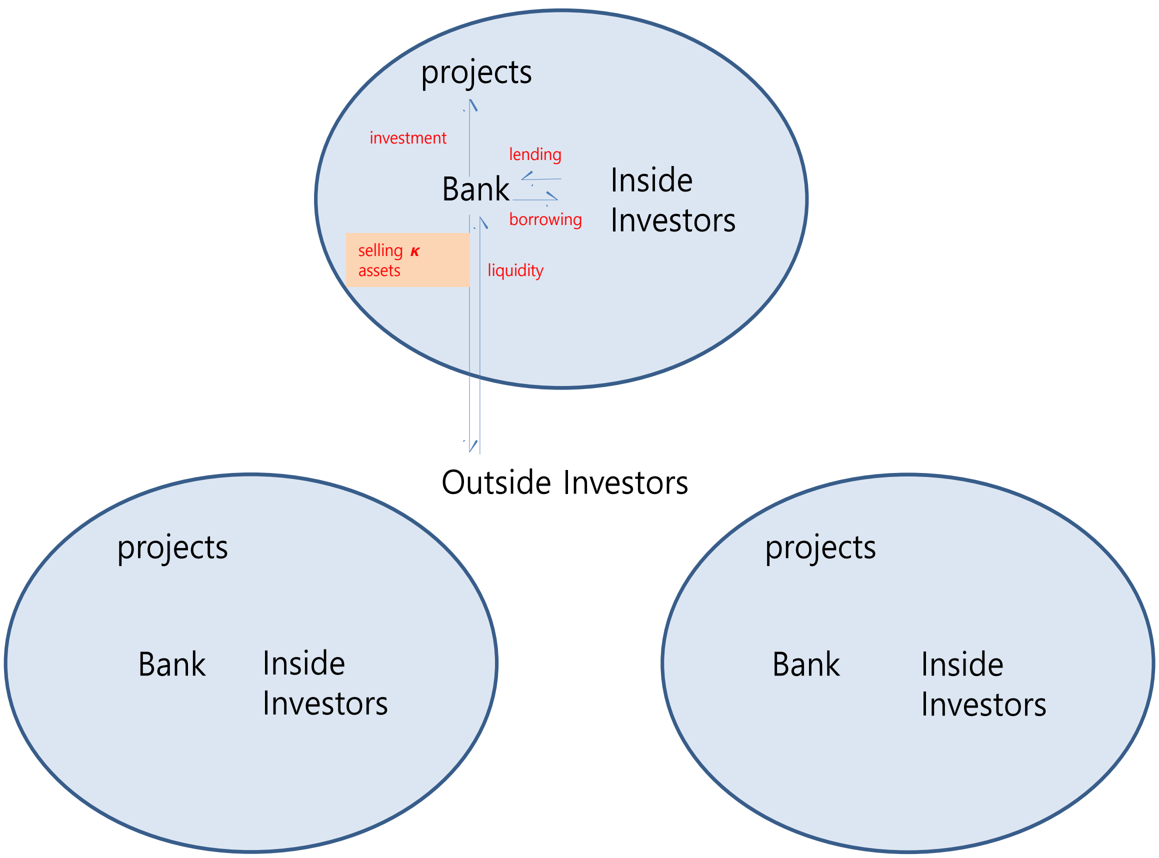


Figure A.4: Securitization

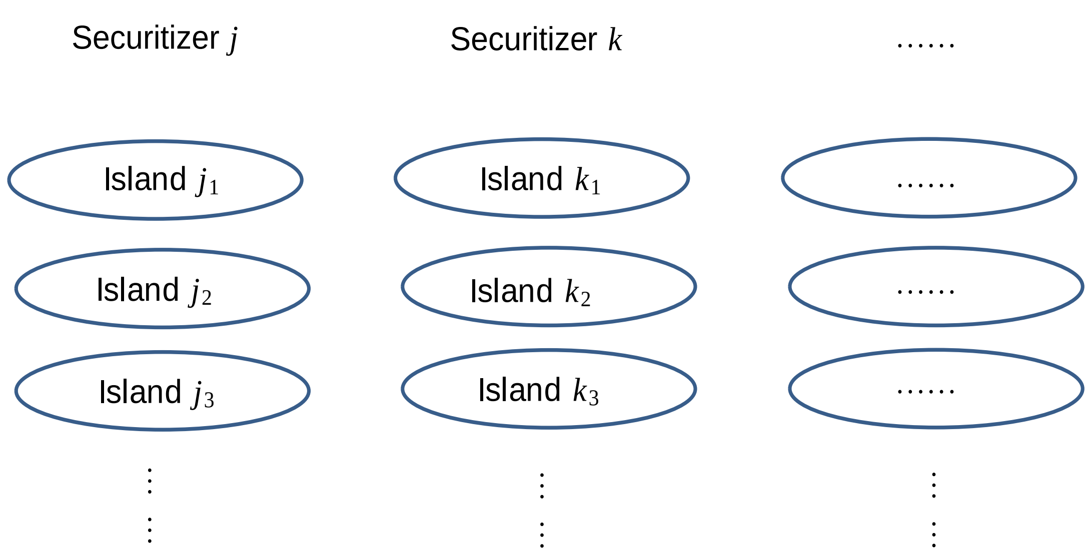


Figure A.5: Securitization

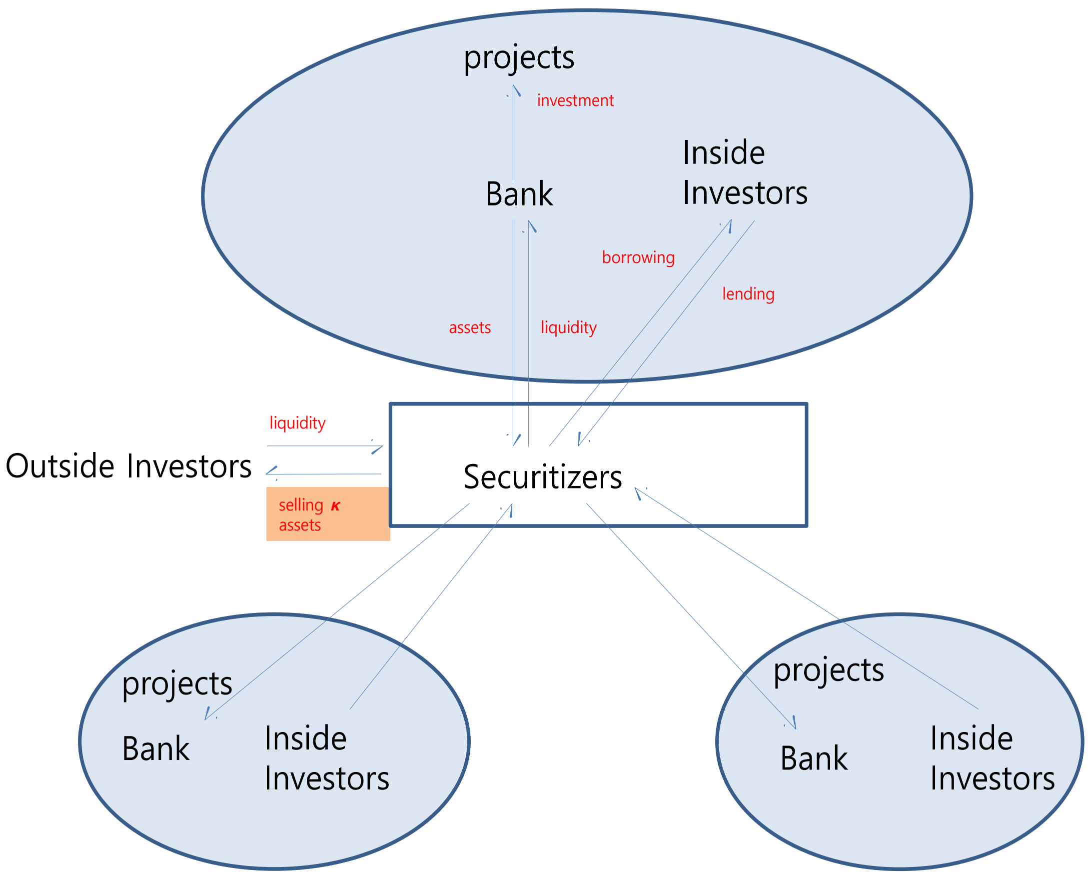


Figure A.6: Information and Timing (Securitization)

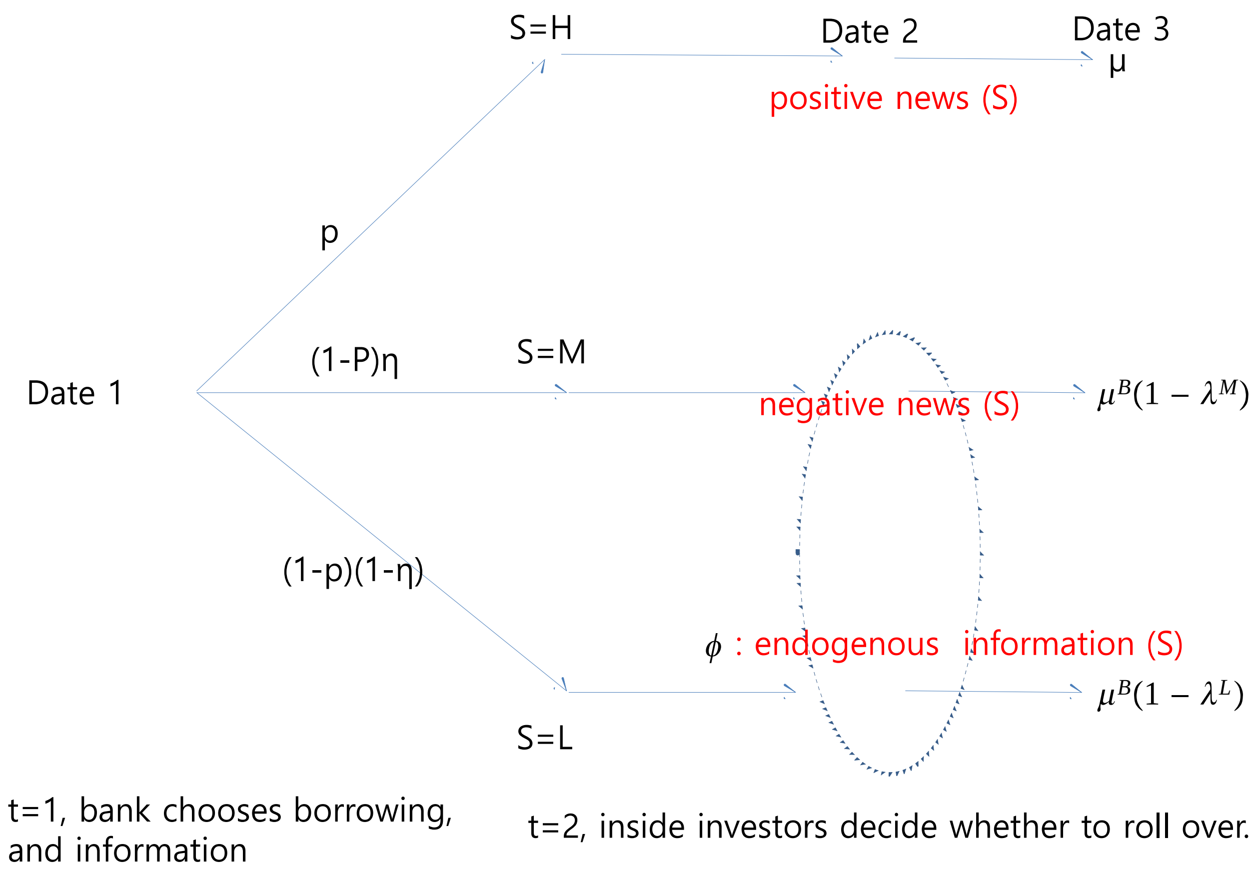


Figure A.7: Benefit of Information

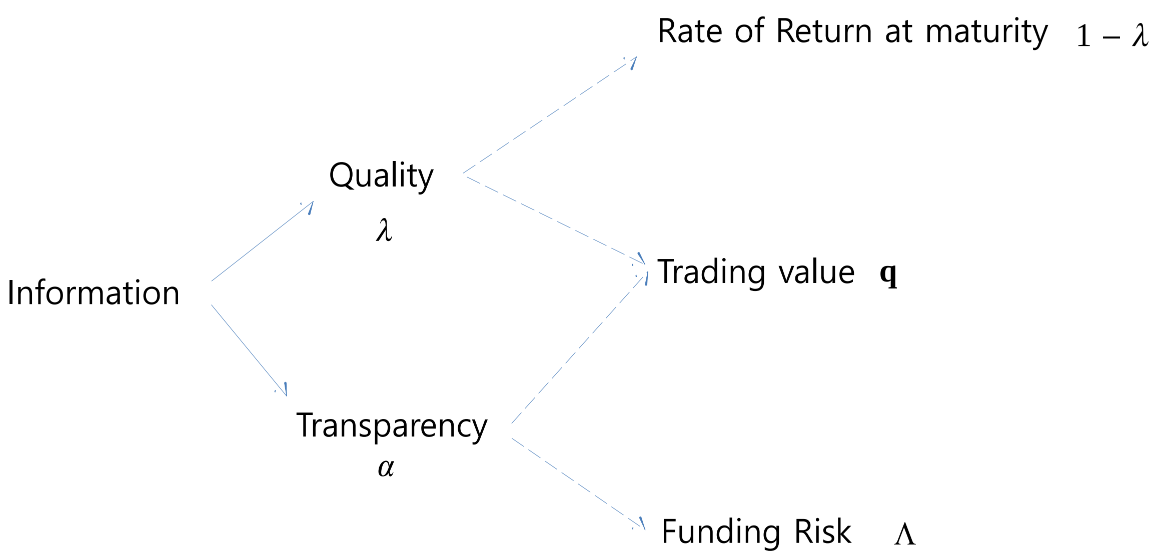


Figure A.8: Financial Innovation and Lending Standards

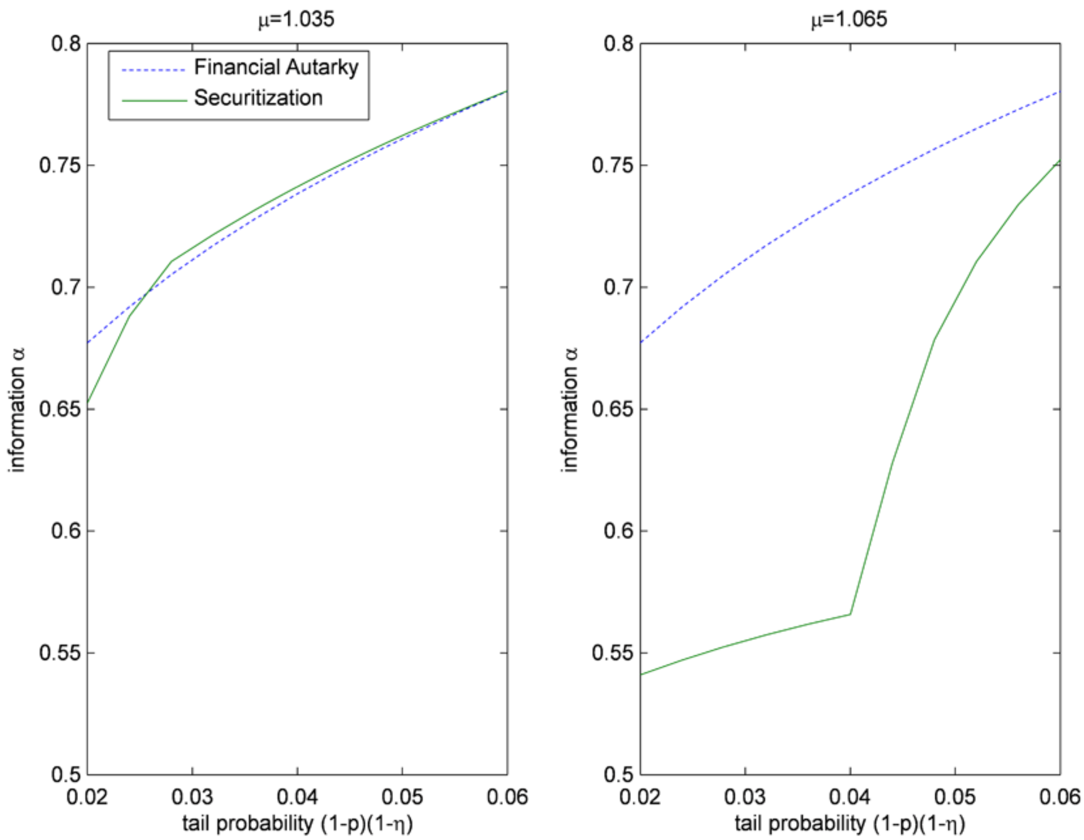


Figure A.9: Securitization and Tail Risk ($C_I = 1/12$)

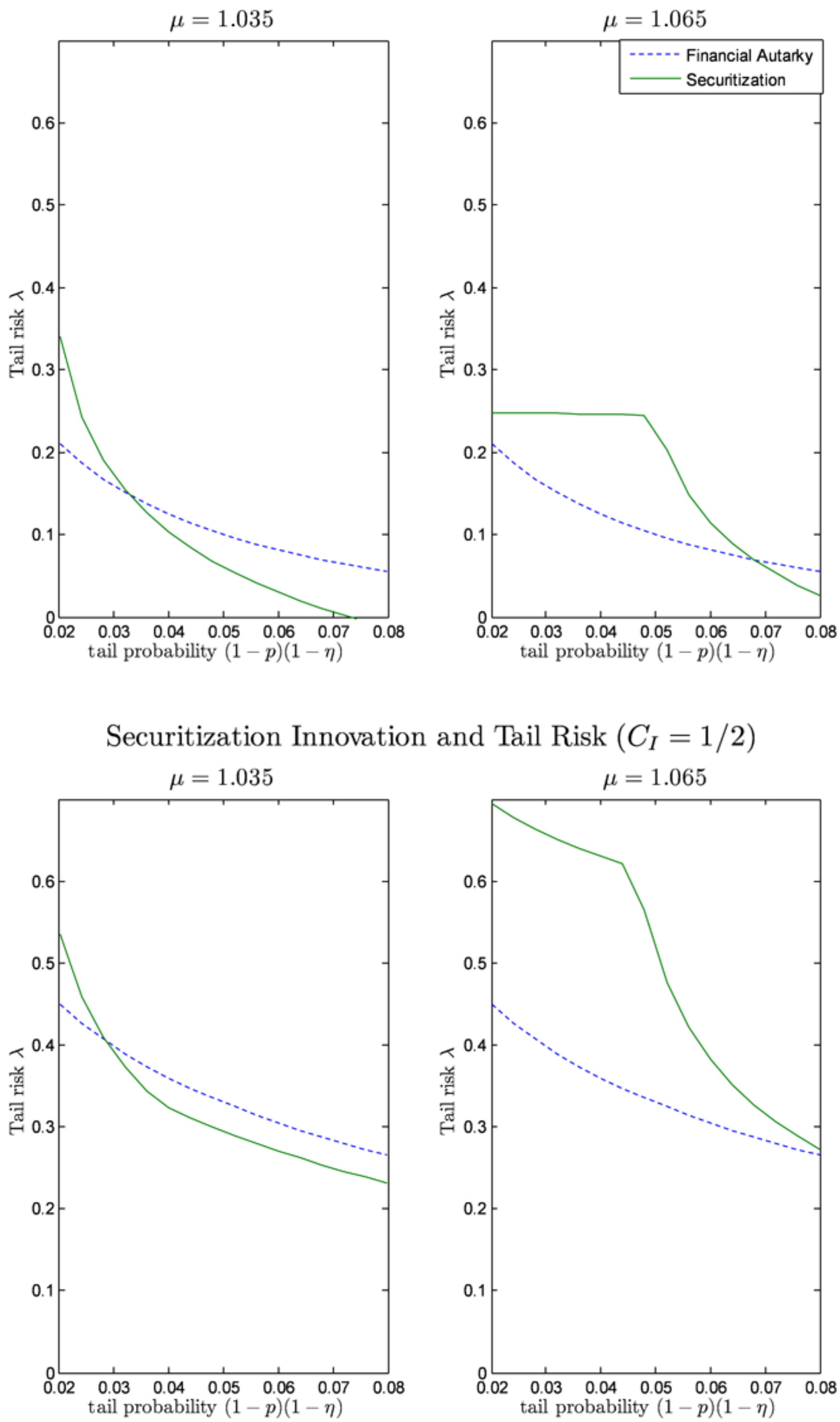


Figure A.10: Securitization and Funding Risk

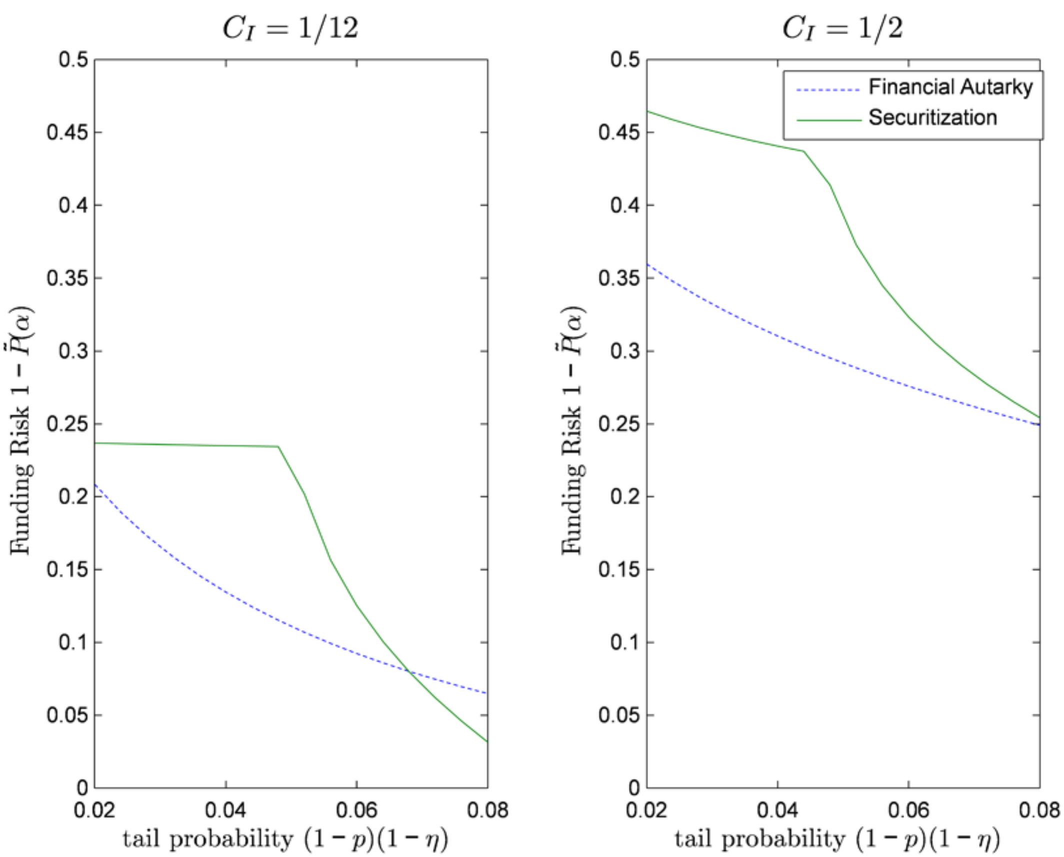


Figure A.11: Private and Socially Optimal Allocation

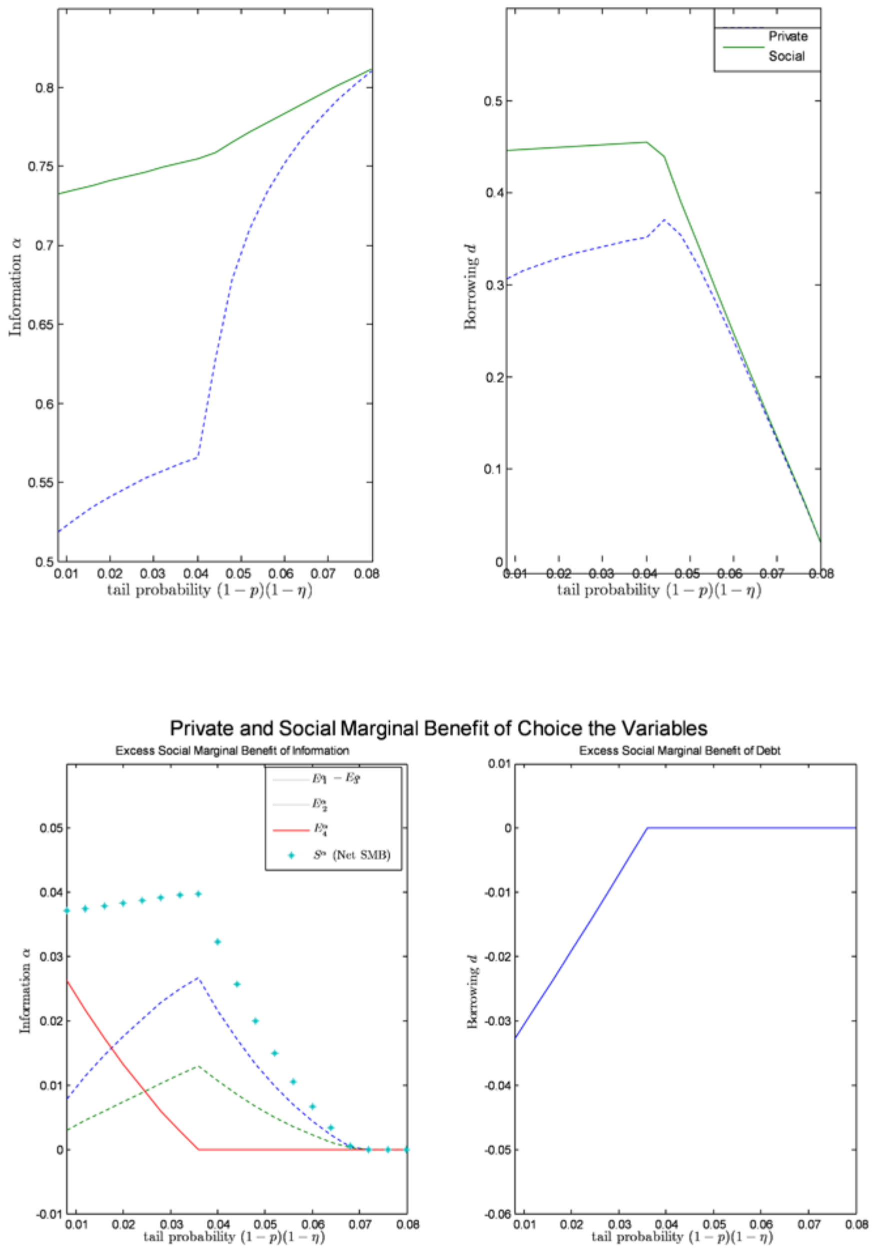


Figure A.12: Private and Socially Optimal Allocation

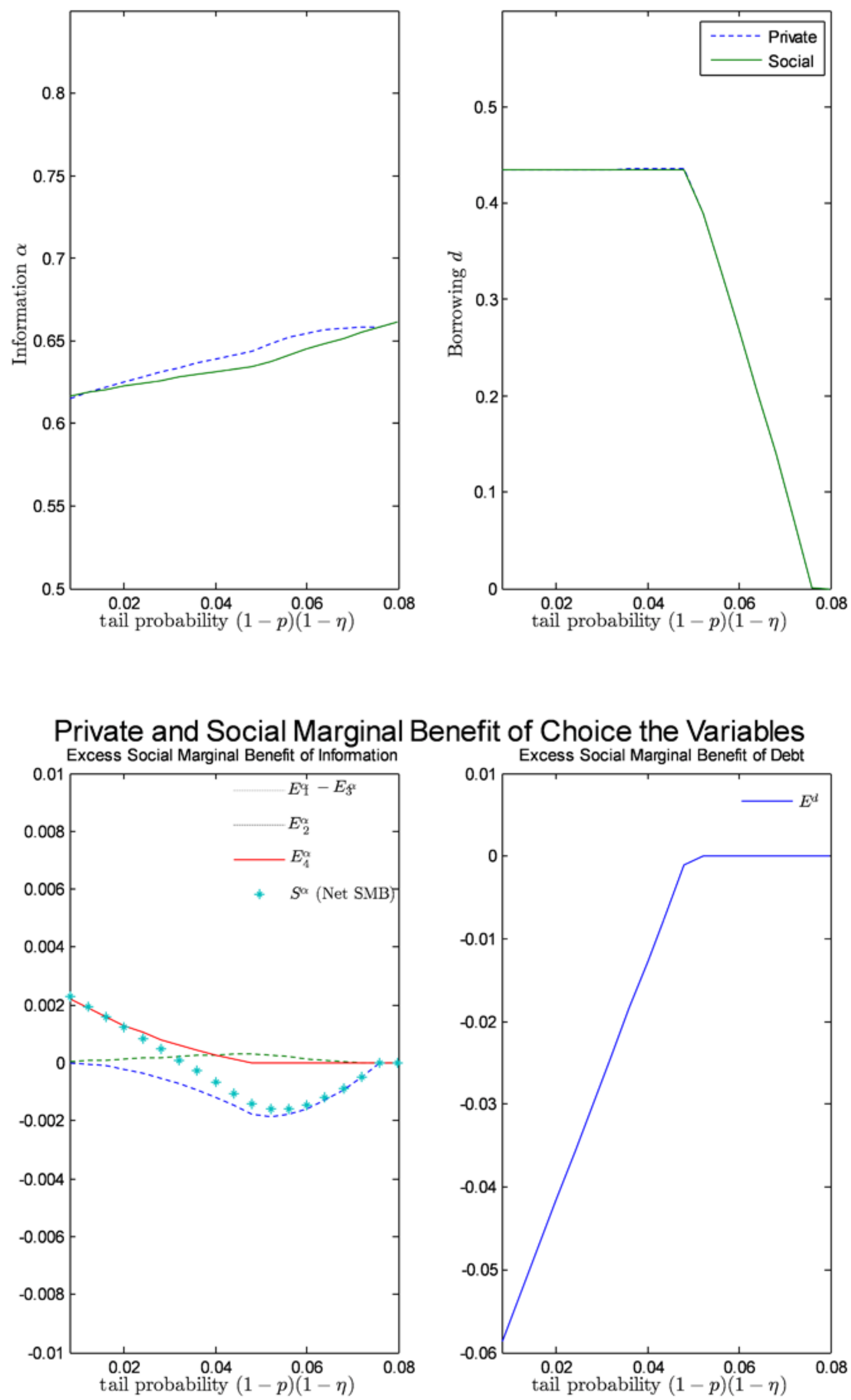


Figure A.13: Liquidity Crisis when Fundamentals are Strong

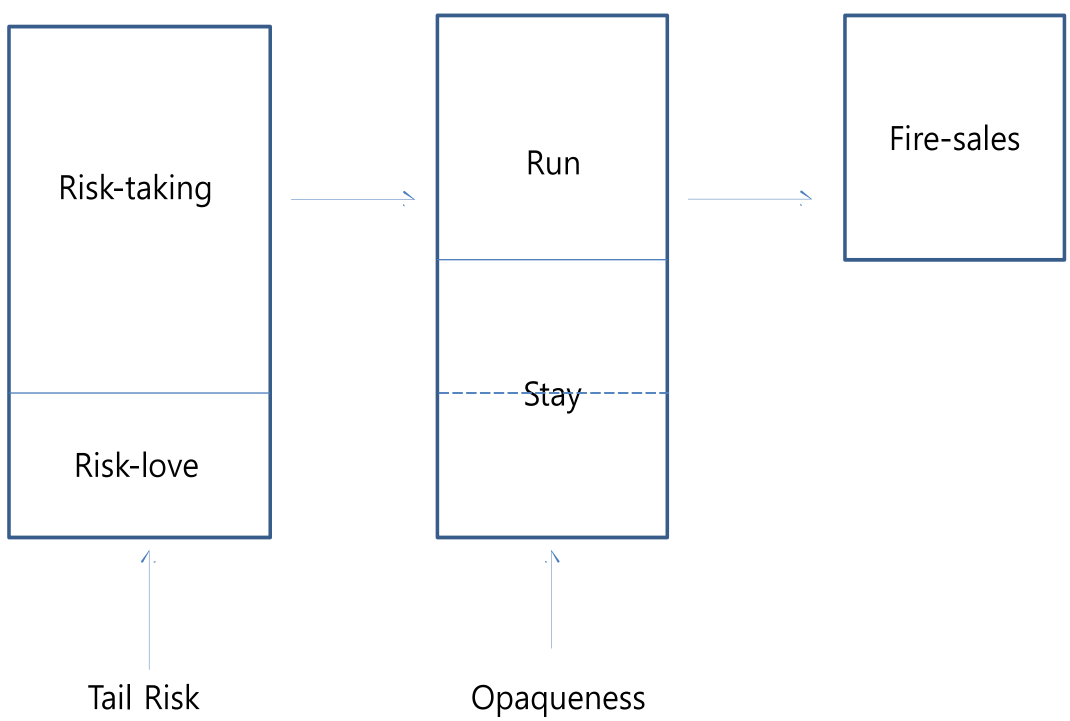
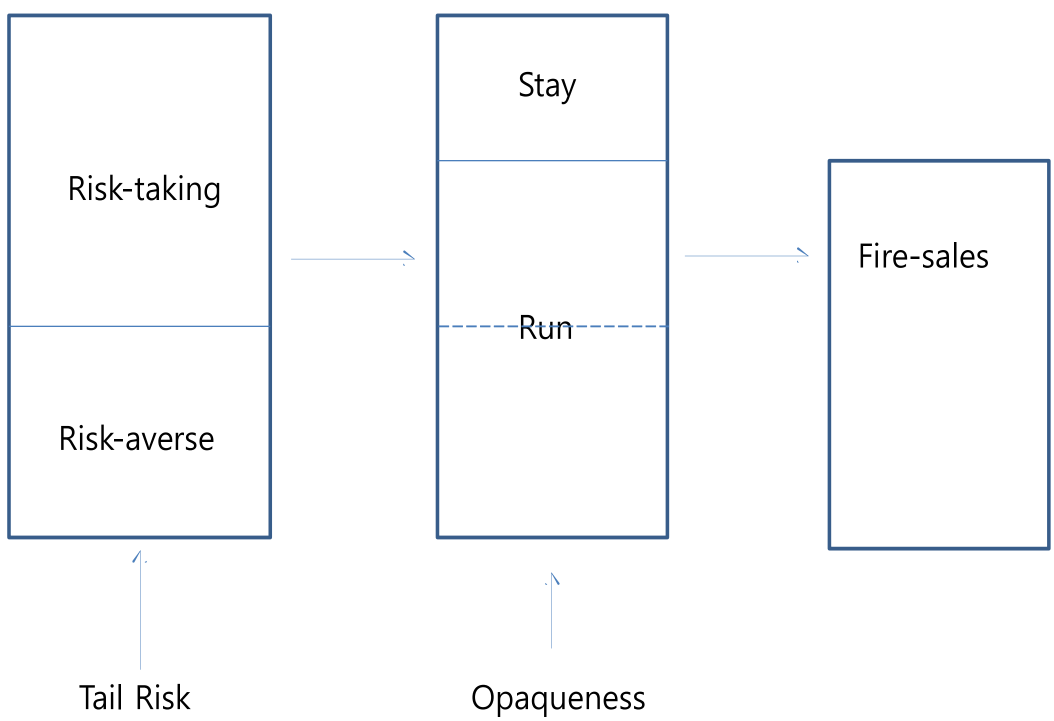


Figure A.14: Liquidity Crisis when Fundamentals are Weak



Appendix B

Appendix for Chapter 2

B.1 Proofs

For simplicity of notation, the subscript j is dropped if there is no confusion.

Proof of Proposition 20. The objective of entrepreneur j given a signal s_j at date 1 is

$$\int_{\lambda} c_j(s_j,\lambda)dF(\lambda|s_j). \tag{B.1}$$

As the budget constraint (2) holds with equality, the objective can be written as follows by substituting (2), (5), and (6) into this objective (B.1).

$$U(b_j,d_j^{NL},d_j^{L}) = \int_{\lambda}[(1-\lambda_j - d_j^{NL}) + b(1-\lambda^M(\lambda))] + A_j[1+p(d_j^{NL}+d_j^{L}-b_j)]dF(\lambda|s) \tag{B.2}$$

As income is increasing in d_j^L and d_j^L does not contribute to capital accumulation, the optimal choice of $d_j^L = \lambda_j$. Notice that the marginal return to sell an additional unit of non-lemon assets, $\frac{\partial U}{\partial d_j^{NL}}$, is equals to $A_j p - 1$, and the marginal return to buy an additional unit of assets in the market, $\frac{\partial U}{\partial b_j}$, is given by $\int_{\lambda}\{1-\lambda^M(\lambda)\}dF(\lambda|s) - A_j p$.

Therefore,

$$\text{seller: } d_j^{NL} = 1 - \lambda_j \text{ and } b_j = 0 \text{ if } A_j > \frac{1}{p},$$

$$\text{buyer: } d_j^{NL} = 0 \text{ and } b_j = \frac{1}{p} + d_j^L \text{ if } A_j < \frac{1}{p}\int_\lambda \{1 - \lambda^M(\lambda)\} dF(\lambda|s),$$

$$\text{keeper: } d_j^{NL} = b_j = 0 \text{ if } \frac{1}{p}\int_\lambda \{1 - \lambda^M(\lambda)\} dF(\lambda|s) < A_j < \frac{1}{p}.$$

Also, notice that entrepreneurs who are in the boundary are indifferent between those choices.

$$\begin{aligned} 0 &\leq d_j^{NL} \leq 1 - \lambda_j \text{ and } b_j = 0 \text{ if } A_j = \frac{1}{p}, \\ d_j^{NL} &= 0 \text{ and } 0 \leq b_j \leq \frac{1}{p} + d_j^L \text{ if } A_j = \frac{1}{p}\int_\lambda \{1 - \lambda^M(\lambda)\} dF(\lambda|s). \end{aligned}$$

■

Suppose $p(\lambda)$ is given. Let $\delta(\lambda;\bar{\delta})$ be a solution to equation (2.15) given $p(\lambda)$ and $\bar{\delta}$, and $J(\delta) \equiv \int_\lambda \delta(\lambda;\bar{\delta}) dF(\lambda)$.

Lemma A.1 (Woodford (2008)). Suppose the information cost $\theta > 0$ is given, and $F(L(\lambda) \neq 0) > 0$ where F is a probability measure associated with the prior distribution of λ. Then [1] there is a unique equilibrium; and [2] there are three kinds of possible solutions: (i) $\delta(\lambda) = 0$ almost surely if and only if

$$\int \exp\{\frac{L(\lambda)}{\theta}\} dF(\lambda) \leq 1, \qquad \int \exp\{-\frac{L(\lambda)}{\theta}\} dF(\lambda) > 1,$$

which implies $J(\bar{\delta}) < \bar{\delta}$ for all $0 < \bar{\delta} < 1$; (ii) $0 < \delta(\lambda) < 1$ almost surely if and only if

$$\int \exp\{\frac{L(\lambda)}{\theta}\} dF(\lambda) > 1, \qquad \int \exp\{-\frac{L(\lambda)}{\theta}\} dF(\lambda) > 1$$

; (iii) $\delta(\lambda) = 1$ almost surely if and only if

$$\int \exp\{\frac{L(\lambda)}{\theta}\} dF(\lambda) > 1, \qquad \int \exp\{-\frac{L(\lambda)}{\theta}\} dF(\lambda) \leq 1.$$

Proof) See Lemma 2 in Woodford (2008).

Proof of Proposition 22 (Sufficient and Necessary Conditions). Define $\phi(\delta,\overline{\delta}) \equiv \delta \log(\frac{\delta}{\overline{\delta}}) + (1-\delta)\log(\frac{1-\delta}{1-\overline{\delta}})$.

Then

$$\min_{\overline{\delta}^*} \int_\lambda \phi(\delta(\lambda),\overline{\delta}^*) dF(\lambda) = \int_\lambda \phi(\delta(\lambda),\overline{\delta}) dF(\lambda) = I(\delta)$$

where $\overline{\delta} = \int_\lambda \delta(\lambda) dF(\lambda)$. Therefore,

$$\max_{\delta(\cdot)} \int_\lambda [\delta(\lambda)L(\lambda) - \theta\phi(\delta(\lambda),\overline{\delta})] dF(\lambda) = \max_{\delta(\cdot)} \max_{\overline{\delta}^*} \int_\lambda [\delta(\lambda)L(\lambda) - \theta\phi(\delta(\lambda),\overline{\delta}^*)] dF(\lambda).$$

Moreover, it can be easily shown that

$$\max_{\delta(\cdot)} \max_{\overline{\delta}^*} \int_\lambda [\delta(\lambda)L(\lambda) - \theta\phi(\delta(\lambda),\overline{\delta}^*)] dF(\lambda) = \max_{\overline{\delta}^*} \max_{\delta(\cdot)} \int_\lambda [\delta(\lambda)L(\lambda) - \theta\phi(\delta(\lambda),\overline{\delta}^*)] dF(\lambda).$$

This implies that we can solve a inner problem separately for each λ given $\overline{\delta}$, and then maximize the object over $\overline{\delta}$.

Given beliefs on the future asset price function $p^B(\lambda)$, let $p(\lambda)$ be the equilibrium strategy which is consistent with Lemma A.1. Provided $\overline{\delta}$ (it can be interpret $\overline{\delta}$ as the expected future liquidity), the first order necessary condition requires that

$$L(\lambda) - \theta\phi_1(\delta(\lambda),\overline{\delta}) = 0, \tag{B.3}$$

which implies that

$$\frac{1-\lambda^M(\lambda;p(\lambda))}{p(\lambda)} - A_L = \theta[\log\frac{\delta}{1-\delta} - \log\frac{\overline{\delta}}{1-\overline{\delta}}] \tag{B.4}$$

where $\lambda^M(\lambda;p(\lambda))$ is given by equation (2.8). Fix λ. There is a unique solution to equation (B.4), $\delta(\lambda;\overline{\delta})$, given $\overline{\delta}$, and an equilibrium choice of $\delta(\lambda;\overline{\delta})$ must satisfy $\overline{\delta} = \int_\lambda \delta(\lambda;\overline{\delta}) dF(\lambda)$. However, $\overline{\delta}$ which satisfies the above conditions does not necessarily correspond to a local maximum. To see this point, substitute the solution $\delta(\lambda;\overline{\delta})$ into the objective (2.14) and differentiating with respect to $\overline{\delta}$, we obtain

$$\begin{aligned} U'(\overline{\delta}) &\equiv \int_{\lambda} \{\delta_{\overline{\delta}}(\lambda)[L(\lambda) - \theta\phi_1(\delta(\lambda;\overline{\delta}), J(\overline{\delta}))] - \theta\phi_2(\delta(\lambda;\overline{\delta}), J(\overline{\delta}))J'(\overline{\delta})\} dF(\lambda) \quad \text{(B.5)} \\ &= \int_{\lambda} \delta_{\overline{\delta}}(\lambda)[\phi_1(\delta(\lambda;\overline{\delta}), \overline{\delta}) - \phi_1(\delta(\lambda;\overline{\delta}), J(\overline{\delta}))] dF(\lambda) \\ &= \int_{\lambda} \delta_{\overline{\delta}}(\lambda)[\log \frac{J(\overline{\delta})}{1-J(\overline{\delta})} - \log \frac{\overline{\delta}}{1-\overline{\delta}}] dF(\lambda). \end{aligned}$$

for any $0 < \overline{\delta} < 1$, where $\delta_{\overline{\delta}}(\lambda) \equiv \frac{\partial \delta(\lambda;\overline{\delta})}{\partial \overline{\delta}} > 0$. The first equality holds by (B.3) and from the fact that $\int_{\lambda} \phi_2(\delta(\lambda;\overline{\delta}), J(\overline{\delta}))dF(\lambda) = 0$.

Note that $U'(\overline{\delta}) > 0$ if and only if $J(\overline{\delta}) > \overline{\delta}$. Therefore, a local maximum $\overline{\delta}^*$ requires (i) if $\overline{\delta}^* > 0$, then there exits $\varepsilon > 0$ such that $J(\overline{\delta}) > \overline{\delta}$ for all $\overline{\delta} \in (\overline{\delta}^* - \varepsilon, \overline{\delta}^*)$; and (ii) if $\overline{\delta}^* < 1$, then there exits $\varepsilon > 0$ such that $J(\overline{\delta}) < \overline{\delta}$ for all $\overline{\delta} \in (\overline{\delta}^*, \overline{\delta}^* + \varepsilon)$. Moreover, by Lemma A.1, there exists a unique solution given the price function $p(\lambda)$ to equation (B.4).

I next turn to the determination of an equilibrium belief on the asset price function $p(\lambda)$. In equilibrium, a market clearing asset price $p(\lambda)$ must be consistent with a belief on the future asset price $p^B(\lambda)$, i.e., $p(\lambda) = p^B(\lambda)$, and $p(\lambda)$ must satisfy equation (2.9).

Let $\delta^*(\lambda;\overline{\delta})$ denote the solution to (B.4) and (2.9) for each λ given $\delta = \overline{\delta}$. The important difference between $\delta^*(\lambda;\overline{\delta})$ and $\delta(\lambda;\overline{\delta})$ is that $\delta^*(\lambda;\overline{\delta})$ is a solution without taking the price $p(\lambda)$ as given.

In general, given λ and $\overline{\delta}$, there may be multiple $\delta^*(\lambda;\overline{\delta})$ which satisfiy both (2.9) and (B.4). However, an equilibrium choice $\delta^*(\lambda;\overline{\delta})$ must be the highest solution among those. To see this point, fix λ and $\overline{\delta}$, and suppose $\delta_1^*(\lambda;\overline{\delta}) > \delta_2^*(\lambda;\overline{\delta})$. Let $p_1\left(\lambda;\overline{\delta}\right)$ and $p_2\left(\lambda;\overline{\delta}\right)$ be corresponding equilibrium prices to $\delta_1^*(\lambda;\overline{\delta})$ and $\delta_2^*(\lambda;\overline{\delta})$ respectively. Note that since $l_M(\lambda;p)$ is non-decreasing in p, the highest solution $\delta^*(\lambda;\overline{\delta})$ corresponds to the highest asset price that is consistent with the equilibrium conditions given $\overline{\delta}$. By equation (B.4), $\frac{1-\lambda^M(\lambda;p_1(\lambda;\overline{\delta}))}{p_1(\lambda;\delta)} > \frac{1-\lambda^M(\lambda;p_2(\lambda;\overline{\delta}))}{p_2(\lambda;\delta)}$. Therefore, only $\delta_1^*(\lambda;\overline{\delta})$ is consistent with the condition that there are no leftover bilateral gains from trade given expected liquidity $\overline{\delta}$.

Define $J^*(\overline{\delta}) \equiv \int_{\lambda} \delta^*(\lambda;\overline{\delta})dF(\lambda)$. Suppose $\overline{\delta}^* = J^*(\overline{\delta}^*)$. If $\overline{\delta}^*$ is a stable equilibrium, it still requires that (i) if $\overline{\delta}^* > 0$, then there exits $\varepsilon > 0$ such that $J^*(\overline{\delta}) > \overline{\delta}$ for all $\overline{\delta} \in (\overline{\delta}^* - \varepsilon, \overline{\delta}^*)$; and (ii) if $\overline{\delta}^* < 1$, then there exits $\varepsilon > 0$

such that $J^*(\bar{\delta}) < \bar{\delta}$ for all $\bar{\delta} \in (\bar{\delta}^*, \bar{\delta}^* + \varepsilon)$. Otherwise, a small disturbance to agents' beliefs over the future asset price (which is equivalent to a disturbance to $\bar{\delta}^*$) causes further divergence from the original point, and their beliefs will converge to a new stable equilibrium.

Note that an equilibrium $\bar{\delta}^*$ needs not to be unique here. Multiplicity can be possible. ■

Lemma A.2. Let $0 \leq \bar{\delta} \leq 1$ be given, and $p(\lambda)$ be a corresponding equilibrium strategy for each λ. Define $\lambda_1 \equiv \sup_{\lambda}\{\lambda | p(\lambda) > \frac{1}{A_M}\}$ and $\lambda_2 \equiv \sup_{\lambda}\{\lambda | p(\lambda) = \frac{1}{A_M}\}$. Then (i) for $\lambda \leq \lambda_1$, $p(\lambda) \geq \frac{1}{A_M}$; (ii) for $\lambda_1 < \lambda \leq \lambda_2$, $p(\lambda) = \frac{1}{A_M}$; and (iii) for $\lambda_2 < \lambda$, $p(\lambda) < \frac{1}{A_M}$; (iv) p is non-increasing in λ and $\delta(\lambda; \bar{\delta})$; (v) $\delta(\lambda; \bar{\delta})$ is non increasing in λ.

Proof of Lemma A.2. Choose any λ such that $p(\lambda) > \frac{1}{A_M}$.

Plugging (2.9) and (2.8) into (B.4), we obtain

$$\frac{(1-\lambda)N_H + l_M N_M}{N_L \delta + h} - A_L = \theta[\log \frac{\delta}{1-\delta} - \log \frac{\bar{\delta}}{1-\bar{\delta}}]. \tag{B.6}$$

As $p(\lambda) > \frac{1}{A_M}$, $l_M(\lambda; p(\lambda)) = 1$ and $\delta(\lambda; \bar{\delta})$ is implicitly defined by the following equation.

$$\frac{(1-\lambda)N_H + N_M}{N_L \delta + h} - A_L = \theta[\log \frac{\delta(\lambda;\bar{\delta})}{1-\delta(\lambda;\bar{\delta})} - \log \frac{\bar{\delta}}{1-\bar{\delta}}]. \tag{B.7}$$

Now, choose any $\lambda' < \lambda$. Guess that there exists the equilibrium asset price $p(\lambda') > \frac{1}{A_M}$, and then $l_M(\lambda', p(\lambda')) = 1$. Because

$$\frac{\partial \delta(\lambda;\bar{\delta})}{\partial \lambda} = -\frac{-\frac{N_H}{N_L\delta + h}}{-\theta(\frac{1}{\delta} + \frac{1}{1-\delta}) - \frac{(1-\lambda)N_H + N_M}{(N_L\delta + h)^2} N_L} < 0,$$

$\delta(\lambda'; \bar{\delta}) > \delta(\lambda; \bar{\delta})$. Notice that $p(\lambda)$ is non-decreasing in $\delta(\lambda; \bar{\delta})$ because l_M is non-decreasing in $p(\lambda)$. (If p decreases in δ, l_M must rise which is contradictory, $p = \frac{N_L\delta + h}{N_H + l_M N_M}$). Since a rise in λ decreases δ for $0 < \bar{\delta} < 1$, p must decrease. Therefore p is non-increasing in λ. Thus, $p(\lambda') > p(\lambda)$. This verifies our guess that $p(\lambda') > \frac{1}{A_M}$.

Let δ_1 be the solution to the equation $A_M = \frac{N_H + N_M}{N_L \delta + h}$, and λ_1 solve

$$A_M(1 - \frac{\lambda_1 N_H}{N_H + N_M}) - A_L = \theta[\log \frac{\delta_1}{1-\delta_1} - \log \frac{\bar{\delta}}{1-\delta}]. \tag{B.8}$$

Then, for $\lambda \leq \lambda_1$, $p(\lambda) \geq \frac{1}{A_M}$.

Next, fix the price at which the marginal investors are indifferent, $p = \frac{N_L \delta(\lambda) + h}{N_H + l_M N_M} = \frac{1}{A_M}$. Note that

$$l_M N_M = A_M(N_L \delta(\lambda) + h) - N_H.$$

Then, the first order condition becomes

$$A_M + \frac{-\lambda N_H}{N_L \delta + h} - A_L = \theta[\log \frac{\delta}{1-\delta} - \log \frac{\bar{\delta}}{1-\delta}]. \tag{B.9}$$

Note that $\frac{\partial \delta(\lambda;\bar{\delta})}{\partial \lambda} < 0$. Let $\delta(\lambda_2)$ be the solution to

$$A_M = \frac{N_H}{N_L \delta + h}. \tag{B.10}$$

Since $\frac{N_H}{N_L + h} < A_M < \frac{N_H}{h}$ (See Assumption A.3), there exists such $\delta(\lambda_2)$. Substituting (B.10) into (B.9), $(\lambda_2, \delta(\lambda_2))$ solves

$$A_M(1-\lambda) - A_L = \theta[\log \frac{\delta}{1-\delta} - \log \frac{\bar{\delta}}{1-\delta}].$$

Therefore, the marginal investors are indifferent for $\lambda_1 < \lambda \leq \lambda_2$.

Finally, since $p(\lambda) < \frac{1}{A_M}$, $l_M(\lambda; p(\lambda)) = 0$ for $\lambda_2 < \lambda$. The market clears and $\delta(\lambda;\bar{\delta})$ solves

$$\frac{(1-\lambda)N_H}{N_L \delta(\lambda;\delta) + h} - A_L = \theta[\log \frac{\delta(\lambda;\bar{\delta})}{1-\delta(\lambda;\delta)} - \log \frac{\bar{\delta}}{1-\delta}]. \tag{B.11}$$

Note that $\frac{\partial \delta(\lambda;\bar{\delta})}{\partial \lambda} < 0$ for $\lambda \geq \lambda_2$, and thus $p(\lambda)$ is decreasing in λ in this region.

This completes the proof. ■

Lemma A.3. $\delta(\lambda;\bar{\delta})$ is increasing in $\bar{\delta}$,.

Proof of Lemma A.3. Let λ_1 and λ_2 be the ones in Lemma A.3. For $\lambda \le \lambda_1$, $\delta(\lambda;\bar{\delta})$ solves equation (B.7). Observe that

$$\frac{\partial \bar{\delta}}{\partial \delta} = -\frac{\frac{\partial f}{\partial \bar{\delta}}}{\frac{\partial f}{\partial \delta}} = -\frac{-\theta(\frac{1}{\delta}+\frac{1}{1-\delta}) - \frac{(1-\lambda)N_H+N_M}{(N_L\delta+h)^2}N_L}{\theta(\frac{1}{\delta}+\frac{1}{1-\delta})} > 0.$$

Similarly, for $\lambda \ge \lambda_2$, $\frac{\partial \bar{\delta}}{\partial \delta} > 0$. For $\lambda_1 < \lambda < \lambda_2$, first note that δ is the highest solution given $\bar{\delta}$ as we suppose that, when indifferent, the seller behaves in the buyer's best interest. Suppose δ' be the solution to (B.9) given $\bar{\delta}'$. Let $\bar{\delta}'' > \bar{\delta}'$. Then the left-hand side of (B.9) is greater than the right-hand side given $\delta = \delta'$ and $\bar{\delta} = \bar{\delta}''$. However, because $\log\frac{\delta}{1-\delta}$ goes to infinity as $\delta \longrightarrow 1$ while the left-hand side is bounded by $A_M - A_L - \frac{\lambda N_H}{N_L+h}$, there exists large enough $\delta^* \ge \delta'$ such that δ^* is the solution to (B.9) given $\bar{\delta}''$. (For large enough $\delta(\lambda)$, the corresponding solution l_M may be greater than 1. As l_M reaches 1 as we increase $\delta(\lambda)$, the equation (B.7) needs to be evaluated instead.) Therefore $\delta(\lambda;\bar{\delta})$ is increasing in $\bar{\delta}$. This completes the proof. ■

Lemmm A.4. (i) If $\bar{\delta}$ is sufficiently closed to 1, $\delta(\lambda;\bar{\delta})$ solves (B.7) for any $\lambda^{\min} \le \lambda \le \lambda^{\max}$; and (ii) If $\bar{\delta}$ is sufficiently closed to 0, $\delta(\lambda;\bar{\delta})$ solves (B.11) for any $\lambda^{\min} \le \lambda \le \lambda^{\max}$.

Proof of Lemma A.4. Define $\Theta_1 \equiv \{(\lambda,\bar{\delta})|A_M \ge \frac{1}{p(\lambda;\bar{\delta})}\}, \Theta_2 \equiv \{(\lambda,\bar{\delta})|A_M < \frac{1}{p(\lambda;\bar{\delta})}\}$, where $p(\lambda;\bar{\delta}) = \frac{N_L\delta(\lambda;\bar{\delta})+h}{N_H+l_M(\lambda;p)N_M}$. It sufficies to show that there exist $\bar{\delta}_1$ and $\bar{\delta}_2$ such that (i) $(\lambda,\bar{\delta}) \in \Theta_1$ for any $\lambda^{\min} \le \lambda \le \lambda^{\max}$ and $\bar{\delta}_1 \le \bar{\delta} \le 1$; and (ii) $(\lambda,\bar{\delta}) \in \Theta_2$ for any $\lambda^{\min} \le \lambda \le \lambda^{\max}$ and $0 \le \bar{\delta} \le \bar{\delta}_2$.

By assumption A.3, $A_M > \frac{N_H+N_M}{N_L+h} = \frac{1}{p(\lambda;1)}$ and $A_M < \frac{N_H}{h} = \frac{1}{p(\lambda;0)}$. This implies that there exist ε_1 and ε_2 such that $\{(\lambda,\bar{\delta})|\varepsilon_1 < \delta(\lambda;\bar{\delta}) \le 1\} \subset \Theta_1$ and $\{(\lambda,\bar{\delta})|0 \le \delta(\lambda;\bar{\delta}) < \varepsilon_2\} \subset \Theta_2$. Since $\delta(\lambda;\bar{\delta})$ is decreasing in λ and increasing in $\bar{\delta}$ by Lemma A.4, and $\delta(\lambda^{\min};0) = 0$ and $\delta(\lambda^{\max};1) = 1$, there exist $\bar{\delta}_1$ and $\bar{\delta}_2$ such that $\delta(\lambda^{\max};\bar{\delta}_1) = \varepsilon_1$ and $\delta(\lambda^{\min};\bar{\delta}_2) = \varepsilon_2$. Choose any $\lambda^{\min} \le \lambda \le \lambda^{\max}$ and $\bar{\delta}_1 \le \bar{\delta} \le 1$. Since $\delta(\lambda^{\max};\bar{\delta}_1) \le \delta(\lambda;\bar{\delta})$, $(\lambda,\bar{\delta}) \in \Theta_1$. Likewise, $(\lambda,\bar{\delta}) \in \Theta_2$ for any $\lambda^{\min} \le \lambda \le \lambda^{\max}$ and $0 \le \bar{\delta} \le \bar{\delta}_2$. ■

Lemmm A.5. For each λ, let $\delta^*(\lambda;\bar{\delta})$ denote a solution to (2.15) given $\bar{\delta}$ as in Proposition 22, and define

$$J^*(\bar{\delta}) \equiv \int_\lambda \delta^*(\lambda;\bar{\delta}) dF(\lambda).$$

and

(i) If

$$\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) \leq 1,$$

then $J^*(\bar{\delta}) < \bar{\delta}$ for $\bar{\delta}$ sufficiently close to 0, in which case $\bar{\delta}^* = 0$ is an equilibrium. If

$$\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) > 1,$$

then $J^*(\bar{\delta}) > \bar{\delta}$ for $\bar{\delta}$ sufficiently close to 0, in which case $\bar{\delta}^* = 0$ cannot be an equilibrium.

(ii) If

$$\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H + N_M}{N_L + h} - A_L)]dF(\lambda) \leq 1,$$

then $J(\bar{\delta}) > \bar{\delta}$ for $\bar{\delta}$ sufficiently close to 1, in which case $\bar{\delta}^* = 1$ is an equilibrium. If

$$\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H + N_M}{N_L + h} - A_L)]dF(\lambda) > 1,$$

then $J^*(\bar{\delta}) < \bar{\delta}$ for $\bar{\delta}$ sufficiently close to 1, in which case $\bar{\delta}^* = 1$ cannot be an equilibrium.

Proof of Lemma A.5. This lemma is similar to Lemma A.1, but the important difference here is that the loss function itself now depends on $\bar{\delta}$. To see this, let $\delta^*(\lambda;\bar{\delta})$ and $l_M^*(\lambda;\bar{\delta})$ denote a solution which is consistent with condition (i) in Lemma A.1 for each λ given $\bar{\delta}$. Substituting them into the loss function, we define

$$L^*(\lambda,\bar{\delta}) \equiv L^*(\lambda,\delta^*(\lambda;\bar{\delta})) \equiv \frac{(1-\lambda)N_H + l_M^*(\lambda;\bar{\delta})N_M}{N_L\delta^*(\lambda;\bar{\delta}) + h} - A_L.$$

Note that, by Lemma A.4, for $\bar{\delta}$ sufficiently close to 0,

$$L^*(\lambda,\bar{\delta}) = \frac{(1-\lambda)N_H}{N_L\delta^*(\lambda;\delta)+h} - A_L \tag{B.12}$$

and, for $\bar{\delta}$ sufficiently close to 1,

$$L^*(\lambda,\bar{\delta}) = \frac{(1-\lambda)N_H + N_M}{N_L\delta^*(\lambda;\bar{\delta})+h} - A_L. \tag{B.13}$$

Note that in those cases, $L^*(\lambda,\bar{\delta})$ is independent of the shape of $l_M^*(\lambda;\bar{\delta})$.

The first order condition (B.6) implies that

$$\delta^*(\lambda;\bar{\delta}) = \frac{\bar{\delta}}{\bar{\delta}+(1-\bar{\delta})\exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))}.$$

Define

$$\begin{aligned}
A &\equiv \bar{\delta}+(1-\bar{\delta})\exp(-\theta^{-1}L^*(\lambda,\bar{\delta})) \\
B &\equiv 1-\exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))+(1-\bar{\delta})\exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))\frac{\partial L^*(\lambda,\delta^*(\lambda;\bar{\delta}))}{\partial\delta^*}\frac{\partial\delta^*}{\partial\bar{\delta}}(-\theta^{-1}) \\
A' &= 1-\exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))+(1-\bar{\delta})\exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))\frac{\partial L^*(\lambda,\delta^*(\lambda;\bar{\delta}))}{\partial\delta^*}\frac{\partial\delta^*}{\partial\bar{\delta}}(-\theta^{-1}).
\end{aligned}$$

(i) Differentiating $J^*(\bar{\delta})$ in the interval $0 \le \bar{\delta} < \bar{\delta}_1$ where $\bar{\delta}_1$ is sufficiently close to 0 (the loss function given by (B.12) is independent of $l_M^*(\lambda;\bar{\delta})$ in this interval),

$$\frac{\partial J^*(\bar{\delta})}{\partial\bar{\delta}} = \int \frac{A-\bar{\delta}A'}{A^2}dF(\lambda)$$

and thus

$$\begin{aligned}
\frac{\partial J^*(\bar{\delta})}{\partial\bar{\delta}}\Big|_{\bar{\delta}=0} &= \int \exp(\theta^{-1}L^*(\lambda,\bar{\delta}))dF(\lambda) && \text{(B.14)} \\
&= \int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda). && \text{(B.15)}
\end{aligned}$$

The second equality comes from the fact that $\delta(\lambda) = \overline{\delta}$ almost surely if $\overline{\delta} = 0$ or $\overline{\delta} = 1$. Therefore, $\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) > 1$ if and only if $J^*(\overline{\delta}) > \overline{\delta}$ for $\overline{\delta}$ sufficiently close to 0.

Claim : $\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) \leq 1$ if and only if $J^*(\overline{\delta}) < \overline{\delta}$ for $\overline{\delta}$ sufficiently close to 0.

Proof of the claim : Note that if $\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) \leq 1$, $\frac{\partial J^*(\overline{\delta})}{\partial \delta}|_{\overline{\delta}=0} \leq 1$. Hence, it suffices to show that $\frac{\partial^2 J}{\partial \overline{\delta}^2}|_{\overline{\delta}=0} > 0$.

Differentiating $J^*(\overline{\delta})$ twice in the interval $0 \leq \overline{\delta} < \overline{\delta}_1$, we obtain

$$\frac{\partial^2 J^*(\overline{\delta})}{\partial \overline{\delta}^2} = \int \frac{-\overline{\delta}A''A^2 - (A - \overline{\delta}A')2AA'}{A^4} dF(\lambda).$$

Observe

$$\begin{aligned}
\frac{\partial^2 J}{\partial \overline{\delta}^2}|_{\overline{\delta}=0} &= -2\int \frac{A'}{A^2} dF(\lambda) \\
&= -2\int \frac{[1 - \exp(-\theta^{-1}L^*(\lambda,\overline{\delta})) + \exp(-\theta^{-1}L^*(\lambda,\overline{\delta}))\frac{\partial L^*(\lambda,\delta^*(\lambda;\overline{\delta}))}{\partial \delta^*}\frac{\partial \delta^*}{\partial \delta}(-\theta^{-1})]}{\exp(-\mu^{-1}L(\theta,\overline{q}))^2} dF(\lambda) \\
&= -2\int [\exp(2\theta^{-1}L^*(\lambda,\overline{\delta})) - \exp(\theta^{-1}L^*(\lambda,\overline{\delta})) \\
&\quad +(-\theta^{-1})\exp(\theta^{-1}L^*(\lambda,\overline{\delta}))\frac{\partial L^*(\lambda,\delta^*(\lambda;\overline{\delta}))}{\partial \delta^*}\frac{\partial \delta^*}{\partial \delta}]dF(\lambda).
\end{aligned}$$

Since $g(x) = x^2$, by Jensen's inequality,

$$\begin{aligned}
\int \exp(2\theta^{-1}L^*(\lambda,\overline{\delta}))dF(\lambda) &\leq \{\int \exp(\theta^{-1}L^*(\lambda,\overline{\delta}))dF(\lambda)\}^2 \\
&= \{\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda)\}^2
\end{aligned}$$

Note that the equality holds only if $L^*(\lambda,\overline{\delta})$ is constant almost surely.

If $\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{N_L\delta^*(\lambda;\delta)+h} - A_L)]dF(\lambda) \leq 1$,

$$\int \exp(2\theta^{-1}L^*(\lambda,\overline{\delta}))dF(\lambda) \leq \int \exp(\theta^{-1}L^*(\lambda,\overline{\delta}))dF(\lambda) \leq 1.$$

The equality holds only if $L^*(\lambda,\bar{\delta}) = 0$ almost surely, which contradicts the assumption that $F(L^*(\lambda,\bar{\delta}) \neq 0) > 0$. Therefore, the inequality must be strict.

Also, $\frac{\partial L^*(\lambda,\delta^*(\lambda;\bar{\delta}))}{\partial \delta^*} > 0$ in thie region. Combining with Lemma A.3,

$$\frac{\partial L^*(\lambda,\delta^*(\lambda;\bar{\delta}))}{\partial \delta^*}\frac{\partial \delta^*}{\partial \bar{\delta}} \geq 0.$$

Therefore,

$$\frac{\partial^2 J}{\partial \bar{\delta}^2}|_{\bar{\delta}=0} > 0.$$

End of claim.

(ii) Similar to case (i), in the interval $\bar{\delta}_1 < \bar{\delta} \leq 1$ where $\bar{\delta}_1$ is sufficiently close to 1 (the loss function given by (B.13),

$$\frac{\partial J^*(\bar{\delta})}{\partial \delta}|_{\bar{\delta}=1} = \int \exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))dF(\lambda) = \int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H+N_M}{N_L+h} - A_L)]dF(\lambda)$$

and

$$\begin{aligned}\frac{\partial^2 J}{\partial \bar{\delta}^2}|_{\bar{\delta}=1} &= -\int A'' + (1-A')2A'dF(\lambda) \\ &= -2\int \exp(-\theta^{-1}L^*(\lambda,\bar{\delta}))\frac{\partial L^*(\lambda,\delta^*(\lambda;\bar{\delta}))}{\partial \delta^*}\frac{\partial \delta^*}{\partial \bar{\delta}} \\ &\quad + \exp(-\theta^{-1}L^*(\lambda,\bar{\delta})) - \exp(-2\theta^{-1}L^*(\lambda,\bar{\delta}))dF(\lambda).\end{aligned}$$

Therefore, if $\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H+N_M}{N_L+h} - A_L)]dF(\lambda) > 1$, $J^*(\bar{\delta}) < \bar{\delta}$ for $\bar{\delta}$ sufficiently close to 1.

If $\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H+N_M}{N_L+h} - A_L)]dF(\lambda) \leq 1$, then $\frac{\partial^2 J}{\partial \bar{\delta}^2}|_{\bar{\delta}=1} < 0$ by the same reasoning as the above, and thus $J(\bar{\delta}) > \bar{\delta}$ for $\bar{\delta}$ sufficiently close to 1.

By Lemma A.1, $\bar{\delta}^* = 0$ can be an equilibrium only if $\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) \leq 1$. Likewise, $\bar{\delta}^* = 1$ can be an equilibrium only if $\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H+N_M}{N_L+h} - A_L)]dF(\lambda) \leq 1$. ■

Proof of Proposition 23 **(Existence).** Define

$$\Delta \equiv \{0 \leq \overline{\delta} \leq 1 | \overline{\delta} = J\left(\overline{\delta}\right), \text{ and } \overline{\delta} \text{ is consistent with the all the conditions in Proposition 22}\}.$$

I will show that Δ is non-empty, i.e., there exists a fixed point $\overline{\delta}$ which satisfies the sufficient and necessary conditions for an equilibrium.

By Lemma A.5, $\overline{\delta} = 0 \in \Delta$ if and only if

$$\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) \leq 1,$$

and $\delta(\lambda;0) = 0$ for all λ. In other words, if $\overline{\delta} = 0$ is chosen as an equilibrium, an agent does not obtain any information and he becomes a buyer with probability 0.

Likewise, $\overline{\delta} = 1 \in \Delta$ if and only if

$$\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H + N_M}{N_L + h} - A_L)]dF(\lambda) \leq 1,$$

and $\delta(\lambda;0) = 1$ for all λ. In this case, an agent does not obtain any information, but he becomes a buyer with probability 1.

Otherwise, because $J^*\left(\overline{\delta}\right)$ is increasing in $\overline{\delta}$ by Lemma A.3, Lemma A.5 implies that there exists an equilibrium $0 < \overline{\delta} < 1$, in which case an agent obtains information, and his probability of becoming an buyer depends on the state λ.

Also, notice that

$$E_\theta[\frac{1-\lambda^M(\lambda;p^*(\lambda;\overline{\delta}=0))}{p^*(\lambda;\overline{\delta}=0)}] = Z^{-1}\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h})]dF(\lambda)$$

and

$$E_{-\theta}[\frac{1-\lambda^M(\lambda;p^*(\lambda;\overline{\delta}=1))}{p^*(\lambda;\delta=1)}] = Z^{-1}\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H + N_M}{N_L + h})]dF(\lambda).$$

■

Proof of Proposition 24. (i) Note $\frac{1-\lambda^M(\lambda;p(\lambda))}{p(\lambda)} - A_L$ is decreasing in λ. Choose any $0 < \bar{\delta} < 1$. As $\theta \longrightarrow 0$,

$$\begin{aligned}
\delta^*(\lambda;\bar{\delta}) &\longrightarrow 1 \text{ for } \lambda^{\min} \leq \lambda < \lambda_1 \text{ such that } \frac{(1-\lambda)N_H + N_M}{N_L + h} - A_L > 0 \\
\delta^*(\lambda;\bar{\delta}) &\longrightarrow 0 \text{ for } \lambda_2 < \lambda \leq \lambda^{\max} \text{ such that } \frac{(1-\lambda)N_H}{h} - A_L < 0
\end{aligned}$$

For $\lambda_1 \leq \lambda \leq \lambda_2$, $0 \leq \delta^*(\lambda) \leq 1$, and $\delta^*(\lambda)$ and $l(p)$ solve

$$\frac{(1-\lambda)N_H + l_M(p)N_M}{N_L\delta^*(\lambda;\bar{\delta}) + h} - A_L = 0$$

and (2.10) where $p = \frac{N_H + l(p)N_M}{N_L\delta^*(\lambda;\delta)+h}$.

Since $J^*(\bar{\delta})$ is positive constant for $0 < \bar{\delta} < 1$, a fixed point $\bar{\delta} = J^*(\bar{\delta})$ is a unique equilibrium, and it coincides with a perfect information equilibrium.

(ii) Choose any $0 < \bar{\delta} < 1$. Note that $\delta^*(\lambda;\bar{\delta}) \longrightarrow \bar{\delta}$ for any λ as $\theta \longrightarrow \infty$. Therefore $J^*(\bar{\delta})$ converges to $\bar{\delta}$ for any $\bar{\delta}$. However, this does not necessarily imply that any $0 \leq \bar{\delta} \leq 1$ can be an equilibrium. In such a case, there are three possibilities. (1) if the price expectation p is given such that $\int_\lambda [\frac{1}{p}(1-\lambda^M(\lambda;p)) - A_L]dF(\lambda) > 0$, then $\bar{\delta} = 1$ is an stable equilibrium; (2) if p is given such that $\int_\lambda [\frac{1}{p}(1-\lambda^M(\lambda;p)) - A_L]dF(\lambda) < 0$, then $\bar{\delta} = 0$ is an stable equilibrium; and (3) There may exist a sequence of p as θ goes to infinity such that $\int_\lambda [\frac{1}{p}(1-\lambda^M(\lambda;p)) - A_L]dF(\lambda)$ converges to 0. In such case, there exists $0 < \bar{\delta} < 1$ such that $\bar{\delta} = J(\bar{\delta})$, in which case. agents seems to play a mixed strategy $\bar{\delta}$ in the limit; agents become a buyer with probability $\bar{\delta}$ in all states. Still, for arbitrarily large θ, $\bar{\delta}$ is stable only if it satisfies condition (ii) in Proposition 22. ■

Proof of Proposition 26. See Lemma A.2. It shows that $\frac{\partial\delta(\lambda;\bar{\delta})}{\partial\lambda} < 0$ for any $0 < \bar{\delta} < 1$. Therefore, in equilibrium, δ is strictly decreasing in λ if $0 < \bar{\delta} < 1$, and constant if $\bar{\delta} = 0$ or 1. Therefore δ is non-increasing in λ in equilibrium. Lemma A.2. also shows that p is non-increasing in λ, which implies that l_M is non-increasing in λ. ■

Proof of Proposition 27. The aggregate investment productiviy A is defined by

$$A \equiv \frac{(1-\delta)N_L A_L + [1+pl_M]N_M A_M + [1+p]N_H A_H}{(1-\delta)N_L + [1+pl_M]N_M + [1+p]N_H}, \tag{B.16}$$

which is the ratio of the aggregate new capital produced to the aggregate investment. Note that the aggregate liquidity is given by

$$N_L\delta + h = p[N_H + l_M N_M], \tag{B.17}$$

and thus the aggregate investment is

$$N_L + h - p[N_H + l_M N_M] + [1+pl_M]N_M + [1+p]N_H = 1+h,$$

and therefore,

$$A \equiv \frac{N_L A_L + N_M A_M + N_H A_H + hA_L + p[N_H(A_H - A_L) + l_M N_M(A_M - A_L)]}{1+h}.$$

For $p > \frac{1}{A_M}$, $l_M = 1$, it becomes

$$A = \frac{N_L A_L + N_M A_M + N_H A_H + hA_L + p[N_H(A_H - A_L) + N_M(A_M - A_L)]}{1+h}. \tag{B.18}$$

Note that the aggregate liquidity is equal to $\delta N_L + h = p(N_H + N_M)$, and therefore, the trading probability δ or the asset price p represents aggregate private market liquidity. Taking derivative (B.18) with respect to p, we obtain

$$\frac{\partial A}{\partial p} = \frac{N_H(A_H - A_L) + N_M(A_M - A_L)}{1+h} > 0.$$

For $p = \frac{1}{A_M}$, $0 \leq l_M \leq 1$, the aggregate investment productivity becomes

$$A = \frac{N_L A_L + N_M A_M + N_H A_H + hA_L + \frac{1}{A_M}[N_H(A_H - A_L) + l_M N_M(A_M - A_L)]}{1+h}.$$

Note that the aggregate liquidity is given by $N_L\delta + h = \frac{1}{A_M}[N_H + l_M N_M]$, which is increasing in l_M. Observe

$$\frac{\partial A}{\partial l} = \frac{\frac{1}{A_M}N_M(A_M - A_L)}{1+h} > 0.$$

For $p < \frac{1}{A_M}$, $l_M = 0$, and $N_L\delta + h = pN_H$. Observe

$$A = \frac{N_L A_L + N_M A_M + N_H A_H + p[N_H(A_H - A_L)] + hA_L}{1+h}.$$

which implies that $\frac{\partial A}{\partial p} > 0$.

Therefore, the aggregate investment productivity is increasing in private market liquidity. ■

Proof of Proposition 28. (i) Choose any $0 < \overline{\delta} < 1$. It suffices to show that $\delta^*(\lambda; \overline{\delta})$ is non-decreasing in A_M for all λ, and there exists a non-measure zero set of λ in which $\delta^*(\lambda; \overline{\delta})$ is strictly increasing in A_M.

Choose A'_M and A''_M such that $A'_M > A''_M$. For each of them, let λ'_1 (λ''_1) and λ'_2 (λ''_2) be values which correspond to Lemma A.2. Then λ_1 and λ_2 is increasing in A_M (λ_1 solves (B.8), and λ_2 solves (B.10). See the proof of Lemma A.2), and thus $\lambda'_1 > \lambda''_1$ and $\lambda'_2 > \lambda''_2$.

Note that $\delta^*(\lambda; \overline{\delta}, A_M)$ is increasing in $\frac{1-\lambda^M(\lambda;p)}{p}$ (1) For $\lambda^{\min} \leq \lambda \leq \lambda''_1$, $\delta^*(\lambda; \overline{\delta}, A'_M) = \delta^*(\lambda; \overline{\delta}, A''_M)$ (See (B.7)) ; (2) for $\lambda''_1 < \lambda \leq \lambda'_1$ and $\lambda''_2 < \lambda \leq \lambda'_2$, $l_M(\lambda)|_{A'_M} > l_M(\lambda)|_{A''_M}$, and hence, $\delta^*(\lambda; \overline{\delta}, A'_M) > \delta^*(\lambda; \overline{\delta}, A''_M)$. (See (B.6)); (3) for $\lambda'_1 < \lambda \leq \lambda''_2$, $\delta^*(\lambda; \overline{\delta}, A'_M) > \delta^*(\lambda; \overline{\delta}, A''_M)$ (See (B.9)); (4) for $\lambda'_2 < \lambda \leq \lambda^{\max}$, $\delta^*(\lambda; \overline{\delta}, A'_M) = \delta^*(\lambda; \overline{\delta}, A''_M)$. This completes the proof of the first part.

(ii) Fix $0 < \overline{\delta} < 1$. Suppose a fraction ψ of A_H entrepreneurs who hold nonlemons become A_M entrepreneurs. Then, the total population of A_H and A_M entrepreneurs is $\lambda N_H + (1-\lambda)(1-\psi)N_H$, and $N_M + (1-\lambda)\psi N_H$ respectively, but there is no change in the total amount of lemons in the economy, λN_H. Let λ'_1 and λ'_2 be values that are consistent with Lemma A.2 before the shock, $\psi' = 0$. Likewise, let λ''_1, λ''_2 be corresponding values after the shock, $\psi'' > 0$. Inspecting (B.8), (B.9), and (B.10), it can be easily seen that $\lambda'_1 = \lambda''_1$ and $\lambda'_2 < \lambda''_2$.

For $\lambda^{\min} \leq \lambda \leq \lambda'_2$, note that $\delta^*(\lambda; \overline{\delta}, \psi') = \delta^*(\lambda; \overline{\delta}, \psi'')$. (See (B.7) and (B.9). Those are robust to the distribution change.).

Next, observe that $\lambda^M(l_M^*(\lambda_2';\psi')) = \lambda^M(l_M^*(\lambda_2';\psi'')) = \lambda$, because δ in (B.9) is invariant to a distribution shock ψ and thus $\lambda^M(\lambda_2')$ is also invariant to ψ :

$$\begin{aligned}\lambda^M &= \frac{\lambda N_H}{\lambda N_H + (1-\lambda)(1-\psi)N_H + l(p)(N_M + (1-\lambda)\psi N_H)} \\ &= \frac{\lambda N_H}{\frac{1}{p}[N_L\delta^*(\lambda;\overline{\delta}) + h]}\end{aligned}$$

where $p = \frac{1}{A_M}$. Note that, for $\lambda_2' < \lambda \leq \lambda_2''$, $\lambda^M(l_M^*(\lambda;\psi'')) > \lambda$. It implies that $\frac{1}{p(\lambda;\psi')}(1-\lambda^M(\lambda;\psi')) > \frac{1}{p(\lambda;\psi'')}(1-\lambda^M(\lambda;\psi''))$ and thus $\delta^*(\lambda;\overline{\delta},\psi') > \delta^*(\lambda;\overline{\delta},\psi'')$ for $\lambda_2' < \lambda \leq \lambda_2''$.

For $\lambda_2'' < \lambda$, $\delta^*(\lambda;\overline{\delta},\psi') > \delta^*(\lambda;\overline{\delta},\psi'')$, because equation (B.11) becomes

$$\frac{(1-\lambda)(1-\psi)N_H}{N_L\delta(\lambda;\delta)+h} - A_L = \theta[\log\frac{\delta(\lambda;\overline{\delta})}{1-\delta(\lambda;\delta)} - \log\frac{\overline{\delta}}{1-\delta}]$$

after a shock $\psi > 0$. This completes the proof. ■

Proof of Proposition 29. Substituting (2.22) into (2.21),

$$W = \int_\lambda 1 + h - \lambda N_H + \int_j \int_s A_i i(s, A_j, \lambda_j) ds\, dj - (1+r)DF(\lambda) \tag{B.19}$$

The aggregate investment output is given by (See also the proof of Proposition **27**)

$$\begin{aligned}\int_i A_i i(s_i, A_i, \lambda_i) di &= \int_s A_L i(s, A_L, 0) N_L ds + A_M i(s, A_M, 0) N_M + A_H i(s, A_H, \lambda) N_H \\ &= (1-\delta)N_L A_L + [1 + p l_M] N_M A_M + [1+p] N_H A_H \\ &= N_L A_L + N_M A_M + N_H A_H + h A_L + p[N_H(A_H - A_L) + l_M N_M (A_M - A_L)]\end{aligned}$$

Since p and l_M is non-decreasing in δ, $\int A_i i_i di$ is non-decreasing in δ, and thus the welfare is maximized when $\delta(\lambda) = 1$ for all λ.

Notice that this information choice, $\delta(\lambda) = 1$, must be consistent with the private sector behavior in the financial market to implement her plan. Remember that the fictitous planner can (i) enforce an information choice to the extent that it is consistent with the private behavior; (ii) pledge future assets which are newly produced to obatain liquidity; and (iii) subsidize a market transaction with the obtained liquidity. I will show that the fictitious planner can implement the optimal plan with the following strategy.

Let us consider the optimal allocation under Assumption A.2.2 first. Note that $\delta(\lambda) = 1$ is consistent with the private behavior only if $\int \frac{1-\lambda^M(\lambda;p)}{p} dF(\lambda) = \int \frac{(1-\lambda)N_H+N_M}{N_L+h} dF(\lambda) > A_L$. (1.i) Suppose $\int \frac{1-\lambda^M(\lambda;p)}{p} dF(\lambda) \geq A_L$ where $p = \frac{N_L+h}{N_H+N_M}$. Note that $p^{\max} = \frac{N_L+h}{N_H+N_M}$. Although an increase in D causes $p > p^{\max}$, it reduces W.(See Remarks on Assumption A.2.2) Therefore, the planner's choice of D is 0. At date 1, the private sector chooses $i(s,A_L,0) = 0$, $i(s,A_M,0) = (1+p^{\max})$, and $i(s,A_H,\lambda) = (1+p^{\max})$ in all states. Clearly, this choice is consistent with the planner's choice $\delta(\lambda) = 1$ and $D = 0$.

(1.ii) If $\int \frac{1-\lambda^M(\lambda;p)}{p} dF(\lambda) < A_L$, the planner should manipulate the asset price p to induce the low productive entrepreneurs to buy assets. Let p' be a value such that $\int \frac{1-\lambda^M(\lambda;p)}{p'} dF(\lambda) = A_L$. p' can be achieved by short selling future assets which are produced with new investment. (The planner can pledge future assets while the entrepreneurs cannot.) Suppose the planner short-sells $\frac{S}{p}$ units of asset which are borrowed from investors and guarantees that buyers will receive $1-\lambda$ units of consumption goods at the same price p as other assets. Then, using the proceeds, the planner subsidizes sellers by p^S which is given by $p^S = p^{\max} - p'$, and distributes the rest of them in a lump-sum manner.

p' satisfies the market clearing condition, $(N_L+h)\frac{1}{p'} = N_H + N_M + \frac{1}{p'}S$, which is equivalent to $p' = \frac{N_L+h-S}{N_H+N_M}$. Since $p^{\max} = \frac{N_L+h}{N_H+N_M}$, p^S is given by $\frac{S}{N_H+N_M}$. Therefore, $i(s,A_L,0) = 0$, $i(s,A_M,0) = (1+p^{\max})$, and $i(s,A_H,\lambda) = (1+p^{\max})$ in all states, which is exactly the same allocation as in (1.i). Note that with lumpsum transfers, the ouput from the legacy assets is still the same, $1-\lambda N_H+h$. To see this, observe

$$\begin{aligned}
& \text{dividend payoff from legacy assets held by low productive entrepreneurs and households} \\
& + \text{net transfers of dividend payoff from short-sold assets} \\
= \; & [1+(1-\lambda^M)\frac{1}{p'}][N_L+h]-(1-\lambda^M)\frac{S}{p'} \\
= \; & [1+\frac{(1-\lambda)N_H+N_M}{N_H+N_M}\frac{N_H+N_M}{N_L+h-S}][N_L+h]-(1-\lambda^M)\frac{S}{N_L+h-S}[N_H+N_M] \\
= \; & N_L+h+(1-\lambda)N_H+N_M \\
= \; & 1+h-\lambda N_H.
\end{aligned}$$

Hence, the planner's choice of $\delta(\lambda)=1$ for all λ is consistent with the private behavior.

Next, I will consider the efficient allocation under Assumption A.2.3, which is a generalization to Assumption A.2.2. Regardless of the assumptions, the welfare is maximized only if the choice of $\delta(\lambda)=1$ for all λ. I will show that it can be consistent with the private behavior, and the optimal choice of D is given by some positive value which depends on production capacity. Let p^* be given as in Assumption A.2.3. Before proceeding, note that $A_L<\frac{1}{p^*}$ in any cases; p^* should not be too high. Otherwise, low productive entrepreneurs sell their assets to invest, and Assumption A.2.1 implies that resources are used inefficiently. (2.i) If $\int\frac{1-\lambda^M(\lambda;p)}{p^*}dF(\lambda)\geq A_L$, the planner will choose $D^*>0$ such that $p^*=\frac{N_L+h+D^*}{N_H+N_M}$. Note that the optimal choice of D^* is increasing in p^*. The optimal investment plan of the private sector is given by $i(s,A_L,0)=0$, $i(s,A_M,0)=(1+p^*)$, and $i(s,A_H,\lambda)=(1+p^*)$ in all states. This plan is indeed consistent with the planner's choice $\delta(\lambda)=1$ and D^*.

(2.ii) If $\int\frac{1-\lambda^M(\lambda;p)}{p^*}dF(\lambda)<A_L$, by the same reasoning as in (1.ii), let p' be one such that $\int\frac{1-\lambda^M(\lambda;p)}{p'}dF(\lambda)=A_L$. The subsidy p^S is given by $p^S=p^*-p'$, and D^* satisfies $p^*=\frac{N_L+h+D^*}{N_H+N_M}$. Observe that $p'=\frac{N_L+h-S}{N_H+N_M}$ and $p^S=\frac{S+D^*}{N_H+N_M}$. The private sector's choice is $i(s,A_L,0)=0$, $i(s,A_M,0)=(1+p^*)$, and $i(s,A_H,\lambda)=(1+p^*)$ in all states. This choice is consistent with the planner's choice $\delta(\lambda)=1$ and D^*. The efficient allocation is the same as (2.i). ■

Proof of Proposition 30. (i) See Proposition **24**.(i). It states that $\delta(\lambda)=0$ for $\lambda>\bar{\lambda}_2$, where $\frac{1-\lambda^M(\bar{\lambda}_2,p)}{p}<A_L$. This implies that the allocation with perfect information on the aggregate state is constrained inefficient.

(ii) Let $\bar{\lambda}_1$, $\bar{\lambda}_2$ and $\bar{\lambda}_3$ be given as in Proposition **24**.(i). For $\lambda < \bar{\lambda}_1$, $\delta(\lambda) = 1$, and thus the allocation is constrained efficient. For $\lambda \geq \bar{\lambda}_1$, let $\tau(\lambda)$ be the one such that $\frac{1-\lambda^M(\lambda;p)}{p} = A_L$ where $p = \frac{(1-\tau(\lambda))(N_L+h)}{N_H+N_M}$. Suppose the planner collects lump-sum taxes $\tau + \varepsilon$ from all agents where $\varepsilon > 0$, and uses the revenues from the taxes to subsidize sellers for each financial transaction. (In fact, there are many possible lump-sum taxes which are consistent with the optimal allocation, but it should not too large because it must be $\frac{1}{p+subsidy} > A_L$.) Each investor's total holding of liquidity is the sum of the endowment liquidity after taxes and the liquidity obtained from financial transactions,

$$\begin{aligned}
(1-\tau)+(p+subsidy) &= (1-\tau)+(p+\frac{\tau(1+h)}{N_H+N_M}) \\
&= 1+\frac{N_L+h}{N_H+N_M}.
\end{aligned}$$

Therefore, the allocation with the appropriate subsidy is constrained efficient.

(iii) See Proposition **23**. Unless $A_L \leq -\theta \log \int \exp[-\frac{1}{\theta}(\frac{(1-\lambda)N_H+N_M}{N_L+h})]dF(\lambda)$, $\delta(\lambda) < 1$ in all states, which does not coincide with the constrained efficient allocation. ■

Lemma A.7. The asset price p is non-decreasing in government asset purchases in all states given $\bar{\delta}$.

Proof of Lemma A.7. Similar to Lemma A.2, fix $0 \leq \bar{\delta} \leq 1$, and define $\lambda_1(D;\bar{\delta}) \equiv \sup\{\lambda | p(\lambda, D) > \frac{1}{A_M}\}$ and $\lambda_2(D;\bar{\delta}) \equiv \sup\{\lambda | p(\lambda;D,\bar{\delta}) = \frac{1}{A_M}\}$, where D is government deficit spending. Here $p(\lambda;D,\bar{\delta})$ denotes the asset price with the government intervention D in the state λ.

$$p(\lambda;D,\bar{\delta}) = \frac{N_L\delta(\lambda;D,\bar{\delta})+h+D}{N_H+l_M(\lambda;D,\delta)N_M}$$

where $\delta(\lambda;D,\bar{\delta})$ and $l_M(\lambda;D,\bar{\delta})$ are equilibrium values in the state λ given D and $\bar{\delta}$. If $D = 0$, the government does not intervene in the market.

Choose arbitrary $D > 0$. Note that $\lambda_1(D;\bar{\delta}) > \lambda_1(0;\bar{\delta})$ and $\lambda_2(D;\bar{\delta}) > \lambda_2(0;\bar{\delta})$ (See the proof of Lemma A.2). It is easy to see that $p(\lambda;D,\overline{\delta}) > p(\lambda;0,\overline{\delta})$ for $\lambda \leq \lambda_1(0;\overline{\delta})$. If not, it must be $\delta(\lambda;D,\overline{\delta}) < \delta(\lambda;0,\overline{\delta})$ and

$$\frac{1-\lambda^M(\lambda;p(\lambda;0,\overline{\delta}))}{p(\lambda;0,\delta)} < \frac{1-\lambda^M(\lambda;p(\lambda;D,\overline{\delta}))}{p(\lambda;D,\delta)}.$$

However, if the above inequality holds, then $\delta(\lambda;D,\overline{\delta}) > \delta(\lambda;0,\overline{\delta})$ by (B.7), which is contradictory because the asset price is non-decreasing in $\delta(\lambda)$. Since p is non-increasing in λ, it is clear that $p(\lambda;D,\overline{\delta}) \geq p(\lambda;0,\overline{\delta})$ for $\lambda_1(0;\overline{\delta}) < \lambda \leq \lambda_2(D;\overline{\delta})$.

Using the same reasoning as above, $p(\lambda;D,\overline{\delta}) > p(\lambda;0,\overline{\delta})$ for $\lambda_2(D;\overline{\delta}) < \lambda$. This completes the proof. ■

Proof of Proposition 31. Suppose the government guarantees that a buyer will receive $\kappa^G(\lambda)$ consumption goods at date 2 for each financial transaction. The government raises lump-sum taxes from all agents at date 2 and transfers those to buyers as subsidies. Thus, it does not change the budget and resource constraints.

If the government fully subsidizes buyers, i.e., $\kappa^G(\lambda) = \lambda$, then

$$\frac{N_H+N_M}{N_L+h} > A_L,$$

and thus

$$\frac{N_H+N_M}{N_L+h}[\frac{(1-\lambda)N_H+N_M}{N_H+N_M} + \kappa^G(\lambda)],$$

$$\int \exp[-\theta^{-1}\{\frac{N_H+N_M}{N_L+h}[\frac{(1-\lambda)N_H+N_M}{N_H+N_M} + \kappa^G(\lambda)] - A_L\}]dF(\lambda) \leq 1,$$

and $\overline{\delta} = 1$ is the unique equilibrium. The low productive entrepreneurs do not need to obtain information and becomes buyers.

Minimum cost intervention $\kappa^G_*(\lambda)$ satisfies

$$\int \exp[-\theta^{-1}\{\frac{N_H+N_M}{N_L+h}[\frac{(1-\lambda)N_H+N_M}{N_H+N_M} + \kappa^G(\lambda)] - A_L\}]dF(\lambda) = 1. \tag{B.20}$$

With the minimum cost intervention, $\bar{\delta} = 1$ is consistent with the equilibrium conditions. However, it does not guarantee the uniqueness of the equilibrium. For instance, the price impact on the quality of assets is large enough, then it may be possible that

$$\int \exp[-\theta^{-1}\{\frac{N_H}{h}[\frac{(1-\lambda)N_H}{N_H} + \kappa^G(\lambda)] - A_L\}]dF(\lambda) \leq 1. \tag{B.21}$$

Both (B.20) and (B.21) hold at the same time only if

$$\int \frac{1-\lambda^M(\lambda; p^*(\mu; \bar{\delta}=0)) + \kappa_*^G(\lambda)}{p^*(\mu; \bar{\delta}=0)} dF(\lambda) < A_L < \int \frac{1-\lambda^M(\lambda; p^{\max}) + \kappa_*^G(\lambda)}{p^{\max}} dF(\lambda),$$

which may hold if N_M is sufficiently large. Therefore the minimum cost intervention may induce $\bar{\delta} = 1$ as an equilibrium, but a multiplicity of equilibria may arise. ■

Proof of Proposition 32. Notice that $E_{-\theta}[\frac{1-\{\lambda^M(\lambda;p^*(\lambda;\bar{\delta}=1))-\kappa_*^G(\lambda)\}}{p^*(\lambda;\bar{\delta}=1)}]$ is increasing in $\kappa_*^G(\lambda)$. From inequality (2.17), the lower bound of $E_{-\theta}[\frac{1-\{\lambda^M(\lambda;p^*(\lambda;\bar{\delta}=1))-\kappa_*^G(\lambda)\}}{p^*(\lambda;\bar{\delta}=1)}]$ that implements the optimal plan is given by A_L. Therefore, the cost-minimizing insurance $\kappa_*^G(\lambda)$ must satisfy $A_L = E_{-\theta}[\frac{1-\{\lambda^M(\lambda;p^*(\lambda;\bar{\delta}=1))-\kappa_*^G(\lambda)\}}{p^*(\lambda;\bar{\delta}=1)}]$. ■

Proof of Proposition 33. (i) Remember that $p^{\max} = \frac{N_L+h}{N_H+N_M}$. Observe

$$\int \exp[-\theta^{-1}(\frac{(1-\lambda)N_H + N_M}{N_L+h+D} - A_L)]dF(\lambda) > \int \exp[-\theta^{-1}(\frac{1-\lambda^M(\lambda; p^{\max})}{p^{\max}} - A_L)]dF(\lambda).$$

It implies that if $\bar{\delta} = 1$ cannot be an equilibrium with $D = 0$, i.e., $\int \exp[-\theta^{-1}(\frac{1-\lambda^M(\lambda;p^{\max})}{p^{\max}} - A_L)]dF(\lambda) > 1$ (See Lemma A.5 (ii)), then $\bar{\delta} = 1$ cannot be an equilibrium with any $D > 0$. Therefore, no policy in this class can implement $\bar{\delta} = 1$ as an equilibrium.

(ii) Note that there exists D^* such that, for $D \geq D^*$

$$\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H + N_M}{h+D} - A_L)]dF(\lambda) \leq 1.$$

Also, the loss function is concave in $\delta(\lambda)$ with large enough D:

$$\frac{d^2L(\delta(\lambda))}{d\delta(\lambda)^2} < 0.$$

Therefore, $\overline{\delta} = 0$ is the unique equilibrium for large enough D.

■

Example 2. (i) Let us start from the case in which $\overline{\delta} = 0$ is the unique market equilibrium without the presence of any government interventions. Suppose the government needs to choose D which maximizes (B.19) subject to the feasibility constraints. Note that the welfare is maximized only if $p = p^{\max} = \frac{N_L+h}{N_H+N_M}$ for each λ, owing to the capacity constraint. $p^{\max}$ denotes the highest price possible with $D = 0$. Remember that, by Lemma A.5, $\overline{\delta} = 0$ is a unique equilibrium only if

$$\int \exp[\theta^{-1}(\frac{(1-\lambda)N_H}{h} - A_L)]dF(\lambda) \leq 1. \tag{B.22}$$

Now, guess that the government can implement the asset price $p^{\max}$ in all states with D^*. Then the entrepreneurs take the state independent asset price $p^{\max}$ as given as they make an information choice. I will show that $D^* = N_L$ is consistent with the private sector's beliefs on the asset price, and $\overline{\delta}^* = 0$, which is the private sector's information choice with $D = D^*$, is the unique equilibrium.

We can exploit Lemma A.1 to prove that $\overline{\delta}^* = 0$ is the unique equilibrium. It suffices to show that the inequalities, which correspond to Lemma A.1 (i), hold.

$$\int \exp[\theta^{-1}(\frac{1-\lambda^M(\lambda;p^{\max})}{p^{\max}} - A_L)]dF(\lambda) \leq 1. \tag{B.23}$$

Since the medium entrepreneurs are seller at $p^{\max}$ ($\frac{1}{p^{\max}} = \frac{N_H+N_M}{N_L+h} < A_M$),

$$\frac{1-\lambda^M(\lambda;p^{\max})}{p^{\max}} = \frac{(1-\lambda)N_H+N_M}{N_L+h}.$$

Observe that for small enough N_M

$$\frac{1-\lambda^M(\lambda;p^{\max})}{p^{\max}} < \frac{(1-\lambda)N_H}{h} = \frac{1-\lambda^M(\lambda;p(\lambda;\bar{\delta}=0))}{p(\lambda;\bar{\delta}=0)}.$$

and thus,

$$\int \exp[\theta^{-1}(\frac{1-\lambda^M(\lambda;p^{\max})}{p^{\max}} - A_L)]dF(\lambda) \leq \int \exp[\theta^{-1}(\frac{1-\lambda^M(\lambda;p(\lambda;\bar{\delta}=0))}{p(\lambda;\bar{\delta}=0)} - A_L)]dF(\lambda) \leq 1$$

for small enough N_M.

Therefore, $\bar{\delta}^* = 0$ with $D^* = N_L$ is the unique equilibrium, and is the optimal allocation with the government purchases in such circumstances.

(ii) If marginal investors are a relatively large fraction of the population, the government can revive the market to some extent. Suppose that

$$\int \exp[\theta^{-1}\{(\frac{(1-\lambda)N_H + N_M}{N_H + N_M})(A_M+\varepsilon) - A_L\}]dF(\lambda) > 1$$

for $\varepsilon > 0$.

Note that the government must commit D' such that $A_M + \varepsilon = \frac{N_H+N_M}{D'+h}$, and therefore this condition is likely to hold if N_M is large enough. Also, if A_M is high, the government can induce the marginal investors to sell without raising the asset price much.

Since $l_M(\lambda) = 1$, the welfare can be written as

$$\begin{aligned} W(D) &= \int N_L A_L + N_M A_M + N_H A_H - \delta(\lambda;D) N_L A_L \\ &\quad + (N_L \delta(\lambda;D) + h + D)\frac{N_M A_M + N_H A_H}{N_M + N_H} - (1+r)D dF(\lambda) \end{aligned}$$

where $\delta(\lambda;D)$ is an equilibrium information choice in the state λ given D.

Taking derivative with respect to D, we obtain

$$\frac{dW(D)}{dD} = \int \frac{N_M A_M + N_H A_H}{N_M + N_H} - (1+r) + \frac{\partial \delta(\lambda;D)}{\partial D} N_L (\frac{N_M A_M + N_H A_H}{N_M + N_H} - A_L) dF(\lambda).$$

■

B.2 Assumption interpretation

Assumption 3 is equivalent to Assumption A.1.

Assumption A.1. (1) There are three different levels of investment productivity:

$$g_A(x) = \begin{cases} N_L,\ x = A_L \\ N_M,\ x = A_M \\ N_H,\ x = A_H \\ 0, \text{otherwise} \end{cases},$$

where $g_A(x)$ is the probability mass function of distribution G, and $N_H + N_M + N_H = 1$;

(i) $A_L < \frac{N_H+N_M}{N_L+h}$; (ii) $\max[\frac{N_H+N_M}{N_L+h}, \frac{(1-\lambda^{\min})N_H}{h}] < A_M < \frac{N_H}{h}$; (iii) $\frac{N_H}{h} < A_H$; where $\lambda^{\min}$ and $\lambda^{\max}$ denote the minimum and maximum value of the support of the random variable λ respectively; h is a mass of the population of households.

(2) Conditional on investment productivity A_j, λ_j has a degenerate distribution as follows:

$$\begin{aligned} z_\lambda^{'}(x|A) &= \begin{cases} 1,\ x = 0 \\ 0,\ \text{otherwise} \end{cases} \quad for\ A \in \{A_L, A_M\}, \\ z_\lambda^{'}(x|A_H) &= \begin{cases} 1,\ x = \lambda \\ 0,\ \text{otherwise} \end{cases}, \end{aligned}$$

where $z_{\lambda}^{'}(x|A)$ is the conditional probability mass function of the distribution Z'. This is equilivalent to assume

$$\lambda_j = 0 \ for \text{ all entrepreneurs with } A_L, A_M,$$
$$\lambda_j = \lambda \ for \text{ all entrepreneurs with } A_H.$$

Remarks on Assumption A.1. (1) The first part of the assumption ensures that I will be able to focus on a case in which only entrepreneurs with productivity A_L acquire information on the underlying state, while entrepreneurs with productivity A_M and A_H optimally choose not to obtain any information on the state.

The population of entrepreneurs with investment productivity A_j is given by N_j, and the total population of entrepreneurs is normalized to 1. Much intuition can be obtained with these three types, and the model becomes tractable.

There are medium productive investors with A_M whose selling decisions depend on the asset price (equivalently, the interest rate of loans, $\frac{1}{p}$), but A_M assumed to be high enough to prevent them from being buyers of assets $(\max \frac{1-\lambda^M}{p} < A_M)$. In addition, they are marginal investors in the sense that whether to sell or not hinge on the financial decisions of other entrepreneurs: A_M is parameterized such that $l_M(\lambda; p(\lambda)) = 1$ if $\delta(\lambda) = 1$ and $l_M(\lambda; p(\lambda)) = 0$ if $\delta(\lambda) = 0$ almost surely. For instance, if there are no entrepreneurs who buy assets, $\delta(\lambda) = 0$, then the asset price is sufficiently low, in which case the marginal investors do not sell their nonlemons, $l_M(\lambda; p(\lambda)) = 0$. (More specifically, $A_M < \frac{N_H}{h} = \min_{\lambda, l_M} \frac{1}{p(\lambda)}|_{\delta(\lambda)=0}$.) In contrast, if the asset price is high enough as asset demand reahces its maximum level, $\delta(\lambda) = 1$, they sell their nonlemons $l_M(\lambda; p(\lambda)) = 1$ $(A_M > \frac{N_H+N_M}{N_L+h} = \max_{\lambda, l_M} \frac{1}{p(\lambda)}|_{\delta(\lambda)=1})$.

Note that $\frac{N_H+N_M}{N_L+h}$ and $\frac{N_H}{h}$ are the minimum and maximum value of possible $\frac{1}{p}$ respectively (p is non-decreasing in $\delta(\lambda)$). This implies that, since A_L is sufficiently low, selling non lemon assets to finance new investment projects is never profitable for entrepreneurs with technology A_L. Similarly, since A_H is sufficiently high, the group of entrepreneurs with A_H eager to look for liquidity to finance their promising investment projects.

(2) The second part implies that only legacy assets owned by high productivity entrepreneurs turn out to be lemons with probability λ. This assumption greatly simplifies our notation. With a slight abuse of notation, I consider λ as

the mean of λ_j, where λ is distributed according to Z.[1]

$D = 0$ for optimality is equivalent to Assumption A.2.1 and A.2.2.

Assumption A.2.1 (i) $\frac{A_H N_H + A_M N_M}{N_H + N_M} > 1 + r$; (ii) $A_H N_H + A_M N_M + A_L N_L < 1 + r$.

Remarks on Assumption A.2.1. First, this assumption implies that the sufficient amount of liquidity must be transferred to more productive entrepreneurs to ensure that the amount of output produced per unit of investment is larger than the cost per unit of public funds borrowed, $1 + r$.

Second, it ensures, the scale of the intervention must be finite. Note that the asset price p is increasing in the scale of intervention D. If D is large enough to raise p to the level higher than $\frac{1}{A_L}$, the low productive entrepreneurs will become sellers and invest an equal amount as the other entrepreneurs. In such a case, the overall efficiency of investment will be less than $1 + r$ by (ii), and the cost of public funds $1 + r$ exceeds its benefit.

However, the optimal choice of D still depends on the parametrization of investment productivity. In order to pin down D to 0, we can make an assumption on production technology.

Assumption A.2.2 Let $A(p)$ denote the average investment goods the amount of liquidity p can produce and $p^{\max}$ denote the maximum asset price with $D = 0$. Assume that the entrepreneurs' production capacity is constrained in that

$$p(N_H A_H(p) + N_M A_M(p)) = \begin{cases} p^{\max}(N_H A_H + N_M A_M) + (p - p^{\max})(1+\xi)(N_H + N_M) & \text{for } p > p^{\max} \\ p(N_H A_H + N_M A_M) & \text{for } p \leq p^{\max} \end{cases}$$

where $\xi < r$.

Remarks on Assumption A.2.2 With Assumption A.2.2, the aggregate production $\int A_i i_i di$ with fully participated high and medium entrepreneurs is given by

$$p\frac{N_H A_H(p) + N_M A_M(p)}{N_H + N_M} = p^{\max}\frac{(N_H A_H + N_M A_M)}{N_H + N_M} + (p - p^{\max})(1+\xi).$$

[1] $z(x, A_{L,M}) = N_L, N_M$ for $x = 0$ and $z(x, A_H) = N_H$ for $x = \lambda$. Therefore, $z(\lambda) = N_H$, $z(0) = N_L + N_M$, and $E[\lambda_j] = \lambda N_H$. Since N_H is non random, it is without loss of generality.

for $p > p^{\max}$. This implies that, while the average productivity is strictly greater than $1+r$ in the interval $p \leq p^{\max}$, the average productivity in the interval $p^{\max} \leq p$ is $1+\xi$, which is less than the cost per unit of public funds, $1+r$. Combining Assumption A.2.1 and A.2.2, it can be easily shown that $D = 0$.(See the proof of Proposition 29.)

Assumption A.2.3. Assume that the entrepreneurs' production capacity is constrained in that there exists $p^* > p^{\max}$ such that

$$\begin{aligned} 1+r &> \frac{N_H A_H(p) + N_M A_M(p)}{N_H + N_M} \text{ for } p \geq p^* \text{ and} \\ 1+r &< \frac{N_H A_H(p) + N_M A_M(p)}{N_H + N_M} \text{ for } p < p^*. \end{aligned}$$

Remarks on Assumption A.2.3 It generalizes our assumption $D = 0$ in that the optimal choice of D can be a positive value here. The assumption implies that the average productivity is less than the cost per unit of public funds for sufficiently large p. Nevertheless, Assumption A.2.2 is without loss of generality in the sense that the optimal policy under Assumption A.2.3 can be shown that it is the simple affine transformation of the optimal policy under Assumption A.2.2.

B.3 Supplementary appendix

The private sector has acess to storage technology $0 \leq \beta \leq 1$.

⋇ The distribution of investment productivity is parameterized in accord with Assumption 3.

Note that if $\beta \leq A_L$, the existence of storage technology does not affect results at all: no one uses such storage technology. In such a case, we can assume $\beta = 0$ without loss of generality.

If $\beta \geq A_M$, the market collapses, as there are no buyers except households: every entrepreneurs wishes to either invest or store their liquidity.

Therefore, it must be $A_L < \beta < A_M$. In such a case, it is equivalent for the low productive entrepreneurs to have productivity of β. However, higher β implies lower private liquidity, as they are likely to store liquidity rather than to buy assets (See equation (2.15)). Therefore, higher β can exacerbate the distortion in liquidity rellocation.■

The model with noisy price observations

Let us introduce unobservable random supply ε which is independent of the state λ into the market clearing condition.

$$\frac{1}{p}[N_L\delta(\lambda)+h] \leq N_H + l_M(\lambda)N_M + \varepsilon.$$

Then the asset price p is the multivariate function of λ and ε, $p(\lambda,\varepsilon)$; the asset price is a noisy signal on λ.

Suppose that entrepreneurs can postulate the current state from the asset price. Once they make an information choice, they receive a signal right after they observe the asset price.

Since $f(\lambda,\varepsilon|s,p) = \frac{f(\lambda,\varepsilon,s|p)}{f(s|p)} = f(s|\lambda,\varepsilon,p)\frac{f(\lambda,\varepsilon|p)}{f(s|p)}$, it follows that

$$\begin{aligned}
I(f|p) &= H(f|p) - H(f|s,p) = -E[\log f(\lambda,\varepsilon|p)] + E[\log f(\lambda,\varepsilon|s,p)] = E[\log\frac{f(\lambda,\varepsilon|s,p)}{f(\lambda,\varepsilon|p)}] \\
&= E[\log\frac{f(s|\lambda,\varepsilon,p)}{f(s|p)}] \\
&= -E[\log f(s|p)] + E[\log f(s|\lambda,\varepsilon,p)] \\
&= \int_{\lambda,\varepsilon,p}\int_s f(s|\lambda,\varepsilon,p)\ln f(s|\lambda,\varepsilon,p)dsdF(\lambda,\varepsilon,p) \\
&\quad -\int_p\int_s[\int_{\lambda,\varepsilon} f(s|\lambda,\varepsilon,p)dF(\lambda,\varepsilon|p)]\ln[\int_{\lambda,\varepsilon} f(s|\lambda,\varepsilon,p)dF(\lambda,\varepsilon|p)]dsdF(p) \\
&= \int_{\lambda,\varepsilon,p} f(1|\lambda,\varepsilon,p)\log f(1|\lambda,\varepsilon,p) + f(0|\lambda,\varepsilon,p)\log f(0|\lambda,\varepsilon,p)dP(\lambda,\varepsilon,p) \\
&\quad -\int_p[f(1|p)\log f(1|p) + f(0|p)\log f(0|p)]dP(p)
\end{aligned}$$

where $F(\lambda,\varepsilon,p)$ is the prior over (λ,ε,p). Then,

$$I(\delta) = \int_\lambda \delta(\lambda,\varepsilon,p)\log\delta(\lambda,\varepsilon,p) + (1-\delta(\lambda,\varepsilon,p))\log(1-\delta(\lambda,\varepsilon,p))dF(\lambda) - \bar{\delta}(p)\log\bar{\delta}(p) - (1-\bar{\delta}(p))\log(1-\bar{\delta}(p))$$

where $\bar{\delta}(p) = \int_{\lambda,\varepsilon}\delta(\lambda,\varepsilon,p)f(\lambda,\varepsilon|p)d(\lambda,\varepsilon)$.

Therefore, an equilibrium $\delta(\lambda,\varepsilon,p)$ solves the following.

$$\max_{\delta(\cdot)}\int_{\lambda,\varepsilon,p}\delta(\lambda,\varepsilon,p)L(\lambda,\varepsilon,p)dF(\lambda,\varepsilon,p)-\theta I(\delta).$$

Suppose beliefs $p(\lambda,\varepsilon)$ are given. Then for each $p(\lambda,\varepsilon)=\bar{p}$, there is an equilibrium fixed point $\bar{\delta}(\bar{p})$. An equilibrium is a set of $\bar{\delta}(p)$ for all possible $p=p(\lambda,\varepsilon)$ that satisfies $\bar{\delta}=\int_p\bar{\delta}(p)f(p)dp$. In the same way, we can add an additional random variable as we allow agents to infer the current state from an additional aggregate variable.■

State-contingent asset purchases

One question is whether state-contingent asset purchases can perform better than the non state-contingent policy if the goal of policy is to revive private securities markets. This type of the policy can be justified on the ground that the asset price is a key variable for an intermediate productive entrepreneur to sell his nonlemons, which leads to an improvement of the quality of assets. In our environment, the scale of the intervention must be large enough to raise the asset price higher or equal than $\frac{1}{A_M}$ to improve the quality of assets traded in the market. Otherwise, the government program just crowds out private liquidity provision and the economy experiences inefficiency from liquidity misallocation.

Consider the government's strategy of state-contingent asset purchases as follows. At date 0, the government promises to purchase a certain amount of assets only in the state in which the asset price is equal or less than $\frac{1}{A_M}$. For those states at date 1, the government attempts to purchase assets until the asset price reaches $\frac{1}{A_M}+\varepsilon$ ($\varepsilon>0$ is arbitrary small) to ensure that the medium productive entrepreneurs sell their nonlemons, i.e.,

$$\begin{aligned}
p^G(\lambda) &= \frac{1}{A_M}+\varepsilon \text{ if } p^O(\lambda)<\frac{1}{A_M}+\varepsilon \\
p^G(\lambda) &= p^O(\lambda) \qquad \text{otherwise}
\end{aligned}$$

where p^G and p^O is the asset price with and without the intervention respectively. The government finances D dollars by a government deficit, $D=\frac{N_H+N_M}{A_M}-[N_L\delta(\lambda)+h]$. At date 2, the government deficit D is repaid with lump sum taxes and revenues generated by the purchased assets. Note that it does not require the government to know about the current state at date 1 to implement this policy, since the asset price is publicly observable.

Proposition 34 *(Inefficiency of State-Contingent Asset Purchases : Price Targeting) Consider the government's strategy of state-contingent asset purchases.* (i) *Suppose* $0 < \overline{\delta} < 1$ *is the unique equilibrium in the absence of the government intervention. No policy in this class can implement the efficient allocation.*
(ii) Suppose $\overline{\delta} = 0$ *(minimum private liquidity) is the unique equilibrium. Then the state-contingent asset purchases are more effective than the non state-contingent policy if the goal of policy is to revive private securities markets.*

The intuition behind this result is that the state-contingent purchases do not raise an asset price as much as the non state-contingent policy. With higher capital gains from assets with the state-contingent policy from the perspective of potential buyers, entrepreneurs are more likely to buy assets traded in the market.

Proof of Proposition 18.

(i) See the proof of Proposition 13.(i).

(ii) As the government targets the asset price, the asset price becomes $\frac{1}{A_M} + \varepsilon$ for $\lambda > \lambda_1$ where ε is an arbitrarily small positive number. For $\lambda \leq \lambda_1$, the government does not intervene in the market, and thus the asset price remains the same. Notice that the scale of the intervention $D(\lambda)$ is state-contingent and satisfies

$$A_M = \frac{N_H + N_M}{N_L \delta(\lambda) + h + D(\lambda)}.$$

Note that the government can revive the market if and only if

$$\int \exp[\theta^{-1}\{(1 - \frac{\lambda N_H}{N_H + N_M})A_M - A_L\}]dF(\lambda) > 1. \tag{B.24}$$

Inequality (B.24) holds only if $\frac{N_M}{N_H}$ or A_M is sufficiently large enough. Otherwise, the government cannot revive the market and $\overline{\delta} = 0$ is the unique equilibrium.

Note that it is straightforward to see that if the non-state contingent asset purchases revive the market, then it the state-contingent asset purchases can also revive the market with larger private liquidity. ■

Appendix C

Appendix for Chapter 3

C.1 Timeline of the model

1. The aggregate productivity shock, A_t, is realized.

2. Firms hire labor and produce the consumption good, Y_t using capital invested from time $t-1$.

3. Households choose C_t, H_t and B_{t+1}.

4. The uncertainty shock σ_{t+1} and idiosyncratic disturbance of each entrepreneur is realized, ω_t^i, where i indexes the infinite number of entrepreneurs. The entrepreneur is able to repay the loan as long as $\omega_t^i \geq \bar{\omega}$; otherwise, the entrepreneur declares default and is monitored by the lender.

5. $(1-\gamma)$ fraction of entrepreneurs exits the economy and consumes residual equity.

6. Entrepreneurs who are still in business make decisions on T_{it}, e_{t+1} and $\bar{\omega}_{it+1}$.

C.2 Parameter Values for the model

Table C.1: Parameter values

Fixed Parameters	
α (capital share)	0.33
β (time discount rate)	0.995
γ (risk aversion)	1
δ (depreciation rate)	0.025
ϕ (elasticity of the price of capital wrt investment)	2
χ (inverse Frisch elasticity of labor supply)	0.7
ψ (relative utility weight of labor)	2.6032
θ (constant elasticity of demand)	10
λ (share of sector 1 output)	0.5
ψ (degree of substitutability between sectors)	0.9
ζ (Calvo prices)	0.75
μ (agency cost)	0.12
v (transfer to a new entrepreneur)	0.01
ρ^{π} (taylor coefficient)	1.5
ρ_A (persistency of aggregate productivity shock)	0.9
ρ_σ (persistency of uncertainty shock)	0.821
sd(ε^A) (s.d. of productivity shock)	0.0056
sd(ε^σ) (s.d. of uncertainty shock)	0.050
Calibrated Parameters	
R_1^k (aggregate return of small firms)	0.015
R_2^k (aggregate return of large firms)	0.0077
σ (volatility of the idiosyncratic shock)	0.2716
a(mean of idiosyncratic productivity in bad projects)	0.9934
b(ratio of volatility between good and bad projects)	2
γ (exit rate)	0.9849
cpb (coefficient on the probability function)	10.5711

λ,ψ,μ from Bernanke et al. (1999); $\rho_\sigma, sd(\varepsilon^A), sd(\varepsilon^\sigma)$ from Christiano et al. (2011).

C.3 Figures

Figure C.1: Comparative Statics

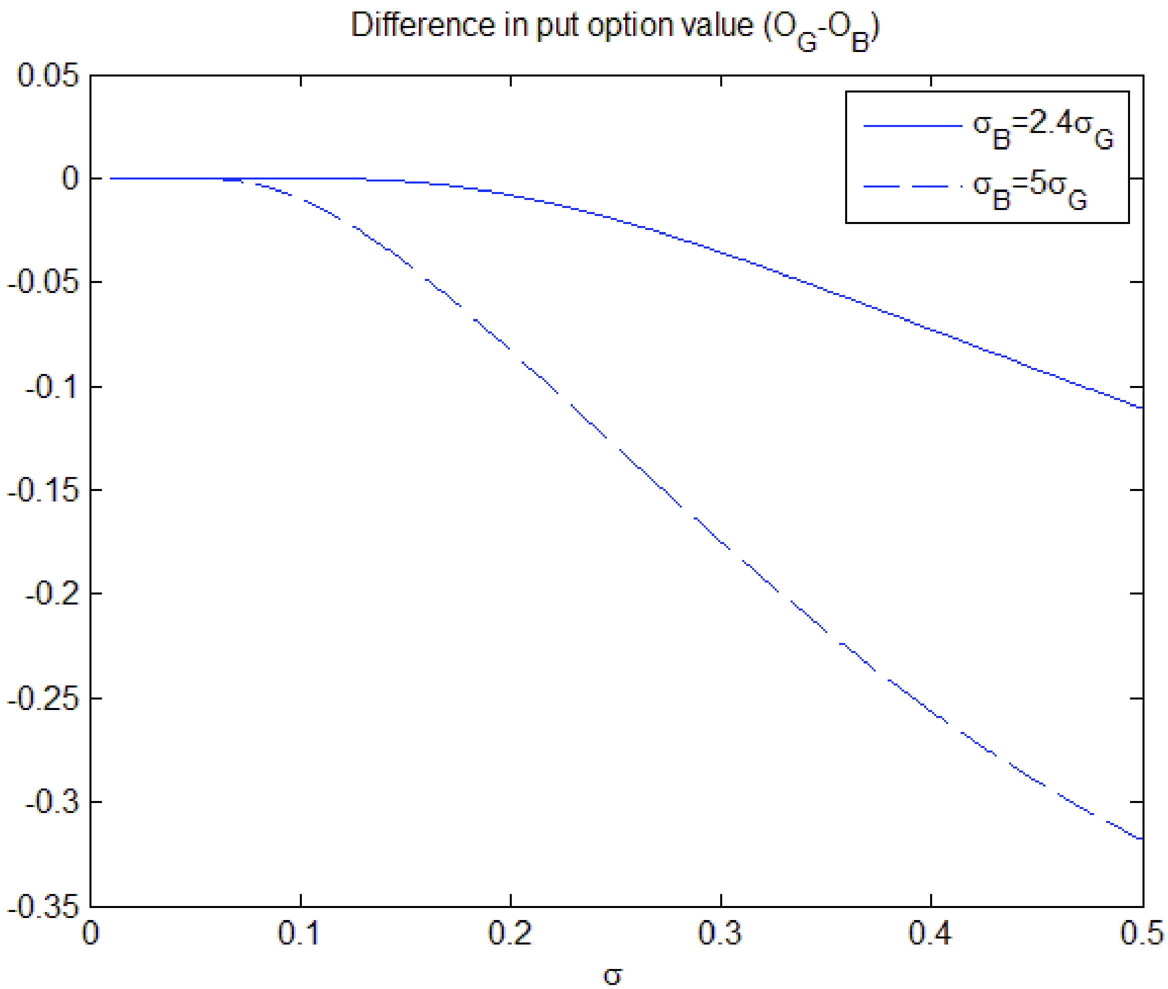


Figure C.2: Comparative Statics

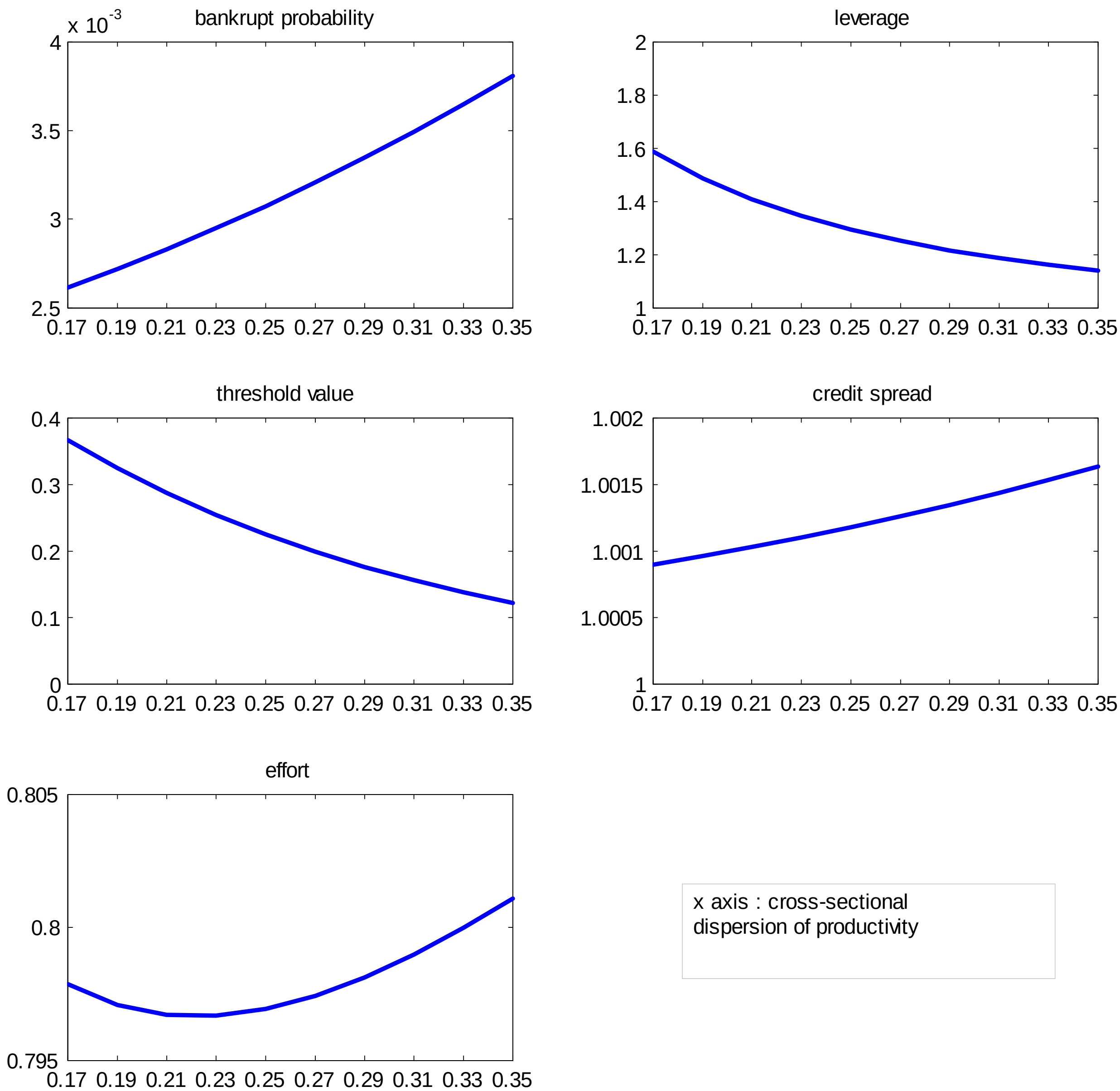


Figure C.3: Comparative Statics

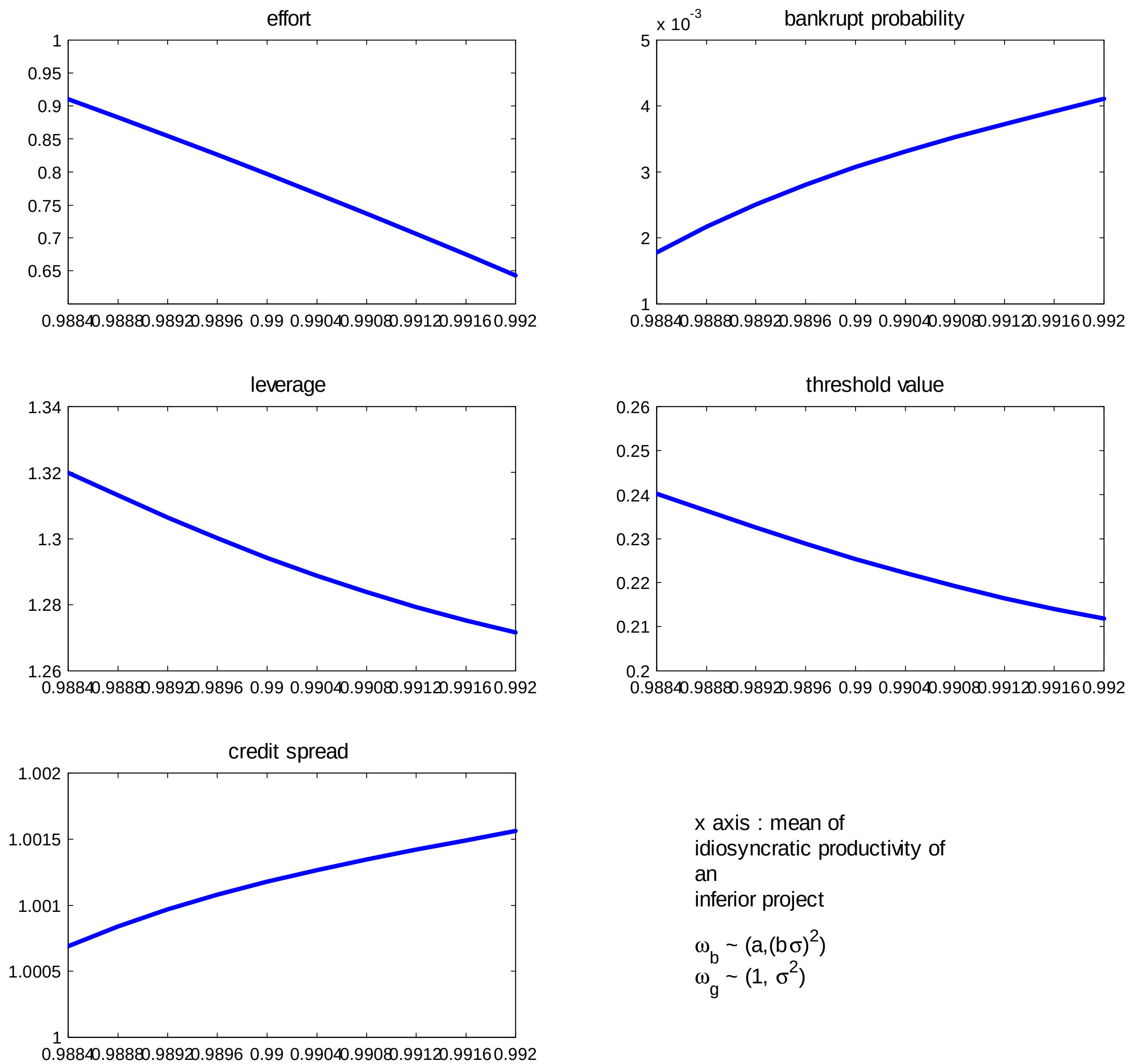


Figure C.4: Comparative Statics

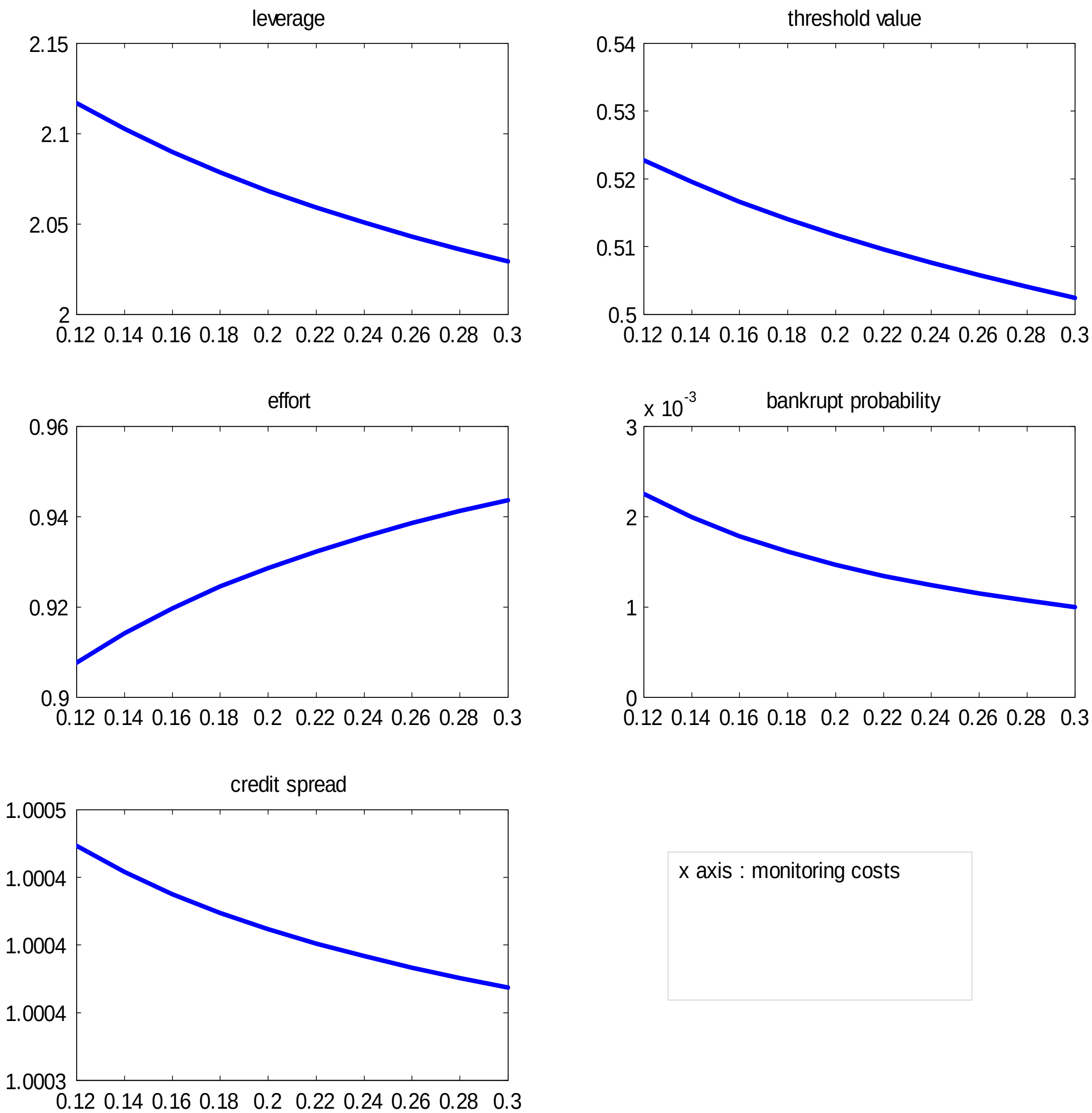


Figure C.5: Baseline model: Impulse Response to an Uncertainty Shock

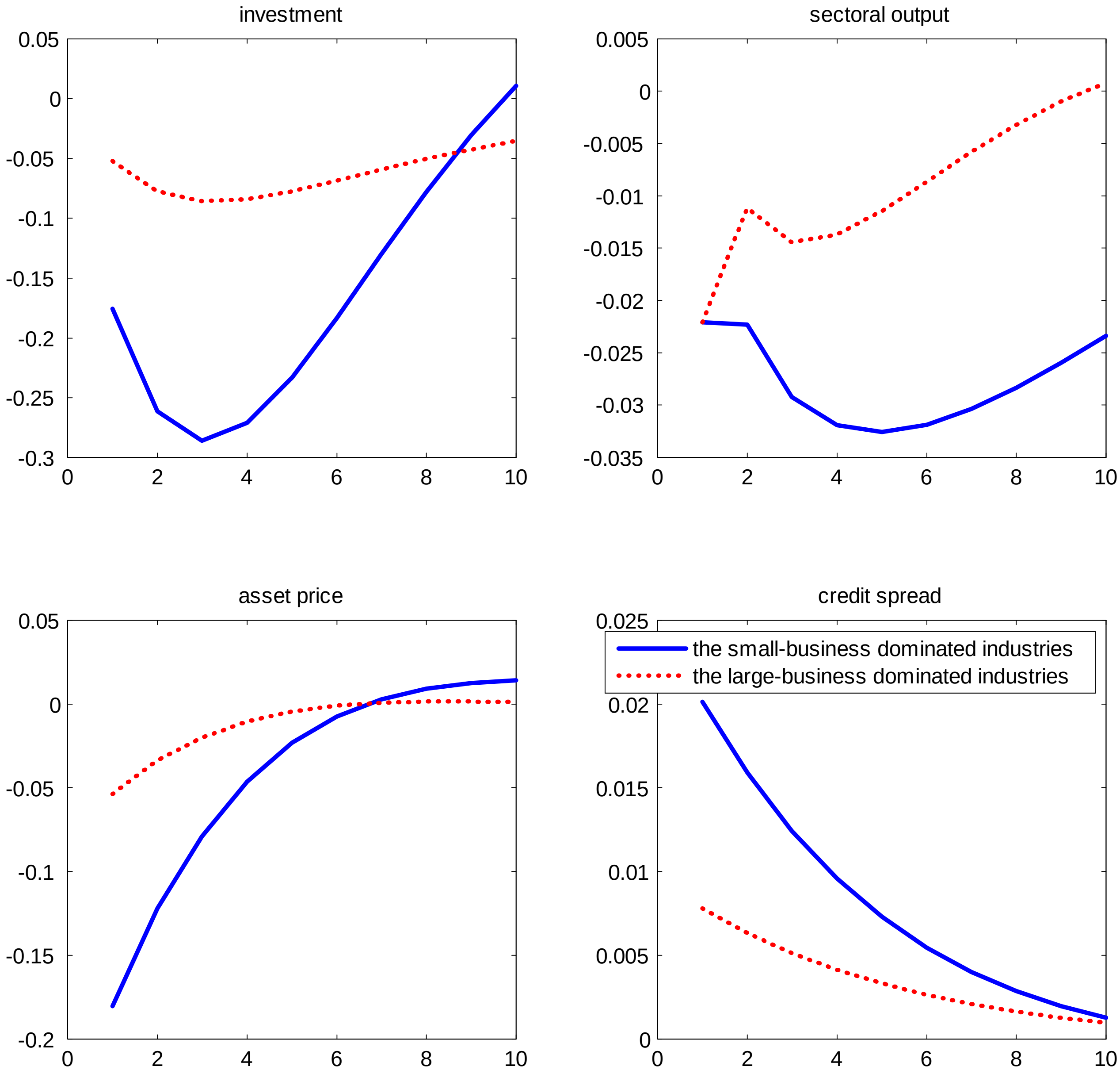


Figure C.6: BGG model: Impulse Response to an Uncertainty Shock

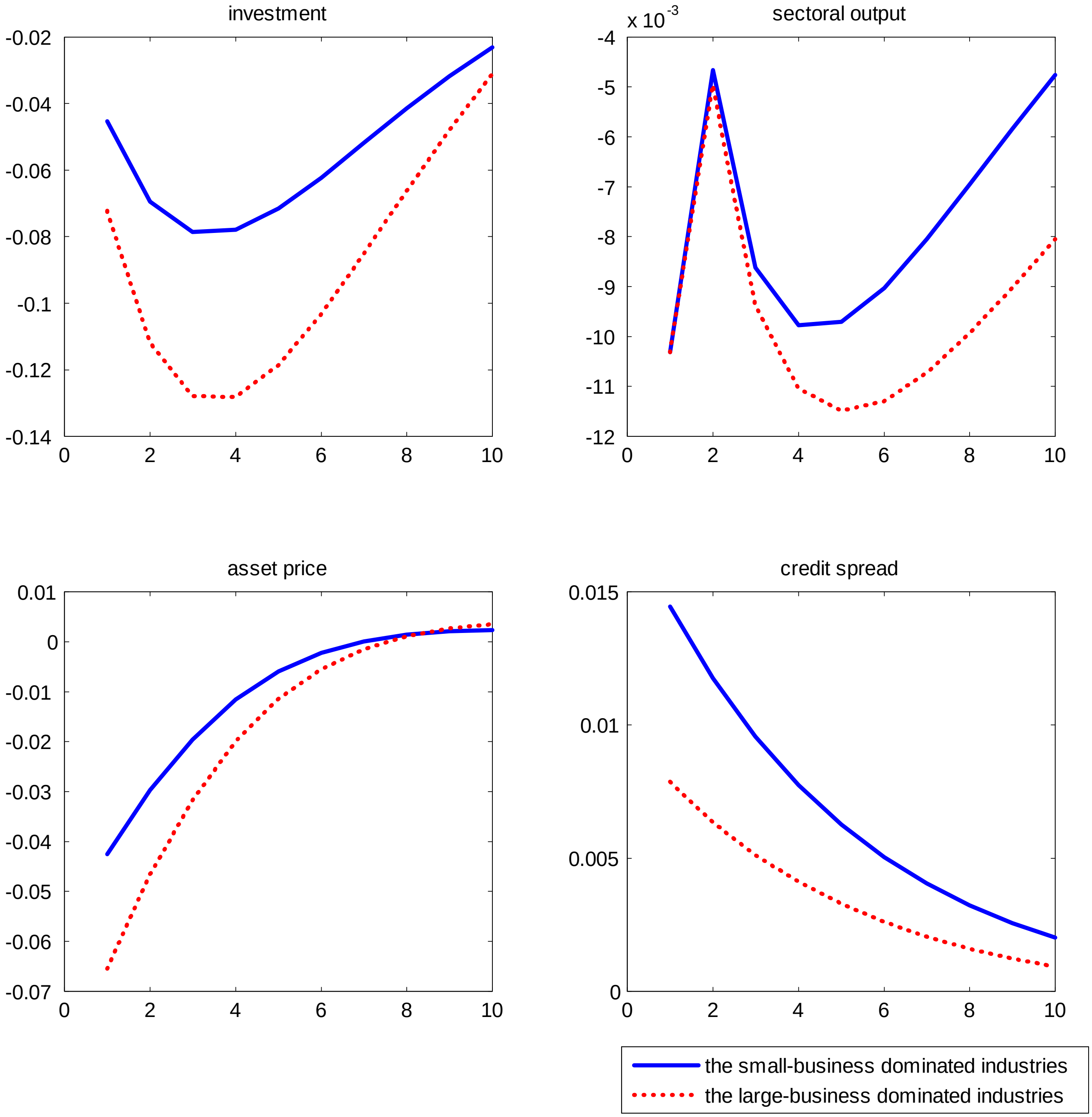


Figure C.7: Baseline model: Impulse Response to a Monetary Shock

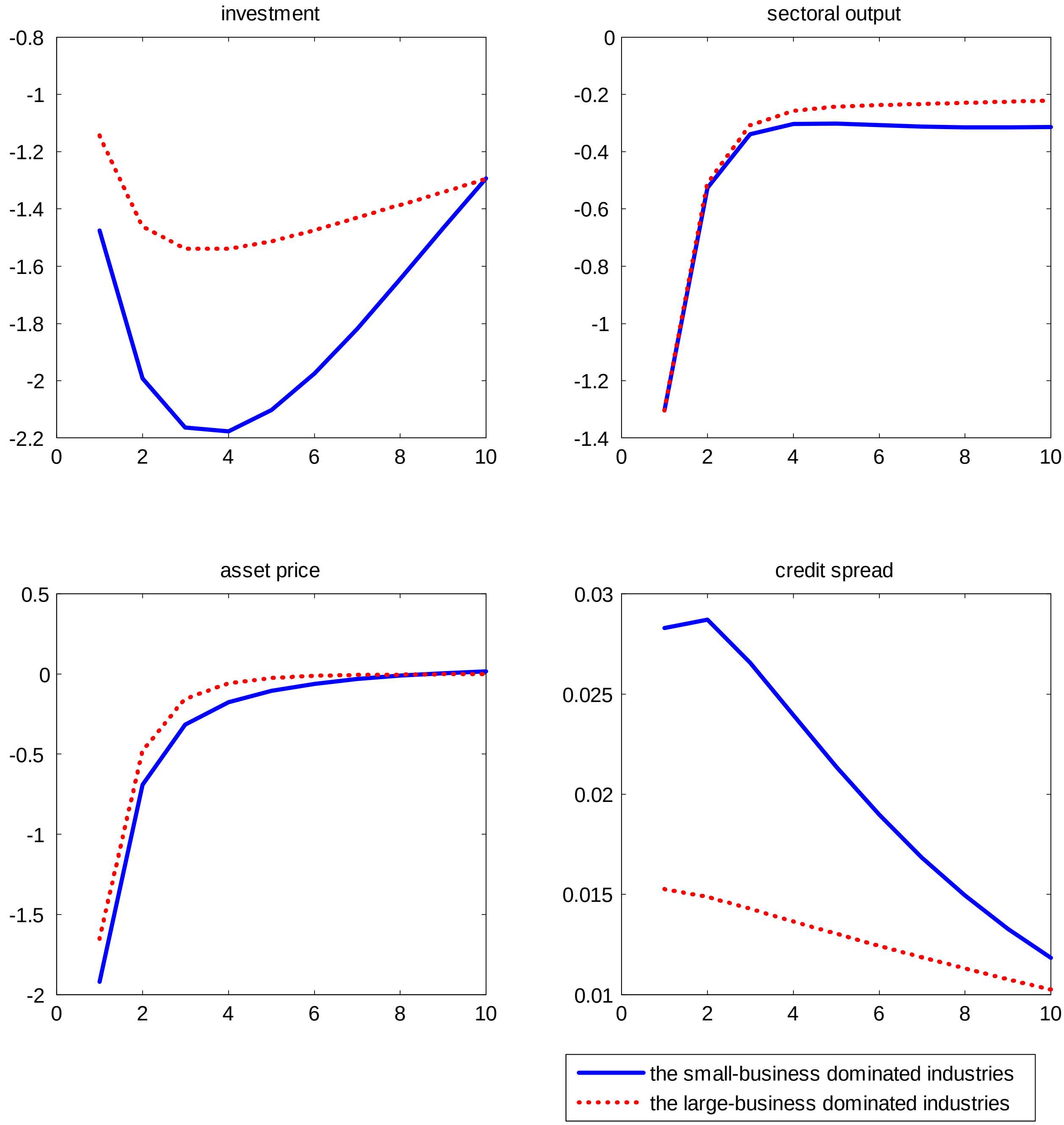


Figure C.8: BGG model: Impulse Response to a Monetary Shock

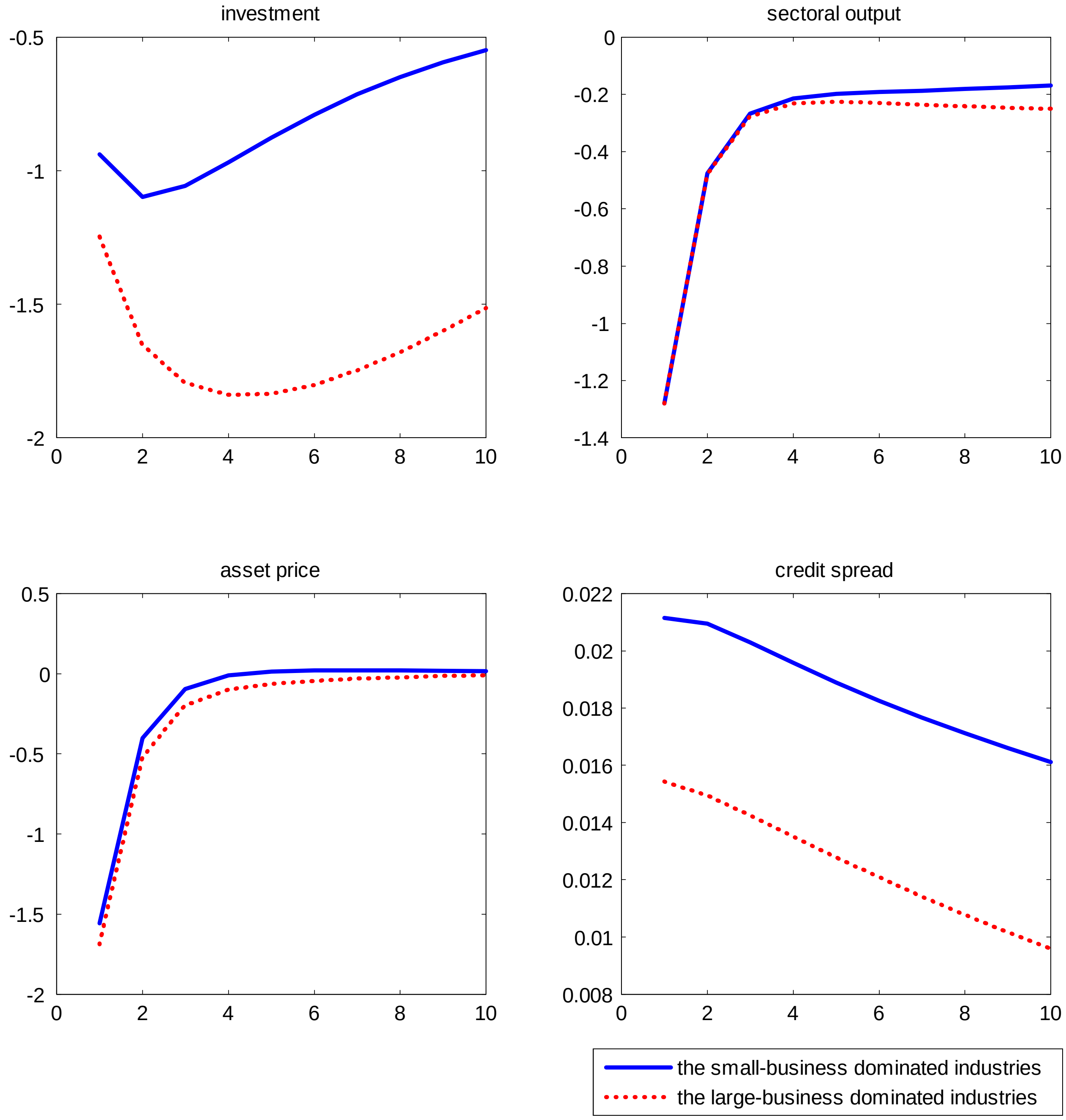


Figure C.9: Model Comparison: Impulse Response to an Uncertainty Shock

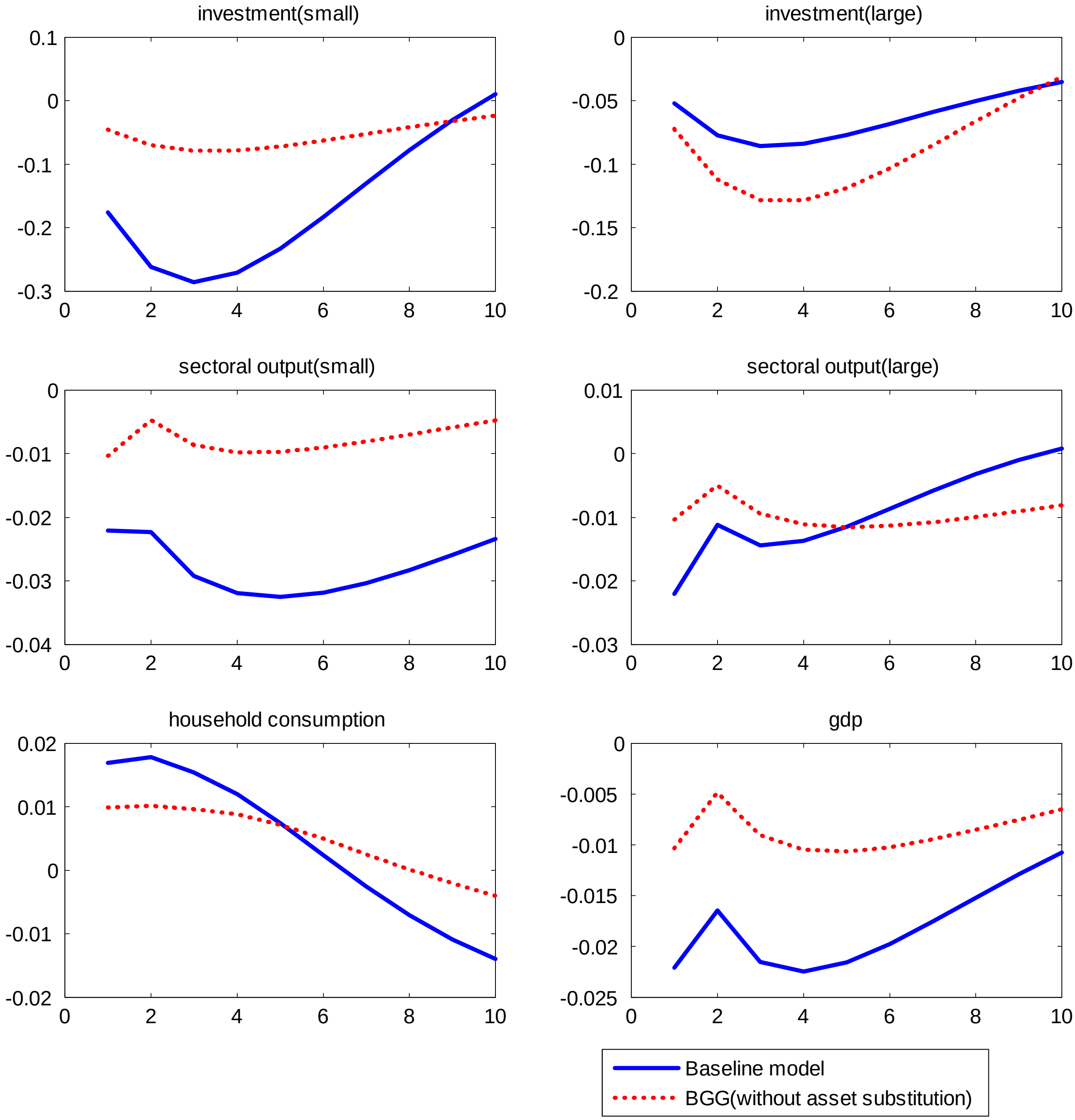


Figure C.10: Model Comparison: Impulse Response to a Monetary Shock