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The Role of Informational Asymmetries in Financial Markets and the Real Economy

Author
Vanasco, Victoria Magdalena

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by

Victoria Magdalena Vanasco

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Committee in charge:

Professor Pierre-Olivier Gourinchas, Chair
Assistant Professor William Fuchs, Co-chair
Assistant Professor Demian Pouzo
Professor Christine Parlour
Professor David Romer

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Abstract

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The stability of national and, increasingly more often, the global economy relies on well-functioning financial markets. Households' consumption and saving decisions, firms' investment choices, and governments' financing strategies critically depend on the stability of financial markets. These markets, however, are composed of individuals and institutions that may have different objectives, information sets, and beliefs, making them a very complex object that we do not fully comprehend. Motivated by this, my dissertation focuses on understanding how informational asymmetries and belief heterogeneity impact financial markets, and therefore, the macro economy. More specifically, this dissertation explores the sources of informational asymmetries among market participants. How do different financial market structures provide incentives for private information acquisition? Is information acquisition desirable? What types of policies can be implemented to increase liquidity and discipline in financial markets? Could business cycles be related to information or belief cycles? I tackle these questions from three separate angles. First, I study how alternative market designs bring forth different levels of private information generation, market discipline, and liquidity. Second, I investigate how information sets of key market participants are determined. Finally, I focus on how information and belief fluctuations may affect key macroeconomic variables and economic fluctuations.

In Chapter 1, *"Information Acquisition vs. Liquidity in Financial Markets,"* I propose a parsimonious framework to study markets for asset-backed securities (ABS). These markets play an important role in providing lending capacity to the banking industry by allowing banks to sell the cashflows of their loans and thus recycle capital and reduce the riskiness of their portfolios. In the financial crash of 2008, however, in which certain ABS played a substantial role, we witnessed a collapse in the issuance of all ABS classes. Given the importance of these markets for the real economy, policy makers in the US and Europe have geared their efforts towards reviving them. A good framework to think about these markets is imperative when thinking about financial regulation. The contribution of this chapter is to propose a model that captures the two main problems that have been shown to be present

in the practice of securitization. First, the increase in securitization has led to a decline in lending standards, suggesting that liquid markets for ABS reduce incentives to issue good quality loans. Second, securitizers have used private information about loan quality when choosing which loans to securitize, indicating that a problem of asymmetric information is present in ABS markets. A natural question then arises: how should ABS be designed to provide incentives to issue good quality loans and, at the same time, to preserve liquidity and trade in these markets?

To address this question, I propose a framework to study ABS where *both* incentives and liquidity issues are considered and linked through a loan issuer's information acquisition decision. Loan issuers acquire private information about potential borrowers, use this information to screen loans, and *later* design and sell securities backed by these loans when in need of funds. While information is beneficial ex-ante when used to screen loans, it becomes detrimental ex-post because it introduces a problem of adverse selection that hinders trade in ABS markets. The model matches key features of these markets, such as the issuance of senior and junior tranches, and it predicts that when gains from trade in ABS markets are 'sufficiently' large, information acquisition and loan screening are inefficiently low. There are two channels that drive this inefficiency. First, when gains from trade are large, a loan issuer is tempted ex-post to sell a large portion of its cashflows and thus does not internalize that lower retention implements less information acquisition. Second, the presence of adverse selection in secondary markets creates informational rents for issuers holding low quality loans, reducing the value of loan screening. This suggests that incentives for loan screening not only depend on the portion of loans retained by issuers, but also on how the market prices the issued tranches. Turning to financial regulation, I characterize the optimal mechanism and show that it can be implemented with a simple tax scheme. The obtained results, therefore, contribute to the recent debate on how to regulate markets for ABS.

In Chapter 2, I present joint work with Matthew Botsch, *"Learning by Lending, Do Banks Learn?"* where we investigate how banks form their information sets about the quality of their borrowers. There is a vast empirical and theoretical literature that points to the importance of borrower-lender relationships for firms' access to credit. In this chapter, we investigate one particular mechanism through which long-term relationships might improve access to credit. We hypothesize that while lending to a firm, a bank receives signals that allow it to learn and better understand the firm's fundamentals; and that this learning is private; that is, it is information that is not fully reflected in publicly-observable variables. We test this hypothesis using a dataset for 7,618 syndicated loans made between 1987 and 2003. We construct a variable that proxies for firm quality and is unobservable by the bank, so it cannot be priced when the firm enters our sample. We show that the loading on this factor in the pricing equation increases with relationship time, hinting that banks are able to learn about firm quality when they are in an established relationship with the firm. Our finding is robust to controlling for market-wide learning about firm fundamentals. This suggests that a significant portion of bank learning is private and is not shared by all market participants.

The results obtained in this study underpin one of the main assumptions of the model presented in Chapter 1: that banks have a special ability to privately acquire valuable information about potential borrowers. While the model is static, the data suggests that the process of lending and of information acquisition is a dynamic one. Consistent with this, the last chapter of this dissertation studies the macroeconomic implications of dynamic learning by financial intermediaries.

Chapter 3 presents joint work with Vladimir Asriyan titled *"Informed Intermediation over the Cycle."* In this paper, we construct a dynamic model of financial intermediation in which changes in the information held by financial intermediaries generate asymmetric credit cycles as the one observed in the data. We model financial intermediaries as "expert" agents who have a unique ability to acquire information about firm fundamentals. While the level of "expertise" in the economy grows in tandem with information that the "experts" possess, the gains from intermediation are hindered by informational asymmetries. We find the optimal financial contracts and show that the economy inherits not only the dynamic nature of information flow, but also the interaction of information with the contractual setting. We introduce a cyclical component to information by supposing that the fundamentals about which experts acquire information are stochastic. While persistence of fundamentals is essential for information to be valuable, their randomness acts as an opposing force and diminishes the value of expert learning. Our setting then features economic fluctuations due to waves of "confidence" in the intermediaries' ability to allocate funds profitably.

To my mom, here,
and to my dad, there.

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Acknowledgments

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[1] Quote from *Carta a mis Hijas*, by Alberto Vanasco, translated by Victoria Vanasco.

Chapter 1

Information Acquisition vs. Liquidity in Financial Markets

1.1 Introduction

Markets for asset-backed securities (ABS) play an important role in providing lending capacity to the banking industry. They allow banks to sell the cashflows of their loans to the market and thus reduce the riskiness of their portfolios. In 2007, more than 25 percent of consumer credit in the U.S. had been funded by ABS, through a process referred to as securitization.[1] In the financial crash of 2008, however, in which certain ABS played a substantial role, we witnessed a collapse in the issuance of all ABS classes. Given the importance of these markets for the real economy, policy makers in the US and Europe have geared their efforts towards reviving them. In a report to the G20, the Financial Stability Board stated that "re-establishing securitization on a sound basis remains a priority in order to support provision of credit to the real economy and improve banks' access to funding."[2]

Two problems have been shown to be present in the practice of securitization in the past decade. First, the increase in securitization has led to a decline in lending standards, suggesting that liquid markets for ABS reduce incentives to issue good quality loans.[3] Second, securitizers have used private information about loan quality when choosing which loans to securitize, indicating that a problem of asymmetric information is present in ABS markets. [4] A natural question then arises: how should ABS be designed to provide incentives to

[1] And by April 2011, the market value of outstanding securitized assets in the US was larger than that of US Treasuries. See Gorton and Metrick (2013)[44].

[2] Financial Stability Board, Progress Since the Washington Summit in the Implementation of the G20 Recommendations for Strengthening Financial Stability, Report of the Financial Stability Board to G20 Leaders (Nov. 2010).

[3] See Bernt and Gupta (2008)[7], Dell'Ariccia et al. (2009)[27], Elul (2009)[35], Jaffee et al. (2009)[51], Mian and Sufi (2009)[60].

[4] See Agarwal (2012)[1], Calem et al. (2010)[17], Downing et al. (2008)[34], Jian et al. (2010)[52], Keys et al. (2008)[53].

issue good quality loans and, at the same time, to preserve liquidity and trade in these markets? The literature on optimal design of ABS has studied these problems –provision of incentives and of liquidity– in isolation.[5]. However, by doing so, a fundamental trade-off between incentives and liquidity has been overlooked: while securities that provide incentives to issue good quality loans may expose the issuer to less liquid secondary markets, securities that maximize trade in these markets tend to worsen incentives to issue good loans in the first place.

This paper proposes a parsimonious framework to study ABS where *both* incentives and liquidity issues are considered and linked through a loan issuer's information acquisition decision. I study the problem of a bank that i) privately invests in information about potential borrowers in a loan screening stage, ii) receives private information about its borrowers once it chooses to lend, and iii) later designs and sells securities backed by its loans to realize gains from trade in secondary markets. This setup captures an important tension present in these markets, where gains from information acquisition and loan screening need to be traded-off with gains from trade in secondary markets.

This paper delivers two sets of results. First, I address some of the main forces at play in ABS markets. The model matches key features of ABS markets, such as the issuance of senior and junior tranches, and it generates new testable predictions, such as a pecking order for tranche issuance. Moreover, I find that when gains from trade are large, the bank has a problem of commitment: even though ex-ante it would like to retain some of its cashflows, ex-post, once information acquisition is sunk, it has an incentive to sell a larger portion of its loans to exploit gains from trade. In this scenario, the presence of adverse selection supports the equilibrium with information acquisition by naturally inducing retention of the bank with good loans. Consistent with this, when adverse selection is not severe, information acquisition and loan screening are inefficiently low. The second set of results characterize the inefficiencies in place and suggest interventions that improve ex-ante efficiency. In particular, I show that regulators should not only focus on retention levels for securitizers, but also on how secondary markets differentially compensate good relative to bad issuers.

The model is stylized and is yet able to capture the complexities inherent to the process of securitization. It has three periods and features a bank and a market of potential investors. The bank has an endowment that it can store or use to finance one risky project (make a loan) that pays in the final period. In the first period, the bank privately invests in information and observes two signals about project quality: while the first signal is used to screen good quality projects; the second signal is observed while holding the issued loan.[6] By investing

[5]On security design for the provision of incentives: Innes (1990)[50], Hartman-Glaser at al. (2013)[48]. On security design with adverse selection: Nachman and Noe (1994)[64], DeMarzo and Duffie (1999)[29], Biais and Mariotti (2005)[10], DeMarzo (2005)[28]

[6]The second signal can be interpreted as the information acquired by the bank that cannot be inferred by the market through the initial screening decision: soft information, or information acquired while establishing a lending relationship (i.e. while holding the loan, as in Plantin (2009) [69] where he introduces the concept of *learning by holding*.)

more in information the bank increases the precision of its private information. In the second period, given this information, the bank sells limited liability securities backed by its loan cashflows to "uninformed" investors to exploit gains from trade. In the final period, loan cashflows are realized and the bank pays investors.

When securities are designed after loan issuance, the bank faces a trade-off between the gains from selling cashflows in secondary markets and the lemon's discount faced in the market given its private information. The paper provides a new rationale for the issuance of senior and junior tranches in secondary markets. In particular, I find that standard debt (the senior tranche) is the security chosen by the bank with good loans, since it minimizes the region where disagreements about the likelihood of cashflows might arise, minimizing the lemon's discount. Consequently, banks with bad loans issue debt to receive an implicit subsidy from the bank with good loans, and issue their remaining cashflows (junior tranches) in a separate market to further exploit gains from trade. I obtain this result by departing from the literature on security design with adverse selection by imposing a *No Transparency* assumption. This assumption implies that in equilibrium the market is unable to fully screen the quality of the bank' s loans.[7] That is, there is a semi-pooling equilibrium in ABS markets where all banks issue the senior tranche of their cashflows, and only banks with bad loans issue in addition a claim to their junior tranche.

The model generates predictions that match some key characteristics of markets for ABS. First, issuers of ABS should slice underlying cashflows into senior and junior tranches that are sold separately in secondary markets. Second, issuers with better quality loans should retain the junior tranches, while those with bad quality loans should sell them. Third, there is a pecking order for tranche issuance: for a given tranche sold in secondary markets, all safer tranches must be sold as well by the same issuer. Fourth, the quality of issued loans is decreasing in the fraction of cashflows being sold in secondary markets (i.e. fraction being securitized). Finally, loans for which very little information (e.g. credit cards) or a lot of information (e.g. corporate loans) is acquired in equilibrium should have more liquid secondary markets than those for which information acquisition is intermediate.

I find that when the bank and the market cannot commit to the design and price of securities ex-ante, the equilibrium is inefficient. In particular, when gains from securitization are large, the bank is tempted to sell a large portion of its cashflows ex-post, and thus information acquisition and loan screening are inefficiently low. Two separate forces drive this inefficiency. First, when the bank is tempted ex-post to sell, it does not internalize that lower retention implements less information acquisition, and thus it "under-retains" in equilibrium. Second, adverse selection in secondary markets further distorts incentives by creating informational rents for the bank holding bad loans, reducing the value of screening. However, when the adverse selection problem in secondary markets is sufficiently severe, trade

[7]The *No Transparency* assumption prevents the market from enforcing retention levels on securitizers. Since retention of cashflows is essential to screen loan quality, when it cannot be enforced, loan quality cannot be screened.

in secondary markets is inefficiently low and information acquisition too high. This suggests that the problem of provision of incentives for information acquisition and loan screening is only relevant for asset classes with liquid secondary markets and high securitization levels.

Given these inefficiencies, I characterize the optimal mechanism that is obtained when the bank and the market *can* commit to the design and the prices of securities chosen before loans are issued. In this case, the design of securities internalizes the effect on information acquisition and loan screening. I show that standard debt continues to be the optimal design because it minimizes the expected adverse selection *and* it provides the best incentives for information acquisition by exposing the bank to the most informationally-sensitive cashflows. Debt levels and market transfers are chosen to optimally trade-off gains from trade with incentives for information acquisition. I find that to improve information acquisition, the bank has to commit to retain cashflows ex-post. However, retention levels are dependent on the quality of the underlying loans. In particular, the bank with good loans underlying its ABS issuance should weakly retain more than the one with bad loans, suggesting that retention levels imposed on securitizers should be weakly decreasing in the quality of underlying cashflows. In addition, incentives for information acquisition are further improved by transferring ex-post all the surplus to the bank with good loans to compensate them for being exposed to a lemon's problem.

I show that a simple tax scheme conditional on market participation and tranche issuance decentralizes the optimal mechanism when commitment tools are not available to the bank or to the market. In particular, subsidies to participation in the market for senior tranches, together with taxes for participation in the market for the junior tranches are beneficial since they improve incentives for information acquisition at no retention cost. This policy compensates banks with good loans for the costs generated by being mimicked by those with bad loans. This result is in contrast with models that only focus on adverse selection, where transfers across banks in secondary markets would not affect ex-ante efficiency. Thus, the model suggests that regulators should not only focus on retention levels for securitizers but also on the way the market compensates good vs. bad issuers since transfer across different quality issuers in secondary market affect ex-ante efficiency by distorting incentives. These transfers combined with policies that tax/subsidize debt levels (or impose retention levels) implement second-best levels of information acquisition and ABS issuance. In particular, the issuance of senior tranches should be taxed –or retention levels imposed– when markets for ABS are sufficiently liquid.

Finally, I use the model to evaluate some of the recently discussed interventions in markets for ABS. Policymakers in the US and Europe have proposed the "Skin in the Game" rule that requires issuers of asset-backed securities to retain a fraction of the underlying assets. My model rationalizes this type of intervention as a means to incentivize loan-screening *only* for ABS that feature high levels of trade in secondary markets. The model further suggests that banks that claim to have good quality loans underlying their ABS should retain more than those that claim to have bad quality loans. As a result, policies that demand the same retention levels of all issuers may impose excessive costs by hindering trade in secondary markets. This result is in contrast with the literature on security design in the presence of moral hazard, where imposing the same retention levels to all securitizers is optimal ex-ante. In addition, I find that incentives are stronger when securitizers retain the junior tranche of underlying cashflows, while proposed regulation is not specific to the type of retention.

The key trade-offs analyzed in this paper are motivated by substantial evidence that the provision of incentives in the loan screening stage and adverse selection in secondary markets are important features of the ABS market. In particular, it has been shown that credit standards in the mortgage market have fallen more in areas where lenders sold a larger fraction of the originated loans, and that performance has been worse for securitized loans (Dell'Ariccia et al. (2008), Elul (2009), Keys, Mukherjee, Seru, and Vig (2008).) Consistent with this, Bernt and Gupta (2008) find that borrowers of the syndicated loan market with more liquid secondary markets under-perform in the long run. Finally, it has been found that differences in unobservable loan characteristics known by the issuer are not fully compensated by loan pricing in secondary markets (Jiang et al. (2010), Downing et al. (2008), Calem et al. (2010), and Agarwal et al. (2012)). The first set of facts suggests that provision of incentives to acquire information to issue good quality loans might be necessary. The second set of facts documents the presence of asymmetric information in ABS markets, suggesting that trade and liquidity in these markets may be affected by the issuer's private information.

Several papers have highlighted the trade-off between incentives to issue good quality assets and secondary market liquidity. Parlour and Plantin (2008)[67] study loan sales and show that even though liquid secondary markets are ex-post efficient, they might not be be socially desirable ex-ante, since they reduce incentives to monitor loan quality. Malherbe (2012) [57] studies the costs and benefits of securitization and finds that for securitization to be an efficient risk-sharing mechanism, market discipline has to be strong.[8] In contrast to their work, I design the optimal securities to be sold in secondary markets given the above mentioned trade-off, and, in addition, I assume that the bank can affect the quality of its private information. Thus, in my setting, adverse selection is endogenous for two reasons: first, the bank chooses the quality of its private information; and second, by designing the issued security the bank can affect the level of adverse selection that it faces in the market. Chemla and Hennessy (2013)[21] study how the presence of adverse selection in ABS markets may affect incentives to exert ex-ante effort to issue high quality assets. As in my paper, they find that mis-pricing in secondary markets reduces ex-ante incentives for asset screening. In contrast to their paper, the level of private information held by the issuer in ABS markets is endogenous in my framework. The trade-offs between incentives and liquidity have also been studied in non-banking contexts by Coffee (1991)[22], Bhide (1993)[9], Maug (1998)[59], Dewatripont and Tirole (2013)[31], Winton (2003)[75], Aghion, Bolton, and Tirole (2004)[2], Faure-Grimaud and Gromb (2004)[40], who focus on the relation between shareholder control on stock market liquidity.

[8] In Malherbe (2012), strong market discipline implies that the securitization market outcome is able to reward diligent loan origination.

My work builds on Myers and Majluf (1984)[63] seminal paper, that addresses the problem of security design in the presence of adverse selection. They find that debt is superior to equity since its value is less sensitive to private information. Their results are extended by Noe and Nachman (1994), who enlarge the set of securities available to the issuer and consider signaling equilibria. They identify the conditions under which debt is the unique optimal design.[9] These papers take the size of the investment, and therefore amount of funds raised in the market, as given. Instead, I follow DeMarzo and Duffie (1999), in assuming that funds raised in secondary markets are an equilibrium outcome that results from the trade-off between the lemon's discount the market assigns to a given security and the gains from trade. DeMarzo and Duffie focus on ex-ante security design and obtain a separating equilibrium, where the issuer signals its private information by retaining a fraction of the designed security. In contrast to their paper, I study security design ex-ante and ex-post, and I take a game theoretic approach instead of focusing on competitive equilibria. By solving a screening game, I eliminate the multiplicity of equilibria that generally arises in these settings. In this sense, my paper is closely related to Biais and Mariotti (2005), where they study optimal security design by solving a screening game and find the optimal mechanism, and to DeMarzo (2005) where an ex-post security design problem is considered. I depart from the literature on security design in the presence of adverse selection by endogeneizing the decision of the issuer to acquire private information in an environment where information is desired to improve the quality of underlying assets, and by imposing the *No Transparency* assumption that eliminates separating equilibria in secondary markets.

My paper also relates to the literature on security design in the presence of moral hazard. Innes (1990) studies a principal-agent model in which the agent needs to be offered a contract that induces him to put effort to improve the quality of an investment project. He finds that when contracts are constrained to be monotonic on underlying cashflows, as in this paper, debt is the optimal design.[10] In this sense, my results are consistent with these findings. In a framework very closely to mine, Fender and Mitchell (2009)[41] study how different contractual mechanism offered in secondary markets affect the incentives of loan originators to screen loans. They focus on different retention mechanism, and find that retention of the first-loss tranche is not always optimal in the presence of systematic risk factors affecting underlying cashflows. In contrast to this paper, I investigate the issue of incentives in a model with security design in secondary markets with adverse selection. In addition, I assume no common risk-factors affect the underlying cashflows. There has also been a growing literature that focuses on the optimal design of securities to provide incentives *to investors* to acquire information. Their main finding is that standard debt is the design that minimizes incentives

[9] Brennan and Kraus (1987)[16] and Constantinides and Grundy (1989)[23] study the ability of an issuer to costlessly signal its private information by designing an optimal financing structure. Their results are applicable to the corporate finance literature, but not in this framework, where the issued securities and their prices can only be contingent on the cashflows of underlying assets.

[10] On a similar note, Cremer, Khalis, and Rochet (1998)[24] study the problem of an agent that has to incur a cost to learn information about the state of nature. The principal will offer contracts that, depending on the cost of information acquisition, try to induce the agent to gather or not to gather information.

to acquire information, and thus should be issued when information acquisition is not desired (Dang et al. (2009)[26], Yang (2012)[76]), while a combination of debt and equity should be issued when information acquisition is valuable (Yang and Zeng (2013)[77]). In contrast with this literature, investors in my model do not acquire information.

Organization. In Section 1.2, I describe the setup of the model, and characterize the first-best of this economy. In Section 1.3, I study the case when securities are designed after loan issuance, as in markets for ABS. Section 1.4 allows for commitment and characterizes the optimal mechanism that is attained when securities are designed and priced ex-ante, before loan issuance. Section 1.5 uses results from the previous two sections and presents the policy implications of the model. In Section 3.4, some extensions to the baseline model are presented. Section 3.5 concludes.

1.2 The Model

Setup

The model has three periods, indexed by $t \in \{0, 1, 2\}$. There is a single bank and a market of potential investors. The bank is risk-neutral with a payoff function $V_0 = \theta c_1 + c_2$ where c_t denotes the cashflows of the bank at time t, and $\theta > 1$ denotes the bank's marginal value of funds in $t = 1$. When $\theta > 1$, the bank values funds more than investors and there are thus gains from trade in the intermediate period.[11] At $t = 0$, the bank has an endowment of $w_b = 1$ and it cannot borrow additional funds from the market. This assumption can be motivated by assuming that the bank is against its capital constraint and therefore can only raise funds by selling assets.

Investment Technology. In the initial period, the bank can store its endowment at the risk free rate, normalized to one, or invest it in risky projects (i.e. loans). There is a unit mass of risky projects that produce cashflows X at $t = 2$ if they receive one unit of investment at $t = 0$. Projects can be of high or low quality, not observed by the bank nor the market. There is a fraction π_H of high quality projects with payoff $X \sim G_H$ and a fraction $1 - \pi_H$ of low quality projects with payoff $X \sim G_L$. These distributions are related by the monotone likelihood ratio property (MLRP); that is, $\frac{g_H(x)}{g_L(x)}$ increasing in x. In addition, I assume that it is not profitable to invest in a project chosen at random: $\pi_H \mathbb{E}_H[X] + (1 - \pi_H)\mathbb{E}_L[X] < 1$; and that there are gains from learning about project quality since it is efficient to invest in high quality projects but not in low quality ones: $\mathbb{E}_L[X] < 1 < \mathbb{E}_H[X]$.

[11]Gains from trade captured by $\theta > 1$ should be interpreted as gains from securitization not addressed in this paper. There are many reasons why a bank might want to raise funds by selling assets. If the bank is against its capital constraints, and new exclusive investment opportunities arise, it will benefit from selling a fraction of its loans to finance these new investments. Alternatively, securitization may allow the bank to share-risks with the market or to reduce bankruptcy costs by creating bankruptcy remote instruments.

Project Screening and Information Acquisition. The bank has access to a technology to privately screen project quality.[12] By investing $C(a)$ in information, the bank has access to signals with precision *"a"* about the underlying quality of projects, where $C:\left[\frac{1}{2},1\right)\to\mathbb{R}^{+}$, $C'\geq 0$, $C''\geq 0$ and $\lim_{a\to 1}C(a)=\infty$. I assume that information acquisition is a bank's hidden action. Privately investing $C(a)$ in information gives the bank access to two independent binary signals, $s_0, s_1\in\{H,L\}$, where s_0 is observed in $t=0$ for all available projects, and s_1 is observed between $t=0$ and $t=1$ for the project that received financing in $t=0$. These signals are distributed identically and independently across projects, with conditional distributions given by $P(s=H|q=H)=a$ and $P(s=L|q=L)=a$, where $q\in\{H,L\}$ denotes project quality. The first signal, s_0, captures the information acquired by the bank to screen loans, while the second signal, s_1, captures the private information received by the bank when establishing a lending relationship.[13] Finally, assuming that the precision of both signals is increasing in information acquisition,"a", captures the fact that once a bank invests time and effort in understanding the quality of a given borrower at the screening stage, it is also better able to interpret information that is later received about that borrower.

After observing a given signal, the bank updates its beliefs about firm quality using Bayes rule. Since the bank evaluates a continuum of projects in $t=0$, it observes a project with $s_0=H$ with probability one, for any level of information acquisition a. Thus, the bank always chooses to finance a project with $s_0=H$.[14] The following two conditional probabilities will be used extensively throughout the paper: (i) the probability of a loan being high quality given the initial screening ($s_0=H$), and defined as $\rho(a)$; and (ii) the probability of receiving the second high signal $s_1=H$ for the issued loan, given the initial screening, defined as $\rho_h(a)$:

$$\rho(a)\equiv\mathbb{P}_a(q=H|s_0=H)=\frac{a\pi_H}{a\pi_H+(1-a)(1-\pi_H)} \tag{1.1}$$

$$\rho_h(a)\equiv\mathbb{P}_a(s_1=H|s_0=H)=a\rho(a)+(1-a)(1-\rho(a)) \tag{1.2}$$

[12]Evidence of banks being special lenders can be found in Fama (1985)[36], and of banks having the ability to acquire private information about borrowers in Mikkelson and Partch (1986)[61], Lummer and McConnell (1989)[56], Slovin, Sushka, Polonchek (1993)[72], Plantin (2009) [69], Botsch and Vanasco (2013)[14], among others.

[13]Alternatively, the second signal can be interpreted as soft information acquired during the screening process that cannot be inferred by the market from the bank screening decisions. The binary signal structure therefore generates a useful partition between information used to screen loans, and thus inferred by the market in equilibrium, and private information that the bank cannot truthfully transmit to the market about the quality of the issued loan.

[14]This restriction is at no loss, since I will show that in equilibrium the bank strictly prefers to lend to a firm with $s_0=H$ if it chooses to acquire information, and is indifferent otherwise. Assuming that a high signal is always observed is a modeling device that ensures that after information is acquired, there is screening of loans in equilibrium; that is, by acquiring information the bank can always improve the expected quality of the issued loans.

Finally, to ensure that there are gains to acquiring information, I assume that there exists an $\underline{a} \in \left(\frac{1}{2}, 1\right]$ s.t. $\rho\left(\underline{a}\right)\mathbb{E}_H\left[X\right] + \left(1 - \rho\left(\underline{a}\right)\right)\mathbb{E}_L\left[X\right] - C\left(\underline{a}\right) > \theta$. In Section 3.4, I extend the model by allowing the precision of the second signal to differ from that of the first one and show that the main qualitative results of the paper remain unchanged. To see why this is the case, note that the conditional distribution of the second signal, given by $\rho_h(a)$, is always a function of "a" through $\rho(a)$; that is, better quality screening improves the probability of observing a second high signal for an issued loan. In this sense, information acquisition in the screening stage always has an impact on the level of informational asymmetries between the bank and the market.

Secondary Markets. At $t = 1$, the bank can raise funds by selling a portion of its loans to investors to exploit gains from trade ($\theta > 1$). In order to raise funds, the bank can issue limited-liability securities backed by its loans. The payoff of these securities can only be made contingent on the realization of loan cashflows. Thus, a security F is given by some function $F : \mathbb{X} \to \mathbb{R}$ and its payoffs are given by $F(X)$. In addition, as is standard in the security design literature, I assume that the bank and the investors have limited-liability: (LL) $0 \leq F(x) \leq x$, and I restrict attention to securities with payoffs that are weakly monotone in underlying cashflows: (WM) $F(x)$ is weakly increasing for all $x \in \mathbb{X}$.[15] Finally, let $\Delta \equiv \{F : \mathbb{X} \to \mathbb{R} \text{ s.t. (LL) and (WM) hold}\}$ denote the set of feasible securities a bank can issue in secondary markets, and if the bank issues more than one security, where $\tilde{F}(X) \equiv \sum_i F_i(X)$, then it must be that $\tilde{F} \in \Delta$ as well.

The bank arrives to secondary markets with private information about its loan cashflows, given by the signals s_0 and s_1 and the hidden-action a. Let $z \in \{z_l, z_h\}$ denote the bank's type in secondary markets, where $z_l \equiv \{s_0 = H, s_1 = L\}$ and $z_h \equiv \{s_0 = H, s_1 = H\}$ denote the bank with the bad loan and the bank with the good loan respectively.[16] Given this, the bank's private valuation of a given security is given by $\mathbb{E}_a[F(X)|z]$ for $z \in \{z_l, z_h\}$, where $\mathbb{E}_a[\cdot|z]$ denotes the expectation operator over cashflows X, conditional on private signals z and the precision of these signals a. I solve a screening problem in secondary markets, where uninformed investors post prices for feasible securities $F \in \Delta$ given their beliefs about information acquisition levels, a, and bank's private information, z, and the z-type bank chooses which securities to issue from the market offered menu. Therefore, the bank faces an inverse demand function $p : \Delta \to \mathbb{R}$ where $p(F)$ is the market price for security F that is determined in equilibrium by the investors' zero-profit condition.

Timing of the Game. At $t = 0$ the bank invests in information, observes signal s_0 and makes its lending decisions. At $t = 1$, when in need of funds and having received signal s_1, the bank issues feasible securities backed by its loan cashflows to investors. At $t = 2$, loan

[15] This restrictions are assumed in Nachman and Noe (1994), DeMarzo and Duffie (1999), Biais and Mariotti (2005), among others. Innes (1990) discusses the implications of restricting attention to contracts that are monotonic on realized returns in environments with moral hazard.

[16] Even though a could also be part of the bank's type, since in equilibrium it is unique and inferred by the market, it simplifies the problem to keep track of a and z separately, even though they are both the bank's private information.

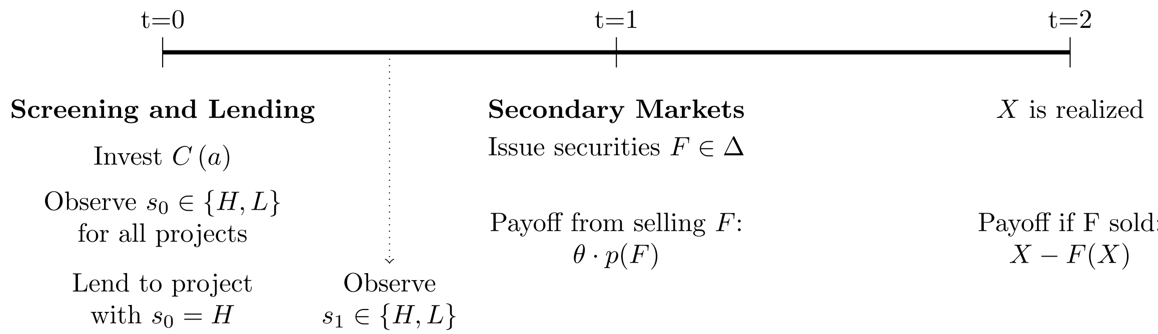

Figure 1.1: Timeline of the Model

cashflows are realized and contracts are executed. The timing of the game is presented in Figure 1.1.

First-Best

Before solving the model with asymmetric information, I characterize the first-best of this economy as a useful benchmark for the remainder of the paper. I solve the model by assuming that information acquisition "a" is observable, and received signals are public information. When funds are needed in $t = 1$, the bank can sell a claim to its future loan cashflows to the market that has the same valuation. Let $F \in \Delta$ be the security issued by the bank, and let $p(F) \in \mathbb{R}^+$ be the price the market offers for this security. The value of the z-type bank in $t = 1$ is given by:

$$\theta p(F) + \mathbb{E}_a [X - F(X)|z] = (\theta - 1) \mathbb{E}_a [F(X)|z] + \mathbb{E}_a [X|z]$$

where the last equality holds because the market values any security F as the bank, and the competitive investors price securities at its expected value; that is, $p(F) = \mathbb{E}_a[F(X)|z]$. It is straightforward that the bank chooses to issue equity, $F^*_{FI}(X) = X$, since it is the issuance that maximizes the gains from trade. Given that all claims are sold at $t = 1$, the bank chooses how much information to acquire to maximize the value of banking in $t = 0$:

$$a^*_{FB} = \arg \max_{a \in \left[\frac{1}{2}, 1\right)} \theta \left[\rho(a) \mathbb{E}_H [X] + (1 - \rho(a)) \mathbb{E}_L [X]\right] - C(a)$$

When choosing how much information to acquire, the bank is fully exposed to the cashflows of its loans and the market fully compensates it for investing in information. It will be useful to keep this benchmark in mind: in the first-best, gains from trade and from information acquisition are maximized when the bank issues a claim to all of its cashflows and when the market fully compensates the bank for its investment in information.

1.3 Markets for ABS: The No Commitment Case

In this section, I study an economy where securities are designed *after* loans have been issued –at $t = 1$. This implicitly assumes that the bank has *no commitment* to securities designed in $t = 0$ before loan issuance. In practice, issuers of ABS design their securities after loan issuance, since they can choose which loans to securitize and which ones to keep on balance sheet. This lack of commitment is capturing the fact that once an issuer has private information about the quality of its loans, it has incentives to re-design the security and it can always find an investor willing to buy. In other words, ex-ante optimal contracts with the market are not renegotiation proof in this environment. Therefore, this case is important for understanding how unregulated markets for ABS may operate and what inefficiencies may arise in environments where commitment to pre-designed securities cannot be enforced. I use the results from this section to answer two main questions that are at the heart of the discussion on optimal regulation in markets for ABS. First, how does information acquisition affect the design of securities sold in secondary markets and the levels of ABS issuance in these markets? And second, how does the design of securities and trade levels in ABS markets affect incentives of the bank to acquire information and issue high quality loans in the first place? In Section 1.4, I study the optimal mechanism, that is attained when both the bank and investors can write contracts ex-ante and commit to securities and prices determined before loan issuance.

At $t = 0$, the bank can store its endowment or invest in information to screen and issue one loan. If the bank chooses to invest $C(a)$ in information, it is able to identify and lend to a project with $s_0 = H$. At $t = 1$, with probability $\rho_h(a)$ the bank observes signal $s_1 = H$ and thus is a z_h-type bank; otherwise, it observes $s_1 = L$ and becomes a z_l-type. Let p_z and F_z denote the funds raised and cashflows sold in secondary markets by type $z \in \{z_l, z_h\}$, and thus $X - F_z(X)$ are the cashflows retained until maturity.[17] Given this, the value of the bank with information acquisition a and type z at $t = 1$ is given by:

$$V_1(a, z) \equiv \theta p_z + \mathbb{E}_a[X - F_z(X)|z]$$

Consistent with this, the value of acquiring information in $t = 0$ is given by:

$$V_0(a, p_{z_l}, p_{z_h}, F_{z_l}, F_{z_h}) \equiv \rho_h(a)\{\theta p_{z_h} + \mathbb{E}_a[X - F_{z_h}(X)|z_h]\} + \tag{1.3}$$

$$(1 - \rho_h(a))\{\theta p_{z_l} + \mathbb{E}_a[X - F_{z_l}(X)|z_l]\} - C(a) \tag{1.4}$$

where the unit cost of investing in a project is incorporated into $C(a)$. The value of storing the endowment in $t = 0$ is given by $V_{store} = \theta$. Finally, let a^e denote the market

[17]Note that in F_z are the cashflows sold by the z-type bank, and these cashflows can potentially be sold through the issuance of more than one security in secondary markets. Consistent with this, p_z are the total funds raised in secondary markets. This clarification is important, since I will show that the bank with the bad loan issues more than one security in equilibrium.

(investors') belief about the hidden action taken by the bank. Since in any equilibrium only one level of information acquisition is implemented, I focus on pure strategy equilibria in which market beliefs are degenerate at some level $a^e \in [\frac{1}{2}, 1)$.[18] The problem is solved by backwards induction. At $t = 1$, for a given level of information acquisition a and market beliefs a^e about this hidden-action, a z-type bank designs and issues feasible securities in secondary markets to raise funds. At $t = 0$, given the secondary markets optimal strategies, the bank chooses how much information to acquire. In what follows, I define the equilibrium with information acquisition in an economy without commitment.

Definition 1. *An equilibrium with information acquisition is given by* $\{a^e, a^*, p^*_{z_l}, p^*_{z_h}, F^*_{z_l}, F^*_{z_h}\} \in \left[\frac{1}{2}, 1\right)^2 \times \mathbb{R}^2_+ \times \Delta^2$ *satisfying the following conditions:*

1. *Given any* a, a^e, $\{p_{z_l}(a^e), p_{z_h}(a^e), F_{z_l}(a, a^e), F_{z_h}(a, a^e)\}$ *are equilibrium outcomes in secondary markets.*

2. *Given any* a^e, $a^*(a^e) = \arg\max_{a \in \left[\frac{1}{2}, 1\right]} V_0\left(a, p_{z_l}(a^e), p_{z_h}(a^e), F_{z_l}(a, a^e), F_{z_h}(a, a^e)\right)$, *from (1.3).*

3. $a^e = a^*$, *and* $p^*_{z_l} = p_{z_l}(a^*), p^*_{z_h} = p_{z_h}(a^*), F^*_{z_l} =, F_{z_l}(a^*, a^*), F^*_{z_h} =, F_{z_h}(a^*, a^*)$

For an equilibrium with information acquisition to exist it must be that:

$$V_0\left(a^*, p^*_{z_l}, p^*_{z_h}, F^*_{z_l}, F^*_{z_h}\right) \geq V_{store} = \theta \tag{1.5}$$

If condition (1.5) does not hold, the bank chooses to store its endowment and does not invest in information nor it extends credit to risky projects. I assume that when there is no information acquisition and lending in equilibrium, market beliefs are given by the level of information acquisition in the equilibrium with information acquisition, i.e. $a = a^*$. The remainder of this section focuses on characterizing the equilibrium with information acquisition, and is organized as follows. First, I solve for the equilibrium outcome in secondary markets. Second, I solve for the optimal level of investment in information chosen by the bank in $t = 0$, given the previously obtained secondary market equilibrium outcomes. Finally, I discuss how results from the model are able to rationalize key features of markets for asset-backed securities, such as the tranching of underlying cashflows and the observed fall in lending standards in the years leading to the crisis.

Equilibrium in Secondary Markets

The bank arrives to secondary markets with a chosen level of information precision, $a \in [\frac{1}{2}, 1)$, which is a bank's hidden action, and private signals $z \in \{z_l, z_h\}$. Both the hidden

[18] Standard regularity conditions on the cost function $C(a)$ are imposed to obtain a unique level of a implemented in equilibrium.

action and the signals determine the bank's valuation of its loan cashflows. Conditional cashflow distributions are given by:

$$g(X|a,z_i) \equiv \pi_i(a)\, g_H(X) + (1-\pi_i(a))\, g_L(X)\,,\ i=\{l,h\} \tag{1.6}$$

$$\text{where}\ \ \pi_h(a) \equiv \mathbb{P}_a(q=H|z=z_h) = \frac{a^2\pi_H}{(1-a)^2+(2a-1)\pi_H} \tag{1.7}$$

$$\pi_l(a) \equiv \mathbb{P}_a(q=H|z=z_l) = \pi_H \tag{1.8}$$

where both are computed using Bayes Rule. Note that $\frac{a^2}{(1-a)^2+(2a-1)\pi_H} \geq 1$ for all $a \in [\frac{1}{2},1)$ and $\pi_H \in [0,1]$, and that $\pi_l(a)$ does not depend on a. That is, information acquisition increases the likelihood of having good cashflows for banks with good quality loans only. This result relies on the symmetry assumption imposed on the signal structure, and simplifies the analysis. I show in Section 3.4 that qualitative results remain unchanged when π_l also depends on a.

A. Strategies

Rather than defining investors' strategies, I model the buyer side of the market as a menu of prices and securities $\{p(F), F\}_{F\in\Delta}$ offered to the bank. This menu needs to satisfy two conditions: (i) *Zero Profits*: investors make zero profits in expectation, and (ii) *No Deals*: there are no profitable deviations for an investor; that is, by offering a price different than the one on the menu for a given security, an investor cannot expect to make profits.[19] In the remainder of the paper, I use the terms investors and the market interchangeably. The strategy of a z-type bank that acquired information a is to choose which securities to issue given the market posted prices.

B. Market Beliefs

Investors enter secondary markets with belief a^e about the bank's hidden-action. In addition, they need to form beliefs about the bank's type z. By offering a menu of securities and respective prices, the market can potentially screen the bank's type.[20] The idea is that the cost of retaining cashflows (i.e. of not selling them) is lower for banks with good assets than for those with bad assets, and this can be used to separate them: those with good assets retain a fraction of their cashflows while those with bad assets reveal their type to

[19] This approach is a useful modeling device to summarize an environment with two or more uninformed, risk-neutral, deep-pockets investors compete by posting prices for all securities. The "No Deals" condition is taken from Daley and Green (2012)[25], and can be also be interpreted as a No Entry condition. This "No Deals" condition needs to be imposed in environments with asymmetric information to ensure there are no profitable deviations for the buyers.

[20] Separating equilibria in this type of market has been found in DeMarzo and Duffie (1999), Biais and Mariotti (2005), DeMarzo (2005), among others.

be able to sell all of their cashflows. Instead, I impose a "No Transparency" assumption that prevents the market to enforce retention levels, and thus screening bank quality is not possible in equilibrium. Gorton and Pennacchi (1995)[47] discuss the commitment to retain a given fraction when selling a loan. They argue that "... no participation contract requires that the bank selling the loan maintain a fraction, so this contract feature would also appear to be implicit and would need to be enforced by market, rather than legal, means." This assumption is therefore motivated by behavior in ABS markets, and it generates novel predictions about potential strategies in ABS markets.[21]

Assumption 1. [No Transparency] *The bank cannot commit to retain cashflows. Or equivalently, balance sheet information is not verifiable and markets are anonymous.*

Given the *No Transparency* assumption, an investor forms her beliefs about bank type only by observing the security the bank is selling to her, and cannot condition on all the securities the bank is selling in secondary markets since this is not observable. More formally, the No Transparency assumption implies that market beliefs about the bank's type are given by some function $\mu : \Delta \to [0,1]$,where $\mu(F)$ denotes the probability of a bank being z_h-type if it chooses to sell security F. Therefore, market beliefs are formed per security sold, and not as a function of the set of securities sold by a bank. Consistent with this, the market valuation for a given security $F \in \Delta$ is denoted by $\mathbb{E}_{a^e,\mu}[F(X)]$, and it is given by:

$$\mathbb{E}_{a^e,\mu}[F(X)] \equiv \mu(F)\,\mathbb{E}_{a^e}[F(X)|z_h] + (1-\mu(F))\mathbb{E}_{a^e}[F(X)|z_l] \tag{1.9}$$

C. Equilibrium

I assume that the bank wants to minimize the number of markets it issues in; that is, the bank prefers to issue one security than to issue several securities when both strategies have the same payoff. I rationalize this by imposing an infinitesimal cost of issuing a positive claim ($F(x) > 0$ in a set of positive measure), $c > 0$.[22] Given this, I can assume without loss that the bank chooses to issue at most N securities, where N can be arbitrarily large. The equilibrium notion in secondary markets is defined as follows:

Definition 2. *Given any level of information acquisition, a, and market beliefs a^e, an equilibrium in secondary markets is given by a market menu $\{F, p(F)\}_{F\in\Delta}$, bank z-type strategy $\sigma(z) = \{F^1(z), ...F^N(z)\}$, and belief function $\mu : \Delta \to [0,1]$, satisfying the following conditions:*

[21] Without imposing this assumption, the ex-post security design problem is like the one presented in DeMarzo (2005), where each type issues one debt contract and retention is used to screen underlying quality. Important qualitative results remain unchanged, but transfers across types in ABS markets differ, and the issuance of multiple securities per bank type cannot be rationalized.

[22] This assumption prevents multiplicity of equilibria arising from the fact that the bank in equilibrium might be indifferent between issuing a given security or any partition of the cashflows underlying that security; and thus simply eliminates a multiplicity of payoff-equivalent equilibria.

1. Bank's Optimality. *Given the market posted menu* $\{p(F), F\}_{F\in\Delta}$, *z-type bank chooses* $F^1, ...F^N$ *to maximize its value at* $t = 1$*:*

$$\sum_{n=1}^{N} \{\theta p(F^n) - \mathbb{E}_a [F^n(X)|z]\} - c\tilde{N} \tag{1.10}$$

   subject to $\sum_{n=1}^{N} F^n(X) \leq X$ *, and where* $\tilde{N}$ *is the number of issued securities.*

2. Belief Consistency. $\mu(F) = \mathbb{P}_{a^e}(z = z_h | Issue\ F)$ *are derived from* $\sigma(z)$ *using Bayes rule when possible.*

3. Zero Profit Condition. $p(F) = \mathbb{E}_{a^e,\mu}[F(X)]$ *for all* $F \in \Delta$.

4. No Deals. *For all* $F \in \Delta$, *it does not exist alternative pricing* $\tilde{p}$ *such that by offering to buy* F *at price* $\tilde{p}$, *an investor expects to make profits.*

The following Lemma presents the first important result of this section, which states that under the No Transparency assumption the bank with the good loan cannot be separated from the one with the bad loan, eliminating the possibility of screening bank quality. As a result, the issuance chosen by the bank with the good loan is always mimicked by the bank with the bad loan, and thus the bank with the good loan faces a lemon's problem in secondary markets. Full proofs are presented in the Appendix.

Lemma 1. ***[No Separation]*** *Under the* No Transparency *Assumption, fully separating equilibria in secondary markets do not exist. In particular, in any equilibrium in secondary markets the* z_l*-type bank mimics the issuance of the* z_h*-type bank.*

The main idea behind the proof is that in any separating equilibrium $\{p_{z_l}, p_{z_h}, F_{z_l}, F_{z_h}\}$, there is a profitable deviation for an investor. Note that in any separating equilibrium, z_l-type bank is identified and thus $p(F_{z_l}) = \mathbb{E}_{a^e}[F_{z_l}(X)|z_l]$ by the zero-profit condition. Given this, consider the following deviation. An investor offers to buy security F' with cashflows $F'(X) = X - F_{z_h}(X)$ at price $p(F') = \mathbb{E}_{a^e}[F'(X)|z_l] - \epsilon$, $\epsilon > 0$, where F_{z_h} is the security issued by z_h-type bank in the separating equilibrium. For ϵ small enough, this offer attracts the bank with the bad loan, that now benefits from issuing a claim to all of its cashflows by issuing: F_{z_h} at price $p(F_{z_h}) > \mathbb{E}_{a^e}[F_{z_h}(X)|z_l]$ to extract rents from the bank with the good loan, and further exploits remaining gains from trade by issuing F' at $p(F')$. Since $\epsilon > 0$, the investor makes profits. Lemma 1 implies that there is pooling in the market for the securities issued by the z_h-type bank. The following proposition characterizes the security design in secondary markets.

Proposition 1. ***[Security Design]*** *Under the* No Transparency *Assumption, in any equilibrium in secondary markets,*

1. *z_h-type bank issues one security, given by standard debt $F_D(X) \equiv \min\{d, X\}$, where debt level d is chosen to maximize the value of the z_h-type bank in $t = 1$:*

$$d(a^e, a) = \arg\max_d \ \theta \cdot \mathbb{E}_{a^e,\mu}\left[\min\{d, X\}\right] - \mathbb{E}_a\left[\min\{d, X\}|z_h\right] \tag{1.11}$$

2. *z_l-type bank issues **two** securities: 1) standard debt F_D, and 2) junior tranche F_J where $F_J(X) \equiv \max\{X - d, 0\}$ are the remaining cashflows.*

3. *The market price for these securities:*

$$p(F_D) = \rho_h(a^e)\mathbb{E}_{a^e}[\min\{d, X\}|z_h] + (1 - \rho_h(a^e))\mathbb{E}_{a^e}[\min\{d, X\}|z_l] \tag{1.12}$$

$$p(F_J) = \mathbb{E}_{a^e}[\min\{0, X - d\}|z_l] \tag{1.13}$$

Four important results are presented in Proposition 1. First, standard debt is always sold in secondary markets. Second, debt levels are chosen to maximize the value of the bank with the good loan. Third, the bank with the bad loan tranches its cashflows into senior (standard debt) and junior (remaining cashflows) tranches that are sold separately in secondary markets, while the bank with the good loan only issues the senior tranche and retains its junior tranche. Finally, prices in secondary markets are such that the bank with the bad loan is subsidized by the bank with the good loan in the market for the senior tranches and it receives a fair value for its junior tranche.

Optimality of Standard Debt. Under the No Transparency assumption, the bank with the good loan faces a lemons problem as the one described in Akerlof (1970)[3] when it participates in secondary markets, since the bank with the bad loan mimics its issuance. For any given security, the lemon's discount faced by the bank with the good loan is given by the difference between its private valuation and the market valuation. Standard debt is the optimal security design because it allows the bank with the good loan to raise funds at the minimum retention cost by minimizing the region where disagreement about the likelihood of cashflows might arise. Thus, standard debt maximizes the gains from trade by minimizing the lemon's discount since it is the design that is least informationally sensitive in the set of feasible securities. In contrast to papers on security design that obtain a separating equilibrium, the reason why high types choose to retain in this framework is not to signal underlying quality, but because the lemon's discount is prohibitively high in the market for the junior tranche. The No Transparency assumption makes signaling through retention not credible to the market, and thus there is pooling in the market where the bank with the good loan issues. As a result, the z_h-type bank implicitly subsidizes the z_l-type in the market for standard debt.

Tranching. The bank with the bad loan tranches underlying cashflows into a senior tranche –i.e. standard debt– and a junior tranche –i.e. remaining cashflows,– and sells both securities in the market. It does so to receive an implicit subsidy in the market for the senior tranche and rip remaining gains from trade by issuing its junior tranche simultaneously. This

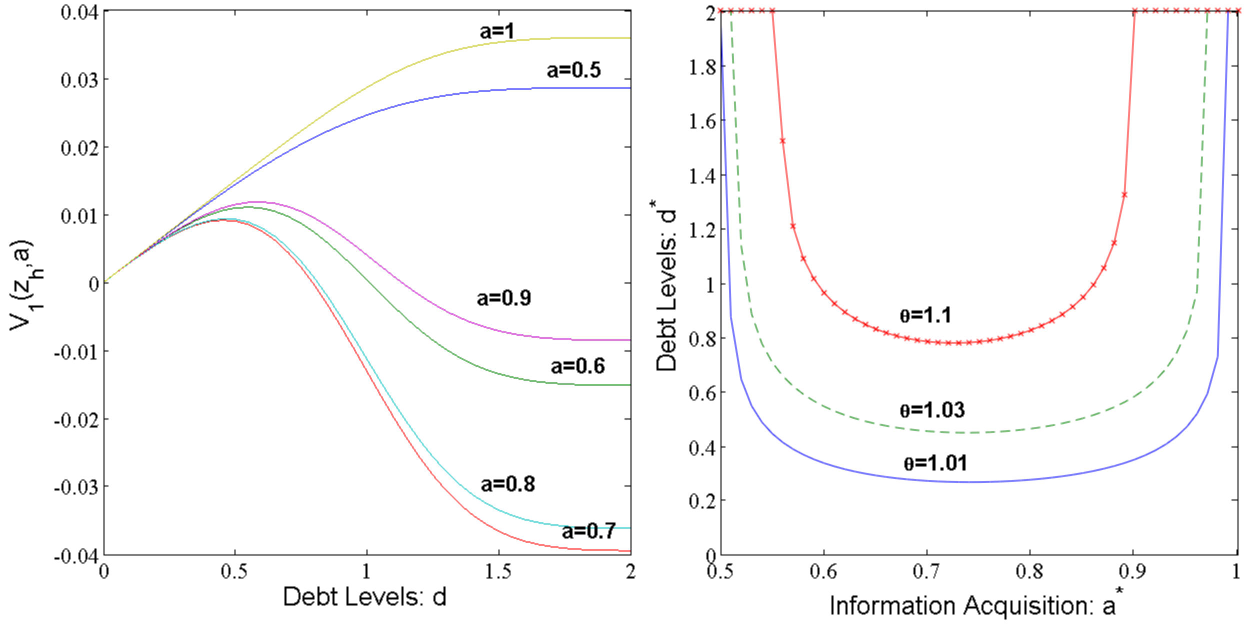

Figure 1.2: Optimal Debt Levels in ABS Markets

$\theta = 1.03$, $\pi_H = 0.5$, the distribution of X is given by a truncated normal in $[0, 2]$ with $\mathbb{E}_H [X] = 1.2$, $\mathbb{E}_L [X] = 0.7, V_G [X] = V_B [X] = 0.2$ respectively for good and bad projects.

result strongly relies on the No Transparency assumption, since the bank with the bad loan can issue its junior tranche without being punished in the market for standard debt for doing so.

Optimal Debt Levels. Debt levels are chosen to maximize the value of the bank with the good loan in $t = 1$. Figure 1.2 plots (a) the payoff of the good bank in $t = 1$ as a function of different debt levels issued in secondary markets, and (b) optimal debt levels, both as a function of different equilibrium levels of information acquisition. Simulations are done to ease the exposition of results since qualitative results do not depend on specific functional forms nor parameters (specified in bottom of each Figure). In the Appendix, I show that highlighted properties hold for general distributions and parameters. As we can see from Figure 1.2, optimal debt levels are non-monotonic in information precision. For a given funding need θ, debt levels are maximized when adverse selection is low. This occurs when information precision is low, and thus private information is not too valuable (see $a = 0.5$ case), and when information precision is high, and thus the quality of initial loan screening is sufficiently high to make private information not valuable (see $a = 1$ case). The following Lemma characterizes optimal debt levels for given equilibrium levels of information acquisition.

Lemma 2. *Let a^* be the equilibrium level of information acquisition. Then, in any equilibrium in secondary markets, if $\theta\rho(a^*) - \pi_h(a^*) < 0$ holds optimal debt levels $d(a^*)$ are given by the solution to:*

$$\underbrace{[\theta\rho(a^*) - \pi_h(a^*)][G_L(d) - G_H(d)]}_{\text{Mg Cost due to Lemon's Discount}} + \underbrace{(\theta - 1)[1 - G_L(d)]}_{\text{Mg. Gains from Trade}} = 0 \tag{1.14}$$

Otherwise, both z-type banks issue equity; that is, $F_D = X$.

Debt levels are continuous, differentiable, and convex in the equilibrium level of information acquisition, a^*, and increasing in funding needs, θ. The bank with the good loan chooses to retain some of its cashflows when $\theta\rho(a^*) - \pi_h(a^*) < 0$. Note that $\rho(a^*)$ is the probability the market assigns to loan cashflows being high quality, while $\pi_h(a^*)$ is the probability the z_h-type assigns to this event. We know that $\rho(a^*) \leq \pi(a^*)$, with strict inequality when $a^* \in (\frac{1}{2}, 1)$.[23] When funding needs are high enough to compensate for the low probability the market assigns to high cashflows, z_h-type bank issues equity. Otherwise, it optimally chooses to retain cashflows (i.e. its junior tranche).

Existence of Equilibrium. I have shown that in any equilibrium with information acquisition, the bank with the good loan issues standard debt in secondary markets at average valuations, and the bank with the bad loan issues both standard debt at average valuations and its remaining cashflows at low valuations, where optimal debt levels are given by Lemma 2. Given this, I show that an equilibrium in secondary markets always exists. For example, for $\mu(F) = 0$ for all $F \in \Delta \neq F_D$ and $a^e = a^*$, there are no profitable deviations for the bank in secondary markets or in $t = 0$. By construction, there are no profitable deviations to investors. An equilibrium can also be supported with less stringent off-equilibrium beliefs.

Information Acquisition

The previous subsection characterized secondary market equilibrium outcomes for a given level of information acquisition a and market beliefs a^e. Now, I proceed to find the optimal level of information acquisition and the determination of market beliefs, given secondary market equilibrium outcomes. At $t = 0$, the bank chooses how much information to acquire to maximize V_0 given by (1.3). The following proposition characterizes optimal levels of investment in information, and completes the characterization of equilibrium allocations.

Proposition 2. *In any equilibrium without commitment and with information acquisition:*

1. *Optimal investment in information, a^*, is given by the solution to:*

$$\rho_h(a^*)\,\pi_h'(a^*)\{\mathbb{E}_H[\max\{X - d(a^*), 0\}] - \mathbb{E}_L[\max\{X - d(a^*), 0\}]\} + \tag{1.15}$$

$$\rho_h'(a^*)\{\mathbb{E}[\max\{X - d(a^*), 0\}|z_h] - \theta\mathbb{E}[\max\{X - d(a^*), 0\}|z_l]\} = C'(a^*) \tag{1.16}$$

[23] Since $\rho(a) = \mathbb{P}(q = G|s_0 = G)$ while $\pi(a) = \mathbb{P}(q = G|s_0 = G, s_1 = G)$.

where $d(a^*)$ is given by (1.14).

2. *Optimal debt level is given by $d^* = d(a^*)$.*

Since the bank's information acquisition choice is a hidden-action, by choosing more or less information, the bank cannot directly affect investor's beliefs. The bank has two motives to acquire information: (i) to improve the quality of the tranches that it expects to retain, and (ii) to affect the probability of being a bank with a good loan, z_h-type, in secondary markets.

Retention of Cashflows. Retention of cashflows improves incentives for information acquisition, since by investing in information the bank can increase the quality of the tranches that it expects to retain. This motive for information acquisition is well understood, and is the rationale behind proposed regulation for securitizers in the U.S. and Europe. Retention levels, however, are determined ex-post in this environment, and depend only on the gains from trade, measured by θ, and the level of adverse selection in secondary markets, given by the level of asymmetric information between the bank and the market.

Secondary Market Payoffs. For a given retention level, the differential payoff between z_h and z_l types in $t = 1$, which strongly depends on secondary market outcomes, also affects incentives for information acquisition. The higher the benefits associated with being a bank with a good loan ex-post –i.e. higher payoff of the z_h-type bank relative to the z_l-type bank,– the higher the incentives to acquire information to screen loans ex-ante. Note that the z_h-type bank is not fully compensated in secondary markets: it implicitly subsidizes the z_l-type bank in the market for debt, and it looses access to the market for its junior tranche, where the lemon's discount is prohibitively high. Thus, transfers across different bank types in secondary markets *do* affect ex-ante efficiency by affecting incentives for information acquisition.

The Value of Adverse Selection. Both of these motives are positive only when the bank expects to retain cashflows in secondary markets, which only occurs when adverse selection is sufficiently high. To see this, note that when adverse selection is secondary markets is not severe, the bank with the good loan chooses ex-post to issue a full claim to its cashflows. In this scenario, there is no retention, and therefore the bank has no incentives to acquire information. When $a^* = 0.5$, there is no screening in equilibrium, and thus the bank prefers to store its endowment. Therefore, with lack of commitment, the presence of adverse selection is essential to sustain an equilibrium with information acquisition, since it implicitly makes the bank with the good loan *commit* to retain its junior tranche.

Discussion

I have fully characterized equilibrium outcomes in an economy where loan-backed securities are designed and priced in secondary markets, after loan issuance. The environment is

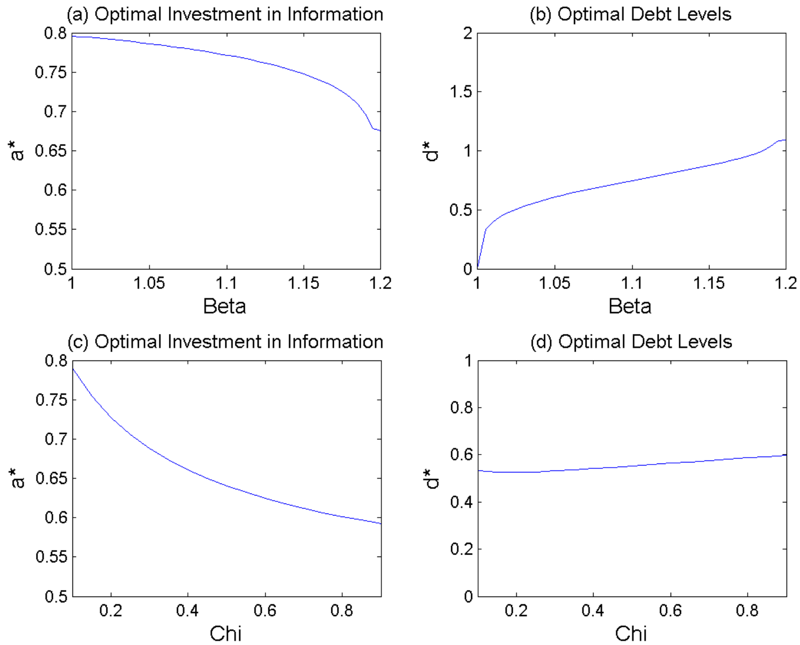

Figure 1.3: Comparative Statics in ABS Markets

The distribution of X is given by a truncated normal in $[0,2]$ with $\mathbb{E}_H[X] = 1.2$, $\mathbb{E}_L[X] = 0.7, V_G[X] = V_B[X] = 0.2$ respectively for good and bad projects, $\pi_H = 0.5$, and information costs are given by $C(a) = -\chi(0.5-a)^2/(1-a)$. Panels (a) and (b) are computed for $\chi = 0.1$, and (c) and (d) for $\theta = 1.03$.

stylized, but rich enough to generate several predictions and new insights. Figure 1.3 shows optimal information acquisition and debt levels as a function of gains from trade, θ, and of costs of information acquisition, χ, where $C(a) = -\chi(0.5-a)^2/(1-a)$. As gains from trade in secondary markets increase, the bank optimally chooses to increase its issuance of ABS in secondary markets. As a result, information acquisition falls and the quality of the issued loan is worsened. This prediction is consistent with what was observed in the decade leading to the crisis: where a rapid increase in securitization was accompanied by a decrease in the quality of issued loans.[24]

I now address the two main questions asked at the beginning of this section. First, how does information acquisition affect the design of securities sold in secondary markets and the levels of ABS issuance in these markets? Standard debt is the optimal design for all levels of information acquisition. Debt levels, however, are shown to be non-monotonic on

[24] Jaffee et al. (2009), Dell'Ariccia, Igan and Laeven (2008), Mian and Sufi (2009), Bernd and Gupta (2008), provide empirical evidence of this fact.

the precision of acquired information. That is, improving initial loan screening does not always increase liquidity and trade secondary markets (See Figure 1.2). This result relies on the dual effect of information acquisition, and predicts that trade is maximized for low and high levels of information precision. This result suggests that secondary markets for loans for which the bank acquires too little or too much information in the issuance stage should be more liquid.

Second, how does the design of securities sold in secondary markets affect incentives of the bank to acquire information and issue high quality loans in the first place? There are two aspects of secondary markets that affect the bank's decision to acquire information. First, to have a relevant level of information acquisition the bank has to retain some of its cashflows –or expect to retain,– in secondary markets. In the absence of commitment, this only occurs when adverse selection in secondary markets is severe enough to have the bank with the good loan not off-loading its entire loan. Consistent with this, larger expected retention levels generate higher levels of information acquisition. The second aspect is related to the payoff received in the market for the securities sold: standard debt and junior tranche. Ex-ante, by acquiring information, the bank can affect the likelihood of showing up in secondary markets with a good loan. Thus, the differential payoff between the bank with the good loan relative to the bank with the bad loan in secondary market matters. As this relative payoff increases, incentives for information acquisition improve; this relative payoff, however, is non-monotonic in retention levels. This force, however, tends to be dominated by the incentives to acquire information as retention levels increase.

1.4 The Optimal Mechanism: The Commitment Case

In the previous section, I have fully characterized equilibrium allocations in an economy where ABS are designed after loan issuance. To highlight the inefficiencies that arise with lack of commitment, I now characterize the optimal mechanism that is obtained when the bank and the market can commit at $t = 0$ to the design and price of securities to be issued in secondary markets. This case is therefore useful to understand which securities and which levels of information acquisition a regulator would want to implement to increase ex-ante efficiency. The results from this section motivate the policy interventions proposed in Section 1.5.

As in the case without commitment, I model the market as a menu $\{F, p(F)\}_{F\in\Delta}$ that satisfies the Zero Profit and No Deals conditions, now imposed at $t = 0$. By the Revelation Principle, we know that for any Bayesian-Nash equilibrium there exists a direct mechanism that is payoff-equivalent and where truthful revelation is an equilibrium. Therefore, I focus on direct revelation mechanisms that stipulate a transfer and a security to be issued as a function of the reported type of the bank, $\hat{z}$; that is, the market offers the bank a menu $(p(\hat{z}), F(\hat{z})) : Z \to \mathbb{R}^+ \times \Delta$. Let $\{p_l, F_l\}$ and $\{p_h, F_h\}$ denote the payments made to and the security assigned to the bank that reports type z_l and z_h respectively.

Definition 3. *An equilibrium with commitment is given by* $\{a^*, p_l, p_h, F_l, F_h\} \in [\frac{1}{2}, 1] \times \mathbb{R}^2_+ \times \Delta^2$ *chosen to maximize the value of the bank in* $t = 0$*:*

$$\rho_h(a^*)\left[\theta p_h + \mathbb{E}_{a^*}\left[X - F_h(X)|z_h\right]\right] + (1 - \rho_h(a^*))\left[\theta p_l + \mathbb{E}_{a^*}\left[X - F_l|z_l\right]\right] - C(a^*)$$

subject to:

1. *The incentive compatibility constraints:*

$$\theta p_l - \mathbb{E}_{a^*}[F_l(X)|z_l] \geq \theta p_h - \mathbb{E}_{a^*}[F_h(X)|z_l] \qquad \theta p_h - \mathbb{E}_{a^*}[F_h(X)|z_h] \geq \theta p_l - \mathbb{E}_{a^*}[F_l(X)|z_h] \tag{1.17}$$

2. *The ex-post participation constraints:*

$$\theta p_h - \mathbb{E}_{a^*}\left[F_h(X)|z_h\right] \geq 0 \qquad \theta p_l - \mathbb{E}_{a^*}\left[F_l(X)|z_l\right] \geq 0 \tag{1.18}$$

3. *Zero-Profit Condition:*

$$\rho_h(a^*)\left[\mathbb{E}_{a^*}\left[F_h(X)|z_h\right] - p_h\right] + (1 - \rho_h(a^*))\left[\mathbb{E}_{a^*}\left[F_l(X)|z_l\right] - p_l\right] = 0 \tag{1.19}$$

4. *The incentive compatibility constraint for information acquisition:*

$$a^* = \arg\max_{a \in [\frac{1}{2}, 1]} \rho_h(a)\left[\theta p_h + \mathbb{E}_a\left[X - F_h(X)|z_h\right]\right] + (1 - \rho_h(a))\left[\theta p_l + \mathbb{E}_a\left[X - F_l(X)|z_l\right]\right] - C(a) \tag{1.20}$$

This problem is similar to the one presented in Biais and Mariotti (2005). They study optimal mechanism design in the presence of adverse selection, where an issuer with private information about asset quality has to issue a security to uninformed competitive liquidity providers. The main difference between their framework and mine is that in their setup, the quality of underlying assets and of the private information held by the issuer are exogenously determined, while in this problem both elements are dependent on information acquisition, which is a bank's hidden action. Therefore, the problem internalizes the effect that different securities have on incentives to acquire information, and the impact that information has on loan screening and on issuance levels in secondary markets.

The No Deals condition is no longer imposed. Since the menu is accepted by the bank at $t = 0$, when there is no asymmetric information, there is no need to impose an extra constraint, as in the ex-post menu design problem. Finally, I impose ex-post participation constraints for the bank. By doing this, I am implicitly assuming that even though the bank can commit to the design of securities, it cannot commit to issue a security if doing so generates a negative payoff. In other words, the bank always has the option not to participate in secondary markets. Imposing ex-post participation constraints, however, does not affect the qualitative predictions of the optimal mechanism. The rest of the constraints are standard.

Lemma 3 incorporates binding and slack constraints to the optimal mechanism design problem. I show in the Appendix that without loss of generality we can focus on mechanisms where the incentive compatibility for the bank with the bad loan binds in equilibrium. Given this, the participation constraint of the bad types is slack, and the incentive compatibility for the good types can be replaced by (1.21). Finally, using the first-order approach, the incentive compatibility for implementable investment in information levels (1.20) can be replaced by its first-order condition. By plugging the binding incentive compatibility constraint for the bad type into the obtained first-order condition, constraint (1.23) is obtained.

Lemma 3. *Equilibrium allocations with commitment, $\{a^*, p_l, p_h, F_l, F_h\}$ solve the following problem:*

$$\max_{p_l,p_h,F_l,F_h} \rho_h(a^*)\left[\theta p_h + \mathbb{E}_{a^*}\left[X - F_h(X)|z_h\right]\right] + (1-\rho_h(a^*))\left[\theta p_l + \mathbb{E}_{a^*}\left[X - F_l(X)|z_l\right]\right] - C\left(a^*\right)$$

subject to:

$$\theta p_h \geq \mathbb{E}_{a^*}\left[F_h(X)|z_h\right] \tag{1.21}$$

$$\mathbb{E}_{a^*}\left[F_l(X) - F_h(X)|z_h\right] \geq \mathbb{E}_{a^*}\left[F_l(X) - F_h(X)|z_l\right] \tag{1.22}$$

$$\rho'\left(a^*\right)\left(\mathbb{E}_H\left[X - F_h(X)\right] - E_L\left[X - F_h(X)\right]\right) - C'\left(a^*\right) = 0 \tag{1.23}$$

where transfers p_l, p_h are given by the binding incentive compatibility constraint of the z_l-type (1.18a) and the Zero Profit condition (1.19).

The following results follow from Lemma 3. First, the incentive compatibility of the z_l-type bank binds in equilibrium because transfers from the bank with a bad loan to the one with the good loan are always desired. These transfers relax the z_h-type bank participation constraint (1.21) and reduce the retention costs associated with an implementable level of information acquisition. That is, they compensate the bank with the good loan –as much as possible. Second, to satisfy the z_h-type incentive compatibility constraint, the z_l-type bank has to issue a claim to at least as many cashflows as the z_h-type bank; that is, the bank with the good loan retains at least as many cashflows as the bank with the bad loan, given by constraint (1.22). Finally, to provide incentives for information acquisition, it is only necessary to have the bank with the good loan retaining a fraction of its underlying cashflows; that is, retention of the bank with the bad loan gives no incentives for information acquisition. This last result strongly depends on the symmetry of signals,that implies that the quality of the bad loan is independent of information acquisition. –signals $s_0 = H$ and $s_1 = L$ cancel each other. I address this point after the presentation of the main results in Proposition 3.

Using the results from Lemma 3, we know that transfers are given by the binding incentive compatibility constraint of the bad type, and by the zero profit condition. Combining these two constraints, we get that transfers are given by:

$$p_h = \{\ \rho_h(a)\mathbb{E}\left[F_h|z_h\right] + (1-\rho_h(a))\,\mathbb{E}\left[F_l|z_l\right]\ \} - (1-\rho_h(a))\,\frac{1}{\theta}[\mathbb{E}\left[F_l|z_l\right] - \mathbb{E}\left[F_h|z_l\right]] \tag{1.24}$$

$$p_l = \{\ \rho_h(a)\mathbb{E}\left[F_h|z_h\right] + (1-\rho_h(a))\,\mathbb{E}\left[F_l|z_l\right]\ \} + \rho_h(a)\frac{1}{\theta}\left[\mathbb{E}\left[F_l|z_l\right] - \mathbb{E}\left[F_h|z_l\right]\right] \tag{1.25}$$

and therefore securities are chosen to maximize V_0 subject to (1.21), (1.22), (1.23), (1.24) and (1.25). The following proposition characterizes the optimal security design in the presence of commitment.

Proposition 3. *In the equilibrium with commitment,*

1. *z_h-type bank issues standard debt with debt level d; that is, $F_h(X) = \min\{d, X\}$, and*
2. *z_l-type bank issues equity; that is, $F_l(X) = X$.*

The proposition states that the bank with the good loan issues standard debt, and thus retains some of its cashflows, while the bank with the bad loan issues a claim to all of its cashflows. This is because there are only gains, and no costs, from increasing the cashflows of security F_l. Doing this increases the value of the bank, and relaxes the remaining constraints. This, however, is not the case for the security issued by the bank with the good loan, F_h. There are costs associated with increasing cashflows issued by the good type: implementable information acquisition levels decrease, and its participation and incentive compatibility constraints get tighter. Therefore, the bank with the good loan might retain some of its cashflows.

Standard debt is optimal because i) given a level of information acquisition a, standard debt minimizes the required retention necessary to implement it, and this is good because retention of cashflows is costly –forgo gains from trade;– and ii) it relaxes the participation and incentive compatibility constraints of the bank with the good loan. As in the no commitment case, standard debt allows the bank to raise funds by loading on payments for which there is less disagreement, and thus less adverse selection in secondary markets. In addition, when securities are designed ex-ante they incorporate the impact on information acquisition, and thus standard debt is also preferable because it exposes the bank to the most informationally sensitive cashflows, improving incentives for information acquisition.

In this economy, demanding the same retention levels for all type of issuers is inefficient, since it reduces gains from trade without improving incentives. In particular, in the optimal mechanism, *no* retention is required for the bank with the bad loan, the z_l-type bank. Only the retention of the z_h-type bank is necessary since information acquisition only affects the expected quality of the loan held by the bank with the good loan. In Section 3.4, I extend the model to admit for the precision of the second signal to differ from that of the first one, and find that in the optimal mechanism retention of the bank with the bad loan may be desired, but that it is always lower than the one required from the bank with the good loan. It is never optimal to impose the same retention levels to all ABS issuers.

It remains to show how debt levels are determined. Let $a\,(d)$ be the implicit function generated by the incentive compatibility of investment in information (1.23), once we take into account that z_h-type bank issues standard debt. Function $a(d)$ is continuous, differentiable, and decreasing in d due to the MLRP. The following Proposition concludes the characterization of the equilibrium with commitment.

Proposition 4. *In any equilibrium with commitment,*

1. *When the participation constraint of the z_h-type bank (1.21) does not bind in equilibrium, optimal debt levels d^* are given by:*

$$\underbrace{\theta\frac{\partial}{\partial a}\left[\rho_h\left(a\left(d\right)\right)p_h+\left(1-\rho_h\left(a\left(d\right)\right)\right)p_l\right]a'\left(d\right)}_{Marginal\ Cost\ of\ \uparrow d}+\underbrace{\left(\theta-1\right)\rho_h(a)\int_d^\infty f\left(X|z_h\right)dX}_{Marginal\ Gain\ from\ \uparrow d}=0 \tag{1.26}$$

When the participation constraint binds in equilibrium, optimal debt levels are given by the binding participation constraint:

$$\theta p_h-\mathbb{E}_{a(d)}\left[\min\left\{d,X\right\}|z_h\right]=0 \tag{1.27}$$

2. *Optimal investment in information is given by $a^*=a(d^*)$.*

By committing to lower debt levels ex-ante, the bank can commit to a certain level of information acquisition, affecting market beliefs. In particular, lower debt levels imply higher market beliefs, which are translated into higher ex-post transfers. This is the first term of equation (1.26), and it reflects the costs associated with increasing the debt level d marginally. The interpretation of the second term is straightforward: gains from trade are increased by increasing debt level d. If the participation constraint of z_h-type is not binding in equilibrium, debt levels are chosen to optimally trade-off the gains from trade with the gains from information acquisition. If the participation constraint is violated for the solution given by (1.26), however, optimal debt levels are given by the binding participation constraint and retention occurs due to the presence of adverse selection. In this scenario, debt levels required to make the bank with the good loan participate are lower –and thus retention levels higher– than the one that implements the desired level of investment in information and thus first-order condition (1.26) is positive at $\{a^*,d^*\}$.

The presence of severe adverse selection in secondary markets alleviates the moral hazard problem. When the lemon's discount faced by the bank with the good loan in secondary markets is large, debt levels are lower than the ones that implement the desired level of information acquisition. This suggests that imposing retention levels for the purpose of incentives is only necessary for ABS classes with liquid secondary markets –and thus high issuance levels. Otherwise, the bank naturally chooses to retain a large fraction of its cashflows. Which force dominates, and therefore determines retention levels, will depend on fundamentals that determine how important the provision of incentives vs. the adverse selection problem in secondary markets is for a given asset class.

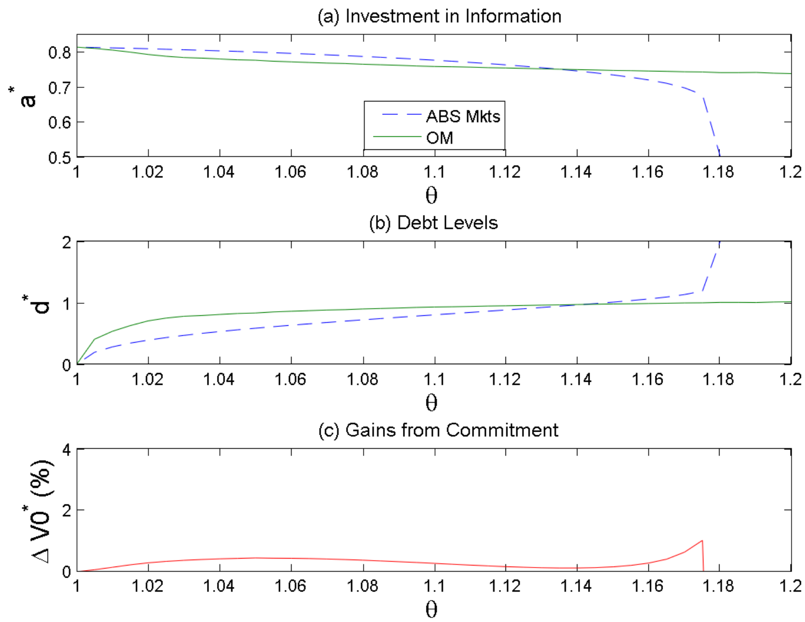

Figure 1.4: Comparative Statics and Gains from Commitment

The distribution of X is given by a truncated normal in $[0,2]$ with $\mathbb{E}_H[X] = 1.2$, $\mathbb{E}_L[X] = 0.7, V_H[X] = V_L[X] = 0.2$ respectively for good and bad projects, $\pi_H = 0.5$, and information costs are given by $C(a) = \chi(a-0.5)^2/(1-a)$ for $\chi = 0.1$

Discussion

There are two key differences between the allocations obtained in the optimal mechanism and those found in Section 1.3, where securities were designed and priced *after* loan issuance as in markets for ABS. First, in the optimal mechanism, the design of securities internalizes its effect on the equilibrium level of information acquisition. Although standard debt continues to be the optimal design, gains from trade may now be sacrificed to implement more information acquisition and better loan screening. Second, because in the optimal mechanism the market Zero Profit condition holds in expectation, there is room to exploit type-contingent transfers. In particular, I have shown that it is optimal to transfer all surplus to the bank with the good loan subject incentive compatibility constraints. These transfers improve the bank's incentives for information acquisition for any given retention level, since they compensate the bank with the good loan for its sold tranches.

Figure 1.4 plots equilibrium debt levels and information acquisition for the commitment (optimal mechanism) and the no commitment (ABS markets) cases, as a function of gains from trade θ. The bottom panel plots the percentage gain in ex-ante welfare arising from commitment. When gains from trade are low, ABS markets have inefficiently low levels of trade, and as a consequence inefficiently high levels of information acquisition. In these cases, the optimal mechanism implements higher issuance in secondary markets (higher debt levels). As θ increases, the bank's incentives to issue ABS ex-post becomes larger. For intermediate levels of gains from trade, the commitment and the no commitment allocations match, although welfare is still higher for the commitment case because transfers are optimally set.

Finally, and most interestingly, when gains from trade are large, the no commitment case implements too much issuance in ABS markets and, as a result, inefficiently low levels of information acquisition. In the extreme case where gains from trade are very large, the bank chooses ex-post to issue a full claim to its loans. In this scenario, there is no information acquisition, and thus lack of commitment generates a collapse in secondary market trading and loan issuance – the bank optimally chooses to store ex-ante.[25] This is the region where gains from commitment are large. Therefore, implementing the optimal mechanism by forcing banks to commit to retain cashflows to provide incentives for information acquisition is desired in markets that exhibit high issuance of ABSs – that is, for asset classes with liquid secondary markets. Policy implications are discussed in the following section.

1.5 Policy Implications: Regulating Markets for ABS

In this section I show that a simple tax scheme can implement the optimal mechanism and therefore improve ex-ante efficiency in markets for ABS. The policy prescriptions presented in this section are only necessary when there are no commitment tools available to the bank and to the market. The following Lemma characterizes the policy intervention.

Lemma 4. *Transfers $\{T_l, T_h\}$ conditional on market participation and debt levels are sufficient to implement the optimal mechanism. In particular,*

1. *The bank that issues standard debt with debt level d receives transfer:*

$$T_h = T + \Gamma_h(d) + \gamma \times d \tag{1.28}$$

2. *The bank that issues the junior tranche receives transfers:*

$$T_l = \Gamma_l(d) \tag{1.29}$$

Remember that in the optimal mechanism all available surplus is transfered ex-post to the bank with the good loan subject to incentive compatibility constraints. A policy that taxes the participation in the market for junior tranches, Γ_l, and subsidizes the issuance of senior tranches, Γ_h, is able to attain this. Optimal debt levels can be implemented by imposing a marginal tax for units of debt issued, $\gamma \in [0, 1]$, returned as a lump sum transfer T. The following proposition characterizes optimal regulation.

[25]When $a^* = 0.5$, the value of banking is maximized with storage.

Proposition 5. *An optimal policy is given by quadruple* $\{T, \Gamma_l, \Gamma_h, \gamma\} \in \mathbb{R}^3 \times [0,1]$ *given by:*

1. *Optimal Transfers:*

$$\Gamma_h^* = (1 - \rho_h(a_c^*)) \left(\frac{\theta - 1}{\theta}\right) \mathbb{E}\left[\max\left\{0, X - d_c^*\right\} | z_l\right] \tag{1.30}$$

$$\Gamma_l^* = -\rho_h(a_c^*) \left(\frac{\theta - 1}{\theta}\right) \mathbb{E}\left[\max\left\{0, X - d_c^*\right\} | z_l\right] \tag{1.31}$$

2. *Optimal Marginal Tax:*

$$\gamma^* = -\frac{1}{\theta}\left[(\theta - 1) G_L\left(d_c^*\right) - \left[\theta\rho\left(a_c^*\right) - \pi_h\left(a_c^*\right)\right]\left[G_H\left(d_c^*\right) - G_L\left(d_c^*\right)\right]\right] \tag{1.32}$$

3. *Budget Constraint:*

$$\rho_h(a_c^*)(T^* + \Gamma_h^* + \gamma^* d_c^*) + (1 - \rho_h(a_c^*))\Gamma_l^* = 0 \quad \Rightarrow \quad T^* = -\gamma^* d_c^* \tag{1.33}$$

where $\{a_c^*, d_c^*\}$ *are the outcomes of the optimal mechanism that are implemented with this policy.*

Note that $\Gamma_h \geq 0$ and $\Gamma_l \leq 0$; that is, the optimal policy subsidizes retention and taxes the issuance of junior tranches. These transfers are found to make $p_j^c = p_j^{nc} + \Gamma_j$ for $j = 0, 1$ where c and nc are used to denote the type contingent transfers received in secondary markets in the commitment and no commitment case respectively. By the Zero Profit condition of the optimal mechanism, these transfers are self-financed. As explained in the previous section, by imposing these transfers incentives for information acquisition are improved for all retention levels. Equation (1.32) is derived using the first-order conditions for debt levels in ABS markets, and γ is chosen so that the bank with the good loan naturally chooses to issue debt level d_c^*. In particular, debt levels (issuance) should be taxed ex-post, $\gamma^* < 0$, when there is too much issuance in ABS markets relative to the optimal mechanism –i.e. $d_c^* < d_{nc}^*$.

Regulators in the US and in Europe are in the process of implementing risk retention rules for all issuers of asset-backed securities. The rules demand all securitizers to retain at least 5 percent of a risk exposure to the cashflows underlying the issued securities, with some exceptions in place. This intervention is usually referred to as the "Skin in the Game" rule and is suggested in the Dodd-Frank Act in the US, and by the EU Capital Requirements Directive (CRD) in Europe. These rules intent to deal with the misalignment of interest between loan originators and investors, believed to have contributed to the financial crash of 2008. My model, by incorporating the frictions that lead to a conflict of interest as the one concerning regulators, is able to rationalize the demand of retention levels as a way to give incentives to improve loan screening standards. However, the model suggests that demanding the same retention levels to all issuers is, in general, inefficient. In particular, retention levels should be larger for issuers that claim to have good assets underlying their securities. Requesting the same retention for issuers that claim to have bad assets underlying their ABS reduces gains from trade without improving incentives. In addition, the model suggests that incentives are better provided when securitizers retain the first-lost piece (junior tranche) of the underlying assets, while the proposed regulation allows issuers to freely choose to which cashflows to be exposed to.[26]

In the US, the Dodd-Frank Act establishes that all issuers of asset-backed securities should retain a fraction of underlying cashflows. In Europe, however, the rule imposed by the EU CRD specifies that banks can only have an exposure to securitized assets for which the originator or sponsor has a 5 percent exposure. In other words, securitizers are free to issue securities without retaining any of the risk, but banks can only invest in asset-backed securities for which the originator retains some of the risk. It may be a difficult task for banks to monitor the risk exposure of the originator or sponsor. One concern is that while the bank can ensure that the sponsor retains 5 percent of the risk at the time of the transaction, it might be cumbersome to monitor that they do not sell or hedge this exposure in the future. This concern is related to the *No Transparency* assumption made in this paper, that suggest that implementing the "Skin in the Game" rule in Europe will only be possible if the banks can enforce retention levels from originators or sponsors.

In addition, the model suggests that there are gains from subsidizing the issuance of safer tranches by taxing the issuance of risker ones. This type of policy is relatively easy to implement, but it has not been discussed in policy circles. Once the notion of adverse selection in ABS markets is introduced, transfers across issuers of ABS with different quality assets also affects incentives for information acquisition for any given retention level. Thus, the model suggests that regulators should not only focus on retention levels for securitizers but also on the way the market compensates good vs. bad issuers.

Finally, regulation on disclosure requirements and originators due diligence is also being implemented. First, it is required that all information regarding the retention and risk exposure levels of originators/sponsors is made available to investors. Second, investors and potential investors need to have access to all material that is relevant to be able to assess the credit quality and performance of the assets underlying the issued securities, and all information that is necessary to perform stress-tests on the values of cashflows and collateral. It stands to reason that this type of regulation is beneficial if possible to fully implement. Giving easy access to all the information required to evaluate underlying cashflows would solve both the moral hazard and the adverse selection problem; retention of underlying cashflows would not be necessary. All policies that address the problem of asymmetric information between originators and investors are, in the environment described in this paper, welfare improving.

[26]Vertical slice, horizontal slice, originator's share, random selection of assets, or even exposure to assets that have the same underlying characteristics as the one backing the issued ABS.

1.6 Extensions

I generalize the model in two main directions, and show that qualitative results presented in this paper remain valid. First, I allow the bank to make multiple loans and to issue securities backed by the pool of these loans in secondary markets. This extension is motivated by the fact that most ABS are backed by pools of loans and not individual loans. Second, I generalize the signal structure by removing the symmetry assumption. By doing this, I can explicitly show how my model incorporates single friction models known in the literature, and I can also characterize policy implications as a function of the severity of the hidden-action problem in the issuance stage vs. adverse selection in secondary markets.

Pooling and Tranching: Multiple Loans

In this section, I extend the previous model to admit more than one loan issuance in primary markets. Let n be the number of loans made by the bank in $t = 0$; that is, $w_b = n > 1$. I continue to assume that at least n good projects can be identified after investing in information; that is, incentives to originate are not in place.[27] The bank therefore issues n loans with $s_0 = H$. Let $Y = \frac{1}{n}\sum_{i=1}^{n} X_i$ denote the cashflows of the bank portfolio at $t = 2$ per loan issued at $t = 0$, where $Y \sim f_y(Y)$.[28]

The bank issues a security backed by the entire pool of loans, Y. That is, the bank is not allowed to choose which loans back the securities it issues in secondary markets and which ones it keeps on its portfolio, a behavior commonly referred to as "cherry picking". The problem of security design with asymmetric information when the issuer is allowed to pick which assets back the issued securities is a complicated one. I abstract from this at the moment, and instead focus on understanding the effects of pooling and of having more than two types. At the end of this section, I discuss the complications that arise when "cherry picking" is allowed.

A bank arrives to secondary markets with private information about each loan in its portfolio $\{z^1, z^2, ..., z^n\}$ with each $z \in \{z_l, z_h\}$. To deal with this, I redefine a bank's type in secondary markets by $\zeta \in \{0, 1, ...n\}$, where a bank's type denotes the number of loans in its portfolio that received $s_1 = G$, and therefore $n - \zeta$ is the number of loans that received $s_1 = H$. The distribution of types is now given by a binomial distribution with probability of success given by $\rho_h(a)$; that is $\zeta \sim B(n, \rho_h(a))$, and thus:

$$\rho_k(a) \equiv \mathbb{P}_a(\zeta = k | s_0 = H) = \begin{pmatrix} n \\ k \end{pmatrix} \rho_h(a)^k \, (1 - \rho_h(a))^{n-k} \tag{1.34}$$

[27]Note that if the bank had funds w_b greater than the number of good projects identified, then the market would understand the probability of a bank issuing a bad loan, and would demand a discount in secondary markets. Incentives to originate worsen the adverse selection problem, but the mechanism discussed in this paper and in this section would still be in place. I abstract from analyzing the impact of incentives to originate in this paper.

[28]To make this section comparable to the main section, I analyze the payoff to the bank per issued loan.

Given the distribution of types, and the fact that the bank issues securities backed by the entire pool of loans, the value of the bank in $t = 0$ is given by:

$$V_0(a, \{p_\zeta, F_\zeta\}) = \sum_{\zeta=0}^{n} \rho_\zeta(a) \left[\theta p_\zeta + \mathbb{E}_a \left[Y - F_\zeta(Y)|\zeta\right]\right] - C(a) \tag{1.35}$$

where $F_\zeta(Y)$ is the sum of the cashflows of all securities issued by the ζ-type bank, and p_ζ is the sum of the prices received in each sale. The expectations operator $\mathbb{E}_a[.]$ is now used to refer to expectations over cashflows Y. There are two main differences with the baseline model with one loan: first, the distribution of Y has less variance than that of X, and thus there's potentially less adverse selection in secondary markets; and second, there are more than two types.

The definition and construction of the equilibrium are as the ones described in the previous section for the commitment and the no commitment case respectively. In the remainder of this section, I use results obtained for the one loan case and extend them to admit multiple types. Proofs are presented in the Appendix.

Markets for ABS: The No Commitment Case. Given the No Transparency Assumption 1, type $\zeta = k < n$ matches the issuance of higher types $\zeta = k+1, ...n$ in secondary markets. Let $Y_k = Y - (F_{k+1}(Y) + F_{k+2}(Y) + ... + F_n(Y))$ denote the remaining cashflows type $\zeta = k$ has after mimicking the issuance of higher types, where $Y_n = Y$. Given the Zero Profit and the No Deals condition, security F_ζ is given by the solution to:

$$\max_{0 \le F \le Y_\zeta} \theta \mathbb{E}_{a^e,\mu}[F(Y)] + \mathbb{E}_a[Y_\zeta - F(Y)|\zeta] \tag{1.36}$$

Market beliefs $\mu(F)$ are given by a probability distribution over types $\zeta \in \{0, 1, ...n\}$ conditional on issuance F. Using the just described strategies, market valuation for security F_ζ for $\zeta = k$ are given by:

$$\mathbb{E}_{a^e,\mu}[F_k(Y)] \equiv \sum_{\zeta=0}^{k} \left[\frac{\rho_\zeta(a)}{G(k;a)} \mathbb{E}_{a^e}[F_\zeta(Y)|\zeta]\right] \tag{1.37}$$

where $G(k;a) = \mathbb{P}_a(\zeta \le k)$ is the unconditional cdf for types, given information acquisition a. The following proposition characterizes equilibrium in secondary markets for the case without commitment.

Proposition 6. *In any equilibrium without commitment,*

1. *Type $\zeta \in \{0, 1, ..., n\}$ mimics the issuance of types $k > \zeta$, and issues standard debt backed by remaining cashflows Y_ζ. Debt levels d_ζ are chosen to maximize the value of the ζ-type bank in $t = 1$:*

$$\max_{d_\zeta} \theta \mathbb{E}_{a^e,\mu}[\min\{d_\zeta, Y_\zeta\}] - \mathbb{E}_a[\min\{d_\zeta, Y_\zeta\}|\zeta] \tag{1.38}$$

2. *Given optimal debt levels as a function of a and a^e, equilibrium level of information acquisition a^* solves:*

$$\sum_{\zeta=0}^{n} \rho'_\zeta(a)\left[\theta p_\zeta + \mathbb{E}_a\left[\max\{Y - d_\zeta, 0\}\,|\zeta\right]\right] + \sum_{\zeta=0}^{n} \rho_\zeta(a)\frac{\partial}{\partial a}\mathbb{E}_a\left[\max\{Y - d_\zeta, 0\}\,|\zeta\right] - C'(a) = 0 \tag{1.39}$$

3. *Zero Profits:*

$$p(F) = \mathbb{E}_{a^e,\mu}[F(Y)] \tag{1.40}$$

The presence of multiple asset qualities in secondary markets rationalizes the high number of tranches issued for a given pool of loans. As in the one loan case, cashflows sold are decreasing in underlying quality; that is, $d_n \leq d_{n-1} \leq ... \leq d_0$. Note that the model does not predict that there are as many tranches as types, since types with an average portfolio quality are very likely to issue the junior tranche if adverse selection is not severe. The intuition behind tranching, however, is the same as the one described in the one loan baseline case. Comparative statics remain unchanged. I find that information acquisition is increasing in expected retention, and on the differential payoff higher types receive in secondary markets relative to lower types.

As the number of loans n in the pool increases, the volatility of cashflows Y decreases.[29] If this reduction in volatility reduces the expected adverse selection in secondary markets, expected retention levels should be therefore lower for larger pools of loans. This suggests that issuing securities backed by large pools of loans decreases incentives for information acquisition by reducing the adverse selection problem the bank expects to face when issuing an ABS. I continue this discussion when addressing the decision to pool loans.

Figure 1.5 plots the resulting issuance in an environments with multiple loans. In this scenario, the best type $\zeta = n$ issues the senior tranche $F_n(Y) = \min\{d_n, Y\}$. The second highest type, $\zeta = n-1$, issues the senior tranche F_n and the mezzanine tranche, $F_{n-1}(Y) = \min\{d_{n-1}, Y - F_n(Y)\}$. Type $\zeta = n-2$ mimics the issuance of types n and $n-1$, and issues the second mezzanine tranche. All types $\zeta < n-2$ issue a claim to all of their cashflows by selling senior and mezzanine tranches, and the reaming junior tranche. In what follows, allocations in environments with commitment are characterized.

The Optimal Mechanism: The Commitment Case. As in the one loan case, it can be shown that each type chooses to sell standard debt, with debt levels decreasing in the quality of underlying cashflows. The following proposition characterizes the solution to the commitment case.

Proposition 7. *In any equilibrium with commitment,*

[29] Note that ex-ante, $\mathbb{E}[Y] = \mathbb{E}[X]$ and that $\mathbb{V}[Y] = \frac{1}{n}\mathbb{V}[X]$.

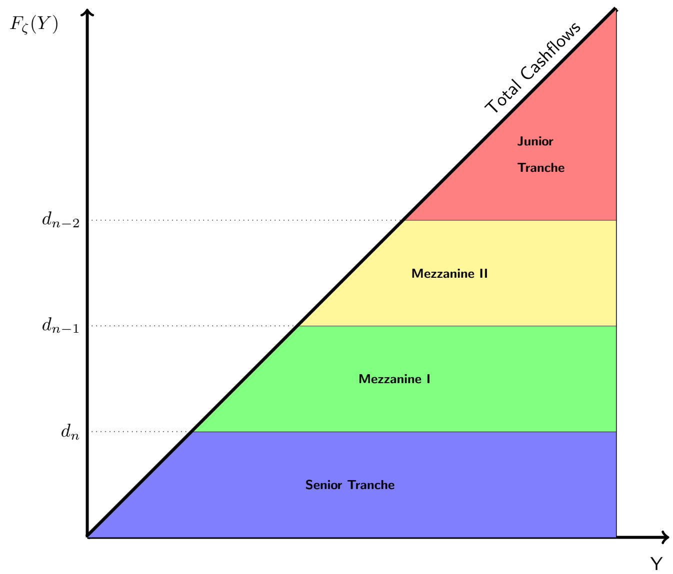

Figure 1.5: Pooling and Tranching

1. *For given debt levels, information acquisition solves:*

$$\sum_{\zeta=0}^{n} \rho_\zeta(a) \frac{\partial}{\partial a}\mathbb{E}_a\left[\max\left\{Y - d_\zeta, 0\right\}|\zeta\right] + \sum_{\zeta=0}^{n} \rho'_\zeta(a)\left\{\theta p_\zeta + \mathbb{E}_a\left[\max\left\{Y - d_\zeta, 0\right\}|\zeta\right]\right\} - C'(a) = 0 \tag{1.41}$$

2. *If the participation constraint for type $k \in \{0, 1, ...n\}$ does not bind in equilibrium, debt level d_k is given by the solution to:*

$$\theta\left(\sum_{\zeta=0}^{n} \rho_\zeta(a) \frac{\partial p_\zeta}{\partial a}\frac{\partial a}{\partial d_k}\right) + \rho_k(a)\int_{d_k}^{\infty} f_Y(y|\zeta = k)\, dy = 0 \tag{1.42}$$

if it $\exists$, if not $d_k = \infty$, where $\frac{\partial a}{\partial d_k}$ is the implicit derivative given by (1.41). Otherwise, d_k is given by the binding participation constraint:

$$\theta p_k + \mathbb{E}_a\left[Y - \min\left\{d_k, Y\right\}|k\right] = 0 \tag{1.43}$$

3. *Zero Profits:*

$$\sum_{\zeta=0}^{n} \rho_\zeta(a)\left[\mathbb{E}_a\left[F_\zeta(Y)|\zeta\right] - p_\zeta\right] = 0 \tag{1.44}$$

4. *Incentive Compatibility:*

$$\theta p_\zeta + \mathbb{E}_a\left[Y - F_\zeta(Y)|\zeta - 1\right] = \theta p_{\zeta-1} + \mathbb{E}_a\left[Y - F_{\zeta-1}(Y)|\zeta - 1\right] \quad \zeta = 1, ..., n \tag{1.45}$$

Transfers p_ζ are given by the Zero Profits and the Incentive Compatibility conditions. Information acquisition is chosen to improve the quality of expected retention and to affect the likelihood of holding a given pool quality in secondary markets. Debt levels are chosen to trade-off the gains from information acquisition with the gains from trade in secondary markets, given by the first and second term of equation (1.42) respectively. The intuition behind these results is the same as the one obtained for the two types baseline case. The results obtained in the baseline case with one loan are robust when the bank issues securities backed by pools of loans. The problem was solved under the assumption that all securities issued are backed by the sum of individual loan's cashflows, and that the bank cannot choose when to pool or not. In what follows, I discuss the implications of giving the bank the ability to choose whether to pool or not.

General Signal Structure

In this section, I remove the assumption that received signals are symmetric by allowing the bank to receive two signals with the following conditional distributions:

$$P\left(s_0 = H|q = H\right) = P\left(s_0 = L|q = L\right) = a \tag{1.46}$$

$$P\left(s_1 = H|q = H\right) = P\left(s_1 = L|q = L\right) = \tau(a) \tag{1.47}$$

where the only constraint is given by $\tau'(a) \geq 0$. Thus, the precision of the second signal can be independent of the initial level of investment in information (i.e. $\tau'(a) = 0$), or increasing in it (i.e. $\tau'(a) > 0$). This provides flexibility to the model where now the importance of the incentives problem in the loan issuance stage vs. the adverse selection in secondary markets can be calibrated.

In this scenario, since only the precision of the second signal has been changed, $\rho(a) = P(q = H|s_0 = H)$ remains unchanged, and the following conditional probabilities need to be re-computed as follows:

$$\rho_h(a) = P(z = z_h|s_0 = H) = \tau(a)\rho(a) + (1 - \tau(a))(1 - \rho(a)) \tag{1.48}$$

$$\pi_h(a) = P(q = H|z = z_h) = \frac{\tau(a)\rho(a)}{\tau(a)\rho(a) + (1 - \tau(a))(1 - \rho(a))} \tag{1.49}$$

$$\pi_l(a) = P(q = H|z = z_l) = \frac{(1 - \tau(a))\rho(a)}{(1 - \tau(a))\rho(a) + \tau(a)(1 - \rho(a))} \tag{1.50}$$

Note, however, that most of the results presented in this paper were given as a function of this conditional probabilities, and do not in general depend on their actual form. In particular, it continues to be true that $\rho_h'(a) > 0$ and that $\pi_h'(a) > 0$, the main difference being that now it is possible to have $\pi_l'(0) \neq 0$; that is, by investing in information the bank can affect the return of the bad loan as well.

Markets for ABS: The No Commitment Case. All qualitative results presented in Section 1.3 remain unchanged. Determination of debt levels in secondary markets is given by equation (1.11) and the choice of information acquisition is given by equation (1.15). Thus, the effect of generalizing the signal structure only affects quantitative results, where now equilibrium debt and information acquisition levels will vary depending on $\tau(a)$. Figure 1.6 shows how information acquisition and debt levels in equilibrium change as $\tau(a)$ changes. In particular, I model $\tau(a) = c + \tau \cdot (a - c)$ and study changes in both c and τ.

The Optimal Mechanism: The Commitment Case. The security design problem and thus determination of retention levels in the optimal mechanism changes slightly once the symmetry assumption is relaxed. To see this, note first that the choice of information acquisition continues to be given by the solution to (1.20), which is now given by:

$$\phi_h(a^*)\left(\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\right) + \phi_0(a^*)\left(\mathbb{E}_H[X - F_l] - \mathbb{E}_L[X - F_l]\right) = C'(a^*) \quad (1.51)$$

where $\phi_h(a) \equiv \rho_h'(a)(\pi_h(a) - \pi_l(a)) + \rho_h(a)\pi_h'(a)$ and $\phi_0(a) \equiv (1 - \rho_h(a))\pi_l'(a)$. Note that $\phi_h(a) \neq \phi_0(a)$ *a.s.* when $\tau'(a) > 0$. The following cases arise: (i) If $\pi_l'(a) \leq 0$, it not optimal for the bad type to retain.[30] (ii) If $\pi_l'(a) > 0$, it may be optimal for the bad type to retain less than the good type (but never more, since (1.22) has to hold). The level of retention imposed to the low type in this case results from the optimal trade-off between the gains from trade vs. gains from information acquisition.

In Case (i), the precision of the second signal is highly dependent on information acquisition. Thus, a very precise second low signal reduces the expected quality of the cashflows of the bad loan, in which case retention worsens incentives. As in the baseline case, the bank with the bad loan does not retain in this scenario and qualitative results are unaffected. For Cases (ii) and (iii), some retention from the bank with the bad loan may be desired since expected quality of retained tranches is increasing in "a" for all bank types. However, by the incentive compatibility constraints of the optimal mechanism, we know that retention can never be higher for the bank with the bad loan. Therefore, when a more general signal structure is allowed, retention levels are weakly decreasing in the quality of underlying cashflows. Since debt continues to be the design that implements a given level of information acquisition at the lowest retention cost, securities issued by the banks with bad loans in cases (ii) and (iii) continue to be standard debt. Optimal debt levels are chosen with the same rationale as in the baseline model (see equation (1.26)) where now there is one first-order condition for each debt level.

Figure 1.6 compares equilibrium allocations for markets for ABS and for the optimal mechanism as $\tau(a) = c$ changes. That is, the precision of the second signal is a constant that does not depend on initial levels of information acquisition. As we can see, welfare gains from implementing the optimal mechanism are larger when the precision of the second signal is small or large, and thus intermediate levels of adverse selection in ABS markets naturally implement welfare levels close the ones obtained with the optimal mechanism. In addition, note that issuance in ABS markets is inefficiently high and thus information

[30] This is the case when $\tau'(a) > \frac{\tau(a)(1-\tau(a))}{a(1-a)}$.

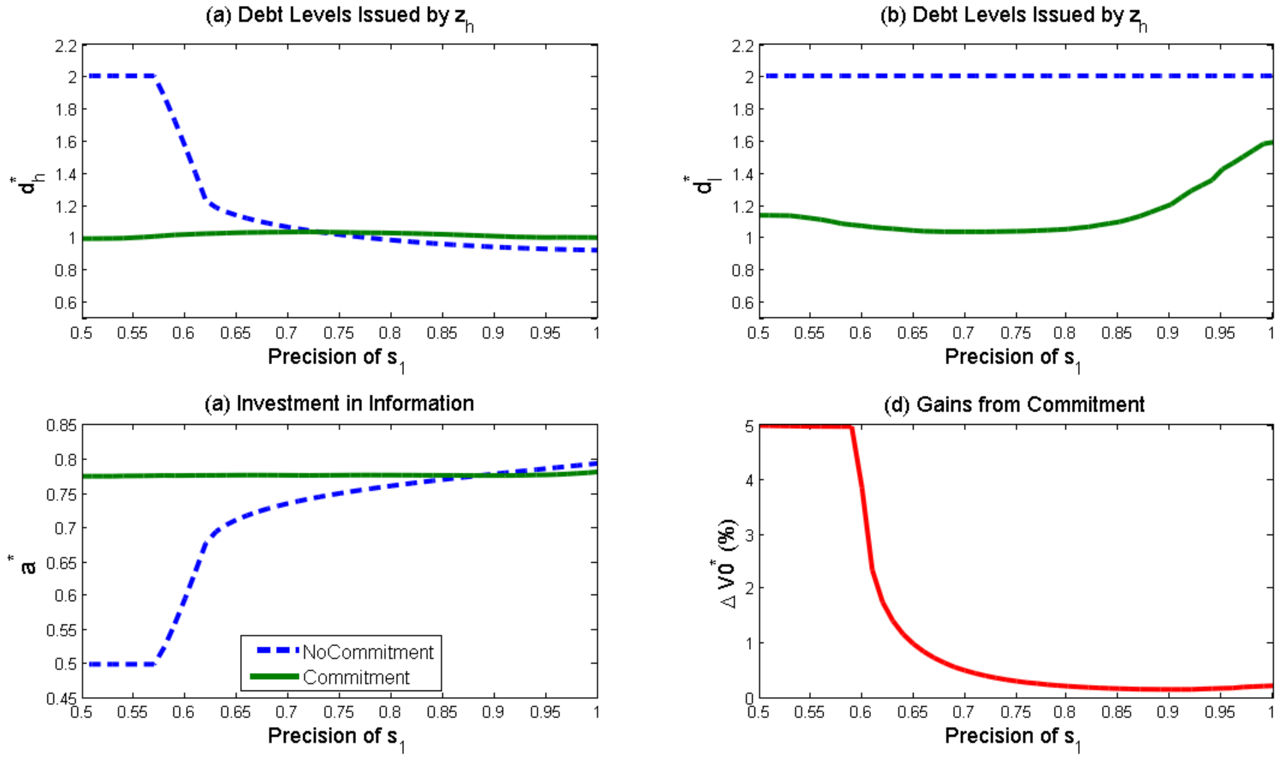

Figure 1.6: A More General Signal Structure

I assume $\tau(a) = c + 0.5(a - c)$. The distribution of X is given by a truncated normal in $[0, 2]$ with $\mathbb{E}_H[X] = 1.2$, $\mathbb{E}_L[X] = 0.7, V_H[X] = V_L[X] = 0.2$ respectively for good and bad projects, $\pi_H = 0.5$, $\theta = 1.15$ and information costs are given by $C(a) = 0.05(a - 0.5)^2 / (1 - a)$

acquisition and loan screening inefficiently low when adverse selection in secondary markets is low –low c. When adverse selection is not severe, and there are gains from trade, the bank with no commitment chooses ex-post to issue a large claim to its underlying cashflows, and thus equilibrium level of information acquisition is low. Conversely, when adverse selection is severe, ABS markets feature inefficiently low levels of trade and the problem is not one of incentives, but one where regulators should incentive issuance in ABS markets.

Other Extensions

In this section, I discuss how results presented in this model might change once other dimensions of markets for ABS are considered. Even though these extensions are not addressed formally in this paper, I believe they are promising questions to address in future research.

Rating Agencies. The role of rating agencies in this environment is straightforward, since it would overcome both the hidden-action and the adverse selection problem. Having the ability to send uninformed investor unbiased signals about loan quality would allow the bank to increase trade in secondary markets, and to be compensated from its investment in information (as long as signals are precise enough). Allocations in the presence of rating agencies might approach (or even attain), first-best allocations. Given the beneficial role that rating agencies have in this environment, it would be interesting to incorporate them by including the agency problems that arise in markets with rating shopping or rating inflation, as modeled by Bolton, Freixas, and Shapiro (2012)[12].

Securitization with Recourse. Securitization with recourse gives investors the ability to seek payment against a loan to the originator of the loan. Securitization with recourse could then help overcome some of the information frictions present in markets for ABS, since the bank is exposed to the cashflows of the sold loans by the guarantees given to the investor of the ABS. There is, however, a cost of securitizing with recourse not captured in my model since the bank is not able to fully share risks with the market –the bank continues to be exposed to the cashflows of the issued ABS. The analysis of how different forms of credit enhancements could help overcome the frictions present in this model is necessary. More formally, it requires removing the assumption that cashflows of the issued ABS can only be backed by the cashflows of the underlying loans; that is, there is no limited liability on the bank. For a discussion on effects of securitization with recourse, see Benveniste and Berger (1987)[5].

Investors Heterogeneity. Heterogeneity in investors preferences is used to rationalize the sophisticated types of tranching observed in practice. There is substantial evidence to suggest that this is the case, and that tranches are designed to tailor different type of investors. This is in addition to the results presented in this paper. By incorporating investors' heterogeneity into this model a richer set of securities might be obtained, but the presented frictions should not be affected by this extension. For the role of investor's heterogeneity see Boot and Thakor (1993)[13], Gorton and Pennacchi (1990)[45], Pagano and Volpin (2009)[66], Chemla and Hennessy (2011)[20], and for a richer discussion on tranching Farhi and Tirole (2012)[39].

Investor's Ability to Acquire Information. I have assumed in this paper that investors are not able to invest in information about bank quality. An interesting extension would then be then be to allow investors to acquire information as well, and study the role the market has on disciplining the bank's behavior. In this scenario, securities will be designed to provide incentives to investors to acquire information about bank quality, and by doing so, the informational frictions might be overcome. Using the predictions of Yang and Zeng (2013), where securities are designed to provide incentives to investors to acquire information in a production economy, we should expect securities in this scenario to differ from standard debt. In their paper, they find that a combination between debt and equity is desired. This suggests that issued ABS should then be more informationally sensitive than debt to enhance investor's incentives for information acquisition and bank monitoring.

1.7 Conclusions

In this paper, I have proposed a parsimonious framework to study markets for asset-backed securities (ABS). The model incorporates some of the key features of these markets, and it exploits the tension between incentives to acquire information to screen loans and liquidity in markets where ABS are issued. Loan issuers acquire private information about borrower quality, and while this information is beneficial ex-ante when used to screen loans, it becomes detrimental ex-post as it hinders gains from trade in markets where ABS are designed and traded. I have highlighted two inefficiencies that arise in these markets. First, the design of securities does not internalize its impact on the issuer's incentives to screen good quality loans. Second, markets for ABS distort the issuer's incentives by implicitly subsidizing issuers with bad loans at the expense of those with good loans (lemon's problem). In the optimal mechanism, these problems are addressed by committing to the design of securities ex-ante and by the appropriate design of transfers in secondary markets across banks with different loan quality.

I show that the optimal mechanism can be decentralized with simple tax scheme. In particular, subsidies to participation in the market for senior tranches, together with taxes for participation in the market for the junior tranches are beneficial since they improve incentives for information acquisition at no retention cost. This policy compensates banks with good loans for being mimicked by those with bad loans in secondary markets. These transfers together with policies that tax/subsidize debt levels implement second-best levels of information acquisition and issuance in ABS markets. In particular, retention levels should be imposed when markets for ABS are sufficiently liquid.

The result of this paper shed light on the costs and benefits of policy proposals for securitization: the "Skin in the Game" rule that requires issuers of asset-backed securities to retain a fraction of the underlying assets. My model rationalizes this type of intervention as a means to give incentives to improve loan screening only in markets with liquid secondary markets. The model further suggests that banks that claim to have good quality loans underlying their ABS may be required to retain more than those that claim to have bad quality loans. As a result, policies that demand the same retention levels of all issuers may impose excessive costs by hindering trade in secondary markets.

Chapter 2

Learning by Lending: Do Banks Learn?

Joint with Matthew Botsch

2.1 Introduction

When a firm approaches a bank to ask for a loan, the bank looks at the firm's observable characteristics to decide whether to approve the loan. It is very unlikely that these observables transmit all necessary information to evaluate how likely the firm is to default on the requested loan. One would expect that over time, if the loan is approved and subsequently monitored, the bank will learn something about the firm that was not reflected in the hard data provided with the initial loan application. In other words, through the process of establishing a relationship with the firm, the lender might obtain relevant but difficult-to-document "soft" information. By this we mean information that is qualitative in nature and consists mainly of ideas, opinions, rumors, feedback, or anecdotes which cannot be easily transmitted or verified by outside parties.

In line with this intuition, several studies have found evidence that borrower-lender relationships improve borrowers' access to credit. Research on relationship lending has shown that (i) there is something special about bank lending; and (ii) longer bank-firm relationships are correlated with cheaper access to credit. Slovin et al. (2003)[72] examine the stock price of borrowing firms after the announcement of the failure of their main bank, Continental Illinois. They find that Continental borrowers incurred negative abnormal returns of 4.2% on average. If bank loans were indistinguishable from corporate bonds, borrowers could borrow directly from the market when their bank disappeared. Similarly, if banks were perfectly substitutable, the failure of one lender should have no impact on borrowers' stock prices. Slovin et al. conclude that Continental had private information about the borrowers unavailable to the rest of the market. Gibson (1997) [43] reaches a similar conclusion by studying the effect of Japanese banks' health on borrowing firms. Petersen and Rajan (1995)

[68] and Berger at al. (1995) [6] show in independent studies that a longer bank relationship (controlling for firm age) implies better access to credit in the form of lower interest rates or collateral requirements.

In this paper, we investigate what mechanisms result in a firm having better access to credit when it has established a relationship with a bank. Does establishing a relationship allow banks to receive soft information about borrowers? Does this learning occur only within a relationship – private learning – or are there spillovers to the market via public learning? To address these questions, we borrow the methodology developed by Farber and Gibbons (1996) [38]. These authors focus on learning and wage dynamics and show that time-invariant variables correlated with ability but unobserved by employers are increasingly correlated with wages as a worker's tenure increases. This evidence supports the idea that firms learn about worker quality over time. In this paper, we focus on interest rate dynamics and show that time-invariant variables correlated with firm fundamentals but unobserved by banks are increasingly correlated with interest rates over the course of a bank-firm relationship. Our results provide evidence that banks are able to privately learn about borrower fundamentals in a way the market cannot.

We construct a panel of lender-borrower pairs ("relationships") observed repeatedly over time using the DealScan database on syndicated loans from Reuters LPC. DealScan provides detailed data for approximately 176,000 contracts comprising 248,000 syndicated loans made between 1981 and 2012. We match this extensive loan-level data with the financial characteristics of borrowing firms from the Compustat-CRSP Merged database. In our baseline loan pricing equations (similar to those developed in the banking literature), we show that even after controlling for observable borrower and loan characteristics, borrowers inside longer relationships pay cheaper loan spreads.

Why is there a discount for longer relationships? To test whether this is partially driven by bank learning about firm fundamentals, we construct a proxy for fundamentals which is not in the bank's information set. Our proxy is the differential response of the firms in our sample to a large negative aggregate shock: the recent financial crisis and the collapse of Lehman Brothers in September 2008. Specifically, we take the idiosyncratic component of firms' stock returns in the three months around the Lehman Brothers bankruptcy, and we orthogonalize it to all publicly-observable pricing variables at the beginning of each borrower-lender relationship in our sample, including the initial interest rate. For our identification strategy to work, the residual from this procedure must contain relevant pricing information about publicly-unobservable firm quality. We can be sure that banks are not learning directly about this proxy because the timing of its construction guarantees that it is never observed – the proxy is computed using future data. Moreover, the proxy is orthogonal to everything the bank used to price loans at the commencement of the relationship. Since we include the initial loan spread in the conditioning set, the orthogonalized proxy cannot be picking up the influence of omitted pricing variables.

However, we find that the orthogonalize proxy is increasingly relevant for loan prices as a relationship progresses. The orthogonalized proxy variable only contains information about firm fundamentals that were unobservable to each bank at the commencement of their relationship in our sample. We suggest that this information is correlated with private information that the bank acquires inside its lending relationship. To support this claim, we separately control for a second, public information proxy which only contains information about firm fundamentals that were unobservable to the market at the time each firm enters our sample. The private information proxy controls for each bank's initial information set, varying across relationships, while the public information proxy controls for the market's initial information set and only varies across firms. We find that even after controlling for market-wide learning about firm fundamentals over time, banks still price differentially on the private information proxy within a relationship. The relevant coefficient is 50 to 60% the magnitude of our initial estimate. This suggests that a significant portion of the value of bank lending is in private learning that occurs inside a relationship and is not shared by all market participants.

The unique structure of our dataset allows us to control for time-varying firm characteristics. Since we observe multiple syndicates lending to the same firm during the same year, we are able to include firm-year fixed effects and control for any time-varying omitted variables which may have a non-stationary correlation with the private information proxy. In these fixed effect specifications we are holding all firm characteristics constant and comparing how two banks with two different length relationships price a loan. We find that the bank with a longer relationship puts greater weight on the private information proxy. Furthermore, the relationship length discount is negligible in this specification, hinting that the only reason why relationship lending matters is because of the transmission of soft information about firm's fundamentals.

In Section 2.2 we present a simple borrower-lender model and discuss the theoretical foundations of our empirical exercise. Section 2.3 is the main part of the paper. First, we discuss the nature of our dataset and the construction of our control and proxy variables. Second, we present our main empirical specifications and their results. Third, we present some robustness tests and discuss our results. Section 3.5 concludes.

2.2 A Simple Theoretical Framework

A Simple Model

Before describing our data and our empirical strategy, we present a simple model of firm borrowing to discuss the determinants of loan agreements, and the role of information in credit markets. We model a competitive banking system of risk-neutral banks with sufficient funds to finance all profitable projects. These banks have access to a risk-free rate R^F, which is exogenously given for an individual bank. Firms have insufficient funds to self-finance their heterogenous risky investment projects. Funds must be invested at the beginning of each period and payoffs are realized at the end of each period.

When a bank meets a firm that is demanding a loan, it determines the interest rate so as to be indifferent between lending to this firm or investing in the risk-free rate. Let I_0 be the information set of the bank when it first meets a firm in the market, at time 0, and let π be the probability of the firm defaulting on the requested loan. We assume π is the firm's private information and we denote the bank's beliefs about π at time 0 by $p_0 = E[\pi|I_0]$, i.e. the bank's expected probability of the firm defaulting on its loan, conditional on all available information at their first encounter. The bank determines the interest rate, R_L, given collateral, C_L, loan amount, L, and beliefs p_0 according to its own binding participation constraint:

$$(1 - p_0) LR_{L,0} + p_0 C_{L,0} = LR^F$$

Let $C_{L,0} = c_{L,0}L$, with $c_{L,0} \in \left(0, R^F\right)$ [1]. Let $r_{L,0}$ be the log excess return charged on a loan, i.e. $r_{L,0} = \log\left(R_{L,0} - R^F\right)$. We can re-write the pricing equation as follows:

$$r_{L,0} = \log\left(\frac{p_0}{1 - p_0}\right) + \log\left(R^F - c_{L,0}\right)$$

This simple model predicts that the spread requested from a given loan increases with the expected default probability, p_0, and with the risk-free rate, and that it decreases with the percentage of the loan being collateralized. All of these results are standard and very intuitive.

We use this simple model to understand how the arrival of private signals about firm quality can affect the observed spreads on loans. If establishing a relationship with a firm allows the bank to observe private information about the firm's fundamentals, the bank should use this information to update its beliefs and recompute the required spreads.

Specifically, let $s^\tau = \{s_0, ..., s_\tau\}$ denote a time-series of i.i.d. private signals a bank receives during its relationship with a firm. The spread charged to the same firm for the same loan amount and same collateral after $\tau > 0$ periods will differ from the initial spread if s^τ is informative. Let $I_\tau = I_0 \bigcup \{s^\tau\}$. If signals are informative, $p_\tau = E[\pi|I_\tau] \neq E[\pi|I_0] = p_0$, and thus

$$r_{L,\tau} = \log\left(\frac{p_\tau}{1 - p_\tau}\right) + \log\left(R^F - c_{L,\tau}\right)$$

Of course, this pricing equation might no longer be valid in the presence of asymmetric information in financial markets since the market is no longer perfectly competitive. We are indirectly assuming that all the surplus that arises from the bank-firm lending contract accrues to the firm. We could relax this assumption by adding an extra term that reflects how much of the reduction in interest rates goes to the borrower, and how much is exploited

[1] Note that if $c_{L,0} \geq R^F$, the loan would be made at the risk-free rate since even in default states the lender can get her outside option. Since we are interested in cases in which default does entails a loss for the lender, we focus on $c < R^F$.

by the bank with private information.[2] What our model requires is that banks price to some extent on the arrival of private information, i.e., that the surplus arising from the relationship is shared. This is empirically the case.

In what follows we will decompose bank b's information set about firm f into three types of variables: $I_{fb,\tau} = \{x_{f,t_\tau}, z_{f,t_\tau}, s^{\tau}_{fb}\}$. The vector $x_{f,t}$ represents publicly-available characteristics of firm f at calendar time t which are observed by the bank but not by the econometrician (omitted variables). The vector $z_{f,t}$ contains public firm characteristics observed by both the bank and the econometrician (included variables). The set $s^{\tau}_{fb} = \{s_{fb,t_0}, s_{fb,t_1}, ..., s_{fb,t_\tau}\}$ represents the collection of private signals which only bank b observed during its relationship with firm f. The number of private signals is increasing in relationship length τ. For exposition purposes, suppose that firm characteristics $(x'_{f,t}, z'_{f,t})$ and other loan features $w_{l,fb,\tau}$ are time-invariant, so the "t" and "τ" subscripts may be suppressed. [3] We relax this assumption in the empirical section of the paper.

Consider a linearized version of the above pricing equation around the true default probability π[4]:

$$r_{l,fb,\tau} \approx \alpha_0 + \alpha_1 E[\pi | x_f, z_f, s^{\tau}_{fb}] + \gamma' w_{l,fb} \tag{2.1}$$

What if an econometrician could include the true default probability π in a panel regression along with observable characteristics $(z'_f, w_{fb,l})$? At relationship time 0, there would be a positive loading on π because of omitted variable bias: the bank's internal model includes variables x_f which are relevant for forecasting default probabilities and setting loan spreads. As a relationship progresses, the bank observes additional signals $s_{fb,t}$ which contain additional information about π not available in $\{x_f, z_f\}$. That is, the loading on π would increase over the course of the relationship due to private bank learning. This observation is at the heart of our empirical strategy.

Framework for the Empirical Strategy

Our aim is not to test this admittedly simple model but to use it as a motivation for our empirical specification. The core idea of our empirical strategy is taken from [38]. These authors focus on learning and wage dynamics and show that time-invariant variables correlated with ability but unobserved by employers are increasingly correlated with wages as a worker's experience increases. In this paper, we instead focus on interest rate dynamics and show that time-invariant variables correlated by firms' fundamentals but unobserved by

[2]When this assumption is relaxed, the pricing equation is given by $r = r_{L,\tau} + f(\Delta, \gamma)$ where $f(\Delta, \gamma)$ is the share assigned to the bank, and depends on the lowest interest rate offerred by a competitor, $r_{L,\tau} + \Delta$, and on the firm's bargaining power, denoted by γ.

[3]The "l" subscript on w counts if there are multiple loans between the same bank-firm pair at the same point in time.

[4]For example, a first-order Taylor series expansion gives $r_{l,fb,\tau} = \frac{-\pi}{1-\pi} + \frac{1}{\pi(1-\pi)} p_{fb,\tau} + \log(R^F - c_{l,fb}) + o(p_{fb,\tau} - \pi)$.

banks are increasingly correlated with interest rates as the bank-firm relationship increases. Our results provide evidence in favor of the idea that banks are able to learn over time about borrowers' fundamentals in a way the market cannot.

In our empirical model, we assume that the fth firm's default probability at time t follows an error-components structure which may depend on the macroeconomic environment m_t, industry-i-specific shocks v_i and idiosyncratic firm shocks $\xi_{f,t}$: $\tilde{\pi}_{f,t} := \eta_f + \tilde{\xi}_{f,t} = \eta_f + \alpha_m' m_t + v_i + \xi_{f,t}$.

We allow for arbitrary forms of cross-sectional and time-series correlation in the m_t and v_i components. These are nuisance parameters which may be removed by including time and industry fixed effects in our model, leaving two firm-specific components:

$$\pi_{f,t} := \eta_f + \xi_{f,t}$$

The parameter of interest to the bank as well as the econometrician is η_f, which we assume the bank does not know. We call this component a firm's latent *quality*. The following assumptions motivate our empirical strategy:

Assumption 2. *There is a stationary distribution* $F\left(\eta_f, \xi_{f,t}, x_{f,t}, z_{f,t}, b_f, s_{fb}^{\tau}, m_t, v_i\right)$ *known by all bankers; i.e. bankers have symmetric information about the underlying distributions.*

Assumption 3. *Our dataset contains a time-invariant, background firm characteristic* b_f *which is correlated with* η_f *but has no direct effect on the probability of default:* $E(\pi_{f,t}|\eta_f, b_f) = E(\pi_{f,t}|\eta_f)$.

Assumption 4. *Non-interest contract features are conditionally uninformative about default probabilities:* $E\left[\pi_{f,t}|x_{f,t}, z_{f,t}, s_{fb}^{\tau}, w_{l,fb,\tau}\right] = E\left[\pi_{f,t}|x_{f,t}, z_{f,t}, s_{fb}^{\tau}\right]$.

Assumption 5. *Firm characteristics* $(x_{f,t}', z_{f,t}')$ *are not informative about the idiosyncratic component of default probabilities:* $E\left[\xi_{f,t}|x_{f,t}, z_{f,t}\right] = 0$.

Assumption 6. *Default probabilities* $\{\pi_{f,t} : t = 1, ..., T\}$ *are cross-sectionally independent draws from a conditional distribution* $G\left(\pi_{f,t}|\eta_f, x_{f,t}, z_{f,t}\right)$*; i.e., shocks are conditionally i.i.d. across firms.*

Unlike Farber and Gibbons, we assume that the information held by banks about firm quality is asymmetric. All banks know the distribution $F\left(\eta_f, \xi_{f,t}, x_{f,t}, z_{f,t}, b_f, s_{fb}^{\tau}, m_t, v_i\right)$, and the conditional distribution $G\left(\pi_{f,t}|\eta_f, x_{f,t}, z_{f,t}\right)$, all observe $\{x_{f,t}, z_{f,t}\}$ and whether a firm has defaulted or not, but they differ on their observed set of signals s_{fb}^{τ} as well as the number of signals (the length of the relationship) τ. The claim that we test in this paper is that access to these private signals allows the inside bank to price loans to firm f better than outside banks with a less-established relationship.

Imagine a panel dataset covering a cohort of firms entering the market for bank loans and taking out one-period loans from initially identical, perfectly competitive banks. The data reveal some firm and loan characteristics relevant for loan pricing ($z_{f,t}$ and $w_{l,fb,\tau}$, respectively) when the loan is applied for at the beginning of each period, but omits some firm characteristics $x_{f,t}$ relied on by the banks. Motivated by our linearized model (2.1), and given Assumptions (2) to (6), we could estimate the following population linear projection:

$$\begin{aligned} E^*[r_{l,fb,\tau}|z_{f,t}, w_{l,fb,\tau}] &= \alpha_t + \alpha_i + \alpha_1 E^*[E[\pi|x_{f,t}, z_{f,t}, s^\tau_{fb}]|z_{f,t}, w_{l,fb,\tau}] + \gamma' w_{l,fb,\tau} \\ &= \alpha_t + \alpha_i + \alpha_1 E^*[\pi|z_{f,t}, w_{l,fb,\tau}] + \gamma' w_{l,fb,\tau} \\ &= \alpha_t + \alpha_i + \beta^{z\prime} z_{f,t} + \beta^{w\prime} w_{l,fb,\tau} \end{aligned} \tag{2.2}$$

We use Assumption (4) to apply the Law of Iterated Linear Projections. The coefficient on w reflects both the substitutability between other loan characteristics and interest rate spreads (γ) and the correlation between w and omitted firm characteristics x and private signals s.[5] Similarly, the coefficient on z incorporates both direct and indirect pricing effects due to omitted variables.

Unobserved Firm Characteristics. b_f is a background firm characteristic in our dataset, but not observed by banks, that is correlated with latent firm quality η_f. We expect that b_f is unconditionally correlated with variables we omit in our pricing equation, $x_{f,t}$, that the bank uses in its forecast model $E[\pi_{f,t}|x_{f,t}, z_{f,t} s^\tau_{fb}]$. To remove this dependency, we use the residual from a regression of b on all observable firm characteristics and on the interest rate of the first loan in each relationship in our dataset. Conditioning on the latter ensures that b^*_{fb} is orthogonal to all the information held by each bank at the start of each relationship in our sample, including x_{f,t_0}. Specifically, let

$$b^*_{fb} = b_f - E^*\left[b_f|z_{f,t_0}, w_{l,fb,0}, r_{l,fb,0}\right] \tag{2.3}$$

This residual removes the influence of all information the bank may have used to price its first loan to a firm from the original background variable, b_f. Unlike the original background variable, b^*_{fb} may vary across banks for the same firm, so it carries an "*fb*" subscript.

Consider adding b^*_{fb} as a regressor to 2.2 with a slope which is allowed to vary over relationship time:

$$r_{l,fb,\tau} = \alpha_t + \alpha_i + \beta' z_{f,t} + \gamma' w_{l,fb,\tau} + \delta_\tau \cdot b^*_{fb} + \varepsilon_{l,fb,\tau} \tag{2.4}$$

We are interested in studying the evolution of the coefficient δ_τ. By the usual partitioned regression logic, if we define $b^\tau_{fb} = b^*_{fb} - E^*[b^*_{fb}|z_{f,t}, w_{l,fb,\tau}, t, i]$ as the residual from regressing b^*_{fb} on all other explanatory variables, then $\delta_\tau = Cov(b^\tau_{fb}, r_{l,fb,\tau})/Var(b^\tau_{fb})$ calculated cross-sectionally across firm-bank pairs at the same relationship time τ. By construction $\delta_0 = 0$. As banks receive additional signals s^τ_{fb}, private information becomes increasingly important in their internal forecast model $E[\pi_{f,t}|x_{f,t}, z_{f,t} s^\tau_{fb}]$. To the extent that b^*_{fb} is correlated with

[5] In our empirical specifications we find that the second factor dominates.For example, loans with more collateral pay higher interest rates, presumably because these firms differ on omitted characteristics.

these private signals, the coefficient δ_τ should increase in magnitude with the number of signals and the length of the relationship τ.

In the next section we describe the construction of our dataset and how we test for private learning by constructing a time-invariant background variable b_f which is correlated with η_f but would have been impossible for banks to observe at the time the loans were made.

2.3 Empirical Analysis

In this section, we being by describing the dataset used for the empirical analysis. Next, we discuss our choice of a proxy variable for latent firm quality, b_f. Using this proxy, we proceed to test whether banks learn about customers as evidenced by an increasing loading on b_f within a specific lender-borrower relationship. We discuss and rule out several alternate explanations which might explain our findings, including public learning, time-varying omitted variables, and selection bias. Our results are consistent with the model described in the previous section. We find robust evidence that banks learn about unobserved firm characteristics while in a relationship.

Data

We construct a panel of lender-borrower pairs ("relationships") observed repeatedly over time. Specifically, we use the DealScan database on syndicated loans from Reuters LPC (April 2012 vintage). DealScan provides data for approximately 176,000 contracts comprising 248,000 syndicated loans made between 1981 and 2012, but the coverage between 1981 and 1987 is extremely limited; more than 99% of loans in the database start in 1988 or later. Syndicated loans are between a single borrower and a syndicate of lenders. One lender acts as the lead arranger and negotiates contract terms for the entire group. Most of the lenders are large commercial banks, but many syndicates include non-bank financial companies. After the contract is agreed to, a lender referred to as the agent monitors the performance of the loan. The lead arranger and agent can be different members of the syndicate. Each contract or "package" can include multiple loans or "facilities" made at the same time. A typical example is a borrower receiving both a term loan and a revolving line of credit.

Many of the rows in the DealScan tables contain missing values. The only filter we impose when tracking relationships over time is that lender and borrower IDs and deal dates are available, reducing our sample by approximately 3,000 facilities. For a given lender-borrower pair, we count every facility where that lender belongs to a syndicate lending to that borrower as an interaction in the relationship. There may be multiple observations at a particular moment in "relationship time" if a package contains multiple loan facilities. Since we care about the information set available to the lender at the time of the agreement, we order interactions by package date ("deal active date") rather than by each facility's specific start date. We restrict our analysis to "lead arranger relationships," defined as bank-firm pairs in which the bank served as the lead arranger for at least one facility. Lenders playing an active role in arranging loan terms have greater incentives to acquire borrower information than passive members of the syndicate. In 56 percent of the relationships in our final sample, the lender served as the lead arranger in every interaction we observe with that borrower.

Our panel dataset requires information on loan prices and firm financial characteristics which the bank might use to set interest rates. Our measure of loan price is the all-included drawn spread over LIBOR, which is the price including fees that a firm would pay if it drew upon 100% of its line of credit (for revolving loans), and simply the spread over LIBOR including fees for term loans. Dropping loans without an all-in spread reduces our sample to XX facilities. We obtain borrower financial data from Compustat using the link file created by Chava and Roberts (2008).[6] This reduces our sample by one half. Since our proxy variable is constructed from market data, we further require that the borrowers be publicly traded over the six-year period 2003-2008 and have stock return data available on CRSP (which we link using the CRSP-Compustat Merged database). Our data requirements restrict the sample to include only larger, more followed, and presumably more transparent firms. This should bias against finding any role for private bank learning. We drop all loans with a start date after 2003 to ensure the unobservability of our 2008-based proxy variable (see below), and we drop relationships in which the lender was never a lead arranger.

Our final dataset has 7,618 facilities and 5,740 relationships between 2,007 unique borrowing firms and 619 unique lenders. The deal active dates span the years 1987 to 2003. The average relationship lasts 3.5 interactions (approximately five years), and 10% of relationships last 7 or more interactions (approximately twelve or more years). Other summary statistics about the final sample of loans and relationships are provided in Table 2.1.

Observable Firm Characteristics

Our model requires that we condition on a subset of financial characteristics used by the bank in setting loan prices, $z_{f,t}$. Ideally these variables would be inclusive, so we do not have to worry about correlation between omitted variables $x_{f,t}$ and our proxy variable b_f (see the discussion below). While we could presumably condition on a laundry list of income statement ratios, we focus on a small subset of variables suggested in the literature on predicting corporate bankruptcies and defaults.

The oldest measure in this literature is Altman's Z score. [4] investigated the determinants of corporate bankruptcy for a sample of 33 manufacturing firms which filed for bankruptcy between 1946-1965 and 33 firms still in existence in 1966 based on random stratified matching by industry and size. He uses discriminant analysis to estimate the following index:

$$Z = (1.2 \cdot WC + 1.4 \cdot RE + 3.3 \cdot EBIT + 0.6 \cdot MVE + .999 * S)/AT$$

[6]We use the version of the link published on August 27, 2010, and made available on Wharton Research Data Services.

	N	Mean	SD	10th Percentile	90th Percentile
Panel A: Relationship Characteristics [1]	**5740**				
Length (# of interactions)		3.50	2.88	1	7
Calendar length (months)		57.6	61.7	1	143
Fraction always lead arranger		0.542			
Fraction sometimes agent		0.993			
Fraction always agent		0.650			
Panel B: Loan Characteristics [1]	**7618**				
All-in spread (bps)		138	116	25	300
Loan Size ($m)		358.4	727.9	10.0	864.0
Maturity (months)		36.4	24.8	12	60
Fraction revolver		0.630			
Fraction collateralized		0.347			
Fraction not collateralized		0.231			
Syndicate size		*todo*	*todo*	*todo*	*todo*
# times appears in relationship panel		1.8	1.2	1	3
Panel C: Borrowing Firm Characteristics [1]	**5509**				
Total assets ($b)		10.803	52.077	0.075	16.851
Average Q [2]		1.376	1.222	0.476	2.572
ROA (%)		3.260	11.598	-2.735	11.322
Z score		2.466	1.713	0.659	4.544
Naïve Probability of Default (% / 100)		0.056	0.179	0.001	0.114
Three-month CAR around Lehman (% / 100)		-0.082	0.367	-0.568	0.322
# facilities per borrower-date [3]		2.6	2.4	1	5

Table 2.1: Summary Statistics

Relationships where lender is sometimes the lead arranger (NTn = 13,954). Panel includes 2,007 unique borrowers and 619 unique lenders. Notes: [1] In Panel A, each observation is a lender-borrower pair; in Panel B, a facility; in Panel C, a firm-date. [2] Q = (E + P + D) / A, where E is market value of common equity, P is liquidating value of preferred stock, D is book value of long-term debt plus current liabilities net of (current assets less inventories), and A is book value of total assets. [3] Count includes multiple facilities per package and multiple packages taken out in same fiscal period.

where WC is working capital, RE is retained earnings, EBIT is earnings before interest and taxes, MVE is market value of equity, S is sales, and AT is total assets.[7] Altman concludes that “firms having a Z score of greater than 2.99 clearly fall into the ’non-bankrupt’ sector, while those firms having a Z below 1.81 are all bankrupt” (p. 606). So lower values of Z indicate an increased likelihood of bankruptcy. We winsorize the top and bottom 0.5% of Z-score observations using the sample of all DealScan firms for which we have data over the years 1985-2012.

Our second measure comes from the observation in [71] that the [11] options pricing model may also be used to calculate the market value of assets in place, by viewing the observed equity price as a call option on the unobserved market value of the entire firm. Once the market value of assets in place V_A has been estimated, a firm’s probability of default T periods into the future is the probability that the value of its assets will drift below the “strike” price–the book value of liabilities. Since the Merton model assumes that

[7] There is an error in the placement of a decimal point in the original 1968 paper. The correct formula is given in subsequent papers–e.g., Altman (1968)[4].

V_A follows a geometric Brownian motion with deterministic drift μ and volatility σ_A, this probability is given by

$$P(V_{A,t+T} \leq L_t | V_{A,t}) = \Phi\left(-\frac{log(V_{A,t}/L_t) + (\mu + \frac{1}{2}\sigma_A^2)T}{\sigma_A\sqrt{T}}\right)$$

To calculate this exact probability, one must solve the Black-Scholes equations for V_A and σ_A. Rather than using a numerical solver, we use the "naive" alternative proposed by Bharath and Shumway (2008). This naive probability of default uses simple rules of thumb for variables in the formula above: L_t is the book value of debt in current liabilities plus one-half the book value long-term debt; V_A is the sum of market value of equity plus book value of liabilities; equity volatility σ_E is the annualized standard deviation of the previous year's daily stock returns; debt volatility $\sigma_L = .05 + .25 \cdot \sigma_E$; and total firm volatility is the weighted sum of σ_E and σ_L. We solve for the naive probability of default for firm f at time t, $NPD_{f,t}$ for a one-year time horizon. In all tables and regressions, we truncate the probability of default to take values in the range $[0.001, 0.999]$.

Our observable firm characteristics which are relevant for loan pricing are thus two measures for predicting corporate bankruptcy or default on debt obligations: $z_{f,t} = (Z_{f,t}, NPD_{f,t})'$.

Construction of the Private Information Proxy

A good background variable b_f cannot be in the bank's information set at any time and it must be correlated with the firm's unobservable latent quality, η_f. Our candidate background variable is the differential response of the firms in our sample to a large negative aggregate shock: the onset of the financial crisis and the collapse of Lehman Brothers in September 2008. Specifically, we consider the idiosyncratic component of firms' stock returns in the three months around the Lehman Brothers bankruptcy. By using equity market data from five years after the last loan in our sample was made, we guarantee that the proxy cannot have been observed by banks in real time. Lehman's bankruptcy filing was a "shock" in the sense that it was not foreseen by market participants and triggered a re-evaluation of expected returns on investments across the entire economy. When Bear Stearns failed six months earlier, the Fed and the Treasury avoided the bankruptcy process and arranged its purchase by JP Morgan Chase precisely to ameliorate turmoil in financial markets.

We require that idiosyncratic stock returns around the Lehman filing were partially driven by firms' latent ability. Suppose that during booms it is hard to differentiate good firms from bad firms, while during busts lemons are easier to identify. Those firms that perform relatively better during crises are spotted as high-quality firms, and investors should incorporate this information into the stock price. Moreover, the returns to identifying lemons might be greater in crisis states of the world; in booms all firms do well, while in busts only good firms do well. If signals about firm quality became more informative after Lehman, or if investors' incentives to acquire costly information increased, then the main news content in the months after this shock should be a reassessment of firm quality. Of course, a component of firms' stock returns during this period undoubtedly reflect subprime-crisis-specific exposure. To the extent that subprime exposure is industry-specific, we can remove this influence with industry fixed effects. Our identifying assumption is that at least part of firms' idiosyncratic returns are due to underlying firm characteristics that were revealed after Lehman, and not to subprime-crisis-specific risk exposure. We do not interpret loadings on the proxy as changes in the perceived probability of a Lehman-style crisis occurring, as we find it implausible that this risk was priced in loans made a decade or more in advance.

We construct b_f as follows. We compute the cumulative abnormal return of each firm in a [-21, +42] day window centered around the collapse of Lehman:[8]

$$b_f := \sum_{s=-21}^{+42} \left(R_{f,s} - R^F\right) - \hat{\beta}'_f \left(R_{factor,s}\right) \tag{2.5}$$

where $R_{f,s}$ and $R_{factor,s}$ denote the daily returns on a firm's stock and the four [37] - [19] factors at time s, R^F denotes the risk-free rate, and $s = 0$ is September 15, 2008. The factor betas are estimated from time-series regressions of daily excess stock returns over 2003-2007:

$$R_{f,t} - R^F = \alpha_f + \beta'_f \left(R_{factor,t}\right) + \varepsilon_{f,t} \tag{2.6}$$

With each firm's CAR in hand, the final **private information proxy** is given by (2.3). We define relationship time 0 as the time of the first loan between a firm-bank pair in our sample. It is likely that the time of first observation is not the first interaction between a bank and firm for many loans. Nevertheless, by orthogonalizing at the first non-censored observation, we can remove the influence both of omitted variables and of any private learning that may have occurred within the censored relationship observations. To the extent that learning is diminishing over time, the inclusion of mature relationships will bias our estimates toward zero.

The orthogonalization guarantees that b^*_{fb} is uncorrelated with relevant omitted firm characteristics at the start of each relationship, x_{f,t_0}. However, a failure of Assumption 4 would pose an identification problem if the idiosyncratic component of default probability $\xi_{f,t}$ and omitted variables $x_{f,t}$ jointly exhibit within-firm autocorrelation. That is, since b^*_{fb} is from the future, the proxy could simply be picking up future innovations in a firm's default probability which are correlated with subsequent movements in publicly available variables. The unique structure of our panel dataset, in which we observe the same borrower in different relationships at the same period in calendar time, will allow us to resolve this problem by applying firm-year fixed effects

The coefficients from the orthogonalization regression are presented in the first column of Table 2. Note in particular that the all-in-spread at time zero is negatively correlated with the Lehman proxy, even after controlling for Z score, naive probability of default, other

[8]Starting on August 14 and ending on November 12.

loan characteristics, and industry fixed effects. A firm paying an additional 100 basis points on its first loan in our dataset is expected to experience an additional 2.7 percentage point negative CAR in thethree-month window around Lehman. This indicates that initial loan prices contain omitted information which is correlated in the correct direction with the proxy variable. The private information proxy b^*_{fb} is simply the residual from this regression.[9]

Testing for Bank Learning

We begin the main part our analysis by estimating a standard pricing equation, to be sure that our data replicates results already highlighted in the literature. We regress the all-in drawn spread of each loan on firm and loan characteristics, and on relationship time:

$$r_{l,fb,\tau} = \alpha_t + \alpha_i + \beta' z_{f,t} + \gamma' w_{l,fb,\tau} + \varphi \cdot \tau + u_{l,fb,\tau} \tag{2.7}$$

where each observation is given by a loan l between firm f and bank b at relationship time τ. We control for year t and two-digit SIC industry i with fixed effects. Results are presented in the second column of Table 2.2. Larger predicted probabilities of default (lower Z score and higher NPD) are associated with higher spreads, while longer relationships are associated with a discount in the spread equal to 3.7 basis points per interaction. Secured loans have on average higher spreads, a seemingly counterintuitive result. This and other loan characteristics are likely reflecting some unobservable characteristic that the bank is pricing. If secured loans are of worse quality on unobservables, then they should pay higher spreads. Finally, we find that longer-term and revolver loans are associated with higher interest rates (although the coefficient on loan maturity is not statistically significant).

The main result from this regression is that having an established relationship with a bank lowers the cost of credit for a firm even after controlling for relevant pricing characteristics. The effect is independent of a borrower's quality, as measured by Z score and NPD. We proceed to test whether this relationship discount is due to unobserved learning or something else.

In our baseline learning specification, we add the private information proxy b^*_{fb} to the previous regression. By construction the proxy variable can have no effect on loan prices at relationship time zero. The test is whether the loading varies over relationship time and whether "better" firms receive a discount. The coefficient of interest is δ_τ in the following specification:

$$r_{l,fb,\tau} = \alpha_t + \alpha_i + \beta' z_{f,t} + \gamma' w_{l,fb,\tau} + \delta_0 \cdot b^*_{fb} + \delta_\tau \cdot \left(b^*_{fb} \times \tau\right) + \varphi \cdot \tau + u_{l,fb,\tau} \tag{2.8}$$

Estimates are presented in the third column of Table 2.2. First note that the inclusion of our proxy variable does not affect any of the results obtained in the baseline case. Second,

[9] If the initial package contained more than one facility, we include in the regression all loans in that package. The private information proxy is then the average of the residuals: $b^*_{fb} = 1/L \sum_{l=1}^{L} b^*_{l,fb}$.

the coefficient on the proxy variable interacted with relationship time has a highly significant effect on the pricing of a firm's loans. Consider a one standard deviation increase in the proxy, an increase in the CAR of 0.37 log units (i.e., 37 percentage points). Holding other firm and loan features constant, this firm would benefit from a reduction in its interest rate on bank loans of (-5.337)·(0.37) = -1.96 basis points per renewal. On an average sized loan ($358 million), this would result in annual savings of $70 thousand per year. Since the average maturity of a loan in our sample is just over four years, the total savings from renewing its loan with an existing lender instead of switching lenders is $280 thousand for the first renewal. The savings increases with relationship length: on the fifth renewal it would be $1.4 million.[10] Put another way, a one S.D. increase in the proxy has the same benefit per renewal on loan prices as a 1.4 percentage point decrease in the Merton-Bharath-Shumway naive probability of default.

We conclude from this regression that the proxy variable is correlated with information that banks use to price loans. Furthermore, the banks did not have this information at the time of the first loan in our sample. In the next section we test whether the effect is unique to banks that have a relationship with a firm. In other words, is learning public or private?

Public vs. Private Learning

The previous regression has shown that banks act "as if" (to quote Milton Friedman) they price loans on what we have referred to as a private information proxy. This proxy derives from stock market returns in the second half of 2008, while the most recent loan in our sample is from August 2003, so banks cannot have actually priced on this proxy. This suggests that information correlated with both the proxy and latent firm quality is revealed to market participants as relationship time increases. However, we have not ruled out the alternate explanation that learning is public. That is, it is possible that banks learn about firm quality over time, but this information is non-excludable and the benefits diffuse across all lenders. To distinguish between private and public learning, we need access to a second proxy which only contains information about firm fundamentals that were unobservable to the market at the time of a firm's first syndicated loan in our sample, t_{00}. By being orthogonalized to information available to the market at the time the firm enters our sample, this proxy should reflect any pricing based on public information. We construct such a **public information proxy** as follows:

$$b_f^* = b_f - E^* \left[b_f | z_{f,t_{00}}, w_{l,fb,00}, r_{l,fb,00} \right] \tag{2.9}$$

The public information proxy only varies across firms, not across relationships. To the extent that learning about firm quality is public, the loading of interest rates on the public information proxy should increase with the time that the firm has been present in the market. If all bank learning about firm quality is public, then the loading on the private information

[10] This savings is about half the magnitude of the baseline relationship effect, a discount of 3.7 basis points per renewal.

Dependent variable:	*Lehman Proxy*	*Interest Rate spread over LIBOR (in bps)*	
	(1)	(2)	(3)
All-in Spread at Rel. Time 0	-0.000268***		
	(0.000)		
Borrower's Z score	0.0228***	-9.674***	-9.611***
	(0.004)	(0.918)	(0.924)
Naïve Probability of Default	-0.0077	143.4***	142.9***
	(0.027)	(9.741)	(9.612)
Relationship Time		-3.731***	-3.743***
		(0.577)	(0.571)
Private Info Proxy (see note)			3.269
			(4.044)
Private Info. Proxy *			-5.337***
Relationship Time			(1.361)
Total Assets ($b)	-0.000103*	-0.151***	-0.152***
	(0.000)	(0.026)	(0.026)
1{loan is secured}	-0.0263*	109.0***	109.0***
	(0.013)	(3.585)	(3.610)
1{loan is not secured}	0.00952	-1.54	-1.596
	(0.010)	(2.068)	(2.074)
Loan Maturity (months)	-0.000598***	6.62E-02	6.63E-02
	(0.000)	(0.046)	(0.046)
1{revolver loan}	0.0157*	6.697***	6.591***
	-0.00931	-2.073	-2.081
Year FX	YES	YES	YES
Industry FX	YES	YES	YES
Observations	7,390	13,954	13,954
R-squared	0.238	0.489	0.49

Standard errors clustered by lender in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 2.2: Do Banks Learn?

OLS Panel regression of bank-firm "relationships" over time. Notes: [1] The "Lehman proxy" is the 3-month cumulative abnormal return from a Fama-French-Carhart four-factor centered around the Lehman bankruptcy of 9/15/2008. [2] Column 1 reports a cross-sectional regression of the proxy on all dependent and independent variables as of the first interaction between each borrower-lender pair in our sample (relationship time 0). This may include multiple facilities per relationship. [3] Columns 2 and 3 uses the residuals from Column 1 as the "orthogonalized" Private Info Proxy. This proxy is re-calculated whenever a borrower changes lenders.

proxy within a specific bank-firm relationship should drop out once we control for market-wide learning. To implement this test we estimate the following regression equation:

$$r_{l,fb,\tau} = \alpha_t+\alpha_i+\beta' z_{f,t}+\gamma' w_{l,fb,\tau}+\delta_0 b^*_{fb}+\delta_\tau\cdot\left(b^*_{fb}\times\tau\right)+\delta_{00}b^*_f+\delta_t\cdot\left(b^*_f\times(t-t_{00})\right)+\varphi_\tau\cdot\tau+\varphi_t\cdot(t-t_{00})+u_{l,fb,\tau} \tag{2.10}$$

Results are presented in the first column of 2.4. The estimated value of δ_τ is -2.7 and of δ_t is -2.8. Both coefficients are about half the magnitude of our baseline estimate of -5.3 from Table 2, column 3, and both are significant at smaller than the 5% level. These results suggest that banks outside a relationship do in fact learn about the firm's quality over time.

This may be due to the evolution of observable fundamentals that we omit from our pricing equation ($x_{f,t}$). It could also indicate that outside banks are able to partially infer the inside bank's private information from publicly-observable signals such as the terms of loan renewals. However, even after controlling for the possible presence of market-wide learning, we continue to find a large and statistically significant loading on the private information proxy. Banks inside a relationship are able to price on firm quality differentially from banks outside a relationship. This is strong evidence in favor of our argument that information about firm quality is privately transmitted inside the bank-firm relationship.

Alternate Explanations

Forecast Window Effect

One potential confounding factor is that our private information proxy is taken from future financial market data. It might be the case that all market participants are forecasting some factor correlated with b^*_{fb}, such as future earnings, and that these forecasts mechanically become more accurate as $t \to 2008$ simply because the forecast window is shrinking. To be confounding, such an effect would have to manifest as an interaction between the private proxy and calendar time. If there were something special merely about time until 2008, it would be picked up by the calendar year fixed effects. Furthermore, we have already controlled for market-wide pricing on the public component of our background variable in Table 3, column 1. An important component of loan pricing specifically appears to occur inside a relationship, which is evidence of private bank learning.

As a robustness test, we re-run regression (2.10) with the private information proxy interacted with indicator variables for each year. This specification should remove any mechanical correlation between the private information proxy and loan rates which depends on calendar time but is independent of relationship time, such as a forecast window effect. The estimates from this specification are presented in the second column of Table 2.4. The results are very similar to our tests for public learning and do not alter our finding that the private proxy interacted with relationship time is an important factor in the bank's pricing decisions.

Omitted Firm Variables

So far we have assumed that the banks can only learn about the permanent component of default probability η_f. This comes from Assumption 4, that firm characteristics are uninformative about the idiosyncratic component of default probabilities $\xi_{f,t}$. A plausible alternative assumption is that firm characteristics and idiosyncratic shocks $(\xi_{f,t}, z'_{f,t}, x'_{f,t})$ exhibit contemporaneous correlation, for example due to a common driving process or a triangular VAR structure. It can be shown that if $\xi_{f,t}$ exhibits serial correlation, then the magnitude of $Cov(b^*_{fb}, x_{f,t})$ is increasing in t. Intuitively, the non-orthogonalized background variable contains information about both the total default probability and omitted firm

Dependent variable:	*Interest Rate spread over LIBOR (in bps)*		
	(1)	(2)	(3)
Borrower's Z score	-9.625***	-9.668***	-6.306
	(0.859)	(0.865)	(5.885)
Naïve Probability of Default	138.8***	137.5***	164.8***
	(9.489)	(9.402)	(57.290)
Relationship Time	-1.953***	-1.850***	0.0424
	(0.502)	(0.495)	(0.131)
Years in Market	-2.391***	-2.481***	*absorbed*
	(0.275)	(0.286)	*by FX*
Private Info Proxy	66.49**	*absorbed*	79.46***
	(26.610)	*by FX*	(19.130)
Public Info Proxy	-54.63**	*absorbed*	*absorbed*
	(26.660)	*by FX*	*by FX*
Private Info Proxy *	-2.703*	-3.153**	-1.440**
Relationship Time	(1.430)	(1.489)	(0.568)
Public Info Proxy *	-2.794***	-2.153***	*absorbed*
Years in Market	(0.705)	(0.789)	*by FX*
Total Assets ($b)	-0.157***	-0.152***	-0.165
	(0.026)	(0.026)	(0.169)
1{loan is secured}	107.3***	106.9***	16.14***
	(3.482)	(3.427)	(4.857)
1{loan is not secured}	-0.276	-0.4	-12.29***
	(1.984)	(1.944)	(2.472)
Loan Maturity (months)	0.0608	0.0597	0.108***
	(0.046)	(0.046)	(0.028)
1{revolver loan}	6.347***	6.371***	-5.718***
	(2.047)	(2.033)	(1.320)
Year FX	YES	YES	YES
Industry FX	YES	YES	YES
Proxy*Year FX		YES	
Borrower*Year FX			YES
Observations	13,954	13,954	13,954
R-squared	0.497	0.502	0.958

Standard errors clustered by lender in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 2.3: Private vs. Public Learning

OLS Panel regression of bank-firm "relationships" over time. Notes: [1] The proxy variables are constructed from a 3-month cumulative abnormal return in a Fama-French-Carhart four-factor model centered around the Lehman bankruptcy of 9/15/2008. [2] The Private Info Proxy is re-orthogonalized to all dependent and independent variables at the beginning of each relationship (Table 2.2 col. 1). The Public Info Proxy is orthogonalized only once: the first time the firm enters the market.

characteristics in 2008. The orthogonalization procedure removes the influence of omitted variables at relationship time 0 but leaves information about total default probability. If subsequent values of x contain information about subsequent innovations in the default probability, this will show up as a correlation with the orthogonalized private information proxy. As the innovations accumulate, the correlation will increase in magnitude. This will exhibit as omitted variable bias in our regressions – we would mistake banks pricing on publicly-observable variables for private learning.

Our data includes multiple banks lending to the same firm during the same calendar year, so it is possible to control for firm-by-time omitted variables $x_{f,t}$ using firm-year fixed effects. Within a firm-year, two banks should price loans differently only if they have access to different private information, s^{τ}_{fb}. This test is very stringent: the fixed effects alone absorb over 96% of the variation in the all-in spread.[11] The remaining variation comes from banks in different syndicates lending to the same firm f in the same calendar year t but with different length relationships τ. The coefficients on relationship time and its interaction with the private information proxy are identified from this remaining variation.

Firm-year fixed effect results are presented in the third column of Table 2.4. The firm-year fixed effects absorb the public information proxy and its interaction with market time, so coefficients on those variables are not shown. The fixed effects absorb most but not all of the variation in the annual firm controls – these variables do not drop out due to heterogeneity in fiscal year-end dates. In particular, the market-based NPD remains significant and similar in magnitude to previous equations.

The coefficient of interest to us is the interaction between the orthogonalized proxy and relationship time. Even in this very demanding specification, the coefficient remains statistically different from zero. The magnitude is about a quarter as big as our baseline estimate: a one S.D. increase in the CAR is now associated with a half basis point discount per renewal. We note with some surprise that relationship length is by itself economically small, not significant, and the wrong sign. This suggests that after controlling for all possible firm characteristics, the only remaining channel through which relationships matter is the transmission of private information.

Our theory once again passes the test: the private information proxy is not merely capturing some publicly-observable, omitted firm characteristic that varies over time. It suggests that within a relationship, banks receive private information that allows them to better estimate firm quality, and that this information is used when pricing a firm's loans.

Other Possible Explanations

In this subsection we discuss other possible explanations for our results.

[11] Also, firms which take out loans from different syndicates in the same year may differ systematically from firms which take out loans with only one syndicate in the same year.

Dependent variable:	*Lehman Proxy*		
	(1)	(2)	(3)
Longest Active Relationship as of 12/2003	0.00432		
	(0.003)		
Longest Relationship in Sample as of 12/2003		0.00583*	
		(0.003)	
Years in Market as of 12/2003			0.00134
			(0.002)
Constant	-0.100***	-0.105***	-0.0990***
	(0.011)	(0.012)	(0.014)
Observations	2002	2002	2002
R-squared	0.001	0.001	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.4: Do Long Relationships Predict our Proxy?

OLS cross-sectional regression of borrowing firms in 2003.

Functional form misspecification. Suppose the true pricing equation is a non-linear function of firm characteristics z, and that the proxy variable is correlated with this non-linear function. Controlling for z in a linear fashion is misspecified and does not remove the relevant correlation. However, any spurious relationship between b^*_{fb} and $r_{l,f,\tau}$ should be constant over time. This does not explain our result that the loading on the proxy increases with relationship time.

Selection bias. Suppose that banks screen on omitted but publicly-observable firm characteristics x, so that only the best firms have long-term relationships. In the extreme case, imagine that there are two firms, G and B. Firm G stays in a long-term relationship with its bank and pays a low interest rate because it is high quality, while firm B switches banks every period and pays a high interest rate because it is low quality. This would create a negative correlation between relationship length and interest rate spreads in our data. However, we control for relationship length and find that the interaction between relationship length and the proxy variable also matters.

Reverse causality. It might be the case that firms with longer relationships had easier access to funds during the credit crunch surrounding Lehman, enabling them to better weather the shock. If firms in longer relationships receive lower interest rates for reasons unrelated to bank learning, we could find a spurious correlation between interest rates and the Lehman CAR which is increasing in relationship length. To address this point, we compute the correlation between the Lehman CAR and the length of a firm's longest active banking relationship in December 2003, the last year of our sample. We label a relationship as "active" if the most recent loan in the relationship either matured after November 2001 or was still in place. The results are presented in Table **??**. We find a weak correlation between a firm's longest relationship and its CAR to Lehman, but the effect is only significant (at the marginal 10% level) when we include both active and inactive relationships. We find no statistically significant correlation between a firm's time in the market or its longest active relationship and its response to Lehman. Moreover, the R-squared from all three specifications is essentially zero, indicating that any possible role for reverse causality is extremely small.

2.4 Conclusions

We began this paper by posing the question, "Do banks learn?" Our answer is a resounding yes. We first verified that borrowers inside longer relationships pay cheaper loan spreads, as previously shown in the literature of relationship lending. We then tested whether this reduction in spreads could be partially driven by banks learning about firm fundamentals using the methodology developed in Farber and Gibbons (1996). We constructed a proxy for firm fundamentals which is orthogonal to the bank's information set, based on the differential response of the firms to the collapse of Lehman Brothers in September 2008. We argue that this contains relevant information about firm's tail risk, which is precisely what lenders care about when pricing loans in this market. We showed that our proxy is increasingly relevant for loan prices as a relationship progresses. Even after controlling for market-wide learning about firm fundamentals over time, banks still price differentially on the private information proxy within a relationship.

Chapter 3

Informed Intermediation Over the Cyle

Joint with Vladimir Asriyan

3.1 Introduction

Credit cycles are a pervasive feature of all modern economies. As documented by Reinhart and Reinhart (2010)[70], financial crises are preceded by long periods of credit expansion and rising leverage, and followed by slow recoveries initiated by flight to quality episodes and strong cuts on new lending that can take up to a decade to recover. Another well documented feature of these crises is the asymmetric behavior of credit and investment: strong booms are followed by sharp declines and gradual rebounds. Since the financial sector plays a prominent role in the intermediation of funds between savers and borrowers, understanding the behavior of financial intermediaries should shed some light on the forces that underpin these credit cycles. Financial intermediaries such as banks, hedge funds, and pension funds manage the major bulk of household financial holdings and are the dominant source of external finance for non-financial businesses in all economies. As Gorton and Winton (2002)[46] state, "the savings-investment process, the workings of capital markets, corporate finance decisions, and consumer portfolio choices cannot be understood without studying financial intermediation." We adopt this view here and present a simple framework that puts a central emphasis on financial intermediaries.

We construct a dynamic model of financial intermediation in which changes in the information held by financial intermediaries allow us to rationalize key features of the documented credit cycles, but also of the financial contracts observed in practice. We suppose that some agents in the economy, whom we call "experts", have a unique ability to acquire information about firm and sector fundamentals. Better information allows for better allocation of resources, and this informational advantage makes these experts the natural contenders to intermediate funds between households and businesses. The level of "expertize" in the economy and the potential gains from intermediation grow in tandem with the information that these experts possess; these gains, however, are hindered since experts' information is inherently private. Financial contracts must be strained to balance allocational efficiency with the provision of appropriate incentives for these experts. The economy therefore inherits not only the dynamic nature of information flow, but also the interaction of information with the contractual setting. We introduce a cyclical component to information by supposing that the fundamentals about which experts acquire information are stochastic. While persistence of fundamentals is essential for information to be valuable, their randomness acts as an opposing force and diminishes the value of expert learning.

The combination of a model of financial intermediation and a dynamic model of private information not only allows us to study credit cycles from a new perspective, but it also provides new testable predictions about the connection between confidence in the financial sector, intermediation fees, and financial players' portfolios. We provide a novel mechanism that connects the severity of credit contractions with structural changes in an economy, understood as changes in the underlying productivities of different economic sectors. In our model, the financial system amplifies and propagates real shocks to fundamentals by contracting credit to productive sectors, and by slowing down the access of these sectors to credit in the years to follow. The intuition of the mechanism is as follows. During stable times, financial intermediaries raise funds, lend, and acquire information. Over time their expertise increases, their perceived uncertainty about the investment set is reduced, and this is reflected in higher credit to risky sectors. On top of this, households' confidence in experts increases, and so do intermediation fees in response. Given the nature of our learning process, unexpected changes in underlying fundamentals act as a volatility shock for financial intermediaries, since their accumulated expertize becomes obsolete. This generates a loss of confidence in financial intermediaries, a reduction in their fees, and a contraction of credit to risky sectors. As time passes, intermediaries accumulate information again, and credit slowly recovers, together with the confidence in the financial sector and its fees.

We find that economic fluctuations can be rationalized by waves of "confidence" in the experts' ability to allocate funds profitably. The asymmetry of credit cycles arises from the asymmetric nature of information acquisition: even though it takes time to acquire information through a learning-by-lending process, expertize can be lost the moment a shock to fundamentals is perceived. Credit to risky sectors responds one to one to these changes in expertize, and so do intermediation fees. These results arise in a framework in which optimal intermediation contracts match those observed in reality: a portfolio manager receives an intermediation fee that is proportional to assets under management, and a percentage of the total portfolio. In the literature on intermediation fees the fraction of the portfolio is referred to as an incentive fee, since in most of the literature moral hazard is the prevalent friction. In our paper, as there is no moral hazard, sharing portfolio returns is the result of risk-sharing between households and experts rather than incentives. We believe both arguments are reasonable, reality is probably in between. Given the optimal contracts that we find, we analyze how allocations evolve as information, and thus financial expertize, is accumulated.

We consider an overlapping generations model with heterogeneous agents. Each generation is exogenously divided between households and experts. There is a storage technology and risky projects available to all agents. We assume agents do not know the true underlying distribution of project returns, but they are born with a prior about it. After investing in a particular project, however, an agent receives a signal about the mean of the distribution that can be used to compute a more precise posterior of project returns. We assume experts have the ability to process these signals in a more sophisticated way, and are thus able to get more precise information than households. This can be rationalized by thinking that experts have access to "soft" information that only they are able to interpret. In this context, we think of financial intermediaries as experts that intermediate funds between households and projects, i.e. they manage households' portfolios. We model the dynamics of information by assuming that information can be freely transmitted to those that can interpret it, i.e. from old to young.

In this context, experts have private information about investment opportunities, and this is an obstacle when they need to raise funds from uninformed households. We solve a signaling model in which experts with superior, private, information are able to signal uninformed households their private information through their own investment choices. The idea that investment choices can signal private information was first introduced by Leland and Pyle (1977)[55]. As in their setting, the presence of asymmetric information introduces an inefficiency. Experts over-invest in risky assets in an attempt to make households overly optimistic and extract higher intermediation fees. In equilibrium households understand this and information is perfectly transmitted, but over-investment in risky assets cannot be avoided.

There is a large strand of literature that tries to rationalize the role of financial intermediaries. Diamond and Dybvig (1983)[33] argue that intermediaries allow households to smooth their uncertain consumption needs, while Holmström and Tirole (1997)[49] show that intermediaries can help firms to pool their liquidity more efficiently. Another view posits that the role of intermediaries is to reduce monitoring costs in the presence of agency problems (Diamond (1984)[32], Williamson (1987)[74]). In this paper, however, we model financial intermediaries as information producers. The main proponents of this theory are Leland and Pyle (1977), Campbell and Kracaw (1980)[18], and Boyd and Prescott (1986)[15]. These papers focus on the ability of an intermediary to solve the classic "reliability" and "apropriability" problems that arise when there are costs to acquiring information. In these models, financial intermediaries are coalitions of agents that acquire information on behalf of others and their existence is endogenous. In our paper, however, the presence of agents with the ability to learn more than households is exogenously given. We view this as a simplifying assumption that can be micro-funded by the previously mentioned papers.

In particular, a recent paper about trust in financial advisers by Gennaioli, Vishny, and Shleifer (2012)[42], connects very closely to our work. They construct a model of money management in which investors delegate their portfolio decision to managers based on "trust," and not only on performance. Their main idea is that a good manager is able to reduce an investor's uncertainty exogenously, by reducing their anxiety about taking risks. Mullainathan at al. (2010)[62] conduct an audit of financial advisers and find evidence to support the fact that investors choose their financial advisers based on factors other than past performance. In particular, they argue that many financial advisers do not advertise based on past performance, but rather on experience and dependability. This is a key feature of our paper, where households choose to delegate their portfolio decisions to those agents with better quality information that they have acquired with experience. In contrast to Gennaioli, Vishny, and Shleifer (2012), the trust households put on our intermediaries is rational, since households understand that experts have more precise information. In both papers, the decision to delegate does not depend on past performance, but on "confidence" in the knowledge of the portfolio manager.

A number of studies have found evidence supporting the theory that intermediaries do possess superior information about borrowers with whom they have established a relationship. The explanation often given is that in the process of establishing a relation with a firm, the lender obtains "soft" information about the firm. Slovin, Sushka, and Polonchek (1993) examine the stock price of bank borrowers after the announcement of the failure of their main bank, Continental Illinois. They find that Continental borrowers incurred negative abnormal returns of 4.2% on average after the failure announcement. If bank loans where indistinguishable from corporate bonds, borrowers could borrow directly from the market when their bank disappeared; this, however, was not the case, leading the authors to the conclusion that the intermediary had some information about the borrowers that the market did not. Gibson (1995) reaches a similar conclusion by studying the effect of Japanese banks' health on borrowing firms. Petersen and Rajan (1994) and Berger and Udell (1995) both show in independent studies that a longer bank relationship (controlling for firms' age), implies better access to credit in the form of lower interest rates or less collateral requirement.

Finally, recent works by Veldkamp (2005)[73], Ordoñez (2009)[65], and Kurlat (2013) [54] emphasize the role of information over the cycle. These papers point to cyclical asymmetries that arise from the naturally asymmetric flow of information over the cycle. In contrast, we study the role of financial intermediaries in generating and amplifying these informational cycles.

The paper is organized as follows. In Section 3.2, the model setup is described. In section 3.3, we solve the static problem and characterize optimal intermediation contracts. In section 3.4, we introduce dynamics and characterize how intermediation activity evolves over time; we also incorporate aggregate shocks and study how intermediaries propagate and amplify shocks to the real economy. We discuss two interesting extensions in Section 3.4. Section 3.5 concludes.

3.2 The Model

We construct an overlapping generations model (OLG) with two-period lived agents. Each generation is of unit mass and is exogenously divided between an equal number of experts (e) and households (h). There is a single consumption good that can be stored at an exogenous gross risk-free rate $R_f \geq 1$.

Preferences and Endowments. Agents are born with an endowment w^j $(j = e, h)$ units of the consumption good. They consume only when old and have preferences $u(c) = -e^{-\gamma^j c}$ with $\gamma^j > 0$ for $j = e, h$. The objective of agent j born at date t is to maximize expected utility $U_t^j = E_t^j \left\{ u\left(c_{t+1}^j\right)\right\}$.

Technology. There are N risky projects and investment in these projects is costly: an agent who makes investments in risky projects experiences a non-pecuniary cost $\chi > 0$. The payoff structure of these projects is summarized by the vector of project returns $R_{t+1} \equiv [R_{1,t+1}, ..., R_{N,t+1}]$ which follows the stochastic process given by

$$R_{t+1} = \theta_t + \varepsilon_{t+1}$$

$$\theta_t = (1 - X_t)\,\theta_{t-1} + X_t \tilde{\theta}_t \quad \forall t > 0$$
$$\theta_0 = \tilde{\theta}_0$$

where we suppose that $\varepsilon_{t+1} \sim^{iid} N(0, \Sigma_\varepsilon)$ and $\tilde{\theta}_t \sim^{iid} N\left(\bar{\theta}, \Sigma_\theta\right)$, and where $X_t \sim Bernoulli\,(p)$ for all $t \geq 0$. The project returns at date $t+1$ are thus decomposed into a transitory component given by ε_{t+1} and a persistent component given by θ_t. The parameter p captures the persistence of returns and thus the degree to which historic data is useful to understanding future investment returns.

Information and Expertize. Experts and households understand the model of the economy but do not know the realization of θ_t. They are born with prior beliefs $\theta_t \sim N\left(\bar{\theta}, \Sigma_\theta^e\right)$ and $\theta_t \sim N\left(\bar{\theta}, \Sigma_\theta^h\right)$ respectively, where $\Sigma_\theta^e = \Sigma_\theta$ and $\Sigma_\theta^h = \Sigma_\theta + \Sigma_N$, i.e. we assume experts know the underlying distribution of θ_t, while households have a more dispersed prior.

Learning. Agents are born with a prior $\theta \sim N\left(\bar{\theta}, \Sigma_\theta\right)$ and after receiving a signal $s \sim N(\theta, \Sigma_s)$, they update their beliefs using Bayes' rule to $\theta \sim N\left(\hat{\theta}, \hat{\Sigma}_\theta\right)$ where

$$\hat{\theta} = E\left[\theta | s\right] = \left[\Sigma_\theta^{-1} + \Sigma_s^{-1}\right]^{-1}\left[\Sigma_\theta^{-1}\bar{\theta} + \Sigma_s^{-1} s\right]$$

$$\hat{\Sigma}_\theta = V\left[\theta | \Sigma_s^{-1}\right] = \left[\Sigma_\theta^{-1} + \Sigma_s^{-1}\right]^{-1}$$

The arrival of signal s reduces the perceived volatility of mean project returns and, in the absence of intermediation, this reduction in volatility is larger for experts than for households. This asymmetry alone is sufficient for the households to want to delegate their investment decisions to the experts, since we will assume that the experts' informational advantage is common knowledge.

Intermediation. Experts have a comparative advantage over households in investment activity since they face a more precise distribution of project returns than households. Therefore, households may want to delegate their portfolio decisions to the experts. We define intermediation as the investment activity that the experts conducts on behalf of the households; that is, experts intermediate funds between the households and the investment projects. In our setting, there are three potential sources of gains from such intermediation. Firstly, there is a fixed non-pecuniary cost of investing in risky assets, and it can be split among agents if investment occurs jointly. Second, the risks from investment activity can be spread more widely across agents. And finally, and more importantly, the funds in the economy can be allocated more efficiently due to the presence of expert information. This last channel is the focus of our paper; the two other motives severely simplify the problem by fixing the outside option of households. To be consistent with Leland and Pyle (1977), we make the following two assumptions to motivate the contractual setting:

Assumption 7. *[Complex Information]*

- *Experts' posterior beliefs are not observable by households, and*
- *Households know the distribution of expert's private signals.*

Assumption 8. *[Contractable Information]*

- *Portfolios chosen by experts are ex-post verifiable by the participating households,*
- *Contractual terms between households and experts are not publicly observable.*

By ex-post verifiable, we mean that portfolio weights can only be verified after contracts have been accepted, i.e. portfolio weights can only be observed when the investment of funds is actually made in a given portfolio. This ex-post assumption is not only realistic, but desirable, since it allows the experts to exploit their informational advantage when offering the contract.

Assumption 9. *[Costly Investment] The non-pecuniary cost of investment* $\chi > 0$ *satisfies:*

$$\frac{1}{2}\left[\mu_0^h - R_f 1_N\right]' \Sigma_0^{h-1}\left[\mu_0^h - R_f 1_N\right] < \chi < \frac{1}{2}\left[\mu_0^e - R_f 1_N\right]' \Sigma_0^{e-1}\left[\mu_0^e - R_f 1_N\right]$$

We now discuss the implications of the above assumptions for the contractual setting. First, note that Assumption (7) implies that the only information that cannot be communicated between experts and households is the mean of the experts' posterior distribution $\hat{\theta}_t$. The reason for this is that the experts' posterior can be fully characterized by its mean and variance, and that the variance of the experts' posterior is common knowledge by Assumption (7). Second, since project returns are public information, Assumption (8) implies that portfolio returns are verifiable. Therefore, Assumption (7) and (8) imply that experts and households can contract upon the precision of the expert information, the expert portfolio choice, and the realized portfolio returns. Finally, assumption (9) ensures that households are not be willing to invest in risky assets on their own, but would do so through an expert.

3.3 Optimal Intermediation Contracts

At each date t, an expert and a household get randomly matched. After the match is realized, the expert offers the household a take it or leave it *intermediation contract* that the household can accept or reject.[1] We define an *intermediation contract* as a contract in which an expert asks the household to deposit its funds in return for payoffs contingent on verifiable outcomes. If the household rejects the contract, then both the expert and the household invest on their own (these are their outside options). If the household accepts the contract, contractual terms are executed.

As Leland and Pyle (1977) have shown, total funds that are invested in the risky asset by the expert are a signal about the expert's private information. We solve a signaling problem, in which experts offer contracts taking into account that their portfolio weights signal to households their private information. Given Assumption (9, contracts can (and will) be contingent on portfolio weights. The timing of the per period problem is as follows. First, the expert offers the household to pull their funds together in exchange for a payoff contingent on the constructed portfolio and on the realized return of the chosen portfolio. To ensure that the household participates, the expert chooses the payoff functions so that the household gets its outside option [2] Second, once the funds have been raised, the expert chooses her preferred portfolio and commits to the per-specified return-contingent payoff function for that particular portfolio choice.

The presence of overlapping generations of experts and households that are randomly matched to enter an intermediation contract allows us to isolate the per period problem, given the state variables: i) the state of the economy $\left\{X_t, \theta_t, \tilde{\theta}_t\right\}$, and ii) the private information of the experts $\{R^t\}$ summarized in their posterior $\{\mu_t, \Sigma_t\}$. First, we focus on the problem of an expert that enters period t with a posterior distribution $\theta \sim N(\mu_t, \Sigma_t)$, and we solve for the optimal intermediation contract, and optimal consumption and investment allocations. Second, we introduce dynamics to characterize the evolution of key variables over time.

For the analyzes of the per period problem, we drop the t subscripts when characterizing the stage problem. Let $\mu = \hat{\theta}_t$ and $\Sigma = \hat{\Sigma}_t$ denote the mean and precision of the expert's information, c^e, c^h denote the consumption allocations of experts and households determined by the contract, and α denote the expert's chosen portfolio. The solve the expert's problem, we formulate the following conjecture.

Conjecture 1. *Portfolio weights chosen by the expert (fully) reveal his private information.*

[1]Our qualitative results do not depend on the distribution of bargaining power.

[2]WLOG, this can modeled as the expert offering a menu to the households, given by $\{c^e(R, \alpha(\mu)), c^e(R, \alpha(\mu)), \alpha(\mu)\}_{\forall\mu}$ where $c^e(R, \alpha(\mu)), c^h(R, \alpha(\mu))$ are the consumption allocations of the expert and the household, contingent on realized returns and on portfolio weights, and μ is the expert's private information (mean of its posterior distribution). In equilibrium, after the contract is accepted, the expert has to choose from that menu the triple consistent with its real $\mu = \hat{\theta}_t$. We show in the Appendix that these two problems are equivalent, and that the mechanism is optimal.

Let $\tilde{\mu}(\alpha)$ denote the signal about underlying beliefs embedded in the portfolio choice, an expert with posterior beliefs characterized by μ solves the following problem:

$$\max_{c^e, c^h, \alpha} E\left[u^e\left(c^e\right)|\mu\right] \tag{3.1}$$

$$E\left[u^h\left(c^h\right)|\tilde{\mu}(\alpha)\right] \geq \bar{U}^h \quad (\lambda_{pc})$$

$$c^e(R) + c^h(R) \leq \left[\alpha'\left(R - R_f 1_N\right) + R_f\right] w \quad (\lambda_{fc1}(R))$$

where w denotes the total funds of an intermediary, and it is given by the sum of experts and households initial endowments, $w = w^h + w^e$; and $E[x|\mu]$ denotes the expected value of x conditional on beliefs characterized by μ (experts), and $\tilde{\mu}(\alpha)$ (households). The experts problem is to maximize its expected utility subject to the participation constraint of the household (multiplier λ_{pc}, and the feasibility constraint (multiplier λ_{fc}).)[3] Since we focus on separating equilibria, we impose the following "truth revelation" condition: $\tilde{\mu}(\alpha(\mu)) = \mu$.

Proposition 8. *Under the optimal intermediation contract the expert receives a fixed payment and a fraction of the returns of the portfolio where all funds are invested. Consumption allocations under the optimal contract are given by*

$$c^e(R, \alpha) = \frac{\gamma^h}{\gamma^h + \gamma^e} R_p w + Z(\alpha)$$

$$c^h(R, \alpha) = \frac{\gamma^h}{\gamma^h + \gamma^e} R_p w - Z(\alpha)$$

where $R_p \equiv R_f + \left[R - R_f 1_N\right]' \alpha$ are the total portfolio returns and $Z(\alpha)$ is a transfer contingent on portfolio weights.

The optimal contract presented in Proposition 8 has a straight-forward interpretation. The first term of the contract is a variable payoff and it is given by the the corresponding fraction of the total portfolio returns that each agent is receives ($\frac{\gamma^e}{\gamma^h+\gamma^e} R_p$ for households and $\frac{\gamma^h}{\gamma^h+\gamma^e} R_p$ for experts). This fraction is chosen to smooth marginal utilities across states between households and experts, to attain full-risk sharing. To see this, note that for a given portfolio α, consumption allocations presented in Proposition 8 guarantee that:

$$u^{e'}\left(c^e(R, \alpha)\right) = \lambda u^{h'}\left(c^h(R, \alpha)\right) \quad \forall R \tag{3.2}$$

for $u^h(c) = -\exp\left[-\gamma^h c\right]$ and $u^e(c) = -\exp\left[-\gamma^e c\right]$.

The last term of the contract is a transfer made from the household to the expert. For exposition purposes, we decompose the transfer into a fixed payment plus a payment

[3] Households outside option $\bar{U}^h$ is given by the utility households derive from investing their endowments in the risk-free firms, i.e. $\bar{U}^h \equiv u^h\left(w^h R_f\right)$.

contingent on portfolio weights: $Z(\alpha) = \bar{f} + f(\alpha)$. The first term of this decomposition, $\bar{f}$, is a constant transfer that ensures that the participation constraint of the household binds. The second term, $f(\alpha)$, is what we refer to as an intermediation fee, since it reflects the value of acquiring the expert's intermediation services. One interesting result is that this fee is contingent on the portfolio weights chosen by the expert. This is because, from Conjecture 1, portfolio weights affect households' beliefs (and thus the value of intermediation) by signaling the expert's private information.

Proposition 9. *For a given portfolio α chosen by the expert, the optimal transfer that the expert receives from the household is given by $Z(\alpha) = \bar{f} + f(\alpha)$ where*

$$\bar{f} = R_f \left[\frac{\gamma^e}{\gamma^h + \gamma^e} w^e - \frac{\gamma^h}{\gamma^h + \gamma^e} w^h \right]$$

$$f(\alpha) = \frac{1}{\gamma^h} \left[\bar{\gamma} \left[\mu(\alpha) - R_f 1_N \right]' \alpha w - \frac{\bar{\gamma}^2}{2} (\alpha w)' \Sigma (\alpha w) \right]$$

Proof. Using Conjecture 1, we take the optimal consumption allocations and make the participation constraint of the households bind. □

The previous results shows that by choosing portfolio weights, α, experts do not only affect the expected returns that arise from the portfolio, but also the fee charged to the households by manipulating their beliefs. This result relies on the fact that the funds invested in risky assets signal the expert's private information about the return of these assets (see also Leland and Pyle (1977)). Using the consumption allocations presented in Proposition 9, we solve for the expert's optimal portfolio choice. We proceed as follows. First, we conjecture the functional relationship between α and μ. Second, given our conjecture, we find the expert's optimal portfolio choice α when both the portfolio and the manipulation of beliefs effects are considered. Finally, we verify our conjecture.

Conjecture 2. *Given expert's private information μ, portfolio weights are given by $\alpha(\mu) = \kappa \left[w \bar{\gamma} \Sigma \right]^{-1} \left[\mu - R_f 1_N \right]$ with $\kappa > 1$.*

In Conjecture 2 we claim that when portfolio weights signal the expert's private information, there is a multiplicative distortion from optimal portfolios. In the absence of private information, optimal portfolios are given by the standard Sharpe ratio $\left[w \bar{\gamma} \Sigma \right]^{-1} \left[\mu - R_f 1_N \right]$. When portfolios signal private information, by investing more in the risky assets the experts can make households more optimistic about portfolio returns and thus increase the fee charged for intermediation. The experts distort their portfolio choice towards riskier positions to increase intermediation fees.

Proposition 10. *The total funds invested in risky projects are given by*

$$\alpha w = \kappa \left(\bar{\gamma} \Sigma \right)^{-1} \left[\mu - R_f 1_N \right]$$

where $\kappa = \frac{\gamma^h + 2\gamma^e}{\gamma^h + \gamma^e}$ and $\bar{\gamma} = \frac{\gamma^h \gamma^e}{\gamma^h + \gamma^e}$.

Proof. Using the FOC with respect to α of the expert's problem (3.1), plugging in the conjecture, and using the method of undetermined coefficients yields result. (See Appendix for details). □

Corollary 1. *The expert with posterior beliefs* $\{\mu^e, \Sigma^e\}$ *charges the following portfolio-contingent intermediation fee:*

$$f = \frac{1}{2}\frac{\gamma^h + 2\gamma^e}{(\gamma^h + \gamma^e)^2}\left[\mu^e - R_f 1_N\right]' (\Sigma^e)^{-1}\left[\mu^e - R_f 1_N\right]$$

When the investment in risky assets signals private information about the underlying quality of these assets, experts overinvest. The distortion in portfolios is generated by the expert's incentives to inflate the household's beliefs about portfolios returns, and thus raise a higher fee from intermediation. This overinvestment occurs despite the fact that in equilibrium the expert's strategy is inferred by households. The distortion to the expert's portfolio choice, $\kappa - 1$, is equal to the percentage of risk that the household is exposed to, $\gamma^e / \left(\gamma^e + \gamma^h\right)$, and is thus increasing (decreasing) in expert's (household's) risk aversion. The more the household is exposed to risk, the larger the expert's gains from convincing the household that risky returns are favorable.

Optimal contracts in our model match qualitatively the contracts offered by many hedge funds and portfolio managers. This is popularly referred to as the 2/20 fee structure, where managers charge a fee of 2% of assets under management, and receive 20% of the returns of the chosen portfolio. As Deuskar et al. (2011)[30] show, however, this type of contracts are a generalization, since when looking at the data on hedge fund fees, there are significant cross-section and time series variations in these amounts. What this means is that in reality, even though the contracts do look like a manager's fee and a fraction of the portfolio, the level of these two components is variable. This is consistent with our model, where fees can vary with the level of expertize of financial intermediaries, and with the set of investment opportunities experts can offer to households. In most of the literature on portfolio managers' fees, the variable component is referred to as the incentive fee. In our model, there is no moral hazard and thus the reasons why experts hold a fraction of the portfolio are: i) that they are actually investing their own funds in these portfolio, and (most importantly), ii) they share risks optimally with households. If moral hazard was introduced into the model, the variable component would not only be a function of the risk aversions, but some distortion might arise to provide incentives to experts. We choose to avoid adding the moral hazard friction to be able to fully focus on the asymmetric information problem that arises when portfolio managers possess superior information about the quality of assets they invest households funds in, since we believe this is an interesting problem on its own.

Finally, we would like to end this section with an interesting fact documented in Mullainathan et al. (2008) in their audit to financial advisers. They find that "some advisers refused to offer any specific advice as long as the potential client has not transferred the account to the company of the adviser," and they argue that this happens because no useful information wants to be revealed before the contract is accepted. This supports the view that there is not only a moral hazard problem present in intermediation, but an asymmetric information problem at the moment of contracting as well. They say: "it makes sense that advisers want to protect their time and insights so that clients do not replicate the advice for free." Even though it makes sense, they find this result puzzling, since investors need to make decisions without knowing what the adviser knows. In our model this is exactly the case. We also present a solution to this puzzle: investors (households in our model) are conceptually being offered a contract that is contingent on portfolio weights, and these weights signal the expert's private information ex-post. As we have shown, the problem of apropriability and reliability of private information is solved when fees are made contingent on the investment choices the advisers make after the contract is accepted.

In the following section we introduce dynamics to understand how private information, and thus portfolios and intermediation fees, evolve over time. The dynamic model provides interesting testable predictions for the correlation between the riskiness of portfolios and intermediation fees, and for the evolution of the overall income of financial intermediaries as a function of confidence in their expertize.

3.4 The Dynamic Economy

The dynamic economy is a straight-forward extension of the static problem presented in the previous section. Due to their short horizon, the contracts between experts and households are still short-term, but the information that the expert possess evolves over time. Before setting up the dynamic problem, we discuss the evolution of learning and how it responds to structural shocks. We have assumed that the mean of project returns follows the process given by:

$$\theta_t = (1 - X_t)\,\theta_{t-1} + X_t\tilde{\theta}_t \quad \forall t > 0$$

where $X_t \sim Binomial\,\{1, p\} \quad \forall t > 0$ and $X_0 = 1$. Thus, the mean θ_t remains unchanged as long as $X_t = 0$, but is redrawn anew from distribution $N\left(\bar{\theta}, \Sigma_\theta\right)$ whenever $X_t = 1$. This process allows to add a cyclical component to information by supposing that the fundamentals about which experts acquire information are stochastic. In particular, while persistence of fundamentals is essential for information to be valuable ($X_t = 0$), their randomness acts as an opposing force and diminishes the value of expert learning (when $X_t = 1$). Since X_t is public information for all t, when computing posterior distributions for θ_t, agents only incorporate signals received after the change of state, i.e. signals received after date T given by $T = sup\,\{\tau < t : \quad X_\tau = 1\}$. The experts' posterior mean and variance are therefore given by

$$\mu_t = \left[\Sigma_\theta^{-1} + \Sigma_{s_t^R}^{-1}\right]^{-1}\left[\Sigma_\theta^{-1}\bar{\theta} + \Sigma_{s_t^R}^{-1} s_t^R\right] \tag{3.3}$$

$$\hat{\Sigma}_{\theta,t} = \left[\Sigma_\theta^{-1} + \Sigma_{s_t^R}^{-1}\right]^{-1} \tag{3.4}$$

where the updating is conditional on signals $s_t^R = (t-T)^{-1} \sum_{\tau=T}^{t} R_\tau$ with precision $\Sigma_{s_t^R}^{-1} = (t-T)\,\Sigma_\epsilon^{-1}$. The expert's problem at time $t \geq 0$, with public information $\left\{\hat{\Sigma}_{\theta,t}, X^t\right\}$, is given by

$$V^e\left(\mu_t, \hat{\Sigma}_{\theta,t}, X_t\right) = \max_{c_{t+1}^e, c_{t+1}^h, \alpha_t} E\left[u^e\left(c_{t+1}^e\right) | \mu_t, \hat{\Sigma}_{\theta,t}\right] \tag{3.5}$$

$$E\left[u^h\left(c_{t+1}^h\right) | \tilde{\mu}_t\left(\alpha_t\right), \hat{\Sigma}_{\theta,t}\right] \geq \bar{U}_t^h \quad (\lambda_{pc})$$

$$c_{t+1}^e\left(R_{t+1}\right) + c_{t+1}^h\left(R_{t+1}\right) \leq \left(\left[R_{t+1} - R_f 1_N\right]' \alpha_t + R_f\right) w \quad \left(\lambda_{fc1}\left(R_{t+1}\right)\right) \;\; \forall R_{t+1}$$

$$R_{t+1} = \theta_t + \varepsilon_{t+1} \quad \varepsilon_{t+1} \sim^{iid} N\left(0, \Sigma_\varepsilon\right)$$

$$\theta_t = \left(1 - X_t\right)\theta_{t-1} + X_t \tilde{\theta}_t \quad \tilde{\theta}_t \sim N\left(\bar{\theta}, \Sigma_\theta\right)$$

where μ_t and $\hat{\Sigma}_{\theta,t}$ are given by equations (3.3) and (3.4) respectively and θ_t is not observed by agents.

It is straightforward to verify that the solution to the dynamic problem matches the solution to the static model, given the prevalent state variables. This is because we have chosen an overlapping generations framework, where agents have short-horizons. The qualitative results of the model would not change if both agents had an infinite horizon, as long as some relevant level of informational asymmetry persists. We chose to avoid long horizons to avoid situations in which after long periods of stability households learn through their own experience with the expert, and thus intermediation is no longer motivated by expertize (information asymmetries become irrelevant when both agents have precise posteriors). We believe that the assumption that experts hold consistently more precise information than households is a realistic one, and this is why we have choose a simple framework where the entrance of new uninformed households allows the informational asymmetry to persist over time. Finally, note that in this model there would be no gains from allowing agents to write long-term contracts, or contracts contingent on past information, as portfolio weights are a sufficient statistic for the expert's private information. Using results from the previous section, we characterize the equilibrium of the dynamic economy.

Proposition 11. *In the dynamic economy, with public information* $\left\{\hat{\Sigma}_{\theta,t}, X^t\right\}$*, and state variables* $\left\{\theta_t, \tilde{\theta}_t, X_t\right\}$*, the consumption allocations are given by*

$$c^e\left(R_{t+1}, \alpha_t\right) = \frac{\gamma^h}{\gamma^h + \gamma^e}\left(\left[R_{t+1} - R_f 1_N\right]' \alpha_t + R_f\right) w + \bar{f} + f\left(\alpha_t\right)$$

$$c^h\left(R_{t+1}, \alpha_t\right) = \frac{\gamma^e}{\gamma^h + \gamma^e}\left(\left[R_{t+1} - R_f 1_N\right]' \alpha_t + R_f\right) w - \bar{f} - f\left(\alpha_t\right)$$

$\forall t > 0$*; the expert's portfolio choice is given by*

$$\alpha_t = \kappa\left[w \bar{\gamma} \hat{\Sigma}_{\theta,t}\right]^{-1}\left[\mu_t - R_f 1_N\right]$$

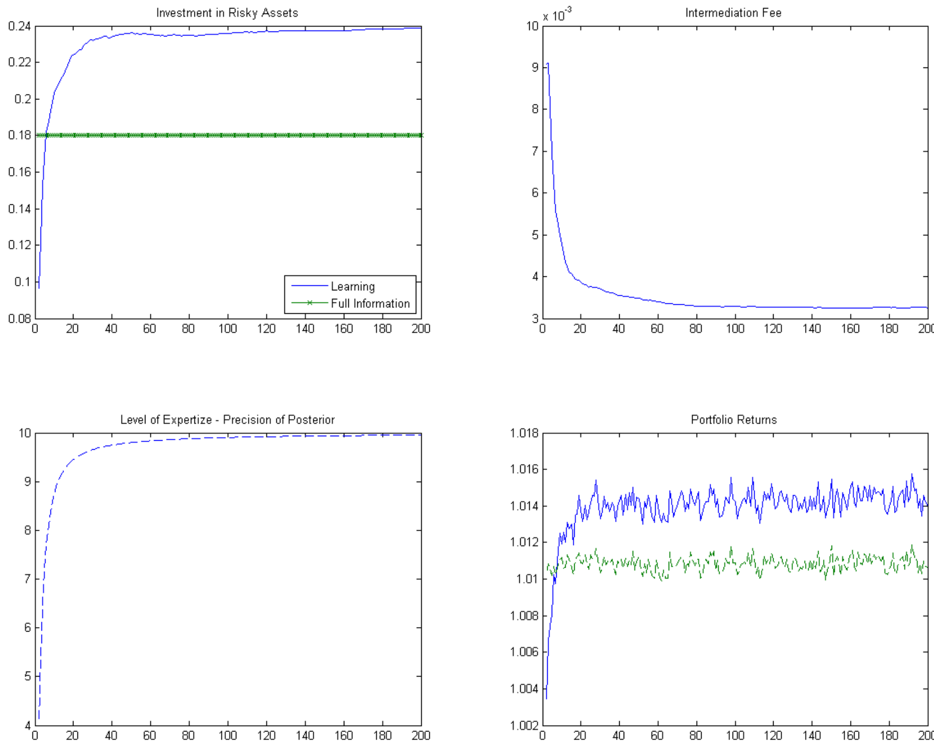

Figure 3.1: Learning by Lending

Number of simulations is 1000. Economy consists of one safe asset and two risky assets with time horizon $T = 200$. Parameter values are: $\gamma^e = 5$,$\gamma^h = 10$, $\omega^e = \omega^h = 1$, $R_f = 1$, $p = 0.01$, $\sigma_0 = 0.1$, $\sigma^e = 0.3$, $\sigma^\eta = 1$, $\theta = \theta_0 = 1.03$.

where $\kappa = \frac{\gamma^h + 2\gamma^e}{\gamma^h + \gamma^e}$, *and* $\left(\mu_t, \hat{\Sigma}_{\theta,t}\right)$ *are given by equations (3.3) and (3.4). Finally, the intermediation fee charged to households is:*

$$f(\mu_t) = \left(\gamma^h\right)^{-1} \left(\kappa - \frac{1}{2}\kappa^2\right) [\mu_t - R_f 1_N]' \, \hat{\Sigma}_{\theta,t}^{-1} [\mu_t - R_f 1_N]$$

Proof. See Propositions 1-3. □

We now illustrate the dynamics of our economy graphically. First, in Figure 3.1, we use a simple parametrization of our model to simulate a period of economic stability following an initial draw of the fundamental state θ. Then, in Figure 3.2, we show the effects of a shock to mean of project returns θ. We use the economy with full information, where all agents know the true value of θ, as a useful benchmark against which to compare our results. Figure 3.1 shows that the economy with learning is more volatile relative to the economy with full

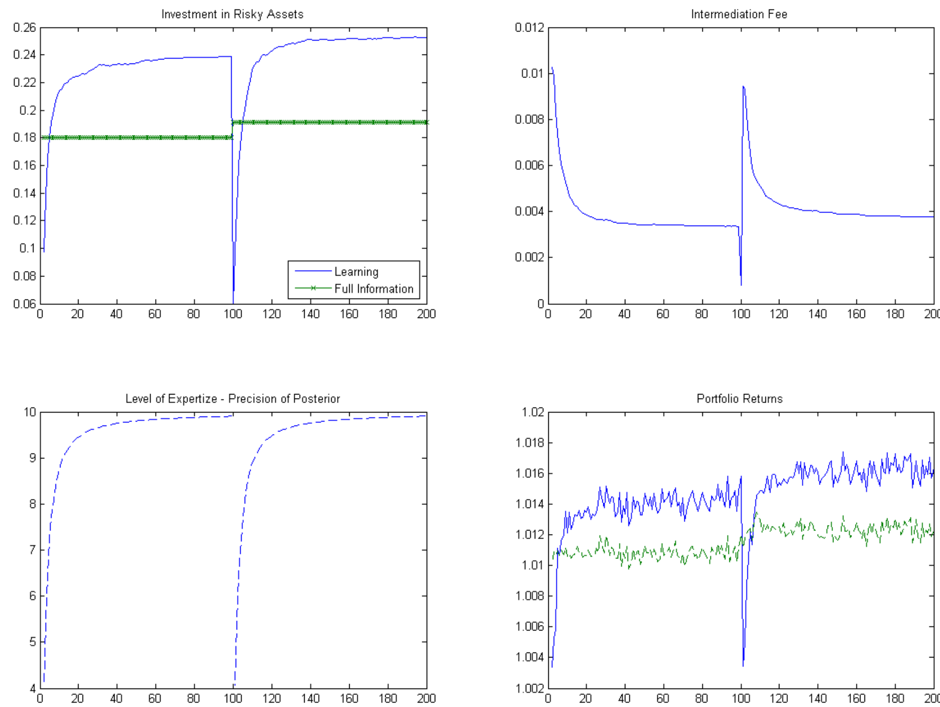

Figure 3.2: Structural Shocks

Same calibration as before. At $T = 100$, there is a structural shock, i.e. $X_T = 1$.

information, but that volatility diminishes over time as the level of expertize (precision of posterior beliefs) in the economy grows. Thus, periods of continued economic stability are associated with periods of gradually declining volatility. Volatility of investment between the two economies is a good case in point. In the full information economy, risky investment is fixed by a sharp ratio that is constant - all agents know the true mean of project returns and the returns are iid. When there is learning, however, both the perceived mean of project returns and their perceived variance change over time.

The mechanism we aim to highlight is the detrimental effect that the loss of "inside" information has when the economy experiences changes in fundamentals. A shock to fundamentals (positive or negative) generates an endogenous volatility shock for experts due to the loss of their expertize, reflected in a decrease in the precision of their private information. As a response, experts contract credit to risky sectors, while they start learning about the new economy. This amplifies and propagates shocks to the real economy, that in a standard model with full information would only generate a once and for all change in allocations at the moment of impact, and no change at all in uncertainty. We do not interpret these type of shocks as drivers of business cycles, these are permanent shocks that alter the distribution of productivities across firms or sectors in an economy. They should be interpreted as technological shocks that change the relative productivity of sectors within an economy. For example, the introduction of the internet affected some sectors positively and other negatively, this is one example of a shock that has altered relative productivities. The dot.com boom is a good example to describe the mechanism we have in mind: while at the beginning it was difficult to raise funding for internet related activities, once credit started going into this sector, optimism increased over time, possibly generating the so called dot.com bubble. Finally, it became clear that the sector was not as profitable as expected, credit to the private sector contracted, the U.S. had a recession, but eventually funds were allocated to new sectors (real state related investment, for example).

Discussion

Re-Allocation of Funds

One interesting feature of our model is that it can generate contractions as a response to a sectoral reallocation of productivities. In the previous simulations, the shock that hits the economy has an impact on aggregate productivity, since it changes the mean of project returns. In response to this, total investment to the risky sectors changes not only as response to the loss of expertize, but also as a response to the changes in fundamentals. In this section, we analyze a shock that shuffles productivities across sectors, but has no impact on aggregate returns if portfolios are re-adjusted accordingly. The response to a shock of this nature in a model with full information is to simply reallocate capital across sectors according to the new distribution of productivities. In our model, experts understand that there is a shock but they do not know how productivities have been re-shuffled. The lack of knowledge about the nature of the shock acts as a volatility shock, generating a fall in credit, and a slow recovery. As experts learn the new distribution of productivities and reallocate funds accordingly, the economy converges to its previous levels. Figure 3 shows the results for a simulation in which the mean return of sectors one and three is interchanged. Notice that in this example, the benchmark economy of full information experiences no change in the levels of investment to the risky sectors.

Unobservable Aggregate States

A natural extension to this model is to make the aggregate state, X_t unobservable. In this scenario, agents should infer the change of state from observed returns. In a model with Bayesian learning, it is very hard to generate strong reactions to bad signals after long periods of stability. In the presence of a negative shock to fundamentals, experts would take a long time to realize that the state has changed, and credit cycles would not be strongly asymmetric as observed in the data. An alternative learning mechanism that allows to generate highly asymmetric responses was introduced by Marcet and Nicolini (2003)[58].

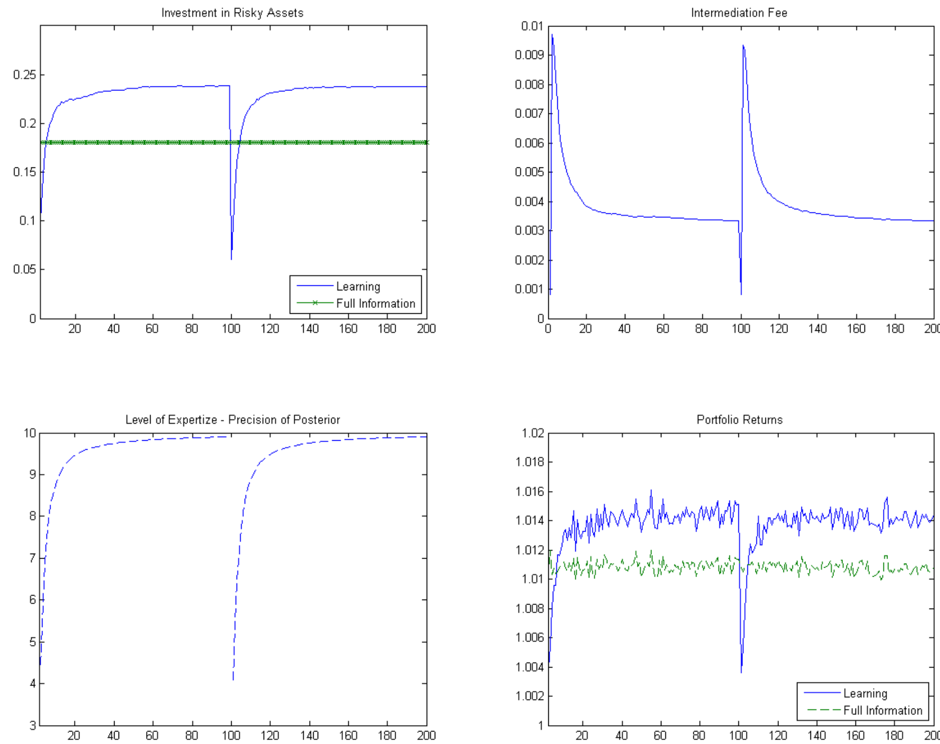

Figure 3.3: Sectoral Reallocation

Same calibration as before. At $T = 100$, there is a structural shock that has no aggregate effect, $\theta_1' = \theta_2$ and $\theta_2' = \theta_1$.

Their paper presents a boundedly rational learning model, where agents re-adjust their beliefs very strongly once they observe realizations that are highly unlikely under their prevalent beliefs. The drawback of this learning mechanism is that it is not fully rational. However, it is extremely intuitive and a good candidate to generate abrupt changes in beliefs. If we were to make the aggregate state X_t unobservable, we would model expert's beliefs as follows: when realizations of returns are very far on the tales of the posterior distribution (a threshold is imposed), agents understand there has been a new draw of fundamentals, and the economy behaves as if the shock had been public. There are two new implications of using this learning mechanism: first, after a negative shock to fundamentals, it might take time for experts to realize this, and thus for some periods returns are going to be low on average. Second, cycles could be generated without having shocks to fundamentals at all. If an outlier is drawn, experts would interpret this as an aggregate shock and start reacting accordingly by putting more weight on recent observations, and disregarding past data. We believe that the results that could be obtained from an alternative learning as the one described here are very interesting, but we postpone that analyzes to future research.

3.5 Conclusions

We presented a dynamic model of financial intermediation in which changes in the information held by financial intermediaries generate asymmetric credit cycles as the ones documented by Reinhart and Reinhart (2010). Our model is able to generate long periods of credit expansion, followed by sharp contractions in lending and slow recoveries. We model financial intermediaries as information producers, we assume they are "expert" agents that have a unique ability to acquire information about firm/sector fundamentals. Better information allows for better allocation of resources, and this informational advantage makes these actors be the natural contenders to intermediate funds between households and businesses. The level of "expertize" in the economy and the potential gains from intermediation grow in tandem with the information that these experts possess; these gains, however, are hindered since experts' information is inherently private. We find the optimal financial contracts that balance allocational efficiency with the provision of appropriate incentives. The economy therefore inherits not only the dynamic nature of information flow, but also the interaction of information with the contractual setting. To generate contractions in credit we introduce a cyclical component to information by supposing that the fundamentals about which experts acquire information are stochastic. While persistence of fundamentals is essential for information to be valuable, their randomness acts as an opposing force and diminishes the value of expert learning. Our setting then features economic fluctuations due to waves of "confidence" in the experts' ability to allocate funds profitably.

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Appendix A

Appendix for Chapter 1

Markets for ABS: The No Commitment Case

Equilibrium in Secondary Markets and Security Design

Let I be the finite set of investors in the economy, that compete by posting prices for feasible securities.

Lemma (Zero Profit Condition). *In any equilibrium, investors must earn zero expected profits in each market.*

Proof. Assume not. Investor j is making positive profits in market $\{F, p_j(F)\}$, in equilibrium. If this is the case, it has to be buying at a price lower than its valuation; that is, $p_j(F) < \mathbb{E}_\mu[F]$. Since for profits to be made, the bank has to be issuing in this market, it must be true that $p_i(F) \leq p_j(F), \forall i \in I$. Let $\Pi > 0$ denote the investors aggregate profits in this market.Then, one investor must be making no more than Π/I. Consider the deviation of this investor to open market $\{p_j(F) - \epsilon, F\}, \epsilon > 0$. This market will attract the bank that was issuing in market $\{F, p_j(F)\}$, without affecting their decisions to participate in other markets. Since ϵ can be chosen to be arbitrarily low, this deviation yields the investor almost Π profits, and so the investor has a profitable deviation. Then, we must have $\Pi \leq 0$ in each market.Because investors cannot incur a loss in any equilibrium (it can always earn zero by posting price zero), all investors in fact earn zero profits. □

Lemma (No Separation). *Under the No Transparency Assumption, separating equilibria do not exist.*

Proof. Assume there is a separating equilibrium and note that when the bank type is fully identified by the market, then given the costs associated with issuing in a given market, $c > 0$, only two securities should be issued in equilibrium. Let F_z be a security issued by the z-type bank in this equilibrium. Separation implies that $\mu(F_{z_h}) = 1$ and $\mu(F_{z_l}) = 0$. By the Zero-Profit Condition, the payoff to type z_l is given by $(\theta - 1)\mathbb{E}[F_{z_l}(X)|z_l]$, since investors make zero profits. Investor j has a profitable deviation: to offer to buy security H defined as follows: $H(X) = [F_{z_l}(X) - F_{z_h}(X)]^+$, at price $p(H) = \mathbb{E}[H|z_l] - \epsilon$ for $\epsilon > 0$. Note that by the incentive compatibility constraint, in any separating equilibrium $H(x) > 0$ on a set of positive measure. This market will attract the z_l-type bank, that will now issue $\{F_{z_h}, p(F_{z_h})\}$, and remaining cashflows $H = [F_{z_l} - F_{z_h}]^+$ at $p(H)$, since for ϵ small enough this strategy generates a higher payoff: $\theta\{\mathbb{E}[F_{z_h}(X)|z_h] + \mathbb{E}[H(X)|z_l] - \epsilon\} - \mathbb{E}[F_{z_h}(X) + H(X)|z_l] > (\theta - 1)\mathbb{E}[F_{z_l}(X)|z_l]$. Then, investor j attracts the z_l-type bank, does not participate in any other market, and makes profits. □

Lemma. *In any equilibrium in secondary markets, (i) the z_h-type bank issues one security, $F_{z_h} \in \Delta$, (ii) and market beliefs are given by $\mu(F_{z_h}) = \rho_h(a^e) < 1$.*

Proof. (i) Assume that the z_h-type type bank is issuing N securities: $F^1, F^2 > 0, ..., F^N$. By feasibility, it must be that $\sum_{n=1}^{N} F^n(x) \leq x, \ \forall x$, and investors make zero profits. Note that by the *No Separation* Lemma, the z_h-type bank is always pooled with the z_l-type, since it can never be separated. Since I focus on pure strategy equilibria, market beliefs in the market for these securities must be given by the unconditional probability assigned to being a z_h-type bank, i.e. $\mu(F^1) = ... = \mu(F^N) = \rho_h(a^e)$. Consider the following deviation for an investor j. Post price $p(F_{z_h}) = \mathbb{E}_{a^e,\mu}[F_h(X)] - \epsilon$ for security $F_{z_h}(X) \equiv \sum_{n=1}^{N} F^n(X)$, where $c > \epsilon > 0$ and $\mu(F_{z_h}) = \rho_h(a^e)$. The z_h-type bank strictly prefers to issue F_{z_h} since $c > \epsilon$. (ii) Note that this is a profitable deviation for investor j for $\epsilon > 0$. Note that the z_l-type bank also prefers to issue F_{z_h} than the N separate securities, and thus $\mu(F_{z_h}) = \rho_h(a^e)$ in equilibrium. □

Lemma. *Let $F_{z_h} \in \Delta$ be the security issued by z_h-type bank in equilibrium. In any equilibrium in secondary markets, (i) junior tranches $F_J(X) \equiv X - F_{z_h}(X)$ are sold by the z_l-type bank, and (ii) market beliefs are given by $\mu(F_J) = 0$.*

Proof. (i) Let security F_J be defined as $F_J(X) \equiv X - F_{z_h}(X)$, positive on a positive measure set (if not, junior tranches are zero and the Lemma is not applicable). By *No Separation*, we know the z_l-type bank is also issuing F_{z_h}. All types are free to sell their remaining cashflows given the *No Transparency* assumption. Assume that in equilibrium the z_l-type bank is not selling the junior tranches. Then, there is a profitable deviation for investor j to post price $p(H) = \mathbb{E}[F_J(X)|z_l] - \epsilon$. This will attract the z_l-type: $\theta(\mathbb{E}_a[H|z_l] - \epsilon) > \mathbb{E}_a[F_J(X)|z_l]$ for ϵ small enough, and the investor makes profits. By revealed preference, the z_h-type bank prefers not to issue $X - F_{z_h}(X)$ at average valuations, and thus is not willing to issue at lower valuations. (ii) Since only z_l-type banks issue the junior tranche, $\mu F_J = 0$. □

For the following proofs, let

$$\Pi_{z_h}(a, a^e, F) \equiv \theta\mathbb{E}_{a^e,\mu}[F(X)] - \mathbb{E}_a[X - F(X)|z_h]$$

denote the value of banking for the z_h-type bank with information acquisition a and where market beliefs are given by a^e.

Lemma. *Assume there exists $F^* \in \Delta$, s.t. $\Pi_{z_h}(a, a^e, F^*) = \sup_{F\in\Delta} \Pi_{z_h}(a, a^e, F)$. Then, in any equilibrium in secondary markets, for given information acquisition a and market beliefs a^e, the z_h-type bank issues security $F_{z_h} \in \arg\sup_{F\in\Delta} \Pi_{z_h}(a, a^e, F)$.*

Proof. F^* is the optimal security for the z_h-type bank among all securities in compact set Δ priced with beliefs $\mu(F) = \rho_h(a^e)$. Assume the z_h-type is issuing $F_{z_h} \in \Delta$, by the $\Pi_{z_h}(a, a^e, F_{z_h}) < \Pi_{z_h}(a, a^e, F^*)$. Given the previous Lemmas, it must be that $\mu(F_{z_h}) = \rho(a^e)$ and the security is priced by the zero-profit condition. Consider the following deviation for an investor j: offer price $p(F^*) = \mathbb{E}_{a^e,\mu}[F^*(X)] - \frac{\epsilon}{\theta}$, $\epsilon > 0$, for security F^*, with $\mu(F^*) = \rho_h(a^e)$. This attracts the z_h-type bank, since $\theta\mathbb{E}_{a^e,\mu}[F^*(X)] - \mathbb{E}_a[F^*(X)|z_h] - \epsilon > \theta\mathbb{E}_{a^e,\mu}[F_{z_h}(X)] - \mathbb{E}_a[F_{z_h}(X)|z_h]$ for ϵ small enough and the investor makes profits. □

Lemma. *In any equilibrium in secondary markets, standard debt is the optimal security issued by the z_h-type bank. In particular, $F^* \in \arg\sup_{F\in\Delta} \Pi_{z_h}(a, a^e, F)$ exists, it is unique, and it is given by $F^*(X) = \min\{d, X\}$ where*

$$d(a, a^e) \in \arg\max_d \theta\mathbb{E}_{a^e,\mu}[\min\{d, X\}] - \mathbb{E}_a[\min\{d, X\}|z_h] \tag{A.1}$$

Proof. We are interested in finding the security F in the supremum of:

$$\theta\mathbb{E}_{a^e,\mu}[F(X)] - \mathbb{E}_a[F(X)|z_h]$$

By the law of iterated expectations, market valuation of security F can be written as

$$\begin{aligned}\mathbb{E}_{a^e,\mu}[F(X)] &= \rho_h(a^e)\,\mathbb{E}_{a^e}[F(X)|z_h] + (1 - \rho_h(a^e))\,\mathbb{E}_{a^e}[F(X)|z_l] \\ &= \rho(a^e)\left[\mathbb{E}_H[F(X)] - \mathbb{E}_L[F(X)]\right] + \mathbb{E}_L[F(X)]\end{aligned}$$

and also remember that:

$$\mathbb{E}_a[F(X)|z_h] = \pi_h(a)\left[\mathbb{E}_H[F(X)] - \mathbb{E}_L[F(X)]\right] + \mathbb{E}_L[F(X)]$$

and thus the problem can be re-written as follows:

$$\max_{F\in\Delta} (\theta\rho(a^e) - \pi_h(a))\left[\mathbb{E}_H[F(X)] - \mathbb{E}_L[F(X)]\right] + (\theta - 1)\,\mathbb{E}_L[F(X)]$$

For $\theta\rho(a^e) \geq \pi_h(a)$, the value of the z_h-type bank is increasing in the cashflows of F, and thus $F^*_{z_h}(X) = X$. In this case, we say the bank issues standard debt with $d = \infty$. For $\theta\rho(a^e) < \pi_h(a)$, the z_h-type faces adverse selection since it values cashflows more than the market. Let G be any feasible security, and let $g \equiv \mathbb{E}_a[G(X)|z_h]$ and $g_m \equiv \mathbb{E}_{a^e,\mu}[G(X)]$, denote the private and the market valuations respectively. Now consider a standard debt security $F_D(X) = \min\{d, X\}$. Let $f \equiv \mathbb{E}_a[\min\{d, X\}|z_h]$ and $f_m \equiv \mathbb{E}_{a^e,\mu}[\min\{d, X\}]$. Given the continuity of f_m on d, pick d so that $g_m = \mathbb{E}_{a^e,\mu}[\min\{d, X\}]$. Let $H = G - F$ and let $h(\mu) = \mathbb{E}_{a^e,\mu}[G(X) - F_D(X)]$, where $h(\rho_h(a^e)) = 0$ by construction –note that μ here refers to the probability assigned to the z_h-type cashflows. Given the monotonicity of G, and the fact that $G(x) \leq x$, $\exists x^*$ s.t. $H(x) = G(x) - \min\{d, x\} > 0$ iff

$x > x^*$. Then, note that $\mathbb{E}_a[H(X)|z_h] > \mathbb{E}_{a^e,\mu}[H(X)] = h(\rho_h(a^e)) = 0$, where the first inequality is given by $\rho(a^e) < \pi_h(a)$ and to the stochastic-dominance of $f_a(X|z_h)$ over $f_{a^e,\mu}(X)$ (abusing notation here). This implies that $g = f + h \geq f$, and then $\Pi_{z_h}(a, a^e, G) \leq \Pi_{z_h}(a, a^e, F)$. Because G was arbitrary, the optimal security preferred by the z_h-type is standard debt. This, standard debt securities are in the supremum of $\Pi(a, a^e, F)$. It is straightforward that debt level d is chosen to $\max_d \theta\mathbb{E}_{a^e,\mu}[\min(d, X)] - \mathbb{E}_a[\min(d, X)|z_h]$, where the solution to this exists and is unique (where $d = \infty$ is an admissible solution). □

Thus, investors post price $p(F_D) = \mathbb{E}_{a^e,\mu}[\min\{d(a^e, a^e), X\}]$ for debt level given by $d(a^e, a^e)$ as defined in previous Lemma, since they cannot observe a. In what follows, to characterize equilibrium debt levels, I may impose the equilibrium condition $a = a^e = a^*$.

Lemma. *Let $a = a^e$. For any $\theta > 1$, there $\exists \underline{a}(\theta), \bar{a}(\theta) \in \left[\frac{1}{2}, 1\right]$ s.t. $\forall\ a \in \left[\frac{1}{2}; \underline{a}(\theta)\right] \cup [\bar{a}(\theta), 1]$, equity is the only security issued in secondary markets. Threshold $\underline{a}(\theta)$ ($\bar{a}(\theta)$) is increasing (decreasing) in funding needs θ.*

Proof. By the previous Lemma, equity is chosen in equilibrium by both bank types when $\theta\rho(a) \geq \pi_h(a)$. i) Existence of $\underline{a}(\theta)$. Note that for $a = \frac{1}{2}$, the signal is uninformative, and thus $\rho(a) = \pi_h(a) = \pi_H$; the constraint is satisfied since $\theta > 1$. Using continuity and monotonicity of the RHS on a, the constraint must hold in an interval close to $a = \frac{1}{2}$, given by $\left[\frac{1}{2}; \underline{a}(\theta)\right]$. To see that the threshold is increasing, note that higher θ makes the constraint less binding. ii) Existence of $\bar{a}(\theta)$. Note that for $a = 1$, both signals are fully informative, and thus the initial screening excludes all bad firms, i.e. $\rho(1) = 1$, and thus the constraint is again satisfied for any $\theta > 1$. Again by continuity and monotonicity of the RHS on a, the constraint must hold for an interval close to $a = 1$, denoted by $[\bar{a}(\theta), 1]$. To see that $\bar{a}(\theta)$ is decreasing in θ, note that the constraint is again less binding for higher θ. Finally, note that if the z_h-type issues equity, so does the z_l-type. □

Lemma. *For given market beliefs, a^e, debt levels are decreasing in information acquisition.*

Proof. Note that debt levels are given by the FOC, and thus implicit function $d(a, a^e)$ is given by:

$$\frac{\pi_h(a) - \theta\rho(a^e)}{\theta - 1} = \frac{1}{\frac{1-G_H(d)}{1-G_L(d)} - 1}$$

i) The RHS is continuous, differentiable, and decreasing in d. The MLRP implies a hazard rate ordering and thus $\frac{1-G_H(X)}{1-G_L(X)}$ is increasing in X, the continuity and differentiability are given by the continuity and differentiability of the cumulative distributions. ii) The LHS is continuous, differentiable, and increasing in a. This follows from the $\pi_h(a)$ being continuous, differentiable, and increasing in a. Therefore, there exists an implicit function $d(a, a^e)$ that is continuous, differentiable, and decreasing in a. □

Corollary 2. *Debt levels are continuous and differentiable on the equilibrium level of information acquisition a^*.*

Proposition. *Let a^* denote the equilibrium level of information acquisition. Then, under the* No Transparency *Assumption, in any equilibrium in secondary markets:*

- *z_h-type bank issues standard debt $F_D^* = \min\{d(a^*, a^*), X\}$ where $d(a^*, a^*)$ is given by (A.1), at price $p_D = \mathbb{E}_{a^*,\mu}[\min\{d(a^*, a^*), X\}]$.*
- *z_l-type bank issues standard debt F_D and junior tranche $F_J^*(X) = X - F_D^*(X)$ at prices p_D and $p_J = \mathbb{E}_{a^*}[X - \min\{d(a^*, a^*), X\}|z_l]$.*

Existence. To fully determine an equilibrium, it rests to determine how to price the securities not issued in equilibrium. The following beliefs support an equilibrium in secondary markets. For all $G \in \Delta$ s.t. $G(X) \leq \min\{d^*(a^e), X\}$, $\mu(G) = \rho_h(a^e)$, otherwise, $\mu(G) = 0$. In addition, $a^e = a^*$. That is, securities with "less" cashflows than the one issued by the z_h-type in equilibrium are evaluated at average valuations, while securities with claims to more cashflows (for a positive measure of outcomes $\mathbb{X}$), are priced at the lowest valuation. Note that for given a^e, the market posts the described menu, and by construction there are no profitable deviations for the market. The bank chooses which security to issue, given the posted menu, and thus there is no room for signaling, the bank has access to the whole set of securities in Δ and issues the one that maximizes the value of banking in $t = 0$.

Choice of Information Acquisition

Given the previously constructed equilibrium outcome in secondary markets, I now focus on the choice of information acquisition done by the bank in $t = 0$. The bank cannot affect market beliefs a^e, and let standard debt $F_D(a, a^e) \equiv \min\{d(a, a^e), X\}$ and junior tranche $F_J(a, a^e) \equiv \max\{X - d(a, a^e), 0\}$ be the securities issued in secondary markets for any level of information acquisition, a, and corresponding market beliefs a^e. The bank's expected utility in $t = 0$ is given by:

$$V_0(a, a^e) \equiv \rho_h(a)\{\theta p(F_D(a, a^e)) + \mathbb{E}_a[X - F_D(a, a^e)|z_h]\} + \tag{A.2}$$
$$(1 - \rho_h(a))\{\theta(p(F_D(a^e, a^e)) + p(F_J(a^e, a^e)))\} - C(a) \tag{A.3}$$

Note that we can use the Envelope Condition to abstract from the impact a has on the choice of security $F(a, a^e)$, since securities are chosen ex-post to maximize the value of the bank in $t = 1$. Also note that independently of what the z_h type issues in secondary markets, the z_l type always issues securities $F_D(a^e, a^e)$ and $F_J(a^e, a^e)$ since this maximizes the rents in can receive from the market. Incorporating this, the optimal choice of investment in information is given by:

$$\rho'(a)\left[\mathbb{E}_H\left[X - F_D(a,a)\right] - \mathbb{E}_L\left[X - F_D(a,a)\right]\right] = \rho_h'(a)(\theta - 1)\,\mathbb{E}_a\left[X - F_D(a,a)|z_l\right] + C'(a) \tag{A.4}$$

Lemma 5. *An equilibrium without commitment always exists.*

Let beliefs for securities not issued in equilibrium be given by:

$$\mu(F) = \begin{cases} \rho_h(a^e) & F \leq F_D^* \\ 0 & o.w. \end{cases} \tag{A.5}$$

where $F \leq F_D^*$ mean that $F(X) \leq \min\{d^*, X\} \equiv F_D^*, \; \forall X$. Let $\left\{\tilde{a}, \tilde{d}\right\}$ be a profitable deviation to $\tilde{a} > a^*$, where $a^e = a^*$. Note that this deviation implies that $\tilde{d} \leq d^*$. In particular, for $\tilde{d} = d^*$, we know the deviation is not profitable by construction, therefore, it must be that $\tilde{d} < d^*$ and thus we know $\mu(\min\{\tilde{d}, X\}) = \rho_h(a^*)$. The payoff to the bank from this deviation is given by:

$$\begin{aligned}
\rho_h(\tilde{a})[\theta\mathbb{E}[\min\{\tilde{d},X\}|\rho_h(a^*)] + \mathbb{E}[X - \min\{\tilde{d},X\}|z_h(\tilde{a})]] + (1-\rho_h(\tilde{a}))V_0^* &\leq ... \\
\rho_h(\tilde{a})[\max_d \theta\mathbb{E}[\min\{d,X\}|\rho_h(a^*)] + \mathbb{E}[X - \min\{d,X\}|z_h(\tilde{a})]] + (1-\rho_h(\tilde{a}))V_0^* &\leq ... \\
\max_{\tilde{a}} \rho_h(\tilde{a})[\max_d \theta\mathbb{E}[\min\{d,X\}|\rho_h(a^*)] + \mathbb{E}[X - \min\{d,X\}|z_h(\tilde{a})]] + (1-\rho_h(\tilde{a}))V_0^* &= ... \\
\rho_h(a^*)\left[\theta\mathbb{E}\left[\min\{d^*,X\}|\rho_h(a^*)\right] + \mathbb{E}\left[X - \min\{d^*,X\}|z_h(a^*)\right]\right] + (1-\rho_h(\tilde{a}))V_0^* &
\end{aligned}$$

Therefore, this deviation is not profitable. Now, consider a deviation to $\{\tilde{a}, \tilde{d}\}$ where $\tilde{a} < a^*$, this deviation can only be profitable if extra cashflows G are issued at lower valuations. The payoff from this deviation is given by:

$$\begin{aligned}
\rho_h(\tilde{a})[\theta\{\mathbb{E}[\min\{d^*,X\}|\rho_h(a^*)] + \mathbb{E}[G|z_l]\} + \mathbb{E}[X - \min\{d^*,X\} - G|z_h(\tilde{a})]] + (1-\rho_h(\tilde{a}))V_0^* &\leq ... \\
\rho_h(\tilde{a})[\theta\mathbb{E}[\min\{d^*,X\} + G|\rho_h(a^*)] + \mathbb{E}[X - \min\{d^*,X\} - G|z_h(\tilde{a})]] + (1-\rho_h(\tilde{a}))V_0^* &\leq ... \\
\rho_h(\tilde{a})[\max_{F\in\Delta}\{\theta\mathbb{E}[F|\rho_h(a^*)] + \mathbb{E}[X - F|z_h(\tilde{a})]\}] + (1-\rho_h(\tilde{a}))V_0^* &\leq ... \\
\max_{\tilde{a}} \rho_h(\tilde{a})[\max_{F\in\Delta}\{\theta\mathbb{E}[F|\rho_h(a^*)] + \mathbb{E}[X - F|z_h(\tilde{a})]\}] + (1-\rho_h(\tilde{a}))V_0^* &= ... \\
\rho_h(a^*)[\theta\mathbb{E}[\min\{d^*,X\}|\rho_h(a^*)] + \mathbb{E}[X - \min\{d^*,X\}|z_h(a^*)]] + (1-\rho_h(\tilde{a}))V_0^* &
\end{aligned}$$

Contradiction. Since a^* is the solution to:

$$a^* = \arg\max_{\tilde{a}} \rho_h(\tilde{a})[\max_{F\in\Delta} \theta\mathbb{E}_{a^*,\mu}[F(X)] + \mathbb{E}_{\tilde{a}}[X - F(X)]] + (1-\rho_h(\tilde{a}))V_0^*$$

And thus, there are no profitable deviations from equilibrium $\{a^*, d^* = d(a^*, a^*)\}$.

The Optimal Mechanism: The Case of Commitment.

To simplify on notation, from now on $\mathbb{E}[F] \equiv \mathbb{E}[F(X)]$, and when not indicated, these expectations are computed for implementable levels of information a^*. The following Lemmas are needed for the results of the main proposition of this section.

Lemma. *It can be assumed without loss that the incentive compatibility for the z_l-type bank binds in equilibrium; that is, $\theta p_l - \mathbb{E}[F_l(X)|z_l] = \theta p_h - \mathbb{E}[F_h(X)|z_l]$.*

Proof.

$$V_0 = \rho(a)\left[\theta p_h + E_a[X - F_h|z_h] + (1-\rho(a))\left[p_l + E_a\left[X - F_l|z_l\right]\right] - C(a)\right.$$

Plugging in the zero profit, we get

$$V_0(a, p_h, p_l, F_h, F_l) = (\theta - 1)\left[\rho(a) E_a[F_h(X)|z_h] + (1-\rho(a)) E_a\left[F_l(X)|z_l\right]\right] + E_a[X] - C(a)$$

Note that in any incentive compatible mechanism where the IC is slack, $F_h(X) < X$. Now, find $\epsilon > 0$ and $F_h' \geq F_h$ s.t. FOC wrt a remains un-affected and the IC continues to be slack, and re-define transfers as follows:

$$p_l' = p_l - \epsilon\left(\frac{1-\rho(\tilde{a})}{\rho(\tilde{a})}\right) \qquad p_h' = p_h + \epsilon\left(\frac{1-\rho(\tilde{a})}{\rho(\tilde{a})}\right)$$

and thus:

$$p_h' - p_l' = p_h - p_l + 2\epsilon\left(\frac{1-\rho(\tilde{a})}{\rho(\tilde{a})}\right)$$

Remember that in the optimal mechanism $\{p_h, p_l, F_h, F_l, \tilde{a}\}$ the following FOC holds:

$$\begin{aligned} &\rho'(\tilde{a})\left\{\theta(p_h - p_l) + E_{\tilde{a}}[X - F_h(X)|z_h] - E_{\tilde{a}}[X - F_l(X)|z_l]\right\} + \\ &\quad \rho(\tilde{a})\pi_h'(\tilde{a})[E_H[X - F_h(X)] - E_L[X - F_h(X)]] + \\ &\quad (1-\rho(\tilde{a}))\pi_l'(\tilde{a})[E_H[X - F_l(X)] - E_L[X - F_l(X)]] - C(\tilde{a}) = 0 \end{aligned}$$

Now, ϵ and F_h' are chosen so that the FOC wrt a is zero at $\tilde{a}$ (the new transfers and securities implement the same level of information acquisition), that is, mechanism $\{p_h', p_l', F_h', F_l\}$ implements $\tilde{a}$:

$$\begin{aligned} &\rho'(\tilde{a})\left\{\theta\left(p_h - p_l + 2\epsilon\left(\frac{1-\rho(\tilde{a})}{\rho(\tilde{a})}\right)\right) + E_{\tilde{a}}[X - F_h'|z_h] - E_{\tilde{a}}\left[X - F_l|z_l\right]\right\} + \\ &\rho(\tilde{a})\pi_h'(\tilde{a})\left[E_H[X - F_h'] - E_L[X - F_h']\right] + (1-\rho(\tilde{a}))\pi_l'(\tilde{a})\left[E_H[X - F_l] - E_L[X - F_l]\right] - C(\tilde{a}) = 0 \end{aligned}$$

Note that the LHS is decreasing in cashflows of F_h , and thus there always $\exists\epsilon > 0$ so that the above exercise is possible. In addition, since

$$\rho'(a)\,\theta 2\epsilon\left(\frac{1-\rho(\tilde{a})}{\rho(\tilde{a})}\right) > 0$$

it must be that $F_h' > F_h$, and thus $E\left[F_h'(X)\,|z_h\right] > E\left[F_h(X)\,|z_h\right]$. Now let

$$\phi = \rho(\tilde{a})\left\{E\left[F_h'(X)\,|z_h\right] - E\left[F_h(X)\,|z_h\right]\right\}$$

and split ϕ evenly to both bank types: $p_h'' = p_h' + \frac{\phi}{2}$ and $p_l'' = p_l' + \frac{\phi}{2}$. This transfer does not distort incentives, and thus mechanism $\{p_h'', p_l'', F_h', F_l\}$ implements $\tilde{a}$ and attains higher welfare. Contradiction.

□

The binding (IC_l) makes the incentive compatibility for high types, (IC_h) slack, meaning that there is no need to impose an extra constraint. Note that the Binding (IC_l) implies:

$$\theta p_l - \mathbb{E}[F_l|z_l] = \theta p_h - \mathbb{E}[F_h|z_l] \Rightarrow \mathbb{E}[F_h|z_l] - \mathbb{E}[F_l|z_l] = \theta(p_h - p_l)$$

First, note that the (PC_l) is slack:

$$\theta p_l - \mathbb{E}[F_l|z_l] = \theta p_h - \mathbb{E}[F_h|z_l] \geq \theta p_h - \mathbb{E}[F_h|z_h] \geq 0$$

Now, all remaining funds are transfered to the good type, and therefore the (IC_h) is slack. To see this, note that from (IC_h) we get:

$$\theta p_h - \mathbb{E}[F_h|z_h] \geq \theta p_l - \mathbb{E}[F_l|z_h] \iff \theta(p_h - p_l) \geq \mathbb{E}[F_h|z_h] - \mathbb{E}[F_l|z_h]$$

using the binding (IC_l)

$$\begin{aligned} &\iff \mathbb{E}[F_h|z_l] - \mathbb{E}[F_l|z_l] \geq \mathbb{E}[F_h|z_h] - \mathbb{E}[F_l|z_h] \\ &\iff \mathbb{E}[F_l - F_h|z_h] \geq \mathbb{E}[F_l - F_h|z_l] \end{aligned}$$

High types need to retain as much as low types in any equilibrium; that is, $\mathbb{E}[F_l - F_h|z] > 0,\ \forall z$.

Lemma. *In the optimal mechanism, the level of information acquisition that can be implemented, a, only depends on the security issued by the z_h-type bank, F_h.*

Proof. By previous Lemmas, we know that the (IC_l) binds in equilibrium. The (IC_a) determines the implementable level of information acquisition, a, which is given by the following FOC:

$$\rho_h'(a)\{\theta(p_h - p_l) + \mathbb{E}[X - F_h|z_h] - \mathbb{E}[X - F_l|z_l]\} - C'(\hat{a}) + ...$$
$$\rho_h(\hat{a})\pi_h'(a)\{\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\} = 0$$

Using the binding (IC_l), $\theta p_l - \mathbb{E}[F_l|z_l] = \theta p_h - \mathbb{E}[F_h|z_l]$, and the fact that $\pi_l(a) = \pi_H$ we get:

$$\rho_h'(a)\{\theta p_h - \mathbb{E}[F_h|z_l] + \mathbb{E}[F_h|z_l] + \mathbb{E}[X - F_h|z_h] - [\theta p_l + \mathbb{E}[X - F_l|z_l]]\} - C'(\hat{a}) + ...$$
$$... + \rho_h(\hat{a})\pi_h'(a)\{\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\} = 0$$
$$\rho_h'(a)(\pi_h(a) - \pi_H)\{\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\} - C'(\hat{a}) + \rho_h(\hat{a})\pi_h'(a)\{\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\} = 0$$
$$\rho'(a)\{\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\} = C'(a)$$

since $\rho'(a) = \rho_h'(a)(\pi_h(a) - \pi_H) + \rho_h(\hat{a})\pi_h'(a)$. Thus, a only depends on F_h. □

Using the results from the previous Lemmas, the optimal mechanism is given by the solution to the following simplified problem:

$$\max_{\{p_l, p_h, F_l, F_h\} \in \mathbb{R}_+^2 \times \theta^2} \rho_h(a^*)[\theta p_h + \mathbb{E}[X - F_h|z_h(a^*)]] + (1 - \rho_h(a^*))[\theta p_l + \mathbb{E}[X - F_l|z_l(a^*)]] - C(a^*)$$

subject to:

$$\begin{aligned} \theta p_h - \mathbb{E}[F_h|z_h(a^*)] &\geq 0 \\ \mathbb{E}[F_l - F_h|z_h(a^*)] &\geq \mathbb{E}[F_l - F_h|z_l(a^*)] \\ \rho'(a)\{\mathbb{E}_H[X - F_h] - \mathbb{E}_L[X - F_h]\} &= C'(a^*) \\ \theta p_l - \mathbb{E}[F_l|z_l(a^*)] &= \theta p_h - \mathbb{E}[F_h|z_l(a^*)] \\ \rho_h(a^*)[\mathbb{E}[F_h|z_h(a^*)] - p_h] + (1 - \rho_h(a^*))[\mathbb{E}[F_l|z_l(a^*)] - p_l] &= 0 \end{aligned}$$

Lemma. *In the equilibrium with commitment, the z_l-type bank issues equity, $F_l = X$.*

Proof. The objective function can be re-written by plugging in the binding (PC_m) as follows:

$$V_0 = (\theta - 1)[\rho_h(a)\mathbb{E}[F_h|z_h] + (1 - \rho_h(a))\mathbb{E}[F_l|z_l]] + \rho_h(a)\mathbb{E}[X|z_h] + (1 - \rho_h(a))\mathbb{E}[X|z_l] - C(a)$$

The value of the bank increases with the cash-flows in F_l. From the binding (IC_l) and (PC_m), we can solve for the transfers made to each type as a function of chosen securities and implementable investment levels:

$$\begin{aligned} p_l &= \rho_h(a)\mathbb{E}[F_h|z_h] + (1 - \rho_h(a))\mathbb{E}[F_l|z_l] + \rho_h(a)\frac{1}{\theta}[\mathbb{E}[F_l|z_l] - \mathbb{E}[F_h|z_l]] \\ p_h &= \rho_h(a)\mathbb{E}[F_h|z_h] + (1 - \rho_h(a))\mathbb{E}[F_l|z_l] - (1 - \rho_h(a))\frac{1}{\theta}[\mathbb{E}[F_l|z_l] - \mathbb{E}[F_h|z_l]] \end{aligned}$$

Therefore, increasing the cashflows in F_l also relaxes the (PC_h) by increasing the transfers made to the good type bank. Finally, the (IC_a) constraint is unaffected. Therefore, since there are only gains from increasing the cash-flows in F_l, it must be that in the optimal mechanism, $F_l = X$. □

Lemma. *In the equilibrium with commitment, the z_h-type bank issues standard debt, $F_h = \min\{d_h, X\}$.*

Proof. Let $\{p_l, p_h, F_l, F_h\}$ be an optimal mechanism where F_h is not standard debt. As shown in the previous Lemmas, (IC_i) and (IC_0) bind, and $F_l = X$ in equilibrium. Therefore, the bank's objective function is maximized:

$$V_0 = (\theta - 1)\left[\rho_h(a)\mathbb{E}\left[F_h|z_h\right] + (1 - \rho_h(a))\,\mathbb{E}\left[F_l|z_l\right]\right] + \rho_h(a)\mathbb{E}\left[X|z_h\right] + (1 - \rho_h(a))\,\mathbb{E}\left[X|z_l\right] - C\left(a\right)$$

subject to:

$$\theta p_h - \mathbb{E}\left[F_h|z_h\right] \geq 0$$
$$\mathbb{E}\left[F_l - F_h|z_h\right] \geq \mathbb{E}\left[F_l - F_h|z_l\right]$$
$$\rho'\left(a\right)\left\{\mathbb{E}_H\left[X - F_h\right] - \mathbb{E}_L\left[X - F_h\right]\right\} = C'\left(a\right)$$

$$p_h = \rho_h(a)\mathbb{E}\left[F_h|z_h\right] + \frac{1}{\theta}\left\{\left(\theta - 1\right)\left(1 - \rho_h(a)\right)\mathbb{E}\left[X|z_l\right] + \left(1 - \rho_h(a)\right)\mathbb{E}\left[F_h|z_l\right]\right\}$$
$$p_l = \rho_h(a)\mathbb{E}\left[F_h|z_h\right] + \frac{1}{\theta}\left\{\left(\theta\left(1 - \rho_h(a)\right) + \rho_h(a)\right)\mathbb{E}\left[X|z_l\right] - \rho_h(a)\mathbb{E}\left[F_h|z_l\right]\right\}$$

Let $F_h = G$ be an arbitrary $G \in \Delta$, with cashflows $\upsilon\left(X\right)$, different than standard debt. Let $F = \min\left\{d, X\right\}$ and choose d so that $\mathbb{E}\left[G|z_h\right] = \mathbb{E}\left[F|z_h\right]$. Let $H = G - F$, and let $h\left(z\right) = \mathbb{E}\left[G - F|z\right]$, where by construction $h\left(z_h\right) = 0$. Note that since $\upsilon\left(X\right) \leq X$, $H\left(x\right) > 0$ iff $x \geq x^*$ for some $x^* \in \Omega$. Therefore, given the MLRP ($g_H\left(X\right)/g_L\left(X\right)$ is increasing in X), $\mathbb{E}_H\left[H\right] - \mathbb{E}_L\left[H\right] > 0$. Therefore,

$$\mathbb{E}_H\left[G\right] - \mathbb{E}_L\left[G\right] > \mathbb{E}_H[F(X)] - \mathbb{E}_L[F(X)]$$
$$\mathbb{E}_H\left[X - G\right] - \mathbb{E}_L\left[X - G\right] < \mathbb{E}_H\left[X - F\right] - \mathbb{E}_L\left[X - F\right]$$

And thus, security F implements the same level of information acquisition at lower retention costs. Also note that since $h\left(z_l\right) < h\left(z_h\right) = 0$,

$$\mathbb{E}\left[H|z_l\right] < 0 \Rightarrow \mathbb{E}\left[G|z_l\right] < \mathbb{E}\left[F|z_l\right] \rightarrow p_h\left(F\right) > p_h\left(G\right)$$

and the (PC_h) is relaxed. Since by construction $h\left(z_h\right) = 0$, the the remaining constraints are unaffected by this change. Therefore, mechanism $\{p_l, p_h, F_l, F\}$ reduces the costs associated with implementing a given level of information acquisition, and relaxes the (PC_h) and the (IC_h). Since $G \in \Delta$ was an arbitrary security different than debt, it must be that the good types issues standard debt in equilibrium; that is $F = \min\left\{d, X\right\}$. □

Let $a(d)$ be the implicit function given by the (IC_a) constraint:

$$\rho'(a)(\mathbb{E}_H[X - \min\{d, X\}] - \mathbb{E}_L[X - \min\{d, X\}]) = C'(a)$$

Note that $a(d)$ is continuous, differentiable, and decreasing in d given that the MLRP. Incorporating this implicit function, the problem becomes:

$$\max_{\{p_l, p_h, F_l, F_h\} \in \mathbb{R}^2_+ \times \Delta^2} \rho_h(a^*)[\theta p_h + \mathbb{E}[X - F_h|z_h(a^*)]] + (1 - \rho_h(a^*))[\theta p_l + \mathbb{E}[X - F_l|z_l(a^*)]] - C(a^*)$$

subject to:

$$\rho'(a^*)\{\mathbb{E}_H[X - \min\{d, X\}] - \mathbb{E}_L[X - \min\{d, X\}]\} = C'(a^*) arrow a^*(d)$$
$$\theta p_h - \mathbb{E}[F_h|z_h] \geq 0 \qquad (\lambda)$$

$$p_h = \rho_h(a)\mathbb{E}[F_h|z_h] + \frac{1}{\theta}\{(\theta-1)(1-\rho_h(a))\mathbb{E}[X|z_l] + (1-\rho_h(a))\mathbb{E}[F_h|z_l]\}$$
$$p_l = \rho_h(a)\mathbb{E}[F_h|z_h] + \frac{1}{\theta}\{(\theta(1-\rho_h(a)) + \rho_h(a))\mathbb{E}[X|z_l] - \rho_h(a)\mathbb{E}[F_h|z_l]\}$$

If $\lambda^* = 0$:

$$\theta\frac{\partial}{\partial a^*}\left\{\rho_h(a^*)p_h(a^*) + (1-\rho_h(a^*))p_l(a^*)\right\}\frac{\partial a^*}{\partial d} +$$
$$\theta[\rho_h(a^*)\frac{\partial p_h(a^*)}{\partial d} + (1-\rho_h(a^*))\frac{\partial p_l(a^*)}{\partial d}] -$$
$$\rho_h(a^*)\int_d^\infty f(X|z_h)dX = 0$$

where

$$\frac{\partial p_h}{\partial d} = \rho_h(a)\int_d^\infty f(X|z_h)dX + \frac{1}{\theta}(1-\rho_h(a))\int_d^\infty f(X|z_l)dX$$
$$\frac{\partial p_l}{\partial d} = \rho_h(a)\int_d^\infty f(X|z_h)dX - \frac{1}{\theta}\rho_h(a)\int_d^\infty f(X|z_l)dX$$

and thus,

$$\theta[\rho_h(a(d))\frac{\partial p_h}{\partial a^*} + (1-\rho_h(a(d)))\frac{\partial p_l(a)}{\partial a^*}]a'(d) + (\theta-1)\rho_h(a)\int_d^\infty f(X|z_h)dX = 0$$

Finally,

$$\frac{\partial p_h}{\partial a} = \rho'(a)[\mathbb{E}_H[F_h] - \mathbb{E}_L[F_h]] - \rho_h'(a)\frac{(\theta-1)}{\theta}\mathbb{E}[X - F_h|z_l]$$
$$\frac{\partial p_l}{\partial a} = \rho'(a)[\mathbb{E}_H[F_h] - \mathbb{E}_L[F_h]] - \rho_h'(a)\frac{(\theta-1)}{\theta}\mathbb{E}[X - F_h|z_l]$$

Therefore,

$$\{\theta\rho'(a)[\mathbb{E}_H[F_h] - \mathbb{E}_L[F_h]] - (\theta-1)\rho_h'(a)\mathbb{E}[X - F_h|z_l]\}a'(d) + (\theta-1)\rho_h(a)\int_d^\infty f(X|z_h)dX = 0$$

If the $\{d, a(d)\}$ given by the previous FOC satisfy the (PC_h), then d is given by the first-order condition, and $\{p_l, p_h\}$ are given by the biding (PC_m) and the (IC_0), and investment in information $a(d)$ is implemented. If the $\{d, a\,(d)\}$ given by the previous FOC violate the (PC_h); then $\lambda^* > 0$ and d is given by the binding (PC_h), transfers are given by the binding (PC_i) and (IC_0) and $a\,(d)$ is implemented. Clearly, when the (PC_h) binds, the previous FOC are positive evaluated at the optimum $\{d^*, a\,(d^*)\}$.

Policy Implications

Let $\{\Gamma_0, \Gamma_h, \gamma, T\}$ be the transfers, marginal and lump-sum transfers that the regulator uses to implement the commitment (optimal mechanism) allocations: $\{d_c^*, a_c^*\}$. Let

Transfers Across Types. Let Γ_0, Γ_h be the transfers received when issuing senior and junior tranches respectively. Transfers need to be set so that:

$$p_{h,nc}^* + \Gamma_h^* = p_{h,c}^*$$
$$p_{l,nc}^* - \Gamma_0^* = p_{l,c}^*$$

Note that given the previous transfers, for a given debt level, information acquisition is given by:

$$\rho'(a)\left[\mathbb{E}_H\left[\min\{d, X\}\right] - \mathbb{E}_L\left[\min\{d, X\}\right]\right] = C'(a) \to a(d)$$

Marginal Tax γ on debt levels. Choose γ so that the FOC of the security design problem in $t = 1$ for $a = a_c^*$ is zero at d_c^*. The problem at $t = 1$:

$$\max_d \theta\left\{\mathbb{E}\left[\min\{d, X\}|\rho_h(a)\right] + \gamma \times d\right\} - \mathbb{E}\left[\min\{d, X\}|z_h(a)\right]$$

with FOC:

$$(\theta\rho(a_c^*) - \pi_h(a_c^*))\frac{1}{\theta}\left[F_H(d_c^*) - F_L(d_c^*)\right] + \frac{\theta - 1}{\theta}F_L((d_c^*)) - \gamma^* = 0$$

$$\gamma^* = \frac{1}{\theta}\left\{(\theta\rho(d_c^*) - \pi_h(d_c^*))(G_H(d_c^*) - G_L(d_c^*)) - (\theta - 1)G_L(d_c^*)\right\}$$

where $a_c^* = a(d_c^*)$ once transfers are made. Note that when $d_{nc}^* > d_c^*$, $\gamma^* < 0$; that is, debt levels are taxed, or equivalently, retention levels are subsidized. *Participation transfer.* Transfer $\Gamma = -\rho_h(a_c^*)\gamma^* d_c^*$ is given to the bank if it participates in secondary markets. Note the bank agrees with this policy since it increases its ex-ante efficiency. Finally, note that by construction, the budget constraint of the regulator is satisfied, that is:

$$\rho_h(a_c^*)\left[\Gamma_h^* + \gamma d_c^*\right] + (1 - \rho_h(a_c^*))\Gamma_h^* + T^* = 0$$

I proceed to compute the transfers.

$$p_l^{nc} = \mathbb{E}[X|z_l] + \rho_h(a)\{\mathbb{E}[F_h|z_h] - \mathbb{E}[F_h|z_l]\}$$
$$p_h^{nc} = \mathbb{E}[F_h|z_h] - (1 - \rho_h(a))\{\mathbb{E}[F_h|z_h] - \mathbb{E}[F_h|z_l]\}$$
$$p_l^c = \rho_h(a)\mathbb{E}[F_h|z_h] + (1 - \rho_h(a))\mathbb{E}[F_l|z_l] + \rho_h(a)\frac{1}{\theta}[\mathbb{E}[F_l|z_l] - \mathbb{E}[F_h|z_l]]$$
$$p_h^c = \rho_h(a)\mathbb{E}[F_h|z_h] + (1 - \rho_h(a))\mathbb{E}[F_l|z_l] - (1 - \rho_h(a))\frac{1}{\theta}\{\mathbb{E}[F_l|z_l] - \mathbb{E}[F_h|z_l]\}$$

Therefore, $\Gamma_h^* = p_h^c - p_h^{nc}$ is given by:

$$\Gamma_h^* = (1 - \rho_h(a))(\frac{\theta - 1}{\theta})\mathbb{E}[\max\{0, X - d\}|z_l]$$

And $\Gamma_0^* = p_l^c - p_l^{nc} =$

$$\Gamma_0^* = -\rho_h(a)(\frac{\theta - 1}{\theta})\mathbb{E}[\max\{0, X - d\}|z_l]$$

Extensions

Pooling and Tranching

Let z^i be the information held by the bank in $t = 1$ about firm i, then $\{z^i\}_{i=1,..,n} \in Z^n$ is the bank's private information. Then $\zeta \in \mathbb{N}$ denotes the bank's type and it is given by the number of loans z_h received for the loans in the pool. Finally, let $\rho_\zeta(a)$ denote the probability of receiving ζ signals $s_1 = G$, given that $s_0 = G$, where $\sum_{\zeta=0}^{n} \rho_\zeta(a) = 1$.

The density of the bank's cashflows, $f_y(y)$, is given by the convolution of n pdfs $f_x\left(\frac{x}{n}\right)$ and $f_y(y|z)$ is given by the convolution of $f_x\left(\frac{x}{n}|z^1\right), f_x\left(\frac{x}{n}|z^2\right), ..., f_x\left(\frac{x}{n}|z^n\right)$ for $z = \{z^1, z^2, ..., z^n\}$, with $\mathbb{E}[Y] = \mathbb{E}[X]$ and $\mathbb{E}[Y|z] = \sum_{i=1}^{n} \mathbb{E}[X|z_i]$ and $V(Y) = \frac{1}{n} V(X)$ and $V(Y|z) = \frac{1}{n}\sum_{i=1}^{n} V(X|z_i)$. In addition, the bank type ζ is distributed with $\zeta \sim \mathit{Binomial}(\rho_h(a), n)$ and thus the probability of the bank being type ζ conditional on initial investment in information a is given by:

$$g(\zeta; n, \rho_h(a)) = \rho_\zeta(a) = \begin{pmatrix} n \\ \zeta \end{pmatrix} \rho_h(a)^\zeta (1 - \rho_h(a))^{n-\zeta}$$

with cumulative distribution $G(k; n, p)$ (denoted by $G(k)$ from now on). This implies that the value of the bank in $t = 0$ is given by:

$$\sum_{\zeta=0}^{n} \rho_{h,\zeta}(a) \left[p(\zeta) + \mathbb{E}[X - F(\zeta)|\zeta]\right]$$

where $F(\zeta)$ are the cash-flows sold by type ζ, and $p(\zeta)$ the funds raised by this type in secondary markets.

Markets for ABS: No Commitment. The definition of equilibrium of the full game, and of equilibrium in secondary markets remains unchanged. I proceed with the security design problem solved by the best type $\zeta = n$. Using the results from the baseline section, the security design problem with multiple types is as follows. By our construction of the two-types equilibrium, we know the high type would choose to issue one security. The problem faced by the high type is given by:

$$\max_{F \in \Delta} \theta p_n - \mathbb{E}[F_n(Y)|n]$$

As in the baseline case, this type is mimicked by lower types in secondary markets. Therefore, since it faces adverse selection, the optimal security continues to be standard debt: $F_n(Y) = \min\{d_n, Y\}$, and that $p_n = \sum_{k=0}^{n} \rho_k(a) \mathbb{E}[\min\{d_n, Y\}|k]$ since all types $k < n$ mimic this issuance n. Since the high type is mimicked by lower types in equilibrium, the problem can be written as:

$$\max_{d} \theta \left[\sum_{k=0}^{n} \rho_k(a) \mathbb{E}[\min\{d_n, Y\}|k]\right] - \mathbb{E}[\min\{d_n, Y\}|n]$$

with FOC

$$\int_{d}^{\infty}\left[\theta\left(\sum_{k=0}^{n-1}\rho_k\left(a\right)f_y\left(y|k\right)\right)+\left(\theta\rho_n\left(a\right)-1\right)f_y\left(y|n\right)\right]dy=0$$

If for $d=\infty$, the LHS is still positive, then all types issue equity. If not, $d_n<0$ is chosen to satisfy the FOC. I continue to solve the problem of the next highest type: $\zeta=n-1$ has remaining cashflows $Y_{n-1}=Y-\min\left\{d_n,Y\right\}$, also monotonic in Y. Bank type $n-1$ solves the same problem, and issues issues debt contract d_{n-1} backed by Y_{n-1}. It issues the safe tranche $F_n=\min\left\{d_n,Y\right\}$ and the mezzanine tranche $F_{n-1}=\min\left\{d_{n-1},Y_{n-1}\right\}$. The latter issuance is mimicked by types $\zeta\leq\zeta_{n-1}$ and therefore the market price is given by:

$$p_{n-1}=\frac{1}{G\left(n-1\right)}\sum_{k=0}^{n-1}\rho_k\left(a\right)\mathbb{E}\left[\min\left\{d_{n-1},Y_{n-1}\right\}|\zeta_k\right]$$

Optimal threshold level d_{n-1} is chosen to maximize:

$$\theta\sum_{k=0}^{n-2}\frac{\rho_k\left(a\right)}{G\left(n-1\right)}\mathbb{E}\left[\min\left\{d_{n-1},Y_{n-1}\right\}|\zeta_k\right]+\left(\theta\frac{\rho_{n-1}\left(a\right)}{G\left(n-1\right)}-1\right)\mathbb{E}\left[\min\left\{d_{n-1},Y_{n-1}\right\}|\zeta_{n-1}\right]$$

This problem continues until type $k\geq 0$ issues equity. It is easy to see that there exists a type $k\geq 0$ that issues a claim to all of its cash-flows. It mimics issuance of types $\left\{\zeta_{k+1},...\zeta_n\right\}$ and issues equity tranche $F_k=Y-\min\left\{d_{k+1},Y\right\}$ at valuation $p_k=\sum_{i=1}^{k}\frac{\rho_i(a)}{1-G(k)}\mathbb{E}\left[\min\left\{d,\max\left\{Y-d_{k+1},0\right\}\right\}|\zeta_i\right]$. Note that type $k=0$ does not face a lemons discount and thus issues an equity tranche.

The choice of information acquisition:

$$a=\arg\max_{\hat{a}\in\left[\frac{1}{2},1\right]}\left\{\sum_{k=0}^{n}\rho_k\left(\hat{a}\right)\left[\theta p\left(F\left(k\right)\right)+\mathbb{E}\left[Y-F\left(k\right)|\zeta_k\left(\hat{a}\right)\right]\right]-C\left(\hat{a}\right)\right\}$$

where $p\left(F\left(k\right)\right)=\sum_{j=k}^{n}p_j$ and $F\left(k\right)=\min\left\{d_k,Y\right\}$. As in the two-types case, the choice of information acquisition is done to increase the expected value of the retained tranches, and to affect the distribution of types. The FOC:

$$\sum_{k=0}^{n} \rho_k' (a) \left[\theta p (F (k)) + \mathbb{E} [X - F (k) | \zeta_k (a)]\right] +$$
$$\sum_{k=0}^{n} \rho_k (a) \pi_k' (a) (\mathbb{E}_H [Y - F (k)] - \mathbb{E}_L [Y - F (k)]) - C' (a) = 0$$
$$\sum_{k=0}^{n} \rho_k' (\hat{a}) \left[\theta p (F (k)) + \mathbb{E} [Y - F (k) | \zeta_k (\hat{a})]\right] +$$
$$\sum_{k=0}^{n} \rho_k (\hat{a}) \frac{\partial}{\partial a} \mathbb{E} [Y - F (k) | \zeta_k (\hat{a})] - C (\hat{a}) = 0$$

For $n \to \infty$, the ex-ante probability of issuing junior tranches increases, while the probability of being of a higher type and retain decreases. Therefore, incentives for info acquisition are very likely to be decreasing in n. While pooling increases the expected gains from trade, it is detrimental since it worsens incentives for information acquisition.

The Optimal Mechanism: Commitment. As in the baseline case, the equilibrium with commitment is given by $\{a, \{p_k, d_k\}_{k=0}^{n}\}$ chosen to:

$$\max_{\{F_\zeta, p_\zeta, a\}} \left\{ \sum_{\zeta=0}^{n} \rho_\zeta (a) \left[\theta p_\zeta + \mathbb{E} [Y - F_\zeta | \zeta (a)]\right] - C (a) \right\}$$

subject to:

1. Incentive compatibility:

$$\zeta = \arg \max_{\hat{\zeta} \in \{0,..,n\}} \theta p_{\hat{\zeta}} + \mathbb{E} \left[Y - F_{\hat{\zeta}} | \zeta \right]$$

2. Ex-Post Rationality Constraints are satisfied.

$$\theta p_\zeta + \mathbb{E} [Y - F_\zeta | \zeta (a)] \geq 0 \quad \forall \zeta \in \{0, ...n\}$$
$$\theta p_\zeta + \mathbb{E} [Y - \min \{d_k, Y\} | \zeta (a)] = 0 \quad \forall \zeta \in \{0, ...n\}$$

3. Zero-Profit Condition:

$$\sum_{\zeta=0}^{n} \rho_\zeta (a) [\mathbb{E} [F_\zeta | \zeta] - p_\zeta] = 0$$

Debt continues to be the optimal design for all types, the arguments used in the baseline case follow through. It can also be shown that transfer of funds to higher types improves can be done at no loss subject to incentive compatibility constrains. Therefore, p_ζ are given by the binding (IC) and the Zero Profit condition. The choice of information acquisition for schedule $\{F_\zeta, p_\zeta\}$ is given by:

$$\max_a \left\{ \sum_{\zeta=0}^{n} \rho_\zeta (a) \left[\theta p_\zeta + \mathbb{E} \left[Y - F_\zeta | \zeta (a) \right] \right] - C (a) \right\}$$

$$\sum_{\zeta=0}^{n} \rho'_\zeta (a) \left[\theta p_\zeta + \mathbb{E} \left[\max \{ Y - d_\zeta, 0 \} | \zeta (a) \right] \right] + \sum_{\zeta=0}^{n} \rho_\zeta (a) \frac{\partial}{\partial a} \mathbb{E} \left[\max \{ Y - d_\zeta, 0 \} | \zeta (a) \right] - C' (a) = 0$$

where $\frac{\partial}{\partial a} \mathbb{E} \left[Y - F_\zeta | \zeta (a) \right] = \int_d^\infty (y - d) \left(\frac{\partial}{\partial a} f_Y (y | \zeta (a)) \right) dy$.

As before, the choice of information acquisition ex-ante is done to affect the quality of retained tranches, and to affect the distribution of types. The previous function generates an implicit function of $a^e = a (d_0, d_1, ..., d_n)$. Given this, when the participation constraint of type k does not bind in equilibrium, debt levels are chosen:

$$\max_d \left\{ \sum_{\zeta=0}^{n} \rho_\zeta (a) \left[\theta p_\zeta (a^e) + \mathbb{E} \left[Y - F_\zeta | \zeta (a) \right] \right] - C (a) \right\}$$

$$(d_k) \qquad \theta \left(\sum_{\zeta=0}^{n} \rho_\zeta (a) \frac{\partial p_\zeta}{\partial a^e} \frac{\partial a^e}{\partial d_k} \right) + \rho_k (a) \int_{d_k}^{\infty} f_Y (y | \zeta = k) \, dy \geq 0 \qquad \forall d_k, k = 1, 2, ...n$$

otherwise, debt levels are given by the binding participation constraint, as in the baseline case. The value of retention is higher for those types that have a large impact on incentives. For this, these types need to be also likely ex-ante, that is, relatively large $\rho_\zeta (a)$. The two previous FOC, together with binding IC and PC constraints and zero profit solve the problem.

Appendix B

Appendix for Chapter 3

Expert's Problem

Let c^e, c^h be the payoff of experts and households receptively, let μ be the mean of the experts' posterior distribution, and let $\tilde{\mu}$ be the households beliefs about the expert's private information (beliefs updated after observing portfolio allocations: α). The expert's problem is given by:

$$\max_{c^e, c^h, \alpha} E\left[u^e\left(c^e\right)|\mu\right]$$
$$E\left[u^h\left(c^h\right)|\tilde{\mu}\right] \geq \bar{U}^h \quad \left(\lambda_{pc}\left(\tilde{\mu}\right)\right)$$
$$c^e\left(R, \alpha\right) + c^h\left(R, \alpha\right) \leq \left[\alpha'\left(R - R_f\right) + R_f\right] w \quad \left(\lambda_{fc1}\left(R, \alpha\right)\right)$$
$$w \leq w^e + w^h \quad \left(\lambda_{fc2}\right)$$
$$\tilde{\mu}\left(\alpha\left(\mu\right)\right) = \mu$$

Proof of Proposition 9. Combining the constraints, the problem of expert with private information μ, can be re-written as follows:

$$\max_{c^e(R,\alpha), \alpha} E\left[u^e\left(\left[\alpha'\left(R - R_f\right) + R_f\right] w - c^h\left(R\right)\right)|\mu\right]$$
$$E\left[u^h\left(c^h\left(R, \alpha\right)\right)|\tilde{\mu}\right] \geq \bar{U}^h \quad \left(\lambda_{pc}\left(\tilde{\mu}\right)\right)$$
$$\tilde{\mu}\left(\alpha\left(\mu\right)\right) = \mu$$

Given that $u'\left(c\right) = \gamma \exp\left[-\gamma c\right]$, the FOC with respect to consumptions evaluated at $\tilde{\mu}\left(\alpha\left(\mu\right)\right) = \mu$ yield:

$$c^e\left(R, \alpha\right) = \frac{\gamma^h}{\gamma^h + \gamma^e}\left[\alpha'\left(R - R_f\right) + R_f\right] w + Z\left(\alpha\right)$$

$$c^h(R,\alpha) = \frac{\gamma^e}{\gamma^h+\gamma^e}\left[\alpha'(R-R_f)+R_f\right]w - Z(\alpha)$$

where $Z(\alpha) = \frac{1}{\gamma^h+\gamma^e} log\left(\frac{\lambda_{pc}\gamma^e}{\gamma^h}\right)$.

Proof of Proposition 8. To solve for $\overline{f}$ and $f(\alpha)$, we find the fee that makes the participation constraint of the households, for given beliefs $\mu(\alpha)$, bind:

$$E\left[u^h\left(\frac{\gamma^e}{\gamma^h+\gamma^e}\left[\alpha'(R-R_f)+R_f\right]w - Z(\alpha)\right)|\mu(\alpha)\right] = \bar{U}^h$$

and using that $u^h(x) = e^{-\gamma^h x}$ and $\mathrm{E}\left\{e^{-\gamma^h x}\right\} = e^{-\gamma^h \mathrm{E}\{x\}+\frac{1}{2}\gamma^{h2}\mathrm{V}(x)}$ for x that is normally distributed, we have

$$-\gamma^h\left(\frac{\gamma^e}{\gamma^h+\gamma^e}\left[R_f+\left[\mu(\alpha)-R_f 1_N\right]'\alpha\right]w - Z(\alpha)\right)+\frac{1}{2}\gamma^{h2}\left(\frac{\gamma^e}{\gamma^h+\gamma^e}\right)^2(\alpha w)'\Sigma(\alpha w) = -\gamma^h R_f w^h$$

$$\Longleftrightarrow$$

$$Z(\alpha) = \frac{\gamma^e}{\gamma^h+\gamma^e}\left[\mu(\alpha)-R_f 1_N\right]'\alpha w - \frac{1}{2}\gamma^h\left(\frac{\gamma^e}{\gamma^h+\gamma^e}\right)^2(\alpha w)'\Sigma(\alpha w) + R_f\left(\frac{\gamma^e}{\gamma^h+\gamma^e}w^e - \frac{\gamma^e}{\gamma^h+\gamma^e}w^h\right)$$

Decomposing the fee as in the text, $Z(\alpha) = \overline{f} + f(\alpha)$, we have that

$$\overline{f} = R_f\left(\frac{\gamma^e}{\gamma^h+\gamma^e}w^e - \frac{\gamma^e}{\gamma^h+\gamma^e}w^h\right)$$

$$f(\alpha) = \frac{\gamma^e}{\gamma^h+\gamma^e}\left[\mu(\alpha)-R_f 1_N\right]'\alpha w - \frac{1}{2}\gamma^h\left(\frac{\gamma^e}{\gamma^h+\gamma^e}\right)^2(\alpha w)'\Sigma(\alpha w)$$

Proof of Proposition 10. Using the results of Proposition 8, the expert's problem can be expressed as:

$$\max_{c^e(R,\alpha),\alpha}\left\{-\gamma^e\left[\frac{\gamma^h}{\gamma^h+\gamma^e}\left[\alpha(\mu-R_f)+R_f\right]w+\overline{f}+f(\alpha)\right]+\frac{1}{2}\gamma^{e2}\left(\frac{\gamma^h}{\gamma^h+\gamma^e}\right)^2(\alpha w)'\Sigma(\alpha w)\right\}$$

$$s.t.$$

$$\overline{f} = R_f\left(\frac{\gamma^e}{\gamma^h+\gamma^e}w^e - \frac{\gamma^e}{\gamma^h+\gamma^e}w^h\right)$$

$$f(\alpha) = \frac{\gamma^e}{\gamma^h+\gamma^e}\left[\mu(\alpha)-R_f 1_N\right]'\alpha w - \frac{1}{2}\gamma^h\left(\frac{\gamma^e}{\gamma^h+\gamma^e}\right)^2(\alpha w)'\Sigma(\alpha w)$$

where as before we use that that $u^h(x) = e^{-\gamma^h x}$ and $\mathrm{E}\left\{e^{-\gamma^h x}\right\} = e^{-\gamma^h \mathrm{E}\{x\} + \frac{1}{2}\gamma^{h2}\mathrm{V}(x)}$ for x that is normally distributed. The first order condition with respect to α yields

$$-\gamma^e \left[\frac{\gamma^h}{\gamma^h + \gamma^e}(\mu - R_f) w + f'(\alpha)\right] + \gamma^{e2}\left(\frac{\gamma^h}{\gamma^h + \gamma^e}\right)^2 w\Sigma\alpha w = 0$$

where

$$f'(\alpha) = \frac{\gamma^e}{\gamma^h + \gamma^e}[\mu(\alpha) - R_f 1_N] w + \frac{\gamma^e}{\gamma^h + \gamma^e}\left[\frac{d}{d\alpha}\mu(\alpha)\right]' \alpha w - \gamma^h \left(\frac{\gamma^e}{\gamma^h + \gamma^e}\right)^2 w\Sigma\alpha w$$

Using Conjecture 1, we have that

$$\frac{d}{d\alpha}\mu(\alpha) = \kappa^{-1}\Sigma$$

and combining these expressions and solving for α yields

$$\alpha = \kappa\Sigma^{-1}[\mu - R_f 1_N]$$

with $\kappa = \frac{\gamma^h + 2\gamma^e}{\gamma^h + \gamma^e}$.

Proof of Corollary 2. Plugging the optimal choice of α from Proposition 8 into the expression for $f(\alpha)$ yields

$$f(\alpha) = \frac{1}{2}\frac{\gamma^h + 2\gamma^e}{(\gamma^h + \gamma^e)^2}[\mu - R_f 1_N]' \Sigma^{-1}[\mu - R_f 1_N]$$

Optimality of Delegation. The household's welfare within the contract is given by

$$U^h = \gamma^h R_f w^h$$

If the household was able to invest in the portfolio with prior beliefs (μ_0, Σ_0), then its welfare would be

$$U^h = \frac{1}{2}[\mu_0 - R_f 1_N]' \Sigma_0^{-1}[\mu_0 - R_f 1_N] + \gamma^h R_f w^h$$

and so if the non-pecuniary cost of investment satisfies $\chi > \frac{1}{2}[\mu_0 - R_f 1_N]' \Sigma_0^{-1}[\mu_0 - R_f 1_N]$, the household will only invest through the expert.