Essays on Banking and Financial Instability

Autor: Jianxing Wei

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DIRECTOR DE LA TESI
Prof. Albert Banal-Estañol
Departament d'Economia i Empresa

Universitat
Pompeu Fabra
Barcelona

This thesis is dedicated to my parents.

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Abstract

This thesis focuses on the issue of bank funding structure and its implications for financial instability. The first chapter investigates how the dynamic interaction between the regulator and banks can endogenously lead to financial instability and generate boom-bust cycles. The model is able to capture pro-cyclical bank leverage, asymmetric credit cycles, and the Minsky moment in a unified framework. The second chapter provides a simple theoretical model to understand bank asset encumbrance and its implications for financial stability. I show that the effect of encumbrance depends on rates of over-collateralization faced by the banks, and I also demonstrate empirical evidence consistent with the predictions of the model. The third chapter revisits a classical issue in the banking literature: would loan sales undermine banks' special role of information production? I highlight the role of banks' insolvency risk and find that loan sales may improve, rather than weaken, banks' screening incentives.

Resum

Aquesta tesi se centra en la qüestió de l'estructura del finançament bancari i les seves implicacions per a la inestabilitat financera. El primer capítol investiga com la interacció dinàmica entre el regulador i els bancs pot conduir, endògenament, a inestabilitat financera i generar cicles economics. El model és capaç de captar l'apalancament bancari pro-cíclic, els cicles de crèdit asimètrics i el moment de Minsky en un marc unificat. El segon capítol proporciona un model teòric per entendre el fenomen d' "asset encumbrance" dels actius bancaris i les seves implicacions per a l'estabilitat financera. Mostrem teoricament que l'efecte depèn dels nivells de sobrecollatilització als que s'enfronten els bancs, i proporcionem evidència empírica consistent amb les prediccions del model. El tercer capítol revisita una pregunta clàssica en la literatura bancària: les vendes de préstecs ("loan sales") debiliten el rol de producció d'informació dels bancs? Destaquem el risc d'insolvència dels bancs i constatem que les vendes de préstecs poden millorar, en lloc de debilitar, els incentius de cribratge dels bancs.

Preface

The global financial crisis that started in 2007 highlights the extremely important role of banks in the economy. In the aftermath of financial crisis, there is a surge in research interest aimed at understanding the relationship between banks and financial instability. What is the role of banks' attempt to circumvent regulator supervision in the credit cycles? What are the implications of asset encumbrance for financial instability? Do loan sales weaken banks' special role of information production? The three chapters of the thesis explore these different issues. While using different modeling frameworks, they have a common emphasis on the bank funding structure.

The first chapter develops a model of financial intermediation in which the dynamic interaction between regulator supervision and banks' loophole innovation generates credit cycles. It is a joint paper with Tong Xu, a PhD from Emory University. In the model, banks' leverages are constrained due to a risk-shifting problem. The regulator supervises the banks to ease this moral hazard problem, and its expertise in supervision improves gradually through learning-by-doing. At the same time, banks can engage in loophole innovation to circumvent supervision, which acts as an endogenous opposing force diminishing the value of the regulator's accumulated expertise. In equilibrium, banks' leverage and loophole innovation move together with the regulator's supervision ability. The model generates pro-cyclical bank leverage and asymmetric credit cycles. We show that a crisis is more likely to occur and the consequences are more severe after a longer boom. In addition, we investigate the welfare implications of a maximum leverage ratio in the environment of loophole innovation.

The second chapter investigates the phenomenon of asset encumbrance. It is a joint paper with Albert Banal-Estañol, Enrique Benito and Dmitry Khametshin. Asset encumbrance refers to the existence of restrictions to a bank's ability to transfer or realize its assets. Asset encumbrance has recently become a much-discussed subject and policymakers have been actively addressing what some consider to be excessive levels of encumbrance. Despite its importance, the phenomenon remains poorly understood. We provide a simple theoretical model that highlights the implications of asset encumbrance for funding and financial stability. We show that the effect of encumbrance depends on rates of over-collateralization faced by the banks. With low levels of overcollateralization, asset encumbrance is negatively associated with bank credit risks as secured funding minimizes bank's exposure to liquidity shocks. When overcollateralization levels are high, encumbrance can exacerbate liquidity risks due to structural subordination effect and, hence, can be positively associated with bank credit risk premiums. We use a novel dataset on the levels of asset encumbrance of European banks and provide further empirical evidence supporting the predictions of the model. Our empirical results point to the existence of a negative association between CDS premia and asset encumbrance. Still, certain bank-level variables play a mediating role in this relationship. For banks that have high exposures to the central bank, high leverage ratio, or are located in southern Europe, asset encumbrance is less beneficial and could even be detrimental in absolute terms.

The third chapter re-examines the classical issue of loan sales and banks' moral hazard by highlighting the role of banks' bankruptcy risk. In the model, banks finance their loan portfolios by issuing risky debt. Due to limited liability, banks are subject to a risk-shifting problem which leads to the under-provision of screening effort. The bank may sell loans to transfer non-diversifiable credit risk. On the one hand, loan sales reduce banks' skin in the game, thus diluting their screening incentives. On the other hand, loan sales lower banks' bankruptcy risk, alleviating the risk-shifting problem. The sign and the magnitude of the effect of loan sales on banks' moral hazard depend crucially on the relative weights of these two opposing effects. When a bank's bankruptcy risk is high, the positive risk-shifting reduction effect of loan sales dominates the negative incentive-dilution effect, thus loan sales might curb rather than exacerbate the bank's moral hazard problem. The results extend to the case in which there is strategic adverse selection of loan sales. I study various extensions of the model.

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Chapter 1

A MODEL OF BANK CREDIT CYCLES

The more effective regulation is, the greater the incentive to find ways around it. With time and considerable money at stake, those within the regulatory boundary will find ways around any new regulation. The obvious danger is that the resultant dialectic between the regulator and the regulated will lead to increasing complexity, as the regulated find loopholes which the regulators then move (slowly) to close.

– Goodhart and Lastra (2010)

1.1 Introduction

Banks and other financial intermediaries play a prominent role in the economy by channeling funds from savers to borrowers. In the wake of the recent financial crisis, there is a surge in research aimed at understanding the relationship between financial intermediaries, financial instability and macroeconomic fluctuations. In this paper, we build a dynamic model of financial intermediation that emphasizes the interaction between the regulator and banks. We show that banks' moral hazard can endogenously lead to financial instability, and generate boom-bust credit cycles. In particular, the longer the boom, the more likely there will be a crisis and the more severe the consequences will be, which corresponds to Minsky (1986)'s hypothesis that good times sow the seeds for the next financial crisis. Moreover, the model's predictions reconcile well with some empirical facts related to credit cycles. For instance, our model predicts that banks' leverage is pro-cyclical, consistent with the findings in Adrian and Shin (2010, 2011). The model also generates asymmetric credit cycles, i.e., long periods of credit booms followed by sudden and sharp busts, while recovery is slow and gradual, as documented in Reinhart and Reinhart (2010).

The key element of our paper is banks' risk-shifting problem. It is now widely accepted that excessive risk-taking by banks contributed to the financial crisis of 2007-2009. While the causes of excessive risk-taking remain subject to debate, many observers and policymakers believe that bank supervision failure is one of the key contributing factors (Acharya and Richardson (2009); Acharya et al. (2011); Freixas et al. (2015)).[1] Indeed, several countries have made great efforts to improve their supervision of banks in the aftermath of the crisis.

What could explain the failure of bank supervision? Among various factors, financial innovation is mentioned as one key factor that can undermine the effectiveness of the regulator's supervision (e.g., Silber (1983); Miller (1986); Kane (1988); Tufano (2003)). Undoubtedly, good financial innovations provide numerous benefits to the economy.[2] However, there are also bad financial innovations that create new ways for financial institutions to get around current supervision and take excessive risks, which we refer to as loophole innovations in this paper. For instance, Stein (2013) argues that second-generation securitization, like subprime CDOs, is a bad financial innovation that evolved in response to flaws in prevailing models and incentive schemes. Another related example is Credit Default Swap (CDS). CDS was widely used to free up regulatory capital in banks' balance sheets prior to the crisis. However, when the risky assets of banks and the insurer are correlated, banks can use CDS to engage in regulatory arbitrage and take excessive risks under the Basel regulatory framework (Yorulmazer (2013)). As is illustrated in the recent financial crisis, the regulator was slow to understand the danger of loophole innovations in some instances, facilitating banks' excessive risk-taking. In this paper, we put a central emphasis on how banks' loophole innovation affects the effectiveness of regulator supervision, and investigate its macroeconomic implications over the credit cycles. To the best of our knowledge, this paper is the first to explicitly model the dynamic interaction between regulator supervision and banks' loophole innovation.

In the model, banks borrow from depositors in the form of debt to finance their investment opportunities. The investment opportunities could be safe or risky projects. Due to limited liability, banks are subject to a risk-shifting problem. Therefore, banks have incentives to take

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[1] Other mentioned factors include, for instance, shortcomings in financial institutions' incentive structures and risk management practices, misplaced reliance on credit rating agencies, etc.

[2] For instance, financial innovations help improve risk sharing, complete the market, reduce trade costs, see Beck et al. (2016) for an excellent survey of the debate on the "bright" and "dark" sides of financial innovation.

on inefficient risky projects, in which they enjoy the upside of payoff if projects succeed but depositors bear the loss if projects fail. One solution to this moral hazard problem is market discipline: depositors impose a leverage constraint on banks. If banks have enough "skin in the game", they will behave properly. However, market discipline is costly in the sense that it limits a bank's investment capacity.

Another complementary solution to the moral hazard problem is supervision by the regulator. In this paper, we formally distinguish regulation from supervision, in terms of the verifiability of bank information and actions, following Eisenbach et al. (2016).[3] Through actively monitoring banks' activities, the regulator can promote banks' safety and soundness. The leverage constraint and supervision from the regulator work together to address banks' risk-shifting problem. The better the regulator's supervision ability, the more banks can relax their borrowing constraint. As a result, the size of the banks depends on depositors' beliefs regarding the regulator's supervision ability. When depositors' confidence in the regulator's competence is high, they will permit banks to take high leverage without worrying about the risk-shifting problem. If the regulator's ability is perceived to be low, depositors have to tighten the leverage constraint to make sure banks behave properly.

Even though regulator supervision helps banks to increase their leverage from an ex ante perspective, banks always have incentives to find loopholes to circumvent regulator supervision ex post. In our paper, we model loophole innovation as discovering a new type of risky project which is not currently supervised by the regulator, thereby providing banks with opportunities to take on risky projects without being monitored by the regulator. This acts as an endogenous opposing force diminishing the regulator's expertise in supervision. When the loophole innovation eventually succeeds, the regulator's supervision becomes less effective. However, the regulator and depositors are not aware of the new loopholes immediately, so banks take on inefficient risky projects, thereby leading to massive defaults and a severe decline in output. After a bust, depositors realize that the regulator's expertise has become obsolete and they lose confidence in the financial system. In response, they constrain banks from taking high leverage to prevent their risk-taking activities, which implies a sharp contraction of the banking sector.

We incorporate regulator supervision and banks' loophole innovation into a dynamic model.

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[3] Regulation is written into law and enforced through the courts, so it can only be contingent on verifiable information. In contrast, supervision involves the assessment of the safety and soundness of banks through monitoring by the regulator, and corrective actions in response to the assessment. Supervision can be contingent on non-verifiable information.

We assume that the regulator's expertise in supervising banks regarding previous loopholes gradually improves through a learning-by-doing process. This assumption is supported by some recent studies on how prudential supervision works in practice (see, e.g., Dahlgren (2011); Dudley (2014); Eisenbach et al. (2016)).[4] As the regulator's expertise grows, it has two effects on banks' moral hazard problem. On the one hand, it eases banks' risk-shifting problem related to previous loopholes, which allows banks to take a higher leverage. Therefore, banks have a larger investment size, and the total output goes up. In this way, the economy experiences a boom accompanied with rising leverage in the banking sector. On the other hand, however, banks will also engage in loophole innovation more actively. When supervision is more effective and banks' leverage is higher, the gain from finding a new loophole is larger. Banks' efforts to conduct loophole innovation increase, and thus banks are more likely to discover a new loophole. If the loophole innovation is successful, it provides banks with a new type of risky project which is not supervised by the regulator. There is a crisis in the economy.

Our main result of the dynamic model is that the interaction between regulator supervision and banks' attempts to circumvent supervision can lead to regime changes in banks' moral hazard problem, and generates macroeconomic fluctuations. In our economy, the sources of the economic downturns endogenously come from banks' loophole innovations. Moreover, the longer the boom, the more likely there will be a crisis and the more severe the consequences will be. This is because as banks' leverage rises in boom periods, they have stronger incentives to find new loopholes. Furthermore, the business cycles are asymmetric in our economy: periods of gradual expansions in banks' leverage, investment, and aggregate output are followed by sudden and sharp contractions, and then the economy starts the gradual growth again. This result arises from the asymmetric nature of loophole innovation. Although the regulator takes time to gradually improve its supervision ability through a learning-by-doing process, its expertise can be severely undermined the moment that new loopholes are discovered.

The 2007-2009 financial crisis is a good example to illustrate our mechanism. Before the crisis, banks discovered vulnerabilities in the rules of regulation and supervision, and by exploiting these loopholes, they took excessive risks. When the massive failures occurred and the

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[4] For instance, according to Eisenbach et al. (2016), "The current structure and organization of FRBNY FISG supervisory staff dates from a significant reorganization that took place in 2011. That reorganization drew on lessons learned during the financial crisis to reshape the internal structure of the group and the way that staff interacts with one another to enhance communication and facilitate identification of emerging risks through a greater emphasis on cross-firm perspectives. The reorganization was designed to foster enhanced and more frequent engagement between senior supervisory staff and senior managers and members of the board of directors at supervised firms".

crisis unfolded, regulators and investors realized that there had been so many cracks in the financial system. As Timothy F. Geithner(Geithner, 2010) recognized, “Our regulatory framework was built in a different era for a long extinct form of finance. It long ago fell behind the curve of market developments. Parts of the system were crawling with regulators but parts of the system were without any meaningful oversight. This permitted and even encouraged arbitrage and evasion on an appalling scale.” In response to the vulnerabilities in the financial system, investors cut their lending to the banks and there was a sharp deleveraging process in the financial sector.

We also investigate the regulation implications of this model. We consider the regulation with a maximum leverage ratio. The regulator’s supervision ability can be seen as the state of the economy. Banks’ loophole innovation effort determines the evolution rules for the regulator’s supervision ability, which characterizes the stationary distribution of the economy in the long run. We find that under certain conditions the regulator would set a maximum leverage ratio to restrict the upper-bound leverage for the banks. This regulation has two effects. First, it reduces banks’ leverage and can potentially decrease output in boom periods. Second, it decreases success probability of loophole innovation. A lower loophole innovation success probability shifts the stationary distribution of the economy towards more favorable states, which improves the average output in the long run. The regulator will trade off these two effects to set the optimal maximum leverage ratio.

The model’s empirical implications are broadly consistent with the stylized facts found in many empirical studies. First, Schularick and Taylor (2012) study 14 developed countries over 140 years, concluding that a long period of credit growth is the best single predictor of financial crises. Second, Reinhart and Reinhart (2010) find that credit cycles are asymmetric: long periods of credit expansion are followed by sudden stops, and then gradual recovery. Third, Adrian and Shin (2010, 2011) find that financial intermediaries’ leverage is pro-cyclical over the business cycles. Fourth, Dell’Ariccia et al. (2014) find that during a boom, financial intermediaries’ lending standards decrease and loan default rates increase, which is accompanied by massive failures in the financial sector. Our model’s results reflect these facts within a unified framework.

This paper contributes to the existing literature in several ways. First, unlike most regulation and supervision literature which focuses on static models, this paper studies regulator supervision in a dynamic framework. Second, complementary to a small but growing literature on endogenous business cycles, which focus on non-financial firms, this paper provides a novel mechanism to generate endogenous credit cycles originated from the financial sector. By analyzing the dynamics of banks' moral hazard problem, this paper is able to rationalize some of the key features of the credit cycles that are not explained by the existing literature. Third, this paper provides a new rationale for the maximum leverage ratio when there is an interaction between regulator supervision and banks' loophole innovation. We show that tightening banks' leverage ratio involves a systemic risk and output trade-off, and the regulator can lower the likelihood of systemic crises at the cost of decreasing output in boom periods.

This chapter's structure is as follows. Section 1.2 discusses the related literature. Section 1.3 presents the static model for bank risk-shifting, supervision, and loophole innovation. Section 1.4 nests the static model in a dynamic model, analyzing the macroeconomic implications of the interaction between banks' loophole innovation and regulator supervision. Section 1.5 investigates the welfare implications of the maximum leverage ratio. Section 1.6 adds learning about unknown loopholes and the regulator's investigation choice in the model. Section 1.7 discusses several setups in the model. Section 1.8 is the conclusion.

1.2 Literature

This paper is linked to different strands of the literature on banks' risk-taking, financial innovation, financial crises, and credit cycles.

Our paper follows the literature on banks' risk-taking and financial stability (e.g., Keeley (1990); Suarez (1994); Matutes and Vives (1996); Boyd and Nicoló (2005) and Martinez-Miera and Repullo (2017)). Unlike most literature, which assumes an exogenous capital structure, in our paper, bank's leverage is endogenously chosen by the bank as a commitment device to reduce moral hazard. In this respect, our paper is mostly related to a recent paper by Dell'Ariccia et al. (2014), in which it is shown how interest rate affects a bank's risk-taking when the bank can choose its leverage optimally. However, none of these papers consider the role of regulator supervision in alleviating banks' moral hazard.

Our work is related to the literature on regulator supervision (e.g., Dewatripont et al. (1994); Bhattacharya et al. (2002); Prescott (2004); Marshall and Prescott (2006); Rochet (2008)). More recently, Eisenbach et al. (2015, 2016) formally distinguish bank supervision and regulation and develop a static framework to explain the relationship between supervisory efforts and bank characteristics observed in the data. We depart from this literature by focusing on the connection between the regulator's competence and credit cycles. In this respect, our paper is closely related to Morrison and White (2005, 2013). They show that crises will only occur when public confidence in the regulator's ability to detect bad banks through screening is low. While the regulator's ability is constant in the static model in Morrison and White (2005, 2013), we study the dynamic interaction between regulator supervision and banks' loophole innovation. In this regard, we consider our model a first attempt to formalize Kane (1988)'s influential idea of "regulatory dialectic".

Our interest in endogenous business cycle relates to Suarez and Sussman (1997), Martin (2008), Favara (2012), Myerson (2012), and Gu et al. (2013). Among these papers, our paper is mostly related to Myerson (2012), who shows how boom-bust credit cycles can be sustained in economies with moral hazard in financial intermediation. Unlike Myerson (2012), our model focuses on the role of regulator supervision in curbing moral hazard in financial intermediation, and more importantly, our paper generates richer macroeconomic implications consistent with stylized facts found in the empirical literature.

Our work is also linked to the literature on asymmetric business cycles. Some papers, including Veldkamp (2005), Ordoñez (2013), and Kurlat (2015), study the asymmetric nature of the credit cycles from the perspective of the asymmetric information flow over the cycles. A recent paper by Asriyan and Vanasco (2014) studies the role of financial intermediaries' learning in generating and amplifying the informational cycles. Our paper also features a regulator whose expertise grows through learning-by-doing. The key difference is that, in our paper, the shock to the fundamental is endogenously generated by the banking sector itself rather than exogenously. And our paper also stresses the role of banks' leverage over the cycle, which is absent in their paper.

There is an emerging literature studying the close relationship between boom and bust in the business cycles. In Gorton and Ordoñez (2014, 2016), booms are associated with loss of information while crises happen when the economy transits from information-insensitive states to information-sensitive states. Boz and Mendoza (2014) and Biais et al. (2015) emphasize the role of investors' belief regarding the strength of a financial innovation in generating boom and bust. Good belief builds up in boom periods, but adverse realization of the fundamental decreases belief dramatically and leads to a bust. Boissay et al. (2016) build a model featuring an interbank market with moral hazard and adverse selection problems. Increased savings during expansions drive down the return on loans, and when the fundamental becomes weak, the interbank market freezes due to an agency problem, which leads to a bank crisis. Unlike these papers, we build a model focusing on the interaction between regulator supervision and banks' loophole innovation.

1.3 Static Model

Consider an economy with a mass-one continuum of banks, a large mass of households, and a regulator. All parties are risk-neutral. Each bank is endowed with w. Banks can use their own money ω and raise deposit (or more generally issue debt liabilities) from households to make investments. A household can invest in a storage technology with a fixed return of r_0, or invest in the banks as a depositor. We assume that the deposit market is competitive, and there is no deposit insurance, so households are willing to invest in the banks as long as they break even relative to the return on storage technology. If a bank borrows x from depositors, the bank's investment size would be $\omega + x$.[5] We denote a bank's leverage as $L \equiv \frac{\omega+x}{\omega}$. Banks are protected by limited liability and repay depositors only in case of success.

Banks can invest in a safe project or in a risky project. The safe project's payoff is R/η^s with probability η^s and zero with probability $1-\eta^s$, so the expected return of the safe project is R. The risky project is more likely to fail than the safe project but will pay more if it succeeds. More specifically, the success probability of the risky project is $\eta < \eta^s$, and the payoff conditional on project success is $\bar{\lambda}R/\eta$, so the expected payoff of the risky project is $\bar{\lambda}R$. Banks can choose the success probability of the risky project, η, within the interval $[\underline{\eta}, \bar{\eta}]$, with $\bar{\eta} < \eta^s$ and $\bar{\lambda}/\bar{\eta} > 1/\eta^s$. As η is lower, the risky project is less likely to succeed, but, conditional on success, the payoff is higher. Therefore, η is also a measure of the riskiness of the risky project. The lower is η, the more risky is the project. We assume that $R > r_0 > \bar{\lambda}R$. Thus, the safe project has the highest expected return, and the risky project has a lower expected return than the storage technology. Banks' project choices are not observed by depositors and are not contractable.

There is a benevolent regulator who can supervise the banks. To model regulator supervision, we assume that the regulator can prevent banks from choosing high riskiness when taking

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[5] In this paper, a bank's capital structure is endogenously determined, rather than exogenously given. This treatment is supported by two observations under existing bank regulations. First, a bank's true leverage may be higher than the regulatory limit because banks can overstate capital by not recognizing losses. Second, banks can save on capital by engaging in regulatory arbitrage of capital requirements.

the risky project.[6] More specifically, when the regulator's supervision ability is η^*, banks can only choose the risky project success probability within the interval $[\eta^*, \bar{\eta}]$. The setup regarding supervision is similar to Eisenbach et al. (2016), where the regulator can take corrective actions to reduce the variance of bank' return.

However, the regulator's supervision is not perfect. Sometimes banks may discover a new type of risky project, which is not immediately known by the regulator and households. We call this discovery a successful loophole innovation. If a loophole innovation succeeds, banks are able to take the new risky project with any riskiness levels, since the regulator does not realize that it exists. Borrowing the setup from technology innovation literature, such as Aghion and Howitt (2009) and Laeven et al. (2015), we assume that only one bank is capable to conduct loophole innovation.[7] We call this bank the capable bank. It is costly for the capable bank to conduct loophole innovation. When the capable bank's effort is $e \in [0, 1]$, the loophole innovation succeeds with probability e. The cost for the capable bank is $\frac{1}{2}ce^2 \cdot (\omega + x)$, where c is the coefficient governing the cost of innovation. If a loophole innovation succeeds, all banks learn about the new loophole, and a risky project immune from supervision is available to them.

The timing of the static model is as follows: at the beginning of the period, each bank offers a deposit menu to households, which specifies the leverage of the bank and deposit rate. Households decide whether or not to make deposits in the banks. After that, one of the banks knows it is the capable one and exerts loophole innovation effort. If the loophole innovation is successful, a new type of risky project emerges, and all other banks learn about it. Banks make project choices and choose riskiness levels under the regulator's supervision if they invest in the risky project. At the end of the period, banks' projects pay off. Banks pay back the depositors if their projects succeed. Otherwise, they default and go bankrupt.

To characterize the equilibrium, we take the following steps. First, we describe banks' menu choice problem, in which banks choose the deposit menus to maximize their expected profits. Second, we solve the capable bank's loophole innovation problem, in which the capable bank chooses the effort to conduct loophole innovation, given its leverage and interest rate. Third, we impose the equilibrium condition that the expected loophole innovation success probability is consistent with the capable bank's innovation effort, and solve the equilibrium.

First, we describe banks' menu choice problem. A bank's expected profit given leverage

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[6] High riskiness would correspond to low success probability in our model.

[7] We can generalize this assumption for N banks, as long as N is finite. Otherwise, innovations succeed every period.

and interest rate is[8]

$$(1-p)\max\{RL-\eta^s r(L-1), \bar{\lambda}RL-\eta^* r(L-1)\}+p\max\{RL-\eta^s r(L-1), \bar{\lambda}RL-\underline{\eta} r(L-1)\} \tag{1.1}$$

where p is the probability that a loophole innovation succeeds in equilibrium, which both banks and households take as given. The first term is bank's expected profit if the loophole innovation fails. When the loophole innovation fails, banks are monitored by the regulator, thus the highest riskiness available to them is η^*. Due to limited liability, banks would like to choose the highest riskiness η^* if they invest in the risky project. Banks optimally decide between the safe project and the risky project with riskiness η^*. The second term is bank's expected profit if the loophole innovation is successful. If the loophole innovation succeeds, it provides banks with a new type of risky project to circumvent the regulator's supervision. In this case, if banks invest in the new risky project, they can choose the riskiness $\underline{\eta}$. Banks decide between the safe project and the risky project with riskiness $\underline{\eta}$ to maximize their expected profits.

In this paper, we focus on the case that banks' leverage is always constrained by the risk-shifting problem, so that their leverage is finite. The following assumption is the sufficient condition that guarantees it.

ASSUMPTION 1.1. $\frac{(1-\bar{\lambda})R}{(\eta^s-\bar{\eta}^*)r_0} < 1$.

This assumption implies two things. First, banks with sufficiently high leverage will choose the risky project. Second, the maximum supervision ability is not high enough to fully eliminate banks' risk-shifting problem.

To analyze banks' menu choice problem, we can divide the possible menus into three areas according to equation (1.1). First, if the deposit menu $\{L, r\}$ satisfies $RL - \eta^s r(L-1) \geq \bar{\lambda}RL - \underline{\eta} r(L-1)$, banks will never choose the risky project since the safe project yields a higher expected profit. Second, if $\{L, r\}$ satisfies $\bar{\lambda}RL - \underline{\eta} r(L-1) > RL - \eta^s r(L-1) \geq \bar{\lambda}RL - \eta^* r(L-1)$, which project banks will choose depends on whether there is a successful loophole innovation or not. If the loophole innovation fails, banks will be under the monitoring of the regulator with supervision ability η^*. Therefore, they choose the safe project. Otherwise, banks will take advantage of the loophole to circumvent the supervision, and choose the new risky project with the highest riskiness. Third, if $\{L, r\}$ is in the area such that $RL - \eta^s r(L -$

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[8] Since there is a continuum of banks and only one of them is capable, each bank expects itself to be the capable one with a probability of measure zero. Thus, banks do not consider the cost of loophole innovation when they choose the leverage at the beginning of the period.

$1) < \bar{\lambda}RL - \eta^* r(L-1)$, banks will always choose the risky project, even if the loophole innovation fails. Banks choosing menus in this area have to offer households very high interest rates to attract deposits, which yields a negative expected profit for banks. Thus, menus in this area are never optimal for banks. In other words, the feasible menus have to provide banks with incentives to invest in the safe project if there is no successful loophole innovation. We can write this incentive compatibility constraint as

$$RL - \eta^s r(L-1) \geq \bar{\lambda}RL - \eta^* r(L-1) \tag{1.2}$$

The left side of the constraint is a bank's expected profit from taking the safe project. The right side is a bank's expected profit from taking the risky project if the loophole innovation fails, in which case the regulator's supervision ability is η^*.

Given the leverage, banks would like to offer the lowest possible interest rate to attract deposit from households. Since households are rational, they would conjecture banks' project choices given the leverage, and demand a deposit rate that leaves them indifferent between depositing in the bank and investing in the storage technology. Therefore, the interest rate in the deposit menu is related to the leverage. We define $L_0 \equiv 1/(1-(1-\bar{\lambda})R\eta^s/((\eta^s - \underline{\eta})r_0)))$ and $L^* \equiv 1/(1-(1-\bar{\lambda})R((1-p)\eta^s + p\underline{\eta})/((\eta^s - \eta^*)r_0)))$. It is easy to see that for a small loophole innovation success probability p, L^* is larger than L_0.

To raise money from depositors, the interest rate needs to be sufficiently high to compensate for the bank's risk. The interest rate that leaves depositors indifferent between depositing in the bank and investing in the storage technology is

$$r = \begin{cases} \frac{r_0}{\eta^s}, & \text{if } L \leq L_0 \\ \frac{r_0}{(1-p)\eta^s + p\underline{\eta}}, & \text{if } L_0 < L \leq L^* \\ \frac{r_0}{\eta^*}, & \text{if } L > L^* \end{cases} \tag{1.3}$$

First, if a menu has a leverage lower than or equal to L_0 and an interest rate r_0/η^s, the bank's expected profit from taking the safe project is always higher than the risky project. Therefore, the bank will never invest in the risky project, even if there is a successful loophole innovation. Since the safe project succeeds with probability η^s, the interest rate for depositors to break even is r_0/η^s. Second, for a menu with a leverage between L_0 and L^* and an interest rate $r_0/((1-p)\eta^s + p\underline{\eta})$, the bank's expected profit from taking the safe project is higher than the risky project when the loophole innovation fails and lower than the risky project when the loophole innovation succeeds. With probability p, the loophole innovation is successful, and banks will choose the risky project with the highest riskiness $\underline{\eta}$. With probability $1-p$, the loophole innovation fails, and banks will choose the safe project. From an ex-ante perspective, the bank succeeds with probability $(1-p)\eta^s + p\underline{\eta}$, thus depositors demand an interest rate of $r_0/((1-p)\eta^s + p\underline{\eta})$. Third, if a bank's leverage is higher than L^*, it will always take the risky project even if the loophole innovation fails, so the interest rate needs to be as high as r_0/η^* to compensate for the risk. It is easy to see that this leads to a negative profit for banks. Therefore, banks will never choose a leverage higher than L^*.

In the case that p is small, we can show that a bank's expected profit with menu $\{L^*, r_0/((1-p)\eta^s + p\underline{\eta})\}$ is higher than that with menu $\{L_0, r_0\}$, so all banks will choose a leverage of L^*. From now on, we will focus on this case.

Next, let us solve the loophole innovation effort problem of the capable bank. After all banks raise deposits, one bank knows that it is the capable one, and it can exert effort to conduct loophole innovation. Given the leverage level and deposit rate, the innovation effort problem of the capable bank is

$$\max_{e}\,(1-e)[RL-\eta^s r(L-1)]+e[\bar{\lambda}RL-\underline{\eta}r(L-1)]-\frac{1}{2}ce^2L \tag{1.4}$$

With probability $1-e$, the loophole innovation fails, so the capable bank chooses the safe project. With probability e, the loophole innovation is successful, so the capable bank chooses the risky project with riskiness $\underline{\eta}$.

The first-order condition can be written as

$$-[R-\eta^s r(1-1/L)]+[\bar{\lambda}R-\underline{\eta}r(1-1/L)]=ce \tag{1.5}$$

First, we can see that given the leverage and interest rate, a higher loophole innovation cost coefficient c reduces the capable bank's innovation effort. Second, other things equal, a higher leverage L induces the capable bank to choose a higher loophole innovation effort. This is because when the bank's leverage is higher, the gain from finding a new loophole is larger. Third, a higher interest rate r results in a higher loophole innovation effort, since a new loophole provides the capable bank with an opportunity to avoid paying interest.

The definition of equilibrium in the static model is as follows.

DEFINITION 1.1. *An equilibrium in the static model consists of the success probability of loophole innovation and decision rules* $\{L(\eta), r(\eta), e(\eta)\}$ *such that (i) the deposit menu* $\{L(\eta), r(\eta)\}$ *solves the banks' problem* (1.1) *given* (1.3)*; (ii)* $e(\eta)$ *solves the capable bank's problem* (1.4)*; (iii) the success probability of loophole innovation is consistent with the capable bank's innovation effort, i.e.,* $p = e$*.*

In equilibrium, the ex ante probability that the loophole innovation succeeds must be equal to the innovation effort chosen by the capable bank, i.e., $p = e$. The break-even condition for depositors implies that the interest rate is

$$r_0 = [(1-e)\eta^s + e\underline{\eta}]r \tag{1.6}$$

Here with probability $1-e$, the loophole innovation fails. Banks take on the safe project, which has a success probability η^s. With probability e, the loophole innovation succeeds,and banks take on the risky project with success probability $\underline{\eta}$. From an ex-ante view, the bank succeeds with probability $(1-e)\eta^s + e\underline{\eta}$. The interest rate r_0 compensates for the bank's default risk.

As we mentioned before, we need the loophole innovation success probability p to be small, so that banks will choose a leverage of L^*. The following lemma shows that a large innovation cost c will guarantee this.

LEMMA 1.1. *Under Assumption 1.1 and a large innovation cost coefficient* c*, the incentive compatibility constraint equation* (1.2) *is always binding for each bank.*

With Lemma (1.1), we can solve the bank's problem in an explicit form. From equations (1.2), (1.6), and (1.5), we can solve the innovation effort, deposit rate, and leverage in equilibrium given the supervision ability η^*,

$$e = \frac{\eta^* - \underline{\eta}}{\eta^s - \eta^*}\frac{(1-\bar{\lambda})R}{c} \tag{1.7}$$

$$r = \frac{r_0}{(1-e)\eta^s + e\underline{\eta}} \tag{1.8}$$

$$L = \frac{1}{1 - \frac{(1-\bar{\lambda})R}{(\eta^s-\eta^*)r}} \tag{1.9}$$

From the above equations, we have the following proposition.

PROPOSITION 1.1. *Under Assumption 1.1 and a large innovation cost coefficient c, as the regulator's supervision ability increases,*

(I) the capable bank's loophole innovation effort increases;

(II) the banks' deposit rate increases;

(III) the banks' leverage increases.

The total output depends on whether the loophole innovation succeeds or not. If the loophole innovation fails, all banks take the safe project, and the total output is $(R - r_0)\omega L$. If the loophole innovation is successful, all banks take the risky project, and the total output is $(\bar{\lambda} R - r_0)\omega L$. Thus, the expected output at the beginning of the period is $\omega \cdot [(1-e)(R-r_0)+e(\bar{\lambda}R - r_0)]L$. We plot these results in Figure 1.1.

Next we study the comparative statics. We focus on how the cost coefficient of loophole innovation (c), the expected payoff of the safe project (R), and the relative payoff of the risky project ($\bar{\lambda}$) will affect banks' deposit rate (r), leverage (L), and capable bank's innovation effort (e).

LEMMA 1.2. *Under Assumption 1.1 and a large innovation cost coefficient c,*

(I) the capable bank's loophole innovation effort e decreases in c, increases in R, and decreases in $\bar{\lambda}$;

(II) the banks' deposit rate r decreases in c, increases in R, and decreases in $\bar{\lambda}$;

(III) the banks' leverage L is increases in c, increases in R, and decreases in $\bar{\lambda}$;

It is easy to see that with a larger innovation cost coefficient c, the capable bank will exert less effort to conduct loophole innovation, thus the success probability of the loophole innovation decreases. A lower loophole innovation success probability will reduce the deposit rate demanded by households, since banks are less likely to take the risky project. And a lower deposit rate relaxes banks' incentive compatibility constraint, so banks can have a higher leverage.

The effects of increasing the expected payoff of the safe project, R, are more complicated. On the one hand, a larger R makes the safe project more attractive, which directly dampens the incentive of loophole innovation. On the other hand, a larger R also increases the leverage of banks, which indirectly gives the capable bank stronger incentive to innovate. The latter effect dominates the former one, so the capable bank's innovation effort increases. Following a similar logic, a larger $\bar{\lambda}$, increases the attractiveness of the risky project, but the low leverage associated with it decreases the capable bank's incentive to innovate. Overall, the capable bank's innovation effort is lower with a larger $\bar{\lambda}$.

1.4 Dynamic Model

1.4.1 Setup

In this section, we extend the static model into a dynamic model. Each bank lives for one period. Each bank is endowed with ω at the beginning of each period. To raise deposit, banks offer deposit menus to households. In each period, only one bank has a capable idea, and it chooses the effort it will make to conduct loophole innovation. The loophole innovation, once successful in one period, spreads in two dimensions. First, all banks in that period learn about it and are able to exploit the loophole, as in the static model. Second, all banks in the periods following the successful loophole innovation will learn about it.

One key element in the dynamic model is the evolution of the regulator's supervision ability. There are two countervailing forces that affect the regulator's supervision ability. On the one hand, a successful loophole innovation discovers a new type of risky project that is off the radar of the regulator's accumulated monitoring skills, which undermines the regulator's expertise. On the other hand, after a successful loophole innovation, the regulator recognizes the existence of a new loophole and starts to investigate it.[9] Over time, the regulator learns more and more about the new loophole, and improves its monitoring skills each period through learning-by-doing. As mentioned in the introduction, the assumption that the regulator engages in learning-by-doing is supported by some recent empirical papers (see, e.g., Dahlgren (2011), Dudley (2014), Eisenbach et al. (2016)). These papers find that, in reality, regulators have drawn on lessons learned during the financial crisis and make effort to improve their supervision abilities.

In this paper, we capture the regulator's learning-by-doing in a reduced form. More specifically, the evolution law for the regulator's supervision ability for a new loophole, i.e., the regulator's supervision ability η_t in the period t since the last loophole innovation that succeeded in

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[9] Since there is an infinite number of banks in the economy, the public can infer the occurrence of a successful loophole innovation from the share of bank failures at the end of the period.

the period $\hat{t}$ is

$$\eta_t = \begin{cases} \eta_k^*, & \text{if } t - \hat{t} = k < K \\ \eta_K^*, & \text{if } t - \hat{t} = k \geq K \end{cases} \tag{1.10}$$

Here k is the period following the last successful loophole innovation. If a loophole innovation is successful in one period, regulator supervision becomes ineffective for this new loophole. From the next period on, the regulator's supervision ability starts to evolve gradually according to the evolution law. We assume that η_k^* increases with k, so regulator's supervision ability regarding the new loophole increases for each period. After K periods, it will stay constant unless another new loophole innovation succeeds. This guarantees that there is an upper-bound for the regulator's supervision ability, so banks' risk-shifting problem always exists. For each loophole, we denote the regulator's supervision ability space as $\{\eta_1^*, \eta_2^*, \ldots, \eta_k^*, \ldots \eta_K^*\}$.

Regarding banks' project choices in each period, we need to consider two possible cases. First, if a loophole innovation is successful, all banks can take the new risky project without being detected by the regulator. Second, if a loophole innovation fails, it is easy to see that if banks want to take risky projects, they would only take the risky project discovered in the latest loophole innovation. This is because the regulator's supervision ability is lowest for the risky project discovered in the latest loophole innovation, so banks can choose the highest riskiness when taking the new risky project.

When banks borrow from depositors at the beginning of each period, whether the loophole innovation will succeed or fail is not yet known. Thus the regulator's supervision ability for the latest discovered loophole determines the deposit contracts between banks and depositors, and the capable bank's loophole innovation effort. Therefore, the regulator's supervision ability related to the latest loophole is sufficient to describe the state for the economy, which implies that regulator's supervision ability space for the latest discovered loophole, $\{\eta_1^*, \eta_2^*, \ldots, \eta_k^*, \ldots \eta_K^*\}$, is also the state space for the economy.

The timing of the dynamic model is as follows: at the beginning of each period, the regulator's supervision ability is updated according to the evolution law, which is common knowledge. Banks offer deposit menus to households. Households decide whether or not to make deposits in the banks. After banks raise deposits, one of the banks knows it is the capable bank, and it chooses to make loophole innovation effort. If the loophole innovation is successful, all other banks can learn from it. Banks make project choices and choose riskiness if they invest in risky projects. At the end of each period, projects pay off. Banks pay back the depositors if their projects succeed. Otherwise, they default. In the next period, the regulator improves its supervision ability on the loopholes according to the evolution law.

1.4.2 Dynamics

Within each period, the problem is the same as the static model. As shown in the static model, in normal times without successful loophole innovation, all banks choose the safe project. However, if loophole innovation is successful, all banks choose the risky project. Given the regulator's supervision ability η_t in the period t, we have the following results

$$e_t = \frac{\eta_t - \underline{\eta}}{\eta^s - \eta_t} \frac{(1-\bar{\lambda})R}{c} \tag{1.11}$$

$$r_t = \frac{r_0}{(1-e_t)\eta^s + e_t\underline{\eta}} \tag{1.12}$$

$$L_t = \frac{1}{1 - \frac{(1-\bar{\lambda})R}{(\eta^s - \eta_t)r_t}} \tag{1.13}$$

As the regulator's supervision ability improves, banks have a higher leverage ratio. If the loophole innovation fails in the period t, all banks choose the safe project. A fraction $1 - \eta^s$ of banks fail at the end of the period, and the output is $y_t^n = \omega \cdot (R - r_0)L_t$. Thus the output in the economy increases as banks' leverage rises. We say that the economy is in boom. However, if the loophole innovation succeeds in the period t, all banks choose the risky project. A fraction $1 - \underline{\eta}$ of banks default, and the output is $y_t^i = \omega \cdot (\bar{\lambda}R - r_0)L_t$. Due to the widespread defaults and declining output, we say that there is a crisis in the economy when a loophole innovation is successful.

PROPOSITION 1.2. *Under Assumption 1.1 and a large innovation cost coefficient c, the longer the boom,*

(I) the higher the bank's leverage;

(II) the more likely a crisis is to occur;

(III) conditional on a crisis occurring, the larger the decline in output.

Since the regulator improves its supervision ability each period through learning-by-doing, the regulator's supervision ability is higher when the boom is longer. From Proposition 1.2, we know that banks' leverage and the capable bank's loophole innovation effort increase with supervision ability. Therefore, banks' leverage is higher for a longer boom, and at the same time capable banks' innovation effort is higher, which implies that crises are more likely to happen. Conditional on loophole innovation being carried out, the output is $y_t^i = \omega \cdot (\bar{\lambda} R - r_0) L_t$. Since $\bar{\lambda} R < r_0$, the greater the leverage, the larger the drop in output.

To illustrate Proposition 1.2, we simulate a certain path of loophole innovation in the economy. The results are in Figure 1.2. Two successful loophole innovations take place in the period 15 and 25, so there are crises in these two periods. The boom period before the first crisis is longer than the one before the second. As we can see, both leverage and output increase in boom periods. The longer the boom, the higher the leverage and output. At the same time, the capable bank's innovation effort also increases, which means there is a higher probability that a crisis is to occur. When the loophole innovation eventually succeeds, banks choose the risky project. As is shown in Figure 1.2, conditional on a crisis occurring, the drop in output is larger in the first crisis.

1.4.3 Long-run Distribution Properties

Next, we investigate the long-run distribution for the economy. As we have shown before, the regulator's supervision ability regarding the latest discovered loophole characterizes the states of the dynamic economy. Given the regulator's supervision ability η_i^*, all banks offer the same contracts to households, which determines the leverage, deposit contract, and capable bank's loophole innovation effort. At the same time, the evolution of the supervision ability state depends on whether loophole innovation succeeds or not. To make a more general case, we let the regulator's supervision ability for known risky projects grow with probability q, and stay at the same level with probability $1-q$. Whether or not the regulator's supervision ability grows is public knowledge. Note that when $q=1$, we go back to the previous case where supervision ability grows in each period with certainty. If the current supervision ability is η_i^*, i.e., $\eta_t = \eta_i^*$, we can write down the general rule for supervision ability evolution. For the case $i < K$,

$$\eta_{t+1} = \begin{cases} \eta_{i+1}^*, & \text{with prob. } q \text{ in case of no successful loophole innovation;} \\ \eta_i^*, & \text{with prob. } 1-q \text{ in case of no successful loophole innovation;} \\ \eta_1^*, & \text{in case of successful loophole innovation.} \end{cases} \tag{1.14}$$

For the case $i = K$,

$$\eta_{t+1} = \begin{cases} \eta_K^*, & \text{in case of no successful loophole innovation;} \\ \eta_1^*, & \text{in case of successful loophole innovation.} \end{cases} \tag{1.15}$$

For supervision ability η_i^*, with probability $1 - e_i$, loophole innovation fails in the current period. In this case, with probability q, the regulator's supervision ability will evolve to η_{i+1}^* if $i < K$, or stay at η_K^* if $i = K$ in the next period. With probability $1 - q$, the regulator will stay at the same level of supervision ability η_i^*. With probability e_i, loophole innovation succeeds in the current period. In this case, the regulator's supervision ability resets to η_1^* in the next period. Thus, the regulator's supervision ability follows a Markov process. We can write the transition matrix for the Markov process as

$$P = \begin{bmatrix} e_1 + (1-q)(1-e_1) & q(1-e_1) & 0 & \dots & 0 \\ e_2 & (1-q)(1-e_2) & q(1-e_2) & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ e_{K-1} & 0 & 0 & \dots & q(1-e_{K-1}) \\ e_K & 0 & 0 & \dots & 1-e_K \end{bmatrix} \tag{1.16}$$

The element P_{ij} denotes the probability that the economy evolves from state i in the current period, to state j in the next period. If the current state is i, the regulator's supervision ability is η_i^*, and the capable bank's innovation effort is e_i. For states $1 \le i < K$, with probability e_i, the loophole innovation succeeds, and the economy will evolve to state 1 in the next period. With probability $1 - e_i$, the loophole innovation fails, and the economy will evolve to the next state $i+1$ with probability q and stay at the same state i with probability $1-q$ in the next period. For state K, the difference is that the economy will stay the same state in the next period if there is no successful loophole innovation in the current period.

Since there is only a finite number of recurrent states which follow a Markov process, we can deduce the following lemma.

LEMMA 1.3. *Under Assumption 1.1 and a large innovation cost coefficient c, there is a stationary distribution π for the supervision ability Markov process, i.e., $\pi = \pi P$.*

The stationary distribution π is a $1 \times K$ row vector, where the ith element π_i is the probability of the economy with supervision ability η_i^*. Since the first state occurs only after a successful loophole innovation, the first element π_1 equals the probability of crises in the long run.

As is shown in Lemma 1.2, when the values of parameters such as c, R, and $\bar{\lambda}$ change, the success probability of loophole innovation changes. This leads to changes in the transition matrix and the stationary distribution. We can deduce the following lemma.

LEMMA 1.4. *Under Assumption 1.1 and a large innovation cost coefficient c, if c increases, R decreases, or $\bar{\lambda}$ increases, the probability of the lowest supervision ability state decreases, and the probability of the highest supervision state increases.*

The intuition is that if c increases, R decreases, or $\bar{\lambda}$ increases, the success probability of loophole innovation in each state decreases. On the one hand, this implies that there are fewer crises, and the economy is less likely to return to the lowest supervision ability state. On the other hand, the economy is more likely to evolve into the state with higher supervision ability, thus the probability of the highest supervision ability state increases.

We can further characterize the property for the whole distribution in the following proposition.

PROPOSITION 1.3. *Under Assumption 1.1 and a large innovation cost coefficient c, if c increases, R decreases, or $\bar{\lambda}$ increases, the new stationary distribution will first-order stochastic dominate the original one.*

First-order stochastic dominance means that the cumulative density function of the new stationary distribution is lower than that of the original one, so the whole distribution shifts to the higher supervision states on average. In other words, the probability that the regulator has a high supervision ability is higher in the long run. In Figure 1.3, we plot the innovation probability and stationary distribution with different innovation cost coefficients. As shown in the figure, we can see that with a small c, the stationary distribution has a higher probability for low supervision ability, i.e., the economy is more likely to stay in the low supervision ability states in the long run.

1.5 Regulation: Maximum Leverage Ratio

In this section, we discuss the policy implications of banks' loophole innovation. When a capable bank engages in loophole innovation, it will not internalize the negative externalities for other banks. The negative externalities of loophole innovation have two dimensions. First, successful loophole innovation will reduce the output in the current period by allowing all banks to invest in inefficient risky projects. Second, after a new loophole innovation, the regulator has to learn about it and improve its supervision ability gradually from the start. This leads to a low leverage for the banks in the following periods. These externalities provide the regulator with justification for setting the maximum leverage ratio to curb loophole innovation probability. As shown before, when the regulator has a high supervision ability, the market allows the banks to have a high leverage. But at the same time, the market-determined leverage results in a high probability of innovation. To curb the high probability of innovation, the regulator can set a maximum leverage ratio for the banks.

Under the regulator's supervision ability η_i^*, let us denote the market-determined leverage as L_i^m. Here L_i^m is the bank's privately optimal leverage where there is no regulation, as in the benchmark model. Now suppose that the regulator sets the maximum leverage ratio as $\bar{L}$. If $L_i^m \leq \bar{L}$, banks can choose the market-determined leverage without violating the regulation. In this case, the maximum leverage ratio will not affect the bank's decision. However, if $L_i^m > \bar{L}$, regulation constrains banks' leverage choices. Banks cannot choose the privately optimal leverage L_i^m due to the regulation, instead they can only take a leverage of $\bar{L}$. From Proposition 1.1, we know that L^m increases with the regulator's supervision ability, so regulation is more likely to be effective when supervision ability is high. We refer to the states that the maximum leverage ratio constrains market-determined leverage as the affected states.

When the leverage regulation is effective, banks optimally choose the regulated maximum leverage, and the incentive compatibility constraint becomes slack. The first order condition for the capable bank's innovation effort is

$$-\left[R-\eta^s r(1-1/\bar{L})\right]+\left[\bar{\lambda}R-\underline{\eta}r(1-1/\bar{L})\right]=ce \tag{1.17}$$

and the interest rate in the equilibrium is

$$r=\frac{r_0}{(1-e)\eta^s+e\underline{\eta}} \tag{1.18}$$

By solving the above two equations, we can get the innovation probability $\bar{e}$ when banks' leverages are restricted by the regulation. Thus, the innovation probability under regulation is

$$e_i^r = \begin{cases} e_i^m, & \text{if } L_i^m \leq \bar{L} \\ \bar{e}, & \text{if } L_i^m > \bar{L} \end{cases} \tag{1.19}$$

Since banks' leverage is constrained with a maximum leverage ratio, the innovation probability under regulation is always smaller than or equal to that without regulation, i.e., $e_i^r \leq e_i^m$. With the above innovation probability, we can write the transition matrix under regulation as

$$P^r = \begin{bmatrix} e_1^r + (1-q)(1-e_1^r) & q(1-e_1^r) & 0 & \dots & 0 \\ e_2^r & (1-q)(1-e_2^r) & q(1-e_2^r) & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ e_{K-1}^r & 0 & 0 & \dots & q(1-e_{K-1}^r) \\ e_K^r & 0 & 0 & \dots & 1-e_K^r \end{bmatrix} \tag{1.20}$$

where the element $P^r(i,j)$ is the probability of moving from state i to state j in the next period. With this transition matrix, we can get the stationary distribution under regulation, π^r. Since we know that certain states' innovation probabilities are smaller with regulation if there are some $L_i^m > \bar{L}$, we can compare the two stationary distributions with and without regulation in the following proposition.

PROPOSITION 1.4. *Under Assumption 1.1 and a large innovation cost coefficient c, if the regulator sets a maximum leverage lower than the highest one determined by the market, the stationary distribution under regulation will first-order stochastic dominate the one without regulation.*

The results are shown in Figure 1.4. The figure includes three cases: without regulation, lenient regulation (high maximum leverage), and strict regulation (low maximum leverage). In fact, we can consider the case without regulation as a special case of regulation, when the maximum leverage ratio is sufficiently high for banks' leverage choice to never be restricted. As we can see in the figure, as regulation becomes stricter, leverage and innovation probability under more states deviate from the case with only market discipline. Also, the leverage and innovation probability in those affected states are lower under stricter regulation. The changes in innovation probability affect the transition matrix and also stationary distribution. As we see in the graph, the stationary distribution shifts more to the high states under stricter regulation.

We assume that the regulator sets the maximum leverage ratio to maximize average output in the long run. The expected output in state i is

$$y_i^r = \omega \cdot [(1 - e_i^r)(R - r_0) + e_i^r(\bar{\lambda} R - r_0)] L_i^r \tag{1.21}$$

and the average output in the stationary distribution is

$$EY = \sum_{i=1}^{K} \pi_i^r y_i^r \tag{1.22}$$

The maximum leverage ratio can affect average output in two ways. First, it can directly affect expected output y_i^r in certain states through its effects on leverage and loophole innovation success probability. Effective regulation decreases banks' leverage in the affected states, which has a negative effect on output in the affected states given the expected output per unit investment. But at the same time, regulation reduces loophole innovation success probability, which increases the expected output per unit investment. The overall effect of regulation on expected output in the affected states depends on which effect dominates. Usually when supervision ability is high, the former effect dominates, so expected output in the affected states will decrease with strict regulation. Second, it can affect the stationary distribution π_i^r through its effect on loophole innovation success probability. Strict regulation will shift the distribution towards high states, which usually have a higher output. If regulation decreases expected output in the affected states, there is a trade-off for the regulator between expected output in affected states and the probability of staying in high states in the stationary distribution.

In certain parameter space, the regulator optimally chooses a maximum leverage level at which the incentive compatibility constraint is not binding when the regulator has a high supervision ability. The results are shown in Figure 1.5. As we can see, the optimal regulation sets a maximum leverage ratio which is effective in some states. Expected output in those affected states becomes lower under regulation. However, the loophole innovation success probability is also reduced in those high supervision ability states, because the capable bank has less incentive to innovate under regulation. The change of loophole innovation success probability shifts the stationary distribution. Compared to the case of no regulation, the economy has a higher probability of staying in high supervision ability states, as shown in the fourth graph.

1.6 Learning about Loophole Innovation

In the previous sections, if a loophole innovation succeeds, the regulator and investors have full knowledge about the existence of the new loophole by the end of the period. Next we study the dynamics when there is some uncertainty concerning whether or not there has been an unknown loophole in the economy.

We assume that there are N banks in the economy. Each bank lives for one period. A finite number of banks can prevent the revelation of the existence of a new loophole through the fraction of failed banks. In each period, one of the N banks is a capable one and can choose to make effort to conduct loophole innovation.

Regarding the uncertainty surrounding an unknown loophole, we assume that at the end of each period, the public only observes the number of bank failures. Therefore, the public needs to infer whether bank failures come from the safe projects or risky ones, and updates its belief about an unknown loophole using this information.[10] Let us denote the public's belief about the probability of there being an unknown loophole as θ.

Unlike in previous sections, we give the regulator the additional role of investigator. Since there is uncertainty about the existence of loophole innovation, the regulator can pay a fixed cost χ/r_0 to investigate the banking sector at the beginning of each period, and the investigation result are publicly observed. We assume that the investigation cost comes from a lump-sum tax from households. If there is a loophole, the public knows about it, and the regulator's supervision ability for it starts to grow gradually from the lowest level. If there is no unknown loophole, it is revealed to the public, and the supervision ability evolves. Thus, investigation plays two roles in the model. First, it eliminates the uncertainty regarding an unknown loophole. Second, it is the starting point for the gradual growth of supervision ability for a certain type of risky project. Eisenbach et al. (2015) show that one of the supervisory jobs for the central bank is "discovery examination", which focuses on understanding a specific business activity and filling the knowledge gap. In our model, investigation from the regulator serves a similar role.

The timing is as follows: at the beginning of each period, the regulator decides whether or not to investigate. If it investigates and finds a loophole, its supervision ability resets to the lowest level. The investigation result is publicly observed, and the public updates its belief

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[10] On the contrary, if the public can observe banks' payoff, they know whether banks have invested in risky projects, and can clearly infer the existence of a loophole.

regarding an unknown loophole. Banks offer menus of leverage and deposit rate to households. Households decide whether or not to make deposits in the banks. After banks raise deposits, banks know whether there is a loophole that is unknown to the regulator, and they learn about the loophole if there is one. One of the banks knows it is the capable bank, and it makes loophole innovation effort. If the innovation innovation is successful, all other banks can learn about it. Then banks make project choices under the regulator's supervision. At the end of each period, projects pay off. Banks pay back the depositors if their projects succeed. Otherwise, they default. The public updates its belief about the existence of an unknown loophole in the economy. In the next period, the regulator's supervision ability on known risky projects evolves.

Consider the deposit menus banks offer to depositors. As in previous sections, we focus on the case where the innovation cost coefficient is large so that the success probability of loophole innovation is small. It is easy to see that banks will offer at most two types of contracts, one with low leverage and the other with high leverage. The first one is that banks offer a leverage and deposit rate menu $\{L_0, r_0/\eta^s\}$, where $L_0 \equiv 1/(1-(1-\bar{\lambda})R\eta^s/((\eta^s-\underline{\eta})r_0)))$. Under this menu, the bank will never invest in any risky project even if there is an unknown loophole, so they only need to pay a low interest rate r_0/η^s to allow the depositors to break even. Also, if the capable bank offers this menu, it will have no incentive to conduct loophole innovation. Thus, the expected profit of the banks choosing this menu is

$$\pi_0 = RL_0 - r_0(L_0 - 1)$$

The second one is a menu with a leverage higher than L_0, and a deposit rate that allows depositors to break even. For a large innovation cost coefficient, the incentive compatibility constraint is binding, i.e., $R - \eta^s r(1-1/L) = \bar{\lambda}R - \eta^* r(1-1/L)$. Since there is uncertainty about an unknown loophole, the belief about the probability that there is an unknown loophole, θ, plays a role in the deposit contract. Note that the capable bank will make loophole innovation efforts only if it chooses the high-leverage menu. Therefore, the number of banks choosing the high-leverage menu affects the success probability of loophole innovation, which also determines the expected profit of banks with high-leverage menus. Let us use n to denote the banks choosing a high-leverage menu. We have the following results related to banks choosing a high-leverage menu

$$e = \frac{\eta^* - \underline{\eta}}{\eta^s - \eta^*} \frac{(1 - \bar{\lambda})R}{c} \tag{1.23}$$

$$r = \frac{r_0}{(1-\theta)(1-\frac{n}{N}e)\eta^s + [\theta + (1-\theta)\frac{n}{N}e]\underline{\eta}} \tag{1.24}$$

$$L = \frac{1}{1 - \frac{(1-\bar{\lambda})R}{(\eta^s - \eta^*)r}} \tag{1.25}$$

This menu is only feasible if the interest rate r is not higher than R/η^s. Since r depends on θ, this implies that the belief that there is an unknown loophole cannot be too large.

The expected profit for banks choosing a high-leverage menu is

$$\begin{aligned} \pi(n, \theta, \eta^*) = (1-\theta)\left(1 - \frac{n}{N}e\right)[RL - \eta^s r(L-1)] \\ + \left[\theta + (1-\theta)\frac{n}{N}e\right][\bar{\lambda}RL - \underline{\eta}r(L-1)] - \frac{1-\theta}{N}\frac{1}{2}ce^2L \end{aligned}$$

With probability $(1-\theta)\left(1 - \frac{n}{N}e\right)$, no unknown loophole existed before this period, and no new loophole innovation is carried out in this period, so banks with a high-leverage menu will choose the safe project. With probability $\theta + (1-\theta)\frac{n}{N}e$, either there is unknown loophole, or a new loophole is discovered in this period, so banks with a high-leverage menu invest in the risky project evading the regulator's supervision. The probability that one high-leverage bank is a capable one is $1/N$, and it will exert innovation effort when there is no unknown loophole. We can see that $\pi^*(n, \theta, \eta^*)$ decreases in n, decreases in θ, and increases in η^* for a large innovation cost coefficient. The number of banks choosing high leverage, n, is endogenously determined in the equilibrium, where no bank has the incentive to switch to the low leverage menu. Let n^* denote the number of banks choosing a high-leverage menu in equilibrium, then

$$n^* = \begin{cases} 0, & \text{if } \pi(1, \theta, \eta^*) < \pi_0 \\ n, & \text{if } \pi(n, \theta, \eta^*) \geq \pi_0 > \pi(n+1, \theta, \eta^*) \\ N, & \text{if } \pi(N, \theta, \eta^*) \geq \pi_0 \end{cases} \tag{1.26}$$

Firstly, if banks' expected profit with the low-leverage menu is higher than with the high-leverage menu, even if only one bank chooses the high-leverage menu, all banks will offer the low-leverage one. This case occurs when the belief is very pessimistic, i.e., θ is large. Secondly, if banks' expected profit with the high-leverage menu is higher than with the low-leverage menu, even if all banks choose low-leverage menu, all banks will offer the high-leverage one. This case occurs when the belief is very optimistic, i.e., θ is small. Thirdly, when θ is in the medium range, some banks may choose the high-leverage menu while others choose the low-leverage one. The number of banks choosing the high-leverage menu is determined in such a way that banks' expected profit with high leverage is higher than or equal to the expected profit with low leverage, with one extra bank switching to the high-leverage menu making banks prefer the low-leverage menu. For a bank that chooses the high-leverage menu, let r^*, L^*, and π^* denote respectively the bank's interest rate, leverage, and expected profit in equilibrium. For a capable bank, let us use e^* to denote its loophole innovation effort in equilibrium.

Next we consider the belief updating problem. At the end of each period, the public can update its belief about the existence of an unknown loophole from the performance of banks in that period. For the banks choosing the low-leverage menu, there is no information about the existence of an unknown loophole since they never choose risky projects. Thus, all the information related to belief updates comes from those banks choosing the high-leverage menu. If the public observes m banks failing out of n^* banks choosing the high-leverage menu, the updated belief is

$$\tilde{\theta}(m,\theta,\eta^*) = \frac{\left[\theta + (1-\theta)\frac{n^*}{N}e^*\right]\underline{\eta}^m(1-\underline{\eta})^{n^*-m}}{(1-\theta)\left(1-\frac{n^*}{N}e^*\right)(\eta^s)^m(1-\eta^s)^{n^*-m} + \left[\theta + (1-\theta)\frac{n^*}{N}e^*\right]\underline{\eta}^m(1-\underline{\eta})^{n^*-m}} \tag{1.27}$$

For a certain belief θ and supervision ability η^*, the updated belief after observing banks' performance can only have n^*+1 possible values. Let us denote by $\mathcal{M}(\theta,\eta^*)$ the set for all possible updated belief,

$$\mathcal{M}(\theta,\eta^*) = \{\tilde{\theta}(m,\theta,\eta^*)|m = 0,1,\ldots,n^*\}$$

For a belief $\tilde{\theta}(m)$ in the set $\mathcal{M}(\theta,\eta^*)$, the probability that the public will have that belief after observing banks' performance is

$$\Gamma(\tilde{\theta}(m)|\theta,\eta^*) = \binom{n^*}{m}(1-\theta)\left(1-\frac{n^*}{N}e^*\right)(\eta^s)^m(1-\eta^s)^{n^*-m} \\ + \binom{n^*}{m}\left[\theta + (1-\theta)\frac{n^*}{N}e^*\right]\underline{\eta}^m(1-\underline{\eta})^{n^*-m}$$

At the beginning of each period, if the public belief is too pessimistic, all banks will offer low-leverage menu, and there is no belief updating. Let $\bar{\theta}(\eta^*)$ denote the threshold belief at which at least one bank will choose the high-leverage menu given the supervision ability η^*. It satisfies the following condition

$$\pi(1, \bar{\theta}(\eta^*), \eta^*) = \pi_0$$

Since $\pi(n, \theta, \eta^*)$ decreases in θ and increases in η^* for a large c, we get the following lemma

LEMMA 1.5. *Under Assumption 1.1 and a large innovation cost coefficient c, there is an unique belief threshold, above which no bank will choose the high-leverage menu, and thus the belief about an unknown loophole is not updated in the period. The belief threshold increases in the regulator's supervision ability.*

When the belief θ is higher than $\bar{\theta}(\eta^*)$, no bank chooses the high-leverage menu, so there is no update about an unknown loophole from the banks' performance. The belief at the end of the period will be the same as θ. We call $\bar{\theta}(\eta^*)$ the belief-update threshold because there is updating of belief only if the belief is lower than $\bar{\theta}(\eta^*)$ for supervision ability η^*.

Next we discuss the effects of changes in belief and supervision ability on the economy. The analysis is complicated by the fact that the number of banks choosing the high-leverage menu also changes with these factors. We use n^*e^*/N, $[(N - n^*)r_0/\eta^s + n^*r^*]/N$, and $[(N - n^*)L_0 + n^*L^*]/N$ to denote expected innovation effort, average interest rate, and average leverage respectively. We have the following proposition

PROPOSITION 1.5. *Under Assumption 1.1 and a large innovation cost coefficient c,*

- *(I) if θ increases, n^* stays the same or decreases.*
  - *(i) if n^* stays the same, expected innovation effort stays the same, average interest rate increases, average leverage decreases;*
  - *(ii) if n^* decreases, expected innovation effort decreases, interest rate may increase, decrease or stay the same, average leverage decreases.*
- *(II) if supervision ability η^* increases, n^* stays the same or increases. Expected innovation effort increases, average interest rate increases, average leverage increases.*

For the first part of Proposition 1.5, the effects of belief θ mainly come from its effect on interest rate. When it is large, depositors worry about the unknown loophole, so banks choosing the high-leverage menu have to pay a high interest rate. A higher interest rate lowers the leverage through incentive compatibility constraint. Its effect on capable bank's loophole innovation effort comes from the extensive margin, i.e., banks switch to low-leverage menu. For the second part of Proposition 1.5, the effects of supervision ability could come from both the intensive and extensive margin. For the intensive margin, banks choosing the high-leverage menu can offer a higher leverage. This also leads to a higher loophole innovation effort if the capable bank chooses the high-leverage menu. If more banks choose the high-leverage menu with increasing supervision ability, this increases the average leverage and expected innovation probability from the extensive margin. This shows that the results in Proposition 1.1 are robust even if we include learning in the model.

Unlike in previous sections, the regulator faces an investigation problem now, i.e., when to pay a fixed cost to investigate whether there is an unknown loophole. The regulator uses a lump-sum tax from households to fund the investigation cost. The regulator has a discount factor β, and its aim is to maximize the discounted expected output including the loss from the investigation cost. The expected output, given belief θ and supervision ability η^*, is

$$\begin{aligned} y(\theta, \eta^*) = n^* \left[(1-\theta)\left(1 - \frac{n^*}{N} e^*\right)(R - r_0) + \left(\theta + (1-\theta)\frac{n^*}{N} e^*\right)(\bar{\lambda} R - r_0) \right] L^* \\ + (N - n^*)(R - r_0) L_0 \quad (1.28) \end{aligned}$$

The regulator makes a decision concerning investigation based on the belief at the beginning of each period, which is the same as updated belief based on banks' performance in the last period. If the regulator does not investigate, the belief stays the same, and banks offer menus based on this belief. Otherwise, the belief will reset to zero after investigation, since the investigation eliminates the uncertainty about an unknown loophole in the economy. If the regulator finds a loophole through investigation, the regulator has to accumulate supervision ability from the beginning for the new type of risky project. If the investigation does not find a loophole, the regulator's supervision ability continues to evolve from the last period. Let $\tilde{\theta}$ be the belief before investigation in the current period, and $\tilde{\theta}'$ be the belief before investigation in the next period. We can write down the regulator's problem in the recursive form

$$\begin{aligned} V(\tilde{\theta}, \eta_i^*) = \max_{d \in \{0,1\}} \quad & (1-d) \quad \left[y(\tilde{\theta}, \eta_i^*) + \beta \textstyle\sum_{\tilde{\theta}' \in \mathcal{M}(\tilde{\theta}, \eta_i^*)} \Gamma(\tilde{\theta}' | \tilde{\theta}, \eta_i^*)(q * V(\tilde{\theta}', \eta_{i+1}^*) + (1-q) * V(\tilde{\theta}', \eta_i^*)) \right] \\ & + d \quad \Big\{ -\chi + \tilde{\theta} \left[y(0, \eta_1^*) + \beta \textstyle\sum_{\tilde{\theta}' \in \mathcal{M}(0, \eta_1^*)} \Gamma(\tilde{\theta}' | 0, \eta_1^*)(q * V(\tilde{\theta}', \eta_2^*) + (1-q) * V(\tilde{\theta}', \eta_1^*)) \right] \\ & \quad + (1-\tilde{\theta}) \left[y(0, \eta_i^*) + \beta \textstyle\sum_{\tilde{\theta}' \in \mathcal{M}(0, \eta_i^*)} \Gamma(\tilde{\theta}' | 0, \eta_i^*)(q * V(\tilde{\theta}', \eta_{i+1}^*) + (1-q) * V(\tilde{\theta}', \eta_i^*)) \right] \Big\} \end{aligned} \tag{1.29}$$

If the regulator chooses not to investigate, i.e., $d = 0$, the expected output is $y(\tilde{\theta}, \eta_i^*)$, the belief in the next period $\tilde{\theta}'$ is updated from $\tilde{\theta}$ through the banks' performance, and the supervision ability evolves to η_{i+1}^* with probability q and stays the same with probability $1 - q$ in the next period. If the regulator chooses to investigate, i.e., $d = 1$, it needs to collect the tax from the household and pay the fixed cost at the beginning of the period, and the related loss in the output is χ. If the regulator finds a loophole through investigation, the regulator has to accumulate its expertise for this new type of risky project from the beginning, and its supervision ability resets to the lowest level. The expected output is $y(0, \eta_1^*)$ in the current period, and the supervision ability and belief evolve following the rules. If the regulator does not find a loophole, the expected output is $y(0, \eta_i^*)$, and the supervision ability and belief evolve. In this economy, the belief $\tilde{\theta}$ and the supervision ability for a known loophole η_i^* are important states characterizing the evolution of the economy.

We can see that if the investigation cost is zero, the regulator will choose to investigate each period, because eliminating uncertainty can increase banks' leverage and reduce the risk related to an unknown loophole. Thus, there is no uncertainty about an unknown loophole when banks offer menus to households. The results will be the same to those in Section 1.4. If the investigation cost is too large, there are some absorbing states with positive probability, where the economy will stay forever once it enters. Since the supervision ability for an known loophole increases with positive probability, the absorbing states can only include the highest supervision ability η_K^*. If the belief at the beginning of the period is higher than the belief-update threshold $\bar{\theta}(\eta_K^*)$, banks will always choose the low-leverage menu if the regulator does not investigate. Given a sufficiently large investigation cost, the regulator would not choose to investigate. In this case, there is no belief update and no evolution for the supervision ability, and the economy stays where it is.

The case with a medium investigation cost is more interesting. We plot the belief thresholds in Figure 1.6 for a certain parameter space where the investigation cost is not too large or too small. The black dashed line denotes the belief-update threshold. If the belief θ is higher than this threshold, all banks will choose the low-leverage menu, and there will be no update regarding an unknown loophole. As is shown in Lemma 1.5, the threshold is higher for high supervision ability, and the black dashed line is higher on the right side. The blue solid line denotes the belief threshold for investigation. If the belief is higher than the threshold, the regulator will investigate whether there is an unknown loophole. We can see that the relationship between the investigation threshold and the supervision ability is not monotonic. Within the belief-update region, on the one hand, higher supervision ability leads to higher leverage, and the drop in the expected output will be larger if there is an unknown loophole. This force leads to the belief threshold decreasing with the supervision ability. In the extreme case where β is zero, it is easy to show that the belief threshold for investigation is a decreasing function for supervision ability. On the other hand, the investigation cost is irreversible, so investigation is an option for the regulator. There could be a wait-and-see effect. The regulator may need more information before paying the fixed investigation cost. This force makes the regulator willing to delay investigation. Within the no-belief-update region, the regulator has an incentive to investigate to eliminate the uncertainty so that banks can have higher leverage. Also, since the belief-update threshold increases with supervision ability, the regulator may withhold investigation to allow the belief to fall below the threshold in the higher supervision ability state. Thus, the relationship between the belief threshold for investigation and supervision ability may not be monotonic.

1.7 Discussion

In this section, we discuss several setups in the model in relation to the loophole innovation and regulator's learning-by-doing.

Regarding the loophole innovation, we assume that there is only one capable bank in each period. We can easily extend the model to the case that there is a finite number of capable banks. In this case, we can show that the choice of innovation effort of one capable bank depends on the choices of other banks. This extension makes the model more complicated, without adding any new insights. Second, we assume that all current and future banks can learn about the new loophole if the capable bank succeeds. There are two reasons that we make this assumption. Firstly, since a successful loophole innovation provides banks with the opportunities to take the risky projects, which the regulator tries to forbid, the capable bank cannot rely on any legal system to protect the successful loophole innovation. Secondly, there is no competition among banks in the model, so the capable bank has no incentive to prevent other banks from taking advantage of the new loophole.

In this chapter, we model the regulator's learning-by-doing process in a reduced form. We do this for two reasons. First, we treat the regulator's supervision as passive in the model, so we can focus on the decisions of banks, especially the loophole innovation. Second, the passive evolution of the regulator's supervision ability makes our model much more tractable. However, in Section 1.6, we add an investigation role for the regulator, which can be considered as a form of active learning-by-doing. In a companion paper on shadow banking that is still working in progress, we provide a complete micro-foundation for investors' learning-by-doing, which we expect to incorporate into this model in the future.

1.8 Conclusion

In this chapter we develop a model on the dynamic interaction between regulator supervision and banks' loophole innovation, and study its implications on banks' credit cycles. In the model, banks' leverages are constrained due to a risk-shifting problem. The regulator supervises the banks to ease this moral hazard problem, and its expertise in supervision improves gradually through learning-by-doing. At the same time, banks can engage in loophole innovation to circumvent supervision, which acts as an endogenous opposing force diminishing the value of the regulator's accumulated expertise. In equilibrium, banks' leverage and loophole innovation move together with the regulator's supervision ability. The model shows that long periods of gradual expansion in banks' leverage, investment, and aggregate output, are followed by sudden and sharp recessions. In our model, even in the absence of exogenous perturbations, banks themselves can become the sources of adverse shocks to the real economy. We show that the longer the boom, the more likely there is a crisis and the more severe the consequences, which corresponds to Minsky's hypothesis that good times sow the seeds for the next financial crisis. The model's empirical implications are broadly consistent with the stylized facts from empirical studies related to credit cycles.

Based on this model, we also discuss the welfare implications of a maximum leverage ratio in the environment of loophole innovation. We show that the regulator faces a trade-off between financial stability and output in boom periods. A higher maximum leverage ratio is associated with higher output in good times but more frequent crises, while a lower maximum leverage ratio is associated with lower output in good times but less frequent crises. Also, we extend the benchmark model by allowing households to have uncertainty regarding the regulator's supervision ability, and study how the economy evolves with both the regulator's supervision ability and households' beliefs regarding the regulator's supervision ability.

In this chapter, the sources of credit cycles come from the interaction between regulator supervision and banks' loophole innovation. Without a doubt, there are other important sources for the credit cycles, which have been widely discussed in the literature. We consider our mechanism as a novel and complementary one to those in the previous literature. To highlight our mechanism, we have omitted other sources for the business cycles from this paper. We can potentially incorporate some common shocks in the business cycle literature into our model.

Although the present model is stylized, it would be interesting to test the implications of this model with data in future work. First, our model shows that longer boom periods predict higher probability of crises and more severe consequences. We can test the relationship between conditional frequency, as well as consequences of crises and the length of boom periods with cross-country data. Second, as more data on regulation and supervision emerges, we can study the linkage between bank regulation and business cycle patterns across countries.

1.9 Appendix

1.9.1 Figures

Figure 1.1: Relationship with Supervision Ability

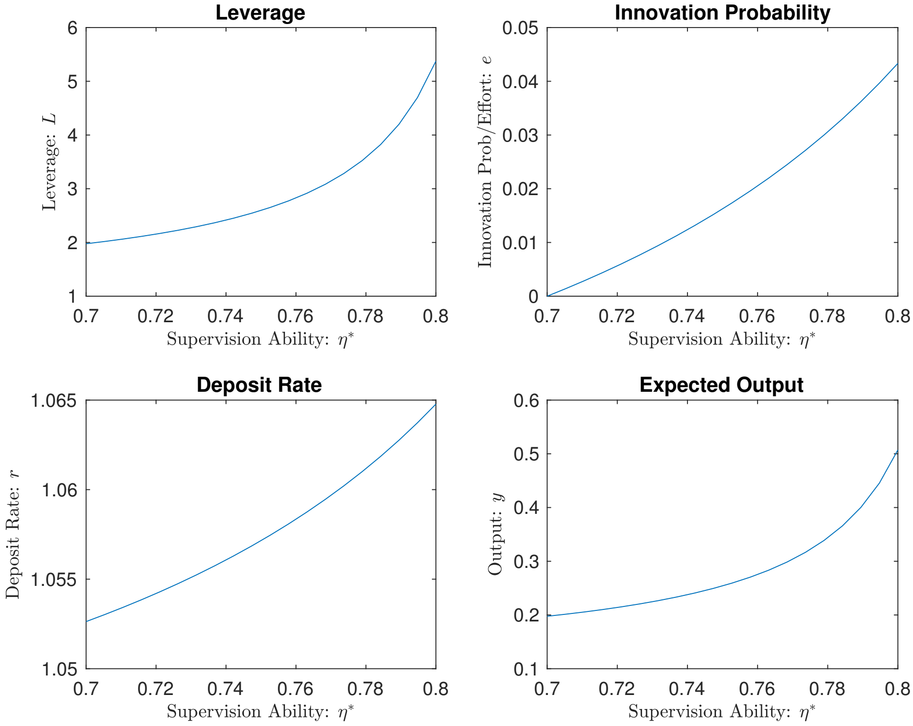
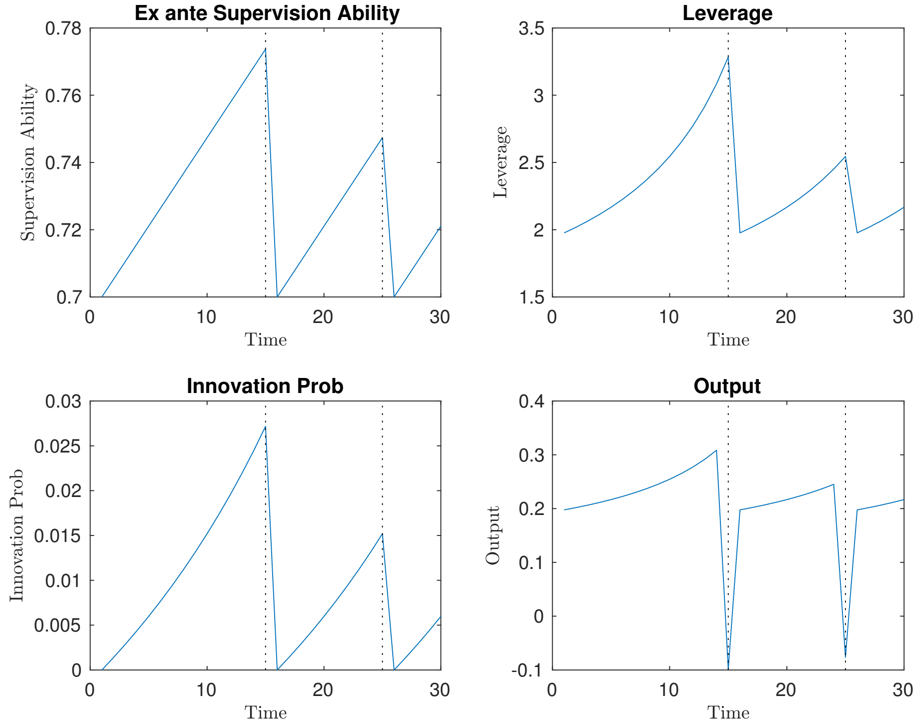


Figure 1.2: Dynamics



Note: The dotted vertical lines indicate the periods when loophole innovation occurs.

Figure 1.3: Long-run Stationary Distribution

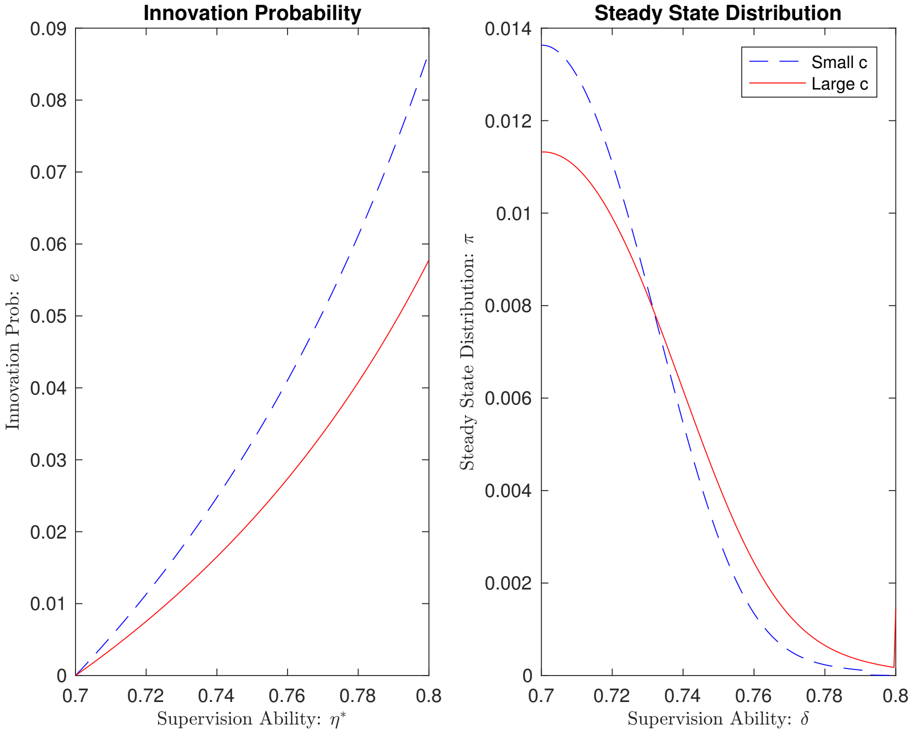
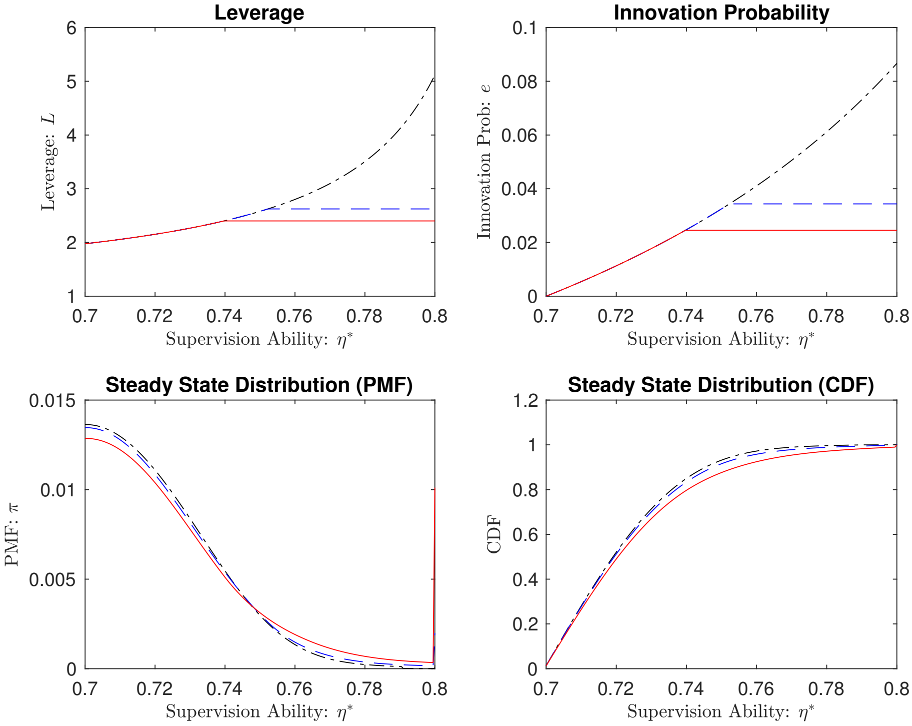
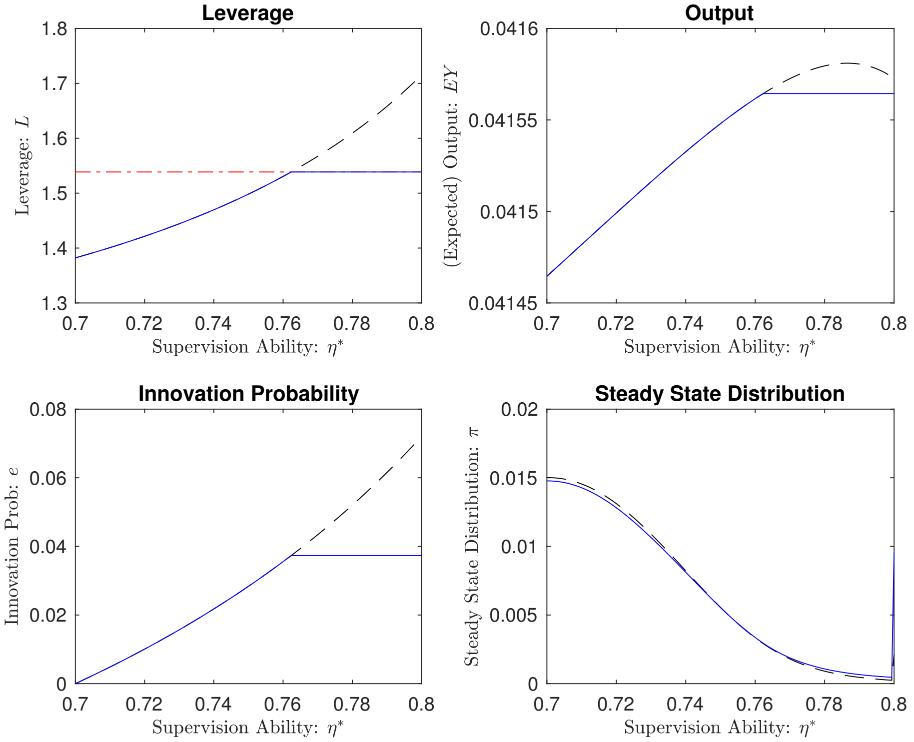


Figure 1.4: Maximum Leverage Ratio



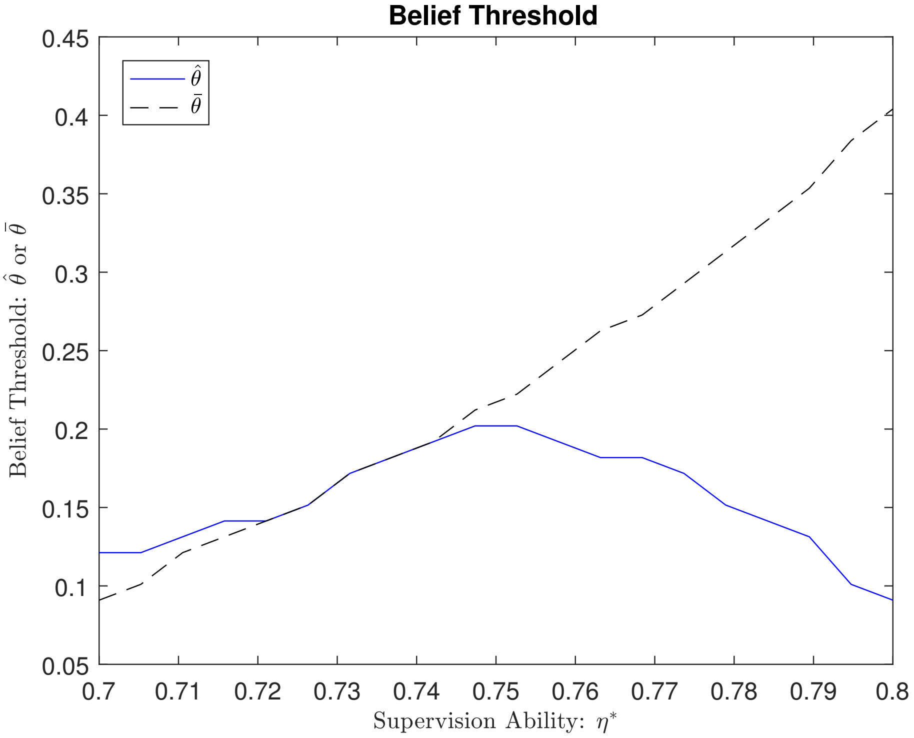
Note: Black dot-dashed line: without regulation; Blue dashed line: lenient regulation; Red solid line: strict regulation.

Figure 1.5: Optimal Regulation



Note: Black dashed line: without regulation; Blue solid line: optimal regulation.

Figure 1.6: Belief Threshold



Note: Black dashed line: belief threshold for no belief update; Blue solid line: belief threshold for investigation.

1.9.2 Proofs

Proof of Proposition 1.1

From equation (1.7), we can get

$$\frac{\partial e}{\partial \eta^*} = \frac{\eta^s - \underline{\eta}}{(\eta^s - \eta^*)^2} \frac{(1-\bar{\lambda})R}{c} > 0 \tag{1.30}$$

Thus, innovation effort (probability) is increasing with supervision ability.

From equation (1.8), we can get

$$\frac{\partial r}{\partial \delta} = \frac{(\eta^s - \underline{\eta})r^2}{r_0} \cdot \frac{\partial e}{\partial \eta^*} > 0 \tag{1.31}$$

Thus, deposit rate is increasing with supervision ability.

From equation (1.9), we can get

$$\frac{\partial L}{\partial \eta^*} = \frac{(1-\bar{\lambda})R}{(\eta^s - \eta^*)^3 c L^2 r_0} [\eta^s(\eta^s - \eta^*)c - (1-\bar{\lambda})(\eta^s - \underline{\eta})(\eta^s + \eta^* - 2\underline{\eta})R] \tag{1.32}$$

From the above equation we can see that, as long as $c \geq \frac{(1-\bar{\lambda})(\eta^s - \underline{\eta})(\eta^s + \bar{\eta}^* - 2\underline{\eta})R}{\eta^s(\eta^s - \bar{\eta}^*)}$ holds, leverage is always increasing with supervision ability.

Q.E.D.

Proof of Lemma 1.2

From equation (1.7), we can get

$$\frac{\partial e}{\partial c} = -\frac{\eta^* - \underline{\eta}}{\eta^s - \eta^*} \frac{(1-\bar{\lambda})R}{c^2} < 0 \tag{1.33}$$

$$\frac{\partial e}{\partial R} = \frac{\eta^* - \underline{\eta}}{\eta^s - \eta^*} \frac{1-\bar{\lambda}}{c} > 0 \tag{1.34}$$

$$\frac{\partial e}{\partial \bar{\lambda}} = -\frac{\eta^* - \underline{\eta}}{\eta^s - \eta^*} \frac{R}{c} < 0 \tag{1.35}$$

From equation (1.8), we can get

$$\frac{\partial r}{\partial c} = \frac{(\eta^s - \underline{\eta})r^2}{r_0} \cdot \frac{\partial e}{\partial c} < 0 \tag{1.36}$$

$$\frac{\partial r}{\partial R} = \frac{(\eta^s - \underline{\eta})r^2}{r_0} \cdot \frac{\partial e}{\partial R} > 0 \tag{1.37}$$

$$\frac{\partial r}{\partial \bar{\lambda}} = \frac{(\eta^s - \underline{\eta})r^2}{r_0} \cdot \frac{\partial e}{\partial \bar{\lambda}} < 0 \tag{1.38}$$

From equation (1.9) and under large innovation cost coefficient c, we can get

$$\frac{\partial L}{\partial c} = -\frac{(1-\bar{\lambda})R}{(\eta^s - \eta^*)L^2 r^2} \cdot \frac{\partial r}{\partial c} > 0 \tag{1.39}$$

$$\frac{\partial L}{\partial R} = \frac{1-\bar{\lambda}}{(\eta^s - \eta^*)^2 c L^2 r_0}[\eta^s(\eta^s - \eta^*)c - 2(1-\bar{\lambda})(\eta^s - \underline{\eta})(\eta^* - \underline{\eta})R] \tag{1.40}$$

$$\frac{\partial L}{\partial \bar{\lambda}} = -\frac{R}{(\eta^s - \eta^*)^2 c L^2 r_0}[\eta^s(\eta^s - \eta^*)c - 2(1-\bar{\lambda})(\eta^s - \underline{\eta})(\eta^* - \underline{\eta})R] \tag{1.41}$$

It is easy to see that for sufficiently large c, $\frac{\partial L}{\partial R} > 0$ and $\frac{\partial L}{\partial \bar{\lambda}} < 0$. In fact, as long as $\frac{\partial L}{\partial \eta^*} > 0$, $\frac{\partial L}{\partial R} > 0$ and $\frac{\partial L}{\partial \bar{\lambda}} < 0$.

Q.E.D.

Proof of Lemma 1.4

From Lemma 1.2, we know that when c increases, R decreases, or $\bar{\lambda}$ increases, the innovation probabilities are lower for each state. If we can show that lower innovation probabilities lead to a lower probability in the lowest state and a higher probability in the highest state, we can prove this lemma. We use superscripts *o* to denote the old states and *n* to denote the new states.

From $\pi = \pi P$, we can get $\pi(I - P) = 0$. We can write down the relationship between the probabilities of two nearby states as follows

$$\pi_{j+1} = \begin{cases} \frac{q(1-e_j)}{1-(1-q)(1-e_{j+1})}\pi_j, & \text{if } 1 < j < K-1 \\ \frac{q(1-e_{K-1})}{e_K}\pi_{K-1}, & \text{if } j = K-1 \end{cases} \tag{1.42}$$

With this relationship, we can write down the relationship between the probability of the lowest state and that of others

$$\pi_j = \begin{cases} \prod_{i=1}^{j-1} \frac{q(1-e_j)}{1-(1-q)(1-e_{j+1})} \cdot \pi_1, & \text{if } 1 < j < K \\ \frac{q(1-e_{K-1})}{e_K} \prod_{i=1}^{K-1} \frac{q(1-e_j)}{1-(1-q)(1-e_{j+1})} \cdot \pi_1, & \text{if } j = K \end{cases} \tag{1.43}$$

We can define Δ_j as

$$\Delta_j = \begin{cases} \prod_{i=1}^{j-1} \frac{q(1-e_j)}{1-(1-q)(1-e_{j+1})}, & \text{if } 1 < j < K \\ \frac{q(1-e_{K-1})}{e_K} \prod_{i=1}^{K-1} \frac{q(1-e_j)}{1-(1-q)(1-e_{j+1})}, & \text{if } j = K \end{cases} \tag{1.44}$$

So $\pi_j = \Delta_j \cdot \pi_1$ for any $j \geq 2$. It is easy to see that as c increases, R decreases, or $\bar{\lambda}$ increases, all e_j's decrease, so all Δ_j's increase. Substitute π_j into $\sum_{j=1}^{K} \pi_j = 1$, we can get $\pi_1 = 1/(\sum_{j=1}^{K} \Delta_j)$, so π_1 decreases.

We will prove $\pi_K^n > \pi_K^o$ by contradiction. If $\pi_K^n \leq \pi_K^o$, since e_j becomes smaller, from equation (1.42), we can get $\pi_j^n < \pi_j^o$ for all $1 < j < K$. And from above, we know $\pi_1^n < \pi_1^o$. So $\sum_{j=1}^{K} \pi_j^n < \sum_{j=1}^{K} \pi_j^0 = 1$, and there is contradiction. Thus, $\pi_K^n > \pi_K^o$.

Q.E.D.

Proof of Proposition 1.3

To prove the new stationary distribution first-order stochastic dominates the original one, we just need to show that the cumulative probability $\sum_{j=1}^{k} \pi_j^n$ is smaller or equal to $\sum_{j=1}^{k} \pi_j^o$ for all k and with strict inequality for some k following the definition of first-order stochastic dominance.

If c increases, R decreases, or $\bar{\lambda}$ increases, $e_j^n < e_j^o$ for all j. From equation (1.42), it is easy to see that (1) if $\pi_j^n > \pi_j^o$ for some j, this inequality holds for all k larger than j; (2) if $\pi_j^n < \pi_j^o$ for some j, this inequality holds for all k smaller than j. From Lemma 1.4, there must exist a $1 < k < K$, where $\pi_k^n \leq \pi_k^o$ and $\pi_{k+1}^n > \pi_{k+1}^o$. For $j < k$, $\pi_j^n < \pi_j^o$, so $\sum_{i=1}^{j} \pi_i^n < \sum_{i=1}^{j} \pi_i^o$. For $j > k$, $\pi_j^n > \pi_j^o$, so $\sum_{i=j}^{N} \pi_i^n > \sum_{i=j}^{N} \pi_i^o$. For $k < j < N$, $\sum_{i=1}^{j} \pi_i^n = 1 - \sum_{i=j}^{N} \pi_i^n < 1 - \sum_{i=j}^{N} \pi_i^o = \sum_{i=1}^{j} \pi_i^o$. Thus, we can show that $\sum_{i=1}^{j} \pi_i^n \leq \sum_{i=1}^{j} \pi_i^o$ for all j and with strict inequality for $j < K$.

Q.E.D.

Proof of Proposition 1.4

With innovation probability under regulation, we can write down the relationship between the probabilities of two nearby states as follows

$$\pi_{j+1}^r = \begin{cases} \frac{q(1-e_j^r)}{1-(1-q)(1-e_{j+1}^r)} \pi_j^r, & \text{if } 1 < j < K-1 \\ \frac{q(1-e_{K-1}^r)}{e_K^r} \pi_{K-1}^r, & \text{if } j = K-1 \end{cases} \tag{1.45}$$

With this relationship, we can write down the relationship between the probability of the lowest state and that of others

$$\pi_j^r = \begin{cases} \prod_{i=1}^{j-1} \frac{q(1-e_j^r)}{1-(1-q)(1-e_{j+1}^r)} \cdot \pi_1^r, & \text{if } 1 < j < K \\ \frac{q(1-e_{K-1}^r)}{e_K^r} \prod_{i=1}^{K-1} \frac{q(1-e_j^r)}{1-(1-q)(1-e_{j+1}^r)} \cdot \pi_1^r, & \text{if } j = K \end{cases} \tag{1.46}$$

We can define Δ_j^r as

$$\Delta_j^r = \begin{cases} \prod_{i=1}^{j-1} \frac{q(1-e_j^r)}{1-(1-q)(1-e_{j+1}^r)}, & \text{if } 1 < j < K \\ \frac{q(1-e_{K-1}^r)}{e_K^r} \prod_{i=1}^{K-1} \frac{q(1-e_j^r)}{1-(1-q)(1-e_{j+1}^r)}, & \text{if } j = K \end{cases} \tag{1.47}$$

From $\sum_{j=1}^{K} \pi_j^r = 1$, we get $\pi_1^r = 1/(\sum_{j=1}^{K} \Delta_j^r)$. If the regulator sets a maximum leverage lower than the highest one determined by the market, there exists at least one e_j^r which is smaller than that without regulation. We can get that all Δ_j^r's are larger than or equal to the correspondent without regulation, Δ_j^m's, and some are strictly larger. Then, $\sum_{j=1}^{K} \Delta_j^r$ is larger, so π_1^r is lower that that without regulation, π_1^m. It is easy to see that π_K^r is higher than the case without regulation, π_K^m.

Since the regulator sets a maximum leverage lower than the highest one determined by the market, there must exist a $1 \leq \bar{k} \leq K$, where all states lower than or equal to $\bar{k}$ are not affected by the regulation, while all states higher than $\bar{k}$ are affected by the regulation. For $j \leq \bar{k}$, $e_j^r = e_j^m$, and for $j > \bar{k}$, $e_j^r < e_j^m$. For equations (1.42) and (1.45), we can see that $\pi_j^r < \pi_j^m$ for $j \leq \bar{k}$. And if $\pi_j^r > \pi_j^m$ for some j, this inequality holds for all k larger than j. Since $\pi_K^r > \pi_K^m$, there must exist one $\bar{k} < \hat{k} \leq K$, where $\pi_j^r \leq \pi_j^m$ for $j < \hat{k}$ and $\pi_j^r > \pi_j^m$ for $j \geq \hat{k}$. For $j < \hat{k}$, $\pi_j^r \leq \pi_j^m$ with some strict inequality, so $\sum_{i=1}^{j} \pi_i^r < \sum_{i=1}^{j} \pi_i^m$. For $j \geq \hat{k}$, $\pi_j^r > \pi_j^m$, so $\sum_{i=j}^{K} \pi_i^r > \sum_{i=j}^{K} \pi_i^m$. For $\hat{k} \leq j < K$, $\sum_{i=1}^{j} \pi_i^r = 1 - \sum_{i=j}^{K} \pi_i^r < 1 - \sum_{i=j}^{K} \pi_i^m = \sum_{i=1}^{j} \pi_i^m$. Thus, we can show that $\sum_{i=1}^{j} \pi_i^r \leq \sum_{i=1}^{j} \pi_i^m$ for all j and with strict inequality for $j < K$. Q.E.D.

Chapter 2

ASSET ENCUMBRANCE AND BANK RISK: THEORY AND FIRST EVIDENCE FROM PUBLIC DISCLOSURES IN EUROPE

2.1 Introduction

As of June 2011, Dexia, a Franco-Belgian bank, reported a strong Tier 1 capital ratio of 11.4%.[1] Out of the 91 institutions analysed in the European Banking Authority (EBA) stress tests, Dexia came joint 12th, with a forecast Core Tier 1 capital ratio of 10.4% under the adverse stress scenario.[2] From a liquidity standpoint, the bank had built up a buffer of €88bn in liquid securities, and its short-term ratings had been reaffirmed as investment grade by the main credit rating agencies. But just three months later, in October 2011, Dexia was partly nationalised by the Belgian and French governments. Several commentators highlighted the high levels of "encumbered" assets as the key factor precipitating its move into government arms.[3,4]

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[1] See Dexia 2Q & 1H 2011 Results and Business Highlights Presentation, 4 August 2011

[2] The Core Tier 1 ratio represents the ratio of very high quality capital (shareholders' capital and reserves) to risk-weighted assets (RWA). The Tier 1 capital ratio includes, in addition to Core Tier 1 capital, other perpetual capital resources such as subordinated debt instruments with conversion features and is also expressed as a fraction of RWA.

[3] See e.g. Financial Times, "Bank collateral drying up in rush for security", October 2011.

[4] More recently, in June 2017, Banco Popular was put into resolution by the European Single Supervisory Mechanism (SSM) and was acquired by Banco Santander for a symbolic amount of €1. Yet, as of year-end 2016, the Spanish bank Banco Popular reported a Tier 1 capital ratio of 12.3% and had passed the EBA stress tests

Asset encumbrance refers to the existence of bank balance sheet assets being subject to arrangements that restrict the bank's ability to transfer or realise them. Assets become encumbered when they are used as collateral to raise funding, for example in repurchase agreements (repos) or in other collateralised transactions such as asset-backed securitisations, covered bonds, or derivatives.[5] In the particular case of Dexia, more than €66bn of its €88bn buffer securities were encumbered through different secured funding arrangements, particularly with the European Central Bank (ECB), and were therefore unavailable for obtaining emergency funding.

Policymakers are acting decisively in order to address what some consider to be excessive levels of asset encumbrance. Some jurisdictions have introduced limits on the level of encumbrance (Australia, New Zealand) or ceilings on the amount of secured funding or covered bonds (Canada, US), while others have incorporated encumbrance levels in deposit insurance premiums (Canada). Several authors have proposed linking capital requirements to the banks' asset encumbrance levels or establishing further limits to asset encumbrance as a back-stop (Helberg and Lindset (2014); IMF (2013); Juks (2012)). As part of the Basel III regulatory package, the Net Stable Funding Ratio (NSFR), which will introduce additional minimum liquidity requirements, heavily penalises asset encumbrance by requiring substantial amounts of stable funding. In Europe, regulatory reporting and disclosure requirements have been introduced and all institutions are required to incorporate asset encumbrance within their risk management frameworks. The Dutch National Bank has even committed to "keeping encumbrance to a minimum" (De Nederlandsche Bank (2016)).

Such policy actions stem from a negative perception of asset encumbrance. First, increasing asset encumbrance reduces the amount of unencumbered assets that a bank can use to meet sudden liquidity demands and the pool of assets that become available to unsecured creditors under insolvency, an effect coined as "structural subordination". In the particular case of Dexia, more than €66bn of its €88bn buffer securities were encumbered through different secured funding arrangements, particularly with the European Central Bank (ECB), and were therefore unavailable for obtaining emergency funding and meet creditors' demands. If unsecured creditors reflect the risks of asset encumbrance into their required returns, institutions would face

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undertaken in 2016 with a solid margin. However, nearly 40% of its total balance sheet assets were encumbered as of December 2016.

[5] Collateralisation is a common method of mitigating counterparty credit risk in derivative markets through the provisioning of margin.

higher overall funding costs. As stated by Dr Joachim Nigel, a former member of the executive board of the Deutsche Bundesbank in a speech at the 2013 European Supervisor Education Conference on the future of European financial supervision: "Higher asset encumbrance has an impact on unsecured bank creditors. The more bank assets are used for secured funding, the less remain to secure investors in unsecured instruments in the case of insolvency. They will price in a risk premium for this form of bank funding."

This paper argues that asset encumbrance may also bring in important benefits. Collateral also provides safety, potentially reducing the bank's overall cost of funds and liquidity risks. We first present a theoretical model exploring the trade-offs of asset encumbrance and their implications for liquidity risk, and banks' risk premia. In our model, asset encumbrance has two opposing effects on liquidity risk. First, as the level of asset encumbrance increases, the bank will have fewer unencumbered assets available to meet creditors demands in case of stress — this is the structural subordination effect of asset encumbrance. On the other hand, as encumbrance increases, the bank has fewer liabilities subject to a run and, hence, lower liquidity risk — this is the stable funding effect of asset encumbrance. Overall, which effect dominates depends crucially on the levels of over-collateralization, i.e. on the haircuts, which may reflect not only the market value of the collateral but also the time it takes to find a buyer in the over-the-counter market, the legal costs of seizing the collateral or the fact that investors value the collateral less than the bank.

We show that the stable funding effect dominates the adverse effect of structural subordination when the haircut just reflects the market value of the collateral. Indeed, secured funding reduces liquidity risk because secured creditors require a lower return than unsecured creditors. However, when the levels of over-collateralization of secured funding are higher, the bank raise a smaller amount of secured funding by pledging the same amount of assets, which reduces the stable funding effect. In turn, the bank needs to raise a larger amount of unsecured funding, which increases the adverse structural subordination effect. When haircuts are high relative to the premia for safety, the structural subordination effect dominates the stable financing effect and liquidity risk increases.

This trade-off generates two distinct predictions on the relationship between encumbrance levels and bank risk. In the case of low haircuts, banks increase the level of asset encumbrance as much as possible, as secured funding is not only cheaper but it also reduces liquidity risk. At the same time, unsecured debt holders would require lower premia to compensate for bank's default risk and recovery rates. Thus, as the availability of bank collateral increases, asset encumbrance increase and unsecured funding rates decrease. Instead, in the case of high haircuts, banks face a trade-off, as secured funding is cheaper but it increases liquidity risk. As a result, we may have banks with higher collateral to choose higher levels of asset encumbrance despite having higher liquidity risk. So, the relationship between asset encumbrance and interest rates may be increasing.

We test these predictions and investigate, in the absence of data on the availability of bank collateral, the association of asset encumbrance and credit risk spreads. We built a novel dataset using information provided in the asset encumbrance disclosures published for the first time throughout 2015 by European banks, following a set of harmonised definitions provided by the EBA (EBA (2014)). In a cross-section of banks, we find that institutions with higher encumbrance levels tend to have lower CDS spreads — i.e. bank risk seems to be negatively associated with asset encumbrance. We also find that some variables play a mediating role in the relationship between asset encumbrance and bank risk. For banks with a high reliance on central bank funding and high levels of liquid assets, such as Dexia, or with a high leverage ratio and high levels of impaired loans, such as Banco Popular, or for banks located in Southern Europe (GIIPS), asset encumbrance is less negatively correlated with bank risk and, in some cases, it is positively related.[6] These findings imply that regulators need to be cautious when assessing asset encumbrance levels and leaping to across-the-board conclusions about its effects.

There is a small but emerging literature studying asset encumbrance and bank risk. In Ahnert et al. (2017), a bank's amount of unsecured debt is fixed and the bank can expand profitable investment through secured funding, which leads to greater asset encumbrance. However, with greater asset encumbrance, fewer unencumbered assets are available to meet unsecured debt withdrawals, thereby exacerbating bank's liquidity risk. As a consequence, Ahnert et al. (2017) predict that bank's asset encumbrance level is positively correlated with the premium of unsecured debt. In our paper, on the contrary, banks can use secured financing to replace unsecured funding. This generates the stable funding effect of asset encumbrance, which is absent in Ahnert et al. (2017). Thus, we predict that bank's asset encumbrance level can be negatively correlated with the premium of unsecured debt when the haircut of over-collateralization is low.

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[6] In the demise of Banco Popular (see footnote 4), the bank had high levels of asset encumbrance and of impaired loans. As of December 2016, almost 15% of Popular's loan portfolio was non-performing compared to a European average of 5.1%. Its Basel III Leverage Ratio was also high (5.31% compared to a weighted average for European banks of 5.2% as per EBA (2017)).

This result also differs from Matta and Perotti (2015). In Matta and Perotti (2015), more secured debt results in more liquidity risk. Therefore, unsecured debt bears more risk, requiring a higher promised yield. Gai and Chapman (2017) also study the implications of bank asset encumbrance for financial instability. However, in their model, bank's funding structure is exogenously given rather than endogenously chosen by the bank.

Our paper is related with the literature on secured debt and more generally firms' debt structure choices. Theoretically, the possible explanations of the use of secured debt include mitigating agency conflicts between shareholders and creditors (Smith and Warner (1979); Stulz and Johnson (1985)), addressing the information asymmetries between the lender and borrower (Chan and Thakor (1987); Berger and Udell (1990); Thakor and Udell (1991)). A recent interesting paper by Donaldson et al. (2017) focus on the role that collateral can serve as a commitment device for the firm. In their model, a firm can not commit not to expropriate the unsecured creditors. Creditors thus require collateral for protection against possible expropriation by collateralized debt in the future. However, collateralized borrowing has a cost since it can constrain firm's future borrowing and investment. Unlike these papers, our paper focus on bank's funding structure and emphasizes a different friction of collateralized borrowing: the interaction between collateralized borrowing and bank's unsecured creditors as well as liquidity risk, which is banking specific.

Empirically, Julio et al. (2007) find that the vast majority of public debt issues are unsecured, while Nini et al. (2009) document that 65 percent of a large sample of private credit agreements between 1996 and 2005 were secured. In the context of banking, Di Filippo et al. (2016) find that that banks with higher credit risk are able to offset a reduction of unsecured borrowing with secured loans, consistent with theories of lender moral hazard. Unlike Di Filippo et al. (2016), we find that better banks may use more secured debt. Besides, our paper focuses on the relationship between asset encumbrance level and the premium of unsecured debt holders. Therefore, our paper can explicitly tackle the issue of structural subordination missing in Di Filippo et al. (2016).

The rest of the chapter is organized as follows. Sections 2.2 describe the model setup and bank liquidity risk. In Section 2.3, we identifie the two effects of secured funding on bank risk. In Section 2.4, we present the theoretical results for the case when collateral haircuts are low and high respectively. In Section 2.5, we provide empirical evidence supporting model predictions. Section 2.6 concludes.

2.2 Theoretical Framework

We now present a simple model of a bank to understand banks' optimal choices of asset encumbrance, as well as the resulting implications of these choices on unsecured debt risk premia.

2.2.1 Bank and Investors

A risk-neutral bank has access to a profitable project that needs one unit of cash at $t = 0$. The bank's project generates a random return $\theta \geq 0$ at $t = 1$ and a fixed return $k < 1$ at $t = 2$. The random return θ follows a uniform distribution with $\theta \sim U[0, \bar{\theta}]$.For notational simplicity, we sometimes denote the (uniform) cumulative distribution function of θ by $F(\theta)$. As $k < 1$ and θ can be zero, the bank is subject to insolvency risk. The bank has limited liability.[7]

At $t = 0$, the bank has no cash at hand, so it needs to raise funds from a competitive credit market. We assume that the bank issues long-term demandable debt.[8] That is, creditors can withdraw their money at $t = 1$, before the debt matures at $t = 2$. The bank can use θ and the proceeds from selling part of the fixed second-period returns k prematurely, at a per-unit fire-sale price of $\phi < 1$. Equivalently, at $t = 1$, there is a bond market where the bank can sell riskless bonds which promise one unit of cash at $t = 2$, at a price $\phi < 1$.[9] Here $1 - \phi$ reflects the fire-sale discount in a market with limited liquidity. Since the project's payoff at $t = 2$ is k, the bank can sell riskless bonds up to a maximum of k. The bank fails if the amount withdrawn exceeds its liquid assets at $t = 1$. Thus, as in Allen and Gale (1994), the bank is subject to liquidity risk.

The bank raises funding by issuing secured and/or unsecured debt funding, so as to maximize the bank's expected profits at $t = 0$. There are two types of creditors. Some are risk neutral but demand a minimum expected return of $1 + \gamma$, with $\gamma > 0$. The others are infinitely risk averse, and willing to lend only if debt is absolutely safe, but they demand a minimum return of just 1.[10] Since infinitely risk averse investors demand a lower expected return, it is optimal for the bank to raise (safe) secured funding from this group of investors, and (risky)

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[7] A storage technology allows the bank to transfer cash from one date to the next without cost.

[8] Diamond and Dybvig (1983), Diamond and Rajan (2001), Calomiris and Kahn (1991) provide microfoundations for demandable debt. For instance, in Calomiris and Kahn (1991) and Diamond and Rajan (2001), demandable debt acts as an instrument to prevent opportunistic behavior by bank managers.

[9] See Freixas and Rochet (2008) for the same setup.

[10] See Gorton et al. (2012); Krishnamurthy and Vissing-Jorgensen (2012) for empirical evidence, and Stein (2012); Caballero and Farhi (2013); Gennaioli et al. (2012) for similar modeling assumptions.

unsecured debt from the risk neutral investors. This setup captures a major advantage of secure funding: it is perceived to carry lower roll-over risks and is generally cheaper than equivalent unsecured funding. We assume that the wealth of each group investors is sufficiently large so that the bank's financing decision will not be constrained by each group of investors' wealth.

2.2.2 Asset Encumbrance

Denote by s the funds raised through (long-term demandable) secured debt to the risk-averse investors. To make they are repaid fully and unconditionally, the bank needs to pledge enough assets. The bank can pledge a fraction of the project's payoff at $t = 2$, up to a maximum of k. The bank's return θ at $t = 1$ cannot be pledged because it is random with the lowest return being equal to 0. Hence, from now on, we refer to k as the available collateral of the bank. Since secured debt is absolutely safe, the face value per unit of secured debt, D_s is equal to 1, which is the minimum return demanded by infinitely risk averse investors.

For each unit of secured funding, the bank needs to pledge $1 + h$ units of collateral, where h reflects the haircut. The minimum possible level of haircut is determined by the liquidity of the collateral in the market, that is, h is such that $(1 + h)\phi = 1$. Indeed, if required, the bank can sell the collateral and recover $(1 + h)\phi = 1$ at $t = 1$ for each unit of secured funding. However, the bank may be required to pledge more collateral, that is, h is such that $(1 + h)\phi > 1$. This may reflect other costs of collateral liquidation, due for instance the time it takes to find a buyer of the collateral in the over-the-counter market, the legal costs of seizing the collateral or the fact that investors value the collateral less than the bank.

The assets pledged to secured debt holders as collateral are encumbered, so they cannot be sold at $t = 1$ to meet unsecured debt holders' withdrawals. In the event of a bank run, secured debt holders can seize the encumbered assets $(1 + h)s$. Because of full collateral protection, they have no incentive to withdraw money in the interim period. In case of bank failure, the bank liquidates the unencumbered assets $k - (1 + h)s$ at a fire-sale price ϕ, which are shared by the unsecured investors on a pro-rata basis.

Denote by $1 - s$ the funds raised trough (long-term demandable) unsecured debt to the risk-neutral investors. The face value per unit of unsecured debt, D_u, is endogeneuosly determined by $1 - s$, via a zero profit condition, taking into account that the risk-neutral investors demand a minimum return of $1 + \gamma$.

The timing of the model is illustrated in Figure 2.1. For simplicity, we assume that the bank's project is profitable even if all the long-term assets are liquidated at $t = 1$ and the bank finances the project entirely through unsecured debt. That is $\frac{\bar{\theta}}{2} + k\phi > 1 + \gamma$.

Our model includes three departures from the Modigliani and Miller framework. First, while some investors are risk neutral, and require a net positive return ($1+\gamma > 1$), others have (strong) preferences for safety and accept a lower return of 1. This gives secured debt two types of benefits. The first is direct: secured debt is relatively cheaper than unsecured debt. The second benefit is indirect: since secured debt is cheaper, the bank's total debt obligations decrease, thus reducing the bank's liquidity risk and the potential costs involved ($\phi < 1$). However, when the bank raises secured funding, there may be additional losses to liquidate the collateral ($h > 1/\phi - 1$). In the case of default, $(1 + h)s\phi - s$ are lost because of this imperfection. As h increases, the cost of issuing secured debt is higher.

2.3 Structural Subordination vs. Stable Funding

This section identifies the two effects of secured funding on liquidity risk, which we name stable funding and structural subordination effects. In the first subsection, we treat the level of secured funding, s, and the face value of a unit of unsecured debt, D_u, as exogenously given. In the second subsection, we endogenize D_u. In the following section, we will endogenize the level of secured funding s.

2.3.1 Exogenous Funding Cost

The bank is exposed to insolvency risk. The bank is insolvent if and only if the total value of bank's assets is inferior to the debt obligations:

$$\theta + k < s + (1 - s)D_u.$$

As $k < 1$, θ can be zero, and $s + (1 - s)D_u > 1$ (as $D_u \geq 1 + \gamma$), there exists a critical solvency return θ^{**} such that the bank is solvent if and only if:

$$\theta > \theta^{**} \equiv s + (1 - s)D_u - k. \tag{2.1}$$

The bank is also exposed to liquidity risk. At $t = 1$, unsecured debt holders can decide whether to withdraw the money or not. The bank can use its period-1 proceeds θ as well as proceeds from the sale of unencumbered assets, $k - (1 + h)s$ at a price of $\phi < 1$ to meet the withdrawal. But, if all the unsecured debt holders choose to withdraw, the bank will fail from a run on the bank at $t = 1$ if the bank's available liquidity is inferior to the investors' withdrawals:

$$\theta + (k - (1 + h)s)\phi < (1 - s)D_u.$$

Hence, we can define a critical liquidity return for the bank θ^*:

$$\theta^* \equiv (1 - s)D_u - (k - (1 + h)s)\phi \tag{2.2}$$

As $\theta^* > \theta^{**}$, the range of θ can be split into three regions. The bank is insolvent if $\theta < \theta^{**}$, solvent but possibly illiquid if $\theta^{**} < \theta < \theta^*$, and liquid and solvent if $\theta > \theta^*$. The intermediate region spans multiple equilibria. In one of them, all unsecured debt holders withdraw and the bank fails. In another equilibrium, all unsecured debt holders choose not to withdraw and the bank survives. For simplicity, we assume that the bad equilibrium prevail, so that the bank also fails if $\theta^{**} < \theta < \theta^*$. In this region, the bank is solvent, but fails because of the unsecured investors' self-fulfilling concern that all the other unsecured debt holders withdraw.[11] As $\theta \sim U[0, \bar{\theta}]$, the bank fails at $t = 1$ with probability $\theta^*/\bar{\theta}$. Clearly, the higher the liquidity cutoff θ^*, the higher the bank's liquidity risk.

Notice that an increase in secured funding, s, has two effects on bank's liquidity risk, θ^*. On the one hand, as s increases $(1 - s)D_u$ decreases, which implies that the bank needs less liquidity to face a potential liquidity shock at $t = 1$. This is the stable funding effect of secured financing. On the other hand, as s increases, $(1+h)\phi s$ increases, which implies that the amount of unencumbered assets available to the unsecured debt holders is lower. This is the structural subordination effect of secured funding. If $(1 + h)\phi = 1$, the marginal effect of s on $(1 - s)D_u$ exceeds the marginal effect on $(1 + h)\phi s = s$ because the interest rate of secured investors is lower, $D_u > 1$. Therefore, θ^* decreases in s. However, when the haircut h is higher, the bank is

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[11] On the contrary, if the good equilibrium is chosen, bank's liquidity risk will disappear. In this case, only solvency risk is relevant for the bank. More generally, we can extend the model to allow for multiple equilibrium. In the more general case, when $\theta < \theta^*$, the bank fails from bank run with exogenous probability q, and survives with probability $1 - q$. Our results still hold in this more general case. In principle, we could also use the global games approach of Goldstein and Pauzner (2005), to select a unique equilibrium. We work with an exogenously chosen equilibrium for tractability.

required to pledge more collateral for secured financing, and bank's liquidity risk is increasing in h. Therefore, with larger h, the negative effect of structural subordination is greater and thus the relative importance of the two effects may be reversed.

2.3.2 Endogenous Funding Cost

In this subsection, we show how the level of secured funding affects the bank's liquidity risk θ^*, taking into account that s and θ^* also affect the face value of unsecured debt D_u. Given s, the break-even condition for unsecured debt holders is indeed given by:

$$\int_0^{\theta^*} [\theta + (k - (1+h)s)\phi] dF(\theta) + \int_{\theta^*}^{\bar{\theta}} (1-s) D_u dF(\theta) = (1-s)(1+\gamma) \tag{2.3}$$

The first term in the left hand side is unsecured debt holders' expected return if the bank fails from a run at $t = 1$. Unsecured debt holders share θ, as well as all the discounted unencumbered collateral, $(k-(1+h)s)\phi$, on a pro-rata basis. The second term in the left hand side is unsecured debt holder's expected return if the bank survives from the run. In this case, unsecured debt holders are fully paid at $t = 2$. The right hand side is the opportunity cost of unsecured debt holders' funding.

As shown in (2.3), the face of value of unsecured debt D_u depends on the bank's liquidity risk θ^* and the level of secured funding s. In turn, the bank's liquidity risk θ^* defined in (2.2) depends on D_u.and s. The following proposition characterizes the effect of secured funding on the bank's liquidity risk.

PROPOSITION 2.1. *Bank's liquidity risk θ^* is strictly decreasing (increasing) in the level of secured funding s if the haircut of secured funding h is such that $(1+h)\phi < 1+\gamma$ ($> 1+\gamma$).*

Proposition 2.1 shows that γ is a key variable in determining whether secured funding decreases or increases bank's liquidity risk. This result is quite intuitive: bank's main trade-off is on the cost of secured funding-inefficiencies of overcollateralisation, and on the benefits of of secured funding-unsecured debt holders require higher rate of return. When γ is high, i.e. $(1+h)\phi < 1+\gamma$, the bank needs to promise high amount of debt payments when raising unsecured funding, in order to make unsecured debt holders break even. High debt obligations imply high liquidity risk. If the bank can replace unsecured funding with secured funding, since secured debt holders require a lower rate of return, the bank's total debt obligations decrease, which reduces bank's liquidity risk. As γ is higher, the savings of funding cost as well as the decrease of liquidity risk through secured funding, is even larger, which makes it more attractive for the bank to issue secured debt. On the contrary, when γ is relatively small, i.e. $(1+h)\phi > 1+\gamma$, the benefit of secured funding on bank's liquidity risk through decreasing debt obligations is limited, whereas the cost of secured funding-inefficiencies of overcollateralisation may be substantial. In this case, secured funding can increase bank' liquidity risk.

2.4 Optimal Asset Encumbrance and Bank Risk

In this section, we determine the bank's optimal level of secured funding, as well as the resulting unsecured funding costs. We consider the two levels of overcollateralization determined in Proposition 2.1: when h is such that $(1+h)\phi < 1+\gamma$ and when h is such that $(1+h)\phi > 1+\gamma$. In each case, our analysis unfolds in three steps. First, we study how the level of secured funding s affects bank's expected profits. Second, we determine the bank's optimal level of secured funding, s^*, and the level of unsecured debt value, as a function of the available collateral k. Third, we make predictions on the relationship between asset encumbrance and unsecured interest in a cross-section of banks with different levels of available collateral k, which are empirically unobservable.

The expected profits of the bank at $t = 0$ is given by:

$$\Pi = \int_{\theta^*}^{\bar{\theta}} [\theta + k - s - (1-s)D_u] dF(\theta). \tag{2.4}$$

When $\theta < \theta^*$, the banks fails at $t = 1$ and shareholders receive 0. When $\theta > \theta^*$, the bank survives and the payoff of the bank's assets is $\theta + k$. At $t = 2$ the bank pays s to secured debt holders and $(1-s)D_u$ to unsecured investors. Clearly, Π is a function of θ^*, D_u and s. As we have shown before, both θ^* and D_u are determined by s. Therefore, Π is determined by s.

2.4.1 Low Rates of Overcollateralization

Secured funding affects bank's expected profit in two ways. First, since secured funding is a cheaper source of finance, higher asset encumbrance reduces bank's overall funding cost: conditional on success, the bank receives larger residual payoffs. Second, in the case of $(1+h)\phi < 1+\gamma$, asset encumbrance reduces bank risk, θ^*. Both effects are positive.

PROPOSITION 2.2. *If the haircut of secured funding* h *is sufficiently low such that* $(1 + h)\phi < 1 + \gamma$*, the bank's profits are strictly increasing in the level of secured funding* s*, which implies that the optimal level of secured funding for the bank is* $s^* = k/(1 + h)$*.*

Thus, the bank should set the level of secured funding as high as possible. We now determine the optimal level of secured funding, as well as the resulting face value of unsecured debt D_u and the bank's liquidity risk θ^*.

PROPOSITION 2.3. *If the haircut of secured funding* h *is sufficiently low such that* $(1 + h)\phi < 1 + \gamma$*, as the amount of available collateral* k *increases (i) the level of secured funding,* s^**, increases. whereas (ii) the unsecured funding cost,* D_u*, decreases.*

The intuition of Proposition 2.3 is as follows. A bank with more available collateral is able to raise more secured funding. As we have shown before, secured funding reduces bank's liquidity risk. Therefore, the liquidity risk of bank failure decreases in asset encumbrance, and unsecured debt holders demand a lower interest rate to compensate for the risk of bank failure.

In our model, bank's asset has two components: θ and k. Even though the amount of total assets may be observable, in reality, it is difficult to separate θ from the collateral available k. To test the predictions of our model, we can find the relationship between bank's unsecured funding cost and bank's level of asset encumbrance. From the model, we have the following hypothesis.

HYPOTHESIS 2.1. *If the haircut of secured funding is low, in a cross-section of banks with an endogenously chosen level of asset encumbrance, bank's unsecured funding cost* D_u *is negatively correlated with bank's level of asset encumbrance* s*.*

As an example, Panel a, b, c of Figure 2.2 plots the optimal level of asset encumbrance as well as the resulting face value of unsecured debt as a function of the level of available collateral k, as well as the relationship between the level of asset encumbrance and the face value of unsecured debt, for the case of $\bar{\theta} = 1, \phi = 0.9, \gamma = 0.05$ and $h = 0.11$.

2.4.2 High Rates of Overcollateralization

In the case in which $(1 + h)\phi > 1 + \gamma$, the bank faces a trade-off when choosing the optimal level of secured funding. On the one hand, secured funding is again cheaper than unsecured funding. But now, as is shown in Proposition 2.1, a higher level of secured funding increases bank's liquidity risk, and unsecured debt holders may demand a higher interest rate.

PROPOSITION 2.4. *If the haircut of secured funding* h *is sufficiently high such that* $(1+h)\phi > 1+\gamma$*, there exists* $\hat{s} \in [0, k/(1+h)]$ *such that for* $s < \hat{s}$*, bank's expected profit* Π *is strictly increasing in* s*, and for* $s > \hat{s}$*,* Π *is strictly decreasing in* s*.*

For high levels of overcollateralization, the optimal level of secured funding may be a corner or an interior solution. This result differs from that in Proposition 2.2, where bank' optimal level of secured funding is always a corner solution. The difference arises from the level of the haircut h relative to the fire-sale discount ϕ. When h is low, over-collateralization is low: the bank needs to ensure that the excess collateral covers only the potential losses of asset liquidation. Since in this case, assets allow for high level of secured funding, the negative effect of asset encumbrance on bank's liquidity risk is dominated by the positive effect of stable liabilities. Alternatively, when h is high, over-collateralization is also high, so the negative effect of asset encumbrance on bank's liquidity risk dominates the positive impact of stable financing.

PROPOSITION 2.5. *There exist* k_h *and* k_l *with* $k_h > k_l$ *such that (i) the optimal level of secured funding is higher for* k_h *than for* k_l *and (ii) the interest rate for unsecured debt holders is higher for* k_h *than for* k_l*.*

If $(1+h)\phi > 1+\gamma$, it is possible that in a cross-section of banks asset encumbrance is positively associated with the premium of unsecured debt. k can affect θ^* in two ways. First, through the direct effect on $k\phi$, when k is larger, the bank's liquidity risk is lower. This is intuitive, since a bank with more collateral is less likely to fail from bank run. Second, banks' choice of s may depend on k, which has an indirect effect on θ^*. Since $(1+h)\phi > 1+\gamma$, if a bank with larger k chooses higher s, then the indirect effect of k on θ^* would be negative, which may lead to higher liquidity risk.

The implications of the above analysis for observable data can be summarized as follows:

HYPOTHESIS 2.2. *If the haircut of secured funding is sufficiently high, in a cross section of banks with endogenously chosen asset encumbrance level, it is possible that bank's unsecured funding cost* D_u *is positively correlated with bank's level of asset encumbrance* s*.*

As an example, Panel a, b, c of Figure 2.3 plots the optimal level of asset encumbrance as well as the resulting face value of unsecured debt as a function of the level of available collateral k, as well as the relationship between the level of asset encumbrance and the face value of unsecured debt, where we set $\bar{\theta} = 1, \phi = 0.9, \gamma = 0.05, h = 0.25$.

We now turn to empirical evidence on the relationship between asset encumbrance and credit risk premiums of banks.

2.5 Empirical evidence

In this section, we provide empirical evidence supporting the theoretical model described above. To do this, we run a set of regressions aimed to capture the association between the observable levels of asset encumbrance and bank credit risk. We further analyze heterogeneity of this relationship related to bank characteristics. This second part of the analysis is thought to show that the relationship between credit risks and encumbrance levels crucially depends on the financial conditions of a bank.

2.5.1 Data and Descriptive Statistics

To implement the regression analysis, we extract data from the risk disclosures of banks, including information on encumbered assets, unencumbered assets, off-balance sheet (OBS) collateral received and available for encumbrance, OBS collateral received and re-used and matching liabilities (the liabilities or obligations that give rise to encumbered assets) as of year-end 2014. We complement the disclosure data with data on total assets and equity extracted from Bankscope to compute the asset encumbrance ratios for each institution.

Our main dependent variable in the multivariate regressions is a measure of bank risk represented by banks' CDS spreads as of year-end 2015. CDS spreads are widely considered to be a good indicator of bank risk and can be a proxy for bank unsecured funding costs (see Babihuga and Spaltro (2014); Beau et al. (4 Q4)). We use implied rather than market-based spreads because only the largest global institutions are involved in CDS issuance. For most banks, Fitch Solutions determines the implied spreads on a daily basis using a proprietary model that includes, as inputs, banks' financial fundamental information, distance-to-default information derived from the equity market, and other market variables. In line with the existing literature, we focus on five-year senior spreads since these contracts account for 85% of the market and are highly liquid. Data is provided by Fitch Solutions and extracted from Bankscope.

Computing asset encumbrance measures at the bank level is not straightforward since accounting data provides limited information to infer the amount of banks' encumbered assets, unencumbered assets and matching liabilities. Accounting statements are accompanied by disclosures which try to shed light on the amount of assets that are collateralising transactions but, as noted by the EBA: "existing disclosures in International Financial Reporting Standards (IFRS) may convey certain situations of encumbrance but fail to provide a comprehensive view on the phenomenon" (EBA (2014)). For this reason, the EBA introduced new guidelines in 2014 proposing the requirement to disclose asset encumbrance reporting templates. EBA guidelines do not constitute a regulatory requirement and, although most did, not all of the European institutions disclosed such information.

Furthermore, there is currently no consensus as to how asset encumbrance shall be measured and different measures have been proposed. We focus on the three key ratios being used by policymakers. The computation of each ratio is illustrated in figure 2.4.

Hence, the asset encumbrance ratios (AERs) capture the amount of encumbered assets as a proportion of total assets. There are two variations:

- The ratio of *encumbered assets to total assets*, which captures the overall proportion of balance sheet assets that have been encumbered. This ratio has been used by the Bank of England and the European Systemic Risk Board (ESRB) to undertake analysis of the UK and European banking sectors respectively (Beau et al. (4 Q4); ESRB (2013)). We denote it as AER1.

- The ratio of *encumbered assets and other collateral received and re-used to total assets and total collateral received*, which captures the overall proportion of encumbered balance sheet assets as well as off-balance sheet collateral. This ratio is used by the EBA to undertake their risk assessment of the European banking system and to apply more comprehensive regulatory reporting requirements (EBA (2016)). We denote this ratio as AER2.

The third ratio focusses instead on unencumbered assets:

- The ratio of *unencumbered assets to unsecured liabilities* (UAUL), which captures the proportion of assets which are not subject to collateral agreements as a proportion of unsecured creditor's claims and provides an indication of the amount of structural subordination of unsecured creditors. According to a report from the Bank of International

Settlements' Committee on the Global Financial System (CGFS (2013)), the UAUL ratio is the most appropriate measure of asset encumbrance.

As opposed to AER1 and AER2, UAUL is a measure of how many assets are available to unsecured creditors under insolvency, and should therefore capture the structural subordination of unsecured creditors more directly than AER1 and AER2. Since UAUL is measured relative to unsecured funding, this ratio would be unable to capture low levels of unencumbered assets relative to the total assets of banks that rely heavily on capital or secured funding. As opposed to AER2, AER1 and UAUL do not capture encumbrance arising from off-balance sheet activities.

For UAUL, we use a slightly modified version which we denote as AUAUL (Adjusted UAUL), calculated as

$$\mathrm{AUAUL}_i = \frac{\max(\mathrm{UAUL}) - \mathrm{UAUL}_i}{\max(\mathrm{UAUL}) - \min(\mathrm{UAUL})},$$

where UAUL_i is bank's i ratio of unencumbered assets to unsecured liabilities and $\max(\cdot)$ and $\min(\cdot)$ return, correspondingly, the sample maximum and minimum of their arguments. This adjustment facilitates comparisons with AER1 and AER2 by ensuring that higher encumbrance is associated with a higher AUAUL and that its values fall between 0 and 1.

Explanatory variables include, in addition to the asset encumbrance measures, CAMEL and control variables. We follow Chiaramonte and Casu (2013) to select the following CAMEL variables:

- Capital Adequacy:
  - The Tier 1 capital ratio, which represents the ratio of high-quality capital (shareholders' capital, reserves and other perpetual capital resources such as subordinated debt), divided by risk-weighted assets (RWA).
  - The leverage ratio, which is calculated as the fraction of common equity to total assets and reflects the level of indebtedness of a firm.
- Liquidity:
  - The net loans to deposits and short-term funding ratio, which is a measure of structural liquidity. A lower value of the ratio means the bank relies to a greater extent

  on more stable deposit funding, as opposed to wholesale funding, to finance its loan book.

  - The liquid assets to total assets ratio, which measures the amount of liquid assets that the bank holds and that could be converted into cash to withstand a liquidity stress event.

- Quality of assets:

  - The ratio of loan-loss reserve to gross loans, which measures the quality of the loan portfolio by indicating the proportion of reserves for losses relative to the banks' loan portfolio.

  - The ratio of unreserved impaired loans to equity, which is another indicator of the quality of the loan portfolio but expressed relative to common equity. It is also known as the "capital impairment ratio".

- Earnings potential:

  - The return on equity ratio (ROE), which measures the bank's income-producing ability as reflected by its net income relative to the bank's common equity.

  - The return on assets ratio (ROA), which is an indicator of the return on a firm's investments and is calculated by dividing the bank's net income over its total assets.

Control variables include bank size (measured by the natural logarithm of total assets), central bank exposure to total assets and off-balance sheet exposure to total assets. We include dummy variables to differentiate the business model of the institution using three categories: "Commercial banks and Bank holding companies (BHC)", "cooperative and savings banks" and "other banks". We also include a dummy variable to identify which banks are investment grade. We use implied ratings in order to avoid compromising the sample size, in a similar fashion to CDS spreads. Implied ratings are provided by Fitch Solutions and derived from proprietary fundamental data. These provide a forward-looking assessment of the stand-alone financial strength of a bank and are categorised according to a 10-point rating scale from A to F where A denotes the maximum creditworthiness, with four interim scores (A/B, B/C, C/D and D/E).

Our final data sample includes institutions with total assets above €1bn for which CDS spreads, asset encumbrance, CAMEL and control variables are available, resulting in 367 banks.

Table 2.1 presents the summary statistics of the variables of study. The mean values of AER1, AER2 and AUAUL are 0.13, 0.14 and 0.60 respectively. Note that there is a wide disparity across banks in our sample. AER1 and AER2 present standard deviations of 0.11 and 0.12 respectively. Although the standard deviation of AUAUL is lower (0.08), the mean and the original standard deviation of UAUL are 1.06 and 0.15.

Table 2.2 presents the correlation matrix of encumbrance ratios. AER1 and AER2 present a high correlation of 0.97 which is expected given their similar construction with the only difference being the inclusion of off-balance sheet collateral in AER2. The correlation coefficients of AUAUL with AER1 and AER2 are 0.39 and 0.36 respectively.

Figure 2.5 shows the mean ratio levels of AER1 (blue, left scale) and AUAUL (green, right scale) for those countries with more than one observation. The countries are shown in four groups corresponding to GIIPS, Nordic countries, core countries including Austria, Belgium, Germany, France, UK, Luxembourg and the Netherlands, and other European countries such as the Eastern European countries and Malta. Results show a wide disparity in mean encumbrance levels across countries. All the GIIPS countries presenthigher mean encumbrance ratios than the sample average, as do Nordic countries such as Denmark and Sweden. Denmark, in particular, presents the highest mean ratio of all countries in the sample. Nordic countries have a long tradition of covered bond issuance, which may help explain these results. Of the remaining countries, Belgium, France and the UK present higher mean encumbrance levels than the overall sample average. Belgium, Malta, Netherlands and the UK present higher mean values of AUAUL than the sample mean. Luxembourg and some of the countries classified as "other" such as Bulgaria, Poland and Malta present the lowest values of AER1 but also the largest differences between AUAUL and AER1.

Table 2.3 shows the mean levels of the two asset encumbrance ratios across rating categories. Banks within the most extreme categories, A/B and E/F, present the lowest mean AER1 and AER2 ratios of all categories. For AUAUL, it is banks in categories D/E and E/F that present the lowest mean values.

As shown in the same table, mean encumbrance levels tend to increase with bank size, measured in terms of total assets, across all ratios. Since securitisations involve substantial costs, mostly of a fixed nature, these should be particularly costly to issue for smaller banks (Adrian and Shin (2010); Carbó-Valverde et al. (2012); Panetta and Pozzolo (2010)).

Table 2.3 also reports the mean ratio levels by type of institution. We distinguish between "commercial banks and bank holding companies (BHC)", "cooperative banks", "savings banks" and "other banks", including mortgage banks and pure investment banks. Savings banks show the lowest levels for both AER1 and AUAUL. Institutions classified as "other" show relatively high values of AER1 but not AUAUL. Cooperative banks show the highest average level of asset encumbrance when measured by AUAUL.

2.5.2 Regression analysis

Table 2.4 presents the summary statistics of the variables of study. The average value of the CDS spread variable is 5.14, corresponding to 171 basis points. The median value is 5.17, corresponding to 176 basis points. In terms of bank CAMELS indicators, we find that, on average, a sample bank has a tier 1 ratio of 0.15, a leverage ratio of 0.08, net loans to deposits and a short-term funding ratio of 0.77, a liquid assets to total assets ratio of 0.18. The average ratio of the loan-loss reserve to gross loans is 0.04, and the ratio of unreserved impaired loans to equity is 0.33. The average ROA and ROE are nearly 0. From all the control variables, central bank exposure presents the lowest standard deviation of 0.01.

Table 2.5 reports the results of the baseline regressions. In all regressions, we control for country fixed effects and cluster errors by bank country-business-type. Country fixed effects are included in all models to help to control for factors affecting CDS premia at the country level, including regulatory particularities common to all banks of a country. To account for the potential correlation of the errors among the banks belonging to the same business category in a given country, we apply country-business model clustering in all our regression models. The latter restricts the inference to rather conservative conclusions in which, for example, German saving banks are effectively treated as one observation when assessing the statistical importance of the effects.

Models 1–3 include the three asset encumbrance measures as explanatory variables. A negative and significant association between banks' implied CDS spreads and asset encumbrance emerges across all models. Thus, our initial evidence suggests a net positive perception of creditors towards asset encumbrance. As suggested in the theoretical discussion, higher collateralisation could lead to a lower probability of default due to liquidity risks and, hence, reduce credit risk premiums.

While the coefficients for AER1 and AUAUL are highly significant, AER2 is significant only at the 10% level. An increase in AER2 is also associated with a lower decrease in CDS spreads when compared to AER1 and AUAUL. In contrast to AER1, AER2 reflects the encumbrance of OBS collateral. This finding could point to a more negative perception of on encumbrance of off-balance sheet collateral compared to on-balance assets. High levels of encumbered OBS collateral are characteristic of investment banks which engage in matched book trading, the activity of carrying large volumes of repos and reverse repos, effectively re-using collateral received to finance repo liabilities.

In contrast to asset encumbrance ratios, the coefficients for capital and liquidity ratios turn out to be insignificant in all models. Variables such as asset encumbrance or asset quality seem to provide more valuable information on bank risk than capital and liquidity ratios. These results are consistent with recent literature pointing to a limited market reliance on capital and liquidity ratios to account for overall bank risk. Podpiera and Ötker (2010) find no significance in capital and liquidity ratios over the period 2004–2008 using a sample of 29 European Large Complex Financial Institutions (LCFI). Chiaramonte and Casu (2013), using a sample of 57 mostly European banks, find no statistical significance for Tier 1 and leverage and a limited statistical significance of liquidity ratios. Hasan et al. (2016) also find no statistically significant relation with the Tier 1 capital or liquidity ratios using a sample of 161 global banks in 23 countries. Kanagaretnam et al. (2016) find in a sample of 27 U.S. Bank Holding Companies (BHC) that the capital ratio is not significantly related to CDS spreads.

The coefficients for the ratio of loan-loss reserve to gross loans ratio are all positive and highly significant. The higher this ratio, the lower the quality of the loan portfolio; and therefore an increase in loan loss reserves should lead to an increase in CDS spreads. This result is consistent with Hasan et al. (2016) who also find a positive relationship between CDS spreads and the loan loss provision ratio.

The coefficients for the ratio of unreserved impaired loans to equity are all negative and significant on a 10% level. Banks with a higher value of this ratio exhibit higher impairments that have not been provisioned. Thus, this result implies that investors are not excessively concerned with such impairments. Chiaramonte and Casu (2013) also obtain this inverse relationship.

We observe opposing signs on the effects of ROA and ROE. The coefficients on ROA are all negative and highly significant. A negative sign for ROA could point to investors perceiving banks with a lower level of operating income relative to a level of investment as riskier. The coefficients for ROE are positive and highly significant, pointing to increased perceived default risk in institutions with higher profitability relative to their capital base. This result is somewhat surprising. Given the subdued profitability in traditional lending businesses in Europe, this finding could point to concerns by markets with banks that engage in highly profitable activities such as trade finance, invoice discounting or securities lending, with a comparatively low capital base. Relatedly, conditional on assets profitability, ROE may signal about bank's leverage: if traditional measures of leverage are not very infromative, one can observe positive CDS dependence on ROE when simultaneously controlling for asset profitability.

The coefficient on the ratio of central bank exposure to total assets turns out to be positive and significant, implying that reliance on central bank funding is positively associated with bank risk. Not surprisingly, credit quality is also strongly associated with lower CDS spreads. Negative and highly significant coefficients are obtained across all models. The coefficient for size turns out to be negative, pointing out to a size advantage. The ratio of off-balance sheet items to total assets and business model variables are not statistically significant.

Our second set of regressions explores the relationship between CDS spreads and key variables, including the interactions of asset encumbrance metrics with CAMEL, control variables, GIIPs and Nordic countries dummies. The results are presented in table 2.6. All models include the individual (non-interacted) CAMEL and control variables but for clarity these are not shown since the coefficients are very much in line with those presented in table 2.6.

We first discuss models 1 and 2 together as they yield very similar results. The stand-alone coefficients of asset encumbrance ratios (AER1 an AER2) are negative and significant. Several coefficients of the interacted CAMEL and control variables are statistically significant at the conventional levels, pointing to the existence of mediating effects in the relationship between asset encumbrance and CDS spreads. We first discuss the results for the interactions with control variables followed by CAMEL variables.

The coefficients for the interaction of asset encumbrance with the GIIPS and Nordic country dummies are significant and have opposite signs. GIIPS and Nordic countries present, on average, the highest levels of asset encumbrance in our sample. For GIIPS, the coefficient is positive, though, it is not large enough to offset the negative relationship between asset encumbrance and the bank risk arising from the main effect. This result indicates that for banks headquartered in economically weak countries the adverse effect of encumbrance coming from structural subordination may dominate its positive stable funding effect. For Nordic countries, the interaction coefficient is negative, i.e. it amplifies the average effect. This may reflect a positive perception towards asset encumbrance arising from the issuance of covered bonds that are typically considered very safe investments.

A positive and significant coefficient is obtained for the interaction with the ratio of central bank exposure to total assets. High asset encumbrance levels in banks with high amounts of central bank funding are negatively perceived by investors. For banks with high levels of central bank exposure (the maximum of which is 0.12 in our sample), the positive effect of the interaction term offsets the negative effect of the stand-alone asset encumbrance coefficient, thus making higher levels of encumbered assets detrimental in absolute terms. This goes well in line with the theoretical model as dependence on central bank funding may indicate worse financial conditions of a bank and, hence, higher collateral haircuts that it faces in the private markets.

A negative and significant coefficient is found for the interaction with the ratio of loan loss reserves to gross loans. Although higher loan loss reserves may point to a lower quality of the loan portfolio, excess reserves may signal a lower probability of incurring unexpected losses in the future and may therefore be perceived positively by markets. A positive and significant coefficient, however, is found for the interaction with the unreserved impaired loans to equity ratio. This could point to concerns by investors in banks with large amounts of encumbered assets that lack the reserves to deal with future loan defaults.

The coefficients for the interactions of asset encumbrance with the Tier 1 capital and leverage ratios have conflictive signs, negative and positive, although the former turns out to be not significant. The leverage ratio is a non-risk-based measure of capital adequacy. A high value of the leverage ratio accompanied by larger amounts of encumbered assets could point to increasing risk in the loan portfolio which in turn would point to higher overall bank risk. Similarly to central bank exposure, the positive effect of the interaction term may offset the negative effect of the stand-alone asset encumbrance coefficient, thus making higher levels of encumbered assets detrimental in absolute terms.

Model 3 presents the results for AUAUL. While the stand-alone coefficient of AUAUL ratio turns out to be not significant, the coefficients corresponding to the interaction with the loan loss reserves to gross loans ratio and the Nordics dummy are both significant and of a negative sign. Consistent with the results of models 1 and 2, banks with high levels of asset encumbrance and with high levels of loan loss provisions, or based in Nordic countries, could benefit from increasing their levels of asset encumbrance. The effects of the remaining interacted variables are less significant but almost all, including central bank exposure and GIIPS, conserve the same sign found for models 1 and 2.

2.6 Conclusion

Asset encumbrance has been a much-discussed subject in recent literature and policymakers have been actively addressing what some regulators consider to be excessive levels of asset encumbrance. In this paper, we provide a theoretical model that captures the relationship between asset encumbrance and bank liquidity risk. According to this model, secured funding serves as a mechanism that change bank's exposure to liquidity risks. When the degree of over-collateralization is not high, a bank can fully exploit the stability of secured financing and reduce its liquidity risks associated with the unsecured debt holders. Hence, asset encumbrance and risk premiums would have a negative relationship.

In an alternative situation when a bank faces high rates of over-collateralization, asset encumbrance can have an opposite effect on bank's liquidity risk. In this case, as collateralization requires relatively large amount of pledgeable assets, the negative structural subordination effect dominates the positive impact of asset encumbrance. Hence, the relationship between encumbrance and bank risk premiums can be positive when a bank faces adverse conditions of collateralization.

We next provide empirical analysis that supports the theoretical predictions. We show that asset encumbrance is, on average, negatively associated with bank risk across different asset encumbrance measures. We also show that certain bank-level variables play a mediating role in the relationship between asset encumbrance and bank risk. Thus, for banks that have a high exposure to the central bank, high levels of unreserved impaired loans, high leverage ratio or located in southern Europe, larger amounts of encumbered assets and encumbered OBS collateral are less beneficial and could even be detrimental in absolute terms. Banks with high levels of loan loss provisions or based in Nordic countries, in contrast, benefit from increased levels of asset encumbrance. These results suggest that regulators need to be cautious before leaping to all-encompassing conclusions when assessing the effects of asset encumbrance levels.

2.7 Appendix

2.7.1 Definitions and Sources of Asset Encumbrance

In this section we review the definitions of asset encumbrance and describe how assets become encumbered. We also review the most common sources of asset encumbrance (i.e. the liabilities or obligations that give rise to encumbered assets).

European regulations define encumbered assets as "*assets pledged or subject to any form of arrangement to secure, collateralize or credit enhance any transaction from which it cannot be freely withdrawn*".[12] The Basel Committee on Banking Supervision (BCBS) defines unencumbered assets as those assets which are "*free of legal, regulatory, contractual or other restrictions on the ability of the bank to liquidate, sell, transfer, or assign the asset*".[13]

To clarify the definition of encumbrance, let us consider a bank (Bank A) whose assets include loans and a portfolio of securities (government or corporate bonds, equities, etc.), financed via equity capital, retail deposits and unsecured wholesale funding, as shown in the left hand side of Figure 2.6. Bank A could obtain additional funding from a counterparty, let us say Bank B, by entering into a secured financing transaction, as shown in the right hand side of Figure 2.6. Under such arrangement Bank A provides collateral to Bank B in order to mitigate the risk of failing to keep interest repayments or repaying the borrowings. In exchange, Bank A benefits from cheaper funding when compared to an equivalent unsecured transaction.[14] The arrangement imposes restrictions to Bank A on its ability to sell, transfer or dispose of the collateral provided during the term of the transaction. Bank A would consider such assets encumbered.

Figure 2.6 represents the securities provided as collateral as recorded or recognised in Bank A's balance sheet rather than being transferred to Bank B's balance sheet. Collateral obtained by Bank B is therefore represented in an off-balance sheet (OBS) rather than an on-balance sheet, and is known as "OBS collateral" or simply "collateral received". The assumption that the collateral remains recognised from Bank A's balance sheet is a necessary condition for being considered an encumbered asset of Bank A. If the assets used as collateral were derecognised by Bank A then they would be recognised by Bank B and they would not be encumbered for Bank A.

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[12] See European Commission (2015).

[13] See BCBS (2013)

[14] In addition, the arrangement may provide for savings in regulatory capital requirements to Bank B as well as lower regulatory liquidity requirements to Bank A and Bank B.

In practice, the recognition or derecognition of collateral provided depends on the contractual terms of the transaction as well as its accounting treatment. Derecognition cannot occur unless the securities are transferred to the counterparty. This can be achieved by using "title transfer" arrangements, whereby full ownership of the collateral is passed on to the counterparty during the term of the transaction.[15] Collateral can also be provided under "security interest" arrangements, which do not transfer ownership but concede rights to the counterparty to obtain full ownership of the collateral under some pre-determined event, such as failure to repay.[16] The use of one technique over the other depends on market practice. Collateral provided in secured financing transactions such as repurchase agreements (i.e. repo) is typically provided by way of title transfer whereas collateral used as a margin for OTC derivatives can be provided using both methods.[17]

The transfer of title over collateral, however, is not a sufficient condition for derecognition to occur, with the actual outcome depending on the applicable accounting treatment. Under International Financial Reporting Standards (IFRS), IAS 39 applies a set of tests to assess whether (i) the risks and rewards and (ii) control over the asset have been transferred.[18] If the risks and rewards have not been transferred, or in other words, if the collateral provider continues to be exposed to the risks of ownership of the assets such as loss in market value and/or the benefits that they generate such as dividends, then the collateral would remain recognised on its balance even if a transfer of assets has occurred. But even if the risks and rewards had been transferred, further control tests are undertaken to understand which entity controls the asset. If the collateral provider could direct how the benefits of that asset are realised, then the collateral would not be derecognised either.

As illustrated in Figure 2.6, the value of securities that Bank A posted as collateral is higher than the value of the borrowings. This practice is known as overcollateralisation and is intended to mitigate the risk of the collateral falling in value during the term of the transaction. It is usually undertaken by means of a "haircut" or "margin ratio".[19] Collateral agreements often require a frequent (sometimes daily) marked-to-market valuation of the collateral and requests

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[15] Under title transfer, Bank B would have to return the collateral (or equivalent securities) to Bank A when the original transaction matures.

[16] Security interest arrangements are also known as collateral pledges.

[17] Under English Law the collateral for OTC derivatives is typically provided by way of title transfer, whereas under New York Law collateral is typically provided under security interest.

[18] The treatment under US GAAP (ASC 860) differs from IFRS since the focus is on whether the transferor has surrendered control over a financial asset.

[19] The agreed haircut or margin ratio determines the percentage by which the market value of a security is reduced for the purpose of calculating the amount of collateral being provided.

to top up the value of collateral, known as collateral calls, may be triggered if its market value falls below certain pre-determined threshold amounts.

Even in the case in which the collateral received is not reflected in its balance sheet, Bank B could reuse some or all of the collateral received from Bank A to obtain financing from a third party (let us say, Bank C). As illustrated in Figure 2.7, this re-use of collateral by Bank B would result in the encumbrance of OBS collateral. As such, encumbrance can affect both on-balance sheet assets as well as OBS collateral. The practice of providing collateral that has been previously received is known as collateral re-use or re-hypothecation. It is common practice and may result in long "collateral chains".[20].

Sources of asset encumbrance

The liabilities or obligations that give rise to encumbered assets are known as "sources of asset encumbrance" or "matching liabilities". The typical bank will have encumbered assets from several sources but the simplest institutions may rely only on a single source or may present no encumbered assets at all. We now discuss some of the most common sources of asset encumbrance.[21]

Secured financing transactions

Secured financing transactions encompass myriad transactions involving the temporary provision of securities to borrow cash or other securities. Common types include repurchase agreements (repos), buy/sell backs or securities borrowing and lending. Collateral in repo is provided under a title transfer but it remains recognised in the balance sheet of the collateral provider's (i.e. the repo seller) since the risks and rewards of the collateral are retained.[22] Thus, repo col-

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[20] The terms re-hypothecation and re-use are often used interchangeably and we will do so here. In practice there are legal distinctions between them that may be relevant in a different context. Recent studies have analysed the concept of re-hypothecation and "collateral velocity". Analytical work includes Adrian and Shin (2010) and Singh (2010) More recent work has focussed on liquidity mismatches and the role of collateral in intermediation chains. Brunnermeier and Krishnamurthy (2014) introduced the Liquidity Mismatch Index (LMI) which compares the market liquidity of assets and the funding liquidity of liabilities, thus capturing the length of collateral intermediation chains.

[21] In addition to the sources covered in this section, transactions that may result in encumbered assets include collateral swaps, also known as collateral upgrade transactions, where collateral of a different quality is exchanged. Collateralised guarantees rely on securities to secure an existing or future liability. Other arrangements, such as factoring which include the transfer of trade receivables to an institution may result in similar encumbrance to securitisations.

[22] If this was not the case, banks could artificially reduce its overall leverage by derecognising collateral in repurchase agreements. This treatment was exploited by Lehman Brothers under the well-known "Repo 105" scheme, characterised by the New York Attorney General Andrew Cuomo as a "massive accounting fraud" and

lateral is encumbered for the collateral provider. Encumbered assets in repo are predominantly government bonds, followed by corporate bonds and covered bonds. Asset-backed securities and equities are also used as collateral. Most of the funding provided by central banks is transacted through repo. Like Dexia, many European banks were, and some still are, heavily reliant on repo financing from the ECB.

Asset-backed securities (ABS) and mortgage-backed securities (MBS)

Another potential source of asset encumbrance is securitisations. These entail ABS and MBS bonds or notes being issued and receivables, which may include retail or commercial mortgages in MBS, or credit card debt or other loans in ABS, being used as collateral.

A traditional two-step securitisation involves the initial transfer of the receivables of the originating bank to a Special Purpose Vehicle (SPV) and the sale of the ABS or MBS to investors. The overall securitisation structure is intended to make sure that there is a true sale of receivables to the SPV and that the SPS is “bankruptcy remote”. Accounting standards however, may require that the SPV is consolidated into the “sponsoring” bank balance sheet, including all of its assets and liabilities, even the receivables.[23] If the underlying receivables were consolidated, this would result in the recognition of such receivables on the sponsor’s balance sheet. However, tests to assess whether the assets meet the criteria for accounting derecognition, as discussed earlier, shall still be undertaken. If derecognition criteria are not met the receivables would be encumbered. This is often the case since it is common for the sponsoring bank to keep an active role in the securitisation, for example, by servicing the assets or providing support by retaining certain tranches to absorb first losses and potential risks in relation to timings in the collection of the receivables.

ABS or MBS can be used as collateral to raise funding with counterparties and central banks. Thus, a common practice across some banks, especially during the Eurozone crisis, is the retention of their self-issued ABS or MBS rather than its sale to investors.[24] If notes are retained, they would not be encumbered. But if the notes are used to raise fresh funding, for example, from the central bank via repo, the receivables would become encumbered as it occurs

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leading to a review by the accounting standard settlers of the accounting treatment of repo transactions.

[23] The consolidation models under IFRS and GAAP are relatively similar and are based on the criteria of entity control over the SPV.

[24] The acceptance of securitised notes as collateral in the ECB facilities led to an important increase in retention levels during the Eurozone crisis, with overall retention as a proportion of total gross issuance increasing from 26% in the first half of 2007 to 42% in the first half of 2012 (IMF (2013)).

in securities' financing transactions.

Figure 2.8 (left-hand side) illustrates how securitised receivables can be encumbered (highlighted in green) by collateralising ABSs that are either (i) sold to investors or (ii) used as repo collateral to obtain funding from another counterparty.

Covered bonds

Covered bonds are similar to MBS but the mortgages used as collateral always remain recognised on the consolidated balance sheet of the issuing entity and thus always generate encumbrance. The issuer and the investors have dual recourse to the collateral. This feature, together with the existence of overcollateralisation requirements and the dynamic replenishment of non-performing loans in the collateral pool imply that these instruments are perceived as being very safe. There is indeed no known default on covered bonds since their inception.

The use of covered bonds as collateral has significantly increased in recent times. For many banks in peripheral European countries (GIIPS) funding collateralised by retained covered bonds became the main source of long-term funding during the Eurozone sovereign crisis, as their access to unsecured markets was partially or fully closed (Van Rixtel and Gasperini (2013)).

Derivatives

Derivatives also generate encumbrance, as collateralisation has become a key method of mitigating counterparty credit risk in derivative markets, both on over-the-counter (OTC) and exchange-traded (ETD) derivatives. Collateralisation occurs because of the provisioning of the margin, in two different forms. A variation margin is posted during the course of the transaction to cover adverse changes in value (i.e. a negative mark-to-market value). Initial margin (also known as an independent amount) is posted at the beginning of a transaction to cover potential future adverse changes in the value of the contract, and is recalculated on a regular basis.

The margin provided is subject to restrictions and therefore constitutes encumbered assets. This is illustrated in Figure 2.8 (right-hand side).[25] The margin can be provided in the form

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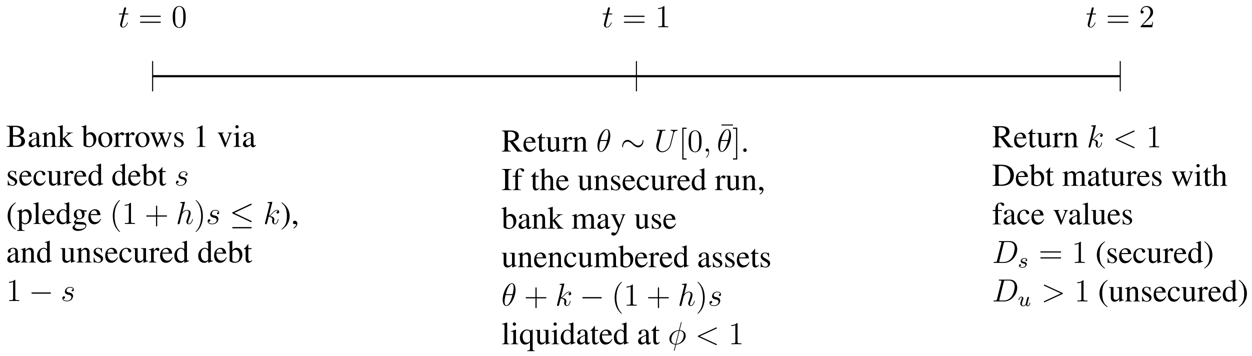
[25] The figure assumes that the variation margin is not offset against the derivative liability (i.e. the negative fair value from the derivative) therefore becoming encumbered. Some contracts allow for such an offsetting of the variation margin. The outstanding exposure between the counterparties is settled and the terms of the derivative contracts are reset so that the fair value is zero, leading to no encumbered assets due to an exchange of the variation margin.

of cash or securities and it is common to provide re-hypothecation rights to the counterparty. According to the latest ISDA Margin Survey, for non-cleared OTC derivatives cash represents 76.6% of the collateral provided, followed by government bonds (13.4%) and other securities (10.1%), including US municipal bonds, government agency/government-sponsored enterprises (GSEs), and equities (ISDA (2015)).

2.7.2 Figures and Tables

Figure 2.1: Timeline

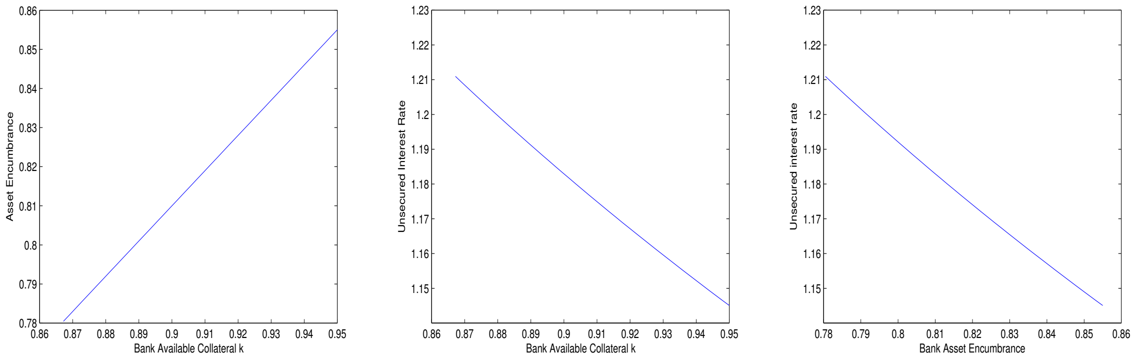


Bank borrows 1 via secured debt s (pledge $(1 + h)s \leq k$), and unsecured debt $1 - s$

Return $\theta \sim U[0, \bar{\theta}]$. If the unsecured run, bank may use unencumbered assets $\theta + k - (1 + h)s$ liquidated at $\phi < 1$

Return $k < 1$
Debt matures with face values
$D_s = 1$ (secured)
$D_u > 1$ (unsecured)

Figure 2.2: Low Rates of Overcollateralization

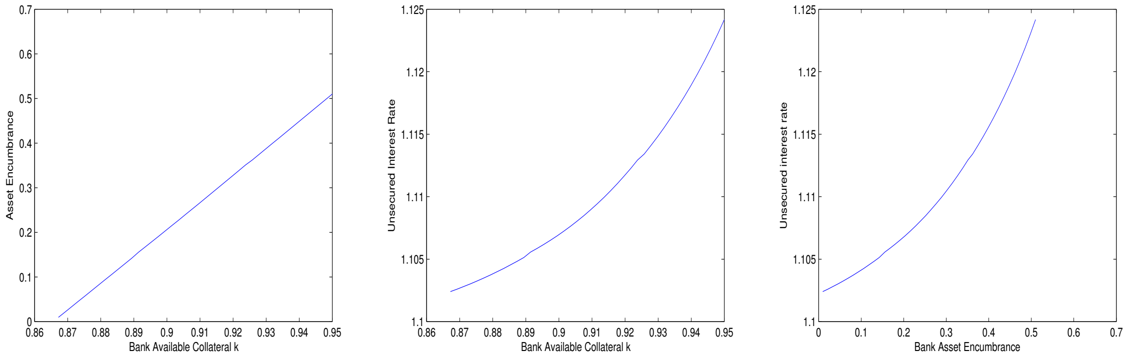


(a) Bank Available Collateral k and Unsecured Debt Interest Rate

(b) Bank Available Collateral k and Asset Encumbrance

(c) Asset Encumbrance and Unsecured Debt Interest Rate

Figure 2.3: High Rates of Overcollateralization



(a) Bank Available Collateral k and Unsecured Debt Interest Rate

(b) Bank Available Collateral k and Asset Encumbrance

(c) Asset Encumbrance and Unsecured Debt Interest Rate

Figure 2.4: Asset Encumbrance Metrics

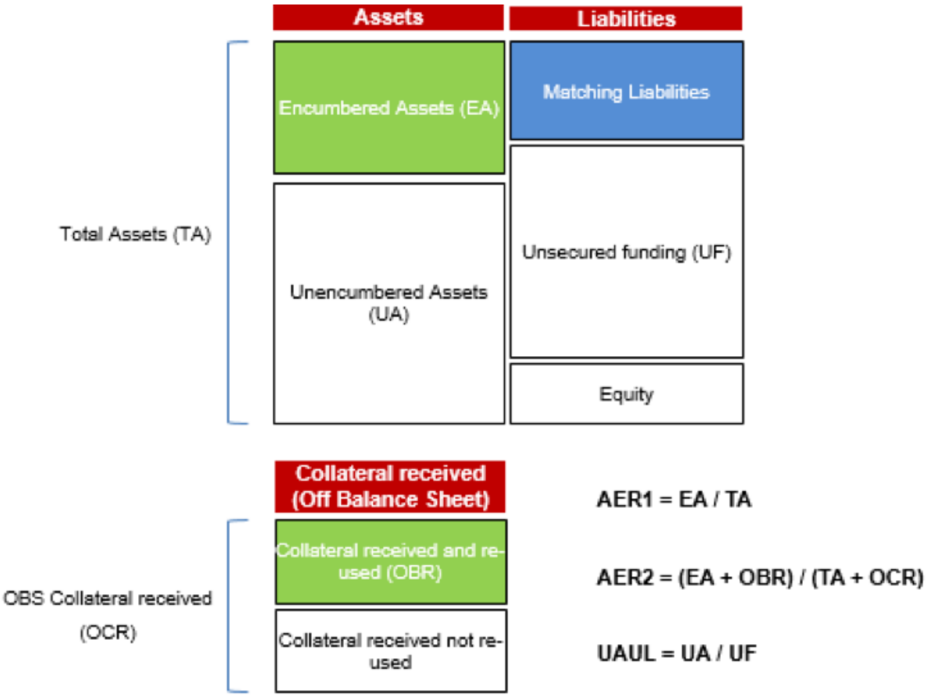


Figure 2.5: Average Asset Encumbrance by Country

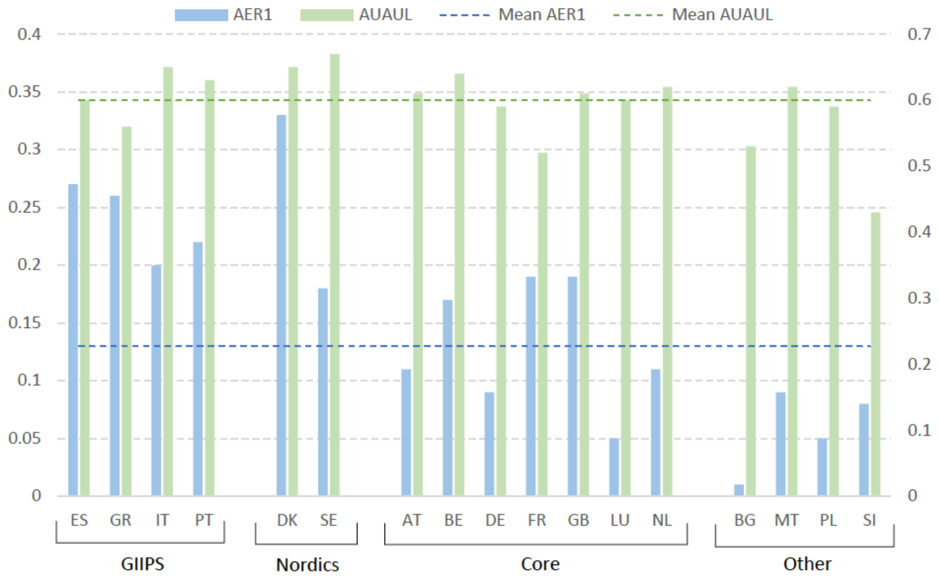


Figure 2.6: Encumbrance of Assets when Obtaining Secured Funding

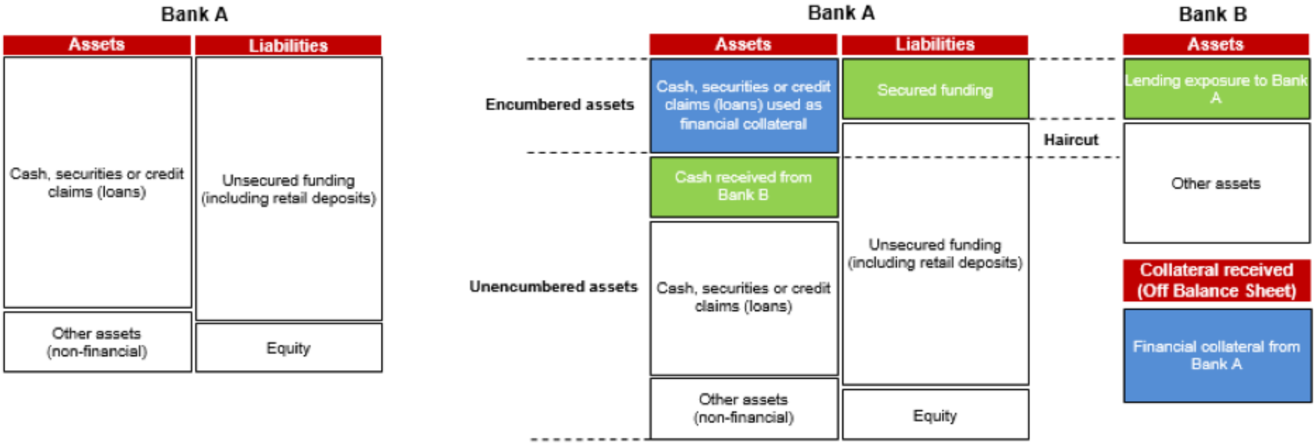


Figure 2.7: Collateral Received and Re-used

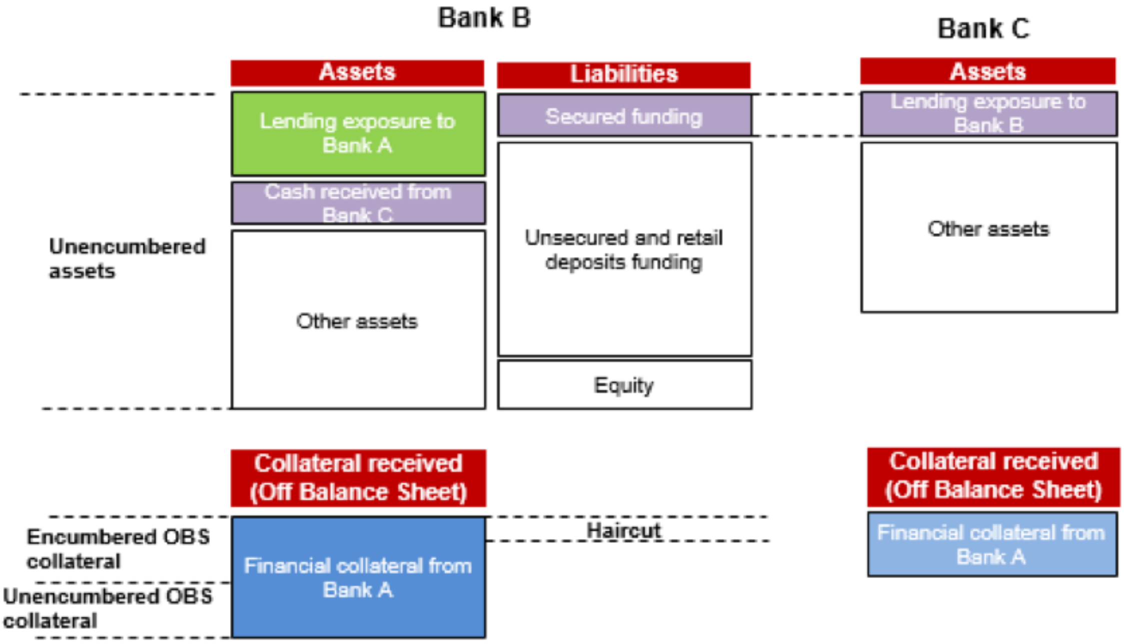


Figure 2.8: Encumbered and Unencumbered Assets from Securitization and Derivative Transactions

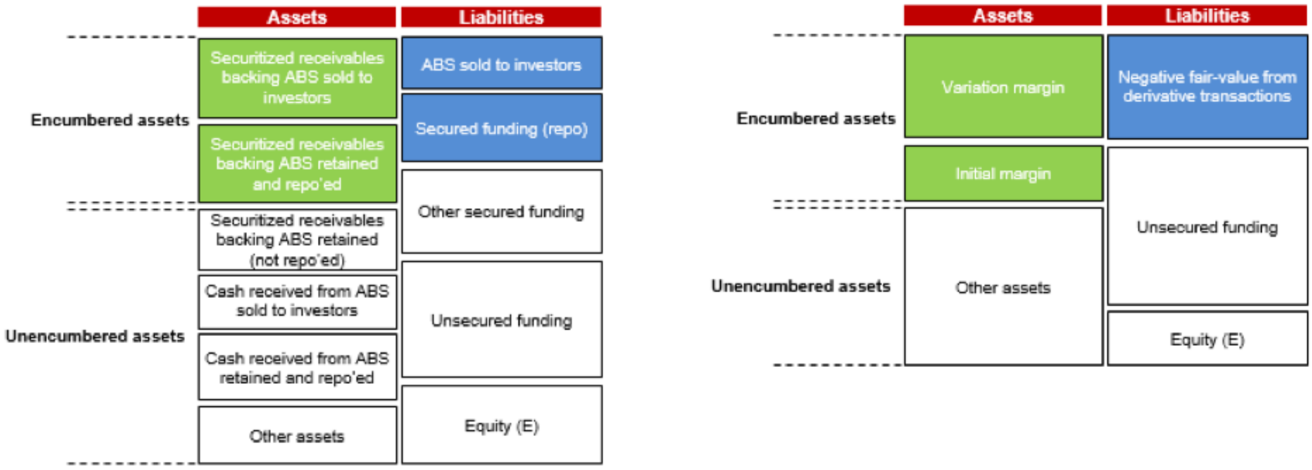


Table 2.1: Summary Statistics of Asset Encumbrance Metrics

	Mean	Median	SD	Min	Max
AER1	0.13	0.09	0.11	0.00	0.68
AER2	0.14	0.10	0.12	0.00	0.70
AER3	0.60	0.59	0.08	0.00	1.00

Table 2.2: Correlation Matrix of Asset Encumbrance Metrics

	AER1	AER2	AER3
AER1	1		
AER2	0.974^{***}	1	
AER3	0.388^{***}	0.363^{***}	1

Table 2.3: Average Levels of Asset Encumbrance, by Bank Groups

	AER1	AER2	AER3
By credit rating			
A/B	0.08	0.08	0.61
B	0.15	0.16	0.61
B/C	0.12	0.13	0.60
C	0.13	0.14	0.60
C/D	0.13	0.14	0.62
D	0.12	0.13	0.63
D/E	0.14	0.14	0.50
E/F	0.03	0.03	0.57
By bank size			
$<$ €3.5bn	0.10	0.11	0.60
€3.5–15bn	0.12	0.13	0.60
€15–50bn	0.19	0.19	0.63
€50–170bn	0.25	0.25	0.56
€170–600bn	0.27	0.28	0.65
$>$ €600bn	0.15	0.20	0.58
By bank type			
BHC & Commercial	0.18	0.19	0.61
Cooperative	0.14	0.14	0.62
Saving	0.09	0.10	0.56
Other	0.22	0.22	0.61

Table 2.4: Summary Statistics, Variables of Study

	Mean	Median	SD	Min	Max
*ln*CDS	5.14	5.17	0.33	4.56	6.56
CAMEL variables					
Tier 1 Ratio	0.15	0.14	0.04	0.05	0.35
Leverage ratio (Equity / TA)	0.08	0.08	0.02	0.01	0.18
Net loans to deposits and ST funding	0.77	0.75	0.24	0.05	2.05
Liquid assets / TA	0.18	0.11	0.23	0.01	2.98
Loan loss reserves / gross loans	0.04	0.02	0.04	0.00	0.27
Unreserved impaired loans / equity	0.33	0.14	0.49	0.00	4.63
ROA	0.00	0.00	0.01	−0.04	0.03
ROE	0.01	0.02	0.10	−1.08	0.32
Control variables					
Central bank exposure / TA	0.01	0.01	0.01	0.00	0.12
OBS / TA	0.08	0.06	0.10	0.00	1.66
Investment grade	0.66	1.00	0.47	0.00	1.00
BHC and commercial banks	0.19	0.00	0.39	0.00	1.00
Saving and cooperative banks	0.75	1.00	0.43	0.00	1.00
Size	6.75	6.41	0.84	6.00	9.32
GIIPS	0.28	0.00	0.45	0.00	1.00
Nordics	0.02	0.00	0.15	0.00	1.00

Table 2.5: Baseline Results

	(1)	(2)	(3)
AER1	-0.177^{***}		
	(0.06)		
AER2		-0.131^{*}	
		(0.07)	
AER3			-0.267^{***}
			(0.10)
Tier 1 Capital Ratio	1.058	1.046	1.103
	(0.93)	(0.92)	(0.92)
Leverage Ratio	-1.164	-1.102	-1.195
	(1.42)	(1.40)	(1.52)
Net loans to deposits & ST funding	-0.049	-0.053	-0.055
	(0.04)	(0.04)	(0.04)
Liquid assets	-0.105	-0.103	-0.108^{*}
	(0.07)	(0.07)	(0.06)
Loan loss reserves	1.927^{***}	1.959^{***}	2.085^{***}
	(0.61)	(0.64)	(0.62)
Unreserved impaired loans	-0.060^{*}	-0.062^{*}	-0.063^{*}
	(0.03)	(0.03)	(0.03)
ROA	-16.398^{***}	-16.369^{***}	-17.019^{***}
	(4.92)	(4.91)	(4.78)
ROE	0.538^{***}	0.528^{***}	0.555^{***}
	(0.18)	(0.18)	(0.17)
Investment grade	-0.466^{***}	-0.466^{***}	-0.464^{***}
	(0.02)	(0.02)	(0.02)
BHC and commercial	0.035	0.039	0.050
	(0.05)	(0.05)	(0.05)
Saving and cooperative	-0.007	-0.002	0.002
	(0.05)	(0.05)	(0.05)
Central bank exposure	1.150^{**}	1.171^{**}	1.190^{**}
	(0.56)	(0.55)	(0.53)
OBS / TA	0.077	0.073	0.072
	(0.09)	(0.09)	(0.08)
Size	-0.149^{***}	-0.149^{***}	-0.157^{***}
	(0.02)	(0.02)	(0.02)
Country FE	y	y	y
R^2	0.79	0.79	0.79
N observations	367	367	367
Nclusters	50	50	50

The dependent variable in all models is *ln*CDS. Standard errors (in parenthesis) are clustered by country-business type of bank. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6: Heterogeneous Effects of Asset Encumbrance

	(1)	(2)	(3)
AER	-0.712^{***}	-0.605^{***}	-0.552
	(0.19)	(0.21)	(0.48)
AER ×			
Tier 1 Capital Ratio	-5.500	-5.182	3.596
	(4.97)	(4.83)	(2.95)
Leverage Ratio	15.409^{**}	15.180^{**}	2.751
	(6.03)	(6.42)	(4.81)
Net loans to deposits & ST funding	0.522^{***}	0.554^{***}	0.172
	(0.16)	(0.17)	(0.34)
Liquid assets	0.845^{**}	0.978^{**}	-0.358
	(0.38)	(0.41)	(0.51)
Loan loss reserves	-12.749^{***}	-11.524^{***}	-8.465^{***}
	(3.66)	(3.49)	(3.15)
Unreserved impaired loans	0.650^{**}	0.595^{**}	0.553
	(0.29)	(0.30)	(0.57)
ROA	15.780	28.157	-52.962
	(29.44)	(36.22)	(67.71)
ROE	-0.430	-1.059	2.658
	(1.41)	(1.83)	(4.32)
Central bank exposure	10.914^{**}	8.900^{*}	9.887
	(4.16)	(4.65)	(10.08)
OBS	-0.012	-0.119	3.054
	(0.82)	(0.81)	(2.15)
Size	0.125	0.073	-0.061
	(0.16)	(0.16)	(0.29)
Investment grade	0.348^{*}	0.351^{*}	0.317
	(0.20)	(0.20)	(0.19)
GIIPS	0.671^{***}	0.466^{**}	0.068
	(0.17)	(0.22)	(0.41)
Nordics	-0.466^{**}	-0.712^{**}	-1.236^{***}
	(0.21)	(0.27)	(0.41)
BHC and commercial	0.048	0.146	0.404
	(0.19)	(0.23)	(0.46)
Saving and cooperative	0.234	0.262	0.539
	(0.18)	(0.19)	(0.32)
Country FE	y	y	y
R^2	0.81	0.81	0.80
N observations	367	367	367
N clusters	50	50	50

The dependent variable in all models is *ln*CDS. Standard errors (in parenthesis) are clustered by country-business type of bank. All continuous explanatory variables are demeaned. All estimates are conditioned on a set of non-interacted control variables similar to Table 2.5 (not reported). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2.7.3 Proofs

Proof of Proposition 2.1

From equation (2.2), we have

$$(1-s)D_u = \theta^* + k\phi - (1+h)\phi s$$

Substituting $(1-s)D_u$ into the participation constraint (2.3), we get:

$$k\phi - (1+h)\phi s + \int_0^{\theta^*} \theta dF(\theta) + \int_{\theta^*}^{\bar{\theta}} \theta^* dF(\theta) = (1-s)(1+\gamma)$$

Differentiating this equation with respect to s, one gets:

$$\frac{\partial\theta^*}{\partial s} = \frac{(1+h)\phi - (1+\gamma)}{1-F(\theta^*)}$$

Clearly, $\partial\theta^*/\partial s > 0$ if $(1+h)\phi > 1+\gamma$, and $\partial\theta^*/\partial s < 0$ if $(1+h)\phi < 1+\gamma$.

Q.E.D.

Proof of Proposition 2.2

We just need to show that the derivative of Π with respect to s is positive. Coupled with the participation constraint (2.3), the bank expected profit can be rewritten as:

$$\Pi = \int_0^{\bar{\theta}} \theta dF(\theta) - s\int_{\theta^*}^{\bar{\theta}} dF(\theta) - (1+h)\phi s\int_0^{\theta^*} dF(\theta) - (1-s)(1+\gamma) + k\int_{\theta^*}^{\bar{\theta}} dF(\theta) + k\phi\int_0^{\theta^*} dF(\theta)$$

By differentiating this equation with respect to s one gets:

$$\frac{\partial\Pi}{\partial s} = -\int_{\theta^*}^{\bar{\theta}} dF(\theta) - (1+h)\phi\int_0^{\theta^*} dF(\theta) + s\frac{\partial\theta^*}{\partial s}f(\theta^*) - (1+h)\phi s\frac{\partial\theta^*}{\partial s}f(\theta^*) - k\frac{\partial\theta^*}{\partial s}f(\theta^*) + k\phi\frac{\partial\theta^*}{\partial s}f(\theta^*) + 1 + \gamma$$

Since $(1+h)\phi > 1$, we have

$$s\frac{\partial\theta^*}{\partial s}f(\theta^*) - (1+h)\phi s\frac{\partial\theta^*}{\partial s}f(\theta^*) > 0$$

Since $\phi < 1$, we have

$$-k\frac{\partial\theta^*}{\partial s}f(\theta^*) + k\phi\frac{\partial\theta^*}{\partial s}f(\theta^*) > 0$$

Since $(1+h)\phi < 1+\gamma$, we have

$$-\int_{\theta^*}^{\bar{\theta}} dF(\theta) - (1+h)\phi \int_0^{\theta^*} dF(\theta) > -(1+\gamma)\int_{\theta^*}^{\bar{\theta}} dF(\theta) - (1+\gamma)\int_0^{\theta^*} dF(\theta) = -1-\gamma$$

Therefore,

$$-\int_{\theta^*}^{\bar{\theta}} dF(\theta) - (1+h)\phi \int_0^{\theta^*} dF(\theta) + 1 + \gamma > 0$$

Clearly,

$$-\int_{\theta^*}^{\bar{\theta}} dF(\theta) - (1+h)\phi \int_0^{\theta^*} dF(\theta) + 1 + \gamma + s\frac{\partial\theta^*}{\partial s}f(\theta^*) - (1+h)\phi s\frac{\partial\theta^*}{\partial s}f(\theta^*) - k\frac{\partial\theta^*}{\partial s}f(\theta^*) + k\phi\frac{\partial\theta^*}{\partial s}f(\theta^*) > 0$$

Therefore, $\frac{\partial\Pi}{\partial s} > 0$.

Q.E.D.

Proof of Proposition 2.3

Under the assumption $h = \phi^{-1} - 1$ and uniform distribution of θ, the liquidity cutoff θ^* at the optimum s^* can be rewritten as

$$\theta^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)}$$

Under the similar assumptions, the definition of the liquidity cutoff simplifies to:

$$\theta^* = (1-s^*)D_u$$

Combining the two, one gets:

$$D_u = \frac{\bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)}}{1-s^*}$$

Taking the derivative of D_u with respect to s^*, one gets

$$\frac{\partial D_u}{\partial s^*} = \frac{\bar{\theta}(1 - \frac{\bar{\theta}-(1+\gamma)(1-s^*)}{\sqrt{\bar{\theta}^2 - 2\bar{\theta}(1-s^*)(1+\gamma)}})}{(1-s^*)^2}$$

Hence, for $\partial D_u/\partial s^*$ to be negative it suffices to show that

$$\sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)} < \bar{\theta} - (1+\gamma)(1-s^*)$$

which is true since

$$\begin{aligned}\bar{\theta} - (1+\gamma)(1-s^*) &= \sqrt{(\bar{\theta} - (1+\gamma)(1-s^*))^2} \\ &= \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*) + (1+\gamma)^2(1-s^*)^2} \\ &> \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma)(1-s^*)}\end{aligned}$$

Q.E.D.

Proof of Proposition 2.4

First, we have

$$\begin{aligned}\frac{\partial \Pi}{\partial s} = (k\phi - k + s - (1+h)\phi s)&\frac{((1+h)\phi - 1 - \gamma)}{\sqrt{\bar{\theta}^2 - 2\bar{\theta}((1+\gamma)(1-s) - k\phi + (1+h)\phi s)}} \\ - ((1+h)\phi - 1)&\frac{\bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}((1+\gamma)(1-s) - k\phi + (1+h)\phi s)}}{\bar{\theta}} + \gamma\end{aligned}$$

It is easy to show that $\frac{\partial^2 \Pi}{\partial s^2} < 0$, so $\frac{\partial \Pi}{\partial s}$ is decreasing in s.

If $\frac{\partial \Pi}{\partial s} \mid_{s=0} < 0$, let $\hat{s} = 0$. Clearly for all $s > \hat{s}$, $\frac{\partial \Pi}{\partial s} < \frac{\partial \Pi}{\partial s} \mid_{s=0} < 0$.

If $\frac{\partial \Pi}{\partial s} \mid_{s=\frac{k}{1+h}} > 0$, let $\hat{s} = \frac{k}{1+h}$. Clearly for all $s < \hat{s}$, $\frac{\partial \Pi}{\partial s} > \frac{\partial \Pi}{\partial s} \mid_{s=0} > 0$.

If $\frac{\partial \Pi}{\partial s} \mid_{s=0} > 0$ and $\frac{\partial \Pi}{\partial s} \mid_{s=\frac{k}{1+h}} < 0$, by the intermediate value theorem, there exists $\hat{s} \in [0, \frac{k}{1+h}]$ such that $\frac{\partial \Pi}{\partial s} \mid_{s=\hat{s}} = 0$. For all $s < \hat{s}$, $\frac{\partial \Pi}{\partial s} > \frac{\partial \Pi}{\partial s} \mid_{s=\hat{s}} = 0$, and for all $s > \hat{s}$, $\frac{\partial \Pi}{\partial s} < \frac{\partial \Pi}{\partial s} \mid_{s=\hat{s}} = 0$.

Q.E.D.

Proof of Proposition 2.5

We need to find a sufficient condition such that the interest rate of unsecured debt for a bank with higher level of asset encumbrance may be larger than a bank with lower level of asset encumbrance. Suppose that there are two levels of available collateral k, k_1 and k_2, with $k_2 > k_1$. For a bank with available collateral k_2, the maximum possible liquidity risk is when the bank chooses the highest asset encumbrance $\frac{k_2}{1+h}$. In this case, bank's liquidity risk is $\theta_2^* = \bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma - \frac{1+\gamma}{1+h}k_2)}$. We can show that for a bank with available collateral k_2, as long as the following condition satisfies, together with the fact that $\frac{\partial \Pi}{\partial s}$ is decreasing in s, the bank's optimal asset encumbrance is indeed $\frac{k_2}{1+h}$, and $D_{2u} = \frac{\bar{\theta} - \sqrt{\bar{\theta}^2 - 2\bar{\theta}(1+\gamma - \frac{1+\gamma}{1+h}k_2)}}{1 - \frac{k_2}{1+h}}$.

$$-\frac{h}{1+h}\frac{(1+h)\phi-1-\gamma}{\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma)(1-\frac{k_2}{1+h})}}k_2-((1+h)\phi-1)\frac{\bar{\theta}-\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma-\frac{k_2}{1+h})}}{\bar{\theta}}+\gamma>0$$

Whereas for a bank with available collateral k_1, the minimum possible liquidity risk is when the bank choose the lowest asset encumbrance 0. In this case, bank's liquidity risk is $\theta_1^* = \bar{\theta}-\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma-k_1\phi)}$. We can show that for a bank with available collateral k_1, as long as the following condition satisfies, together with the fact that $\frac{\partial \Pi}{\partial s}$ is decreasing in s, the bank's optimal asset encumbrance is indeed 0, and $D_{1u} = \bar{\theta}-\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma-k_1\phi)}$.

$$(\phi-1)\frac{(1+h)\phi-1-\gamma}{\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma)(1-\phi k_1)}}-((1+h)\phi-1)\frac{\bar{\theta}-\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma-\phi k_1)}}{\bar{\theta}}+\gamma<0 \tag{2.5}$$

As long as h is sufficiently high such that $\bar{\theta}-\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma-k_1\phi)} < \frac{\bar{\theta}-\sqrt{\bar{\theta}^2-2\bar{\theta}(1+\gamma-\frac{1+\gamma}{1+h}k_2)}}{1-\frac{k_2}{1+h}}$, D_{2u} can be higher than D_{1u}, even though $k_2 > k_1$.

Q.E.D.

Chapter 3

LOAN SALES AND BANK MORAL HAZARD

3.1 Introduction

The literature on financial intermediation (Diamond (1984); Ramakrishnan and Thakor (1984); Fama (1985); Boyd and Prescott (1986)) shows that banks play a special role in the financial system. Banks can produce valuable information of borrowers through screening and monitoring, and overcome some of the asymmetric information problems. Traditionally, after loan origination, banks used to hold the loans on the balance sheets until maturity. However, starting around 1990, the loan sales market grew tremendously. According to Drucker and Puri (2008), in the United States, secondary loan market volume has grown from a mere 8 billion in 1991 to 176.3 billion in 2005. In some sense, there is a model shift in the banking sector from originate-to-hold to originate-to-distribute. The recent development of the secondary loan market has raised concerns about whether banks' special role in information production would be undermined by loan sales (Pennacchi (1988); Gorton and Pennacchi (1995); Parlour and Plantin (2008)). Especially in the wake of the 2007-2009 financial crisis, loan sales have been blamed for contributing to the loosening lending standards and deterioration in loan quality that led to the mortgage crisis (Keys et al. (2010); Purnanandam (2010); Jiang et al. (2013)).

The logic of the moral hazard problem posed by loan sales seems straightforward: for a bank to screen or monitor diligently, it must be given appropriate incentives. If the bank holds the loans that it originates, it bears the full consequences of loan performance, and as a consequence, has sufficient incentive to screen or monitor the borrowers. If a portion of the loan portfolio was sold, however, the bank has less skin in the game. It will not be fully rewarded for the costly screening or monitoring activities, thus the bank has less incentive to perform diligently.

In this chapter, I re-examine the classical issue of loan sales and banks' moral hazard. I highlight banks' own capital structures and bankruptcy risk, which is a key departure from the existing literature. I show that if loan sales act as a risk-sharing device for banks, it can improve the banks' screening incentives under some conditions. Therefore, banks' special role in information production can even be strengthened, rather than weakened, by loan sales. This suggests that the popular view in the existing literature that loan sales necessarily weaken banks' screening or monitoring incentive may be incomplete.

In the model, there is a bank, a large mass of borrowers and investors. Borrowers raise funds from the bank to invest in profitable projects. The bank can exert costly effort to screen borrowers, and extend loans to them. The bank finances its loan portfolio by issuing debt to investors. Due to the presence of aggregate risk for its loan portfolio, the bank is exposed to bankruptcy risk. There is a bankruptcy cost when the bank defaults. The bank is protected by limited liability and it repays investors only when successful. Therefore, the bank only values the payoff of the loan portfolio conditional on solvency. Given that screening is costly, the bank is subject to a risk-shifting problem. Compared with a social planner who values the payoff of the loan portfolio in all states, the bank will under-provide screening effort.

The bank can hold the entire loan pool on its balance sheets until maturity, or pass a portion of them on to competitive outside buyers, such as Special Purpose Vehicles (SPV), in the form of loan sales. In this paper, loan sales act as a risk sharing device for the bank. Through loan sales, the bank can transfer some aggregate risk to outside loan buyers. By reducing the riskiness of a bank's cash flow, loan sales minimize the probability of bankruptcy, and thus bankruptcy cost. Empirical papers on loan sales support our view that loan sales enable banks to transfer and manage their credit risk better. For instance, Pavel et al. (1987) and Demsetz (2000) find that risk diversification is one primary factor affecting loan sales by commercial banks. Cebenoyan and Strahan (2004) find that the loan sales market improves banks' ability to manage credit risk.

There are two opposing effects of loan sales on the bank's moral hazard. On the one hand, as the conventional wisdom suggests, loan sales make the bank's returns less sensitive to its effort, thus weakening its screening incentives. This is a negative incentive-dilution effect. On the other hand, loan sales also reduce the probability of the bank going bankrupt. Since the bank is protected by limited liability, reduced probability of default implies that the bank is more likely to be rewarded for its screening effort. This greater payoff for effort increases the bank's incentives to screen its loans. This is a positive risk-shifting reduction effect. The sign and the magnitude of the effect of loan sales on a bank's moral hazard depend crucially on the relative weights of these two opposing effects.

The analysis unfolds in two steps. First, I provide an existence result, pinning down the conditions under which loan sales can improve a bank's screening incentives. I first show that when a bank's insolvency risk is sufficiently high, the risk-shifting reduction effect of loan sales is substantial, which may dominate the incentive-dilution effect. Therefore, under these conditions, loan sales can curb rather than exacerbate the bank's incentive problem. I also show that as the average quality of borrowers improves, the bank's screening incentives are more likely to be improved by loan sales. This is because loan buyers are willing to pay a higher price for the loans with better average quality. As the average quality of the loan pool improves, the bank can sell a smaller portion of the loans to avoid bankruptcy risk, which implies that the incentive-dilution effect of loan sales is mitigated. Therefore, the risk-shifting reduction effect is more likely to outweigh the incentive-dilution effect.

Second, I characterize the conditions under which banks will choose to sell loans in equilibrium. I find that the banks can be divided into three groups. For a bank with high bankruptcy risk, loan sales can both reduce bankruptcy cost and improve the bank's screening incentives. So the bank will always choose to sell loans. For a bank with a moderate or low bankruptcy risk, it is more subtle. On the one hand, loan sales reduce bankruptcy cost, which is beneficial to the bank. On the other hand, it reduces the bank's screening incentives compared with the case without loan sales, which is costly to the bank. When a bank's bankruptcy risk is moderate, the bank is willing to sell loans even if the screening incentive is diluted. This occurs because the reduction in bankruptcy cost associated with loan sales outweighs the negative effect on a bank's screening incentives. Banks with very low bankruptcy risk, on the contrary, choose not to sell loans. For these banks, the negative effect of loan sales on screening effort is so large that they are willing to hold the entire loan until maturity, which exposes them to bankruptcy risk.

In the benchmark model, I assume that the bank has no private information about the quality of loans to be sold. I then relax this assumption. If the bank has superior information about the loans, the bank can strategically allocate the worst loans to buyers. This leads to the bank's strategic adverse selection problem. I find that strategic adverse selection will not undermine the efficiency of bank loan sales. The intuition is as follows. The motive for a bank to sell loans is to transfer the aggregate risk to outside buyers. As long as bad loans and good loans have the same exposure to the aggregate risk, from the perspective of risk transfer, it is equally efficient for the bank to sell bad loans or good loans. Therefore, strategic adverse selection will not undermine the efficiency of bank loan sales in our paper.

I then study various extensions of the model. First, I consider the effect of capital requirement. Under the capital requirement, the bank finances its loan portfolio with both equity and debt, so the bank borrows less from the investors. The bank can sell a smaller portion of the loan portfolio to avoid bankruptcy risk, which implies that the incentive-dilution effect of loan sales is mitigated. Therefore, under the capital requirement, the risk-shifting reduction effect is more likely to outweigh the incentive-dilution effect. Second, I introduce a flat deposit insurance into the benchmark model. With a flat deposit insurance, the insurance fund will pay back the investors when the bank defaults. Thus the interest rate demanded by the investors will not reflect the bank's default risk. In this case, the bank has no incentives to sell loans to avoid bankruptcy cost. The bank's privately optimal choice of loan sales may be socially inefficient. Third, I consider other possible motives for banks to sell loans. Banks may sell loans to increase the size of investment, or to fund new investment opportunities. Under these alternative motives, I show that as long as loan sales help banks to reduce bankruptcy risk, the main results of our model still hold.

Empirical evidence on whether loan sales reduce a bank's screening and monitoring incentive is mixed. Papers by (Keys et al. (2010); Purnanandam (2010); Jiang et al. (2013)) document the adverse consequences of loan sales on a bank's moral hazard problem. Keys et al. (2010) shows that securitization does adversely affect the screening incentives of mortgage lenders. Purnanandam (2010) show that banks with high involvement in the originate-to-distribute lending market before the crisis originated excessively poor quality mortgages. Jiang et al. (2013) document banks' lack of incentive to collect valuable soft information about borrower quality when a bank securitizes loans. However, Drucker and Puri (2008) find that contrary to the concerns that loan sales weaken lending relationships, there are more durable lending relationships when loans are sold. Bubb and Kaufman (2014) also report that there is no evidence that securitization was an important factor in the decline in underwriting standards in the run-up to the financial crisis. Gande and Saunders (2012) find that banks still maintain their traditional specialness as monitors and information producers for outside agents, even if there is a secondary market for loans. Our paper provides a unified framework to understand the ambiguous effect of loan sales on banks' moral hazard problem.

Our finding that loan sales can improve banks' screening incentives is novel. Pennacchi (1988) rationalize the existence of loan sales as a mechanism for the bank to reduce funding costs. When the cost of internal financing is sufficiently high, banks may sell loans. Greater deposit market competition can lead to a rise in some banks' internal funding costs, and thus result in an increase in aggregate loan sales. Unlike Pennacchi (1988), loan sales act as a risk-shifting device in my paper. Gorton and Pennacchi (1995) study the optimal loan sales contracts that minimize the negative incentive effect of loan sales after having sold the loan. Fender and Mitchell (2009) examine how different contractual mechanisms influence an originator's choice of costly effort to screen borrowers when the originator plans to securitise its loans. In Gorton and Pennacchi (1995) and Fender and Mitchell (2009), however, there is no bankruptcy risk for the bank. They focus on the optimal design of loan sales contract, and only consider the asset side effect of loan sales. My paper, by introducing bank's bankruptcy risk, which is missing in the existing literature, considers both the asset side effect and liability side effect of loan sales. Some recent papers (Parlour and Plantin (2008); Chemla and Hennessy (2014); Vanasco (2017)), highlight the trade-off between incentives to originate good assets and the liquidity of the secondary loan sales market. In these papers, banks' incentives are always diluted by loan sales. My paper, on the contrary, demonstrates the possible positive effect of loan sales on bank's screening incentives.

The rest of this chapter is organized as follows. In Section 3.2, I set out the model, and show under which conditions loan sales improve a bank's screening incentives, and under what conditions the bank would choose to sell loans. In Section 3.3, I study how strategic adverse selection affects a bank's choice of loan sales. Section 3.4 explores various extensions of the model. Section 3.5 concludes.

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3.2 Model

3.2.1 Model Setup

Consider a simple two-period economy with a bank, a large mass of borrowers and investors. The risk-free rate of interest is normalized to zero, and all parties are risk neutral.

At $t = 0$, each borrower has access to a risky investment project. The borrower's investment project requires one unit of funds. At $t = 2$, the project yields a cash flow of $R > 0$ when it succeeds and 0 when it fails. Each borrower has to raises funds through a bank loan.[1]

There are two types of borrowers in the economy: good (G) and bad (B), where the types are distinguished by differing probabilities of success. Good borrowers represent a proportion γ of the population, while bad borrowers represent a proportion $1 - \gamma$ of the population.

The bank has the specific skills required to screen the borrowers. I assume that bank's screening effort can reduce the probability of accepting a B borrower and, therefore, the proportion of B borrowers in the loan portfolio. The bank chooses to make the effort to screen the borrowers.[2] Screening is a costly activity to the bank and unobservable to outsiders. I assume that the per-loan cost of screening is $c(e) = \frac{1}{2}ce^2$, with $e \in [0, 1]$.[3] If the bank chooses screening effort e, there will be a proportion $1 - \gamma - e$ of B borrowers, and a proportion $\gamma + e$ of G borrowers in the loan portfolio.

A borrower's probability of success depends upon the type of the borrower and the aggregate state. The aggregate state is random, which can be high (H) or low (L), where H denotes a high state of the economy and L denotes a low state. With probability q, the aggregate state is L, and with probability $1 - q$, the aggregate state is H. Probabilities of success for each type of borrower are as follows. In the low state, B borrowers succeed with probability θ_B, and G borrowers succeed with probability θ_G, with $0 < \theta_B < \theta_G < 1$. In the high state, B borrowers succeed with probability $\theta_B + \epsilon$, and G borrowers succeed with probability $\theta_G + \epsilon$, with $0 < \epsilon \leq 1 - \theta_G$. Conditional on the aggregate state, each borrower's payoff is independent.

Next I turn to the bank's own financing decision. For simplicity, I assume that the bank can extend a continuum of loans to borrowers. In order to finance the borrowers, the bank needs to raise 1 unit of funds from investors. At $t = 0$, the bank finances itself with an amount of debt 1.

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[1] I assume that investors, unlike the bank, do not have the required skills to originate loans.

[2] Note that screening can also be interpreted as monitoring. The model based on screening and monitoring would be essentially identical.

[3] The results would be the same if the bank pays a cost to determine the precision of screening technology.

I assume that the debt market is perfectly competitive and there is no deposit insurance, so that the bank will always set the face value of debt at the level required for investors to recover their opportunity cost of funds of 1. Lastly, I assume that the bank is protected by limited liability, so it repays investors only when it succeeds. In Section 3.4.1, I introduce capital requirement into the model.

The bank can hold the entire loan pool on its balance sheet until maturity, or pass a portion of them on to competitive outside buyers, such as a Special Purpose Vehicles (SPV), in the form of loan sales. I assume that before the bank raises debt from investors, it decides whether a fraction of the loan portfolio will be sold after loan origination. If the bank decides to sell, it signs a contract with the loan buyers, which specifies the amount of loans to be sold at $t = 1$ and their price.[4] The proceeds from loan sales are used to pay down on-balance sheet debt. Note that I could also allow the bank to finance a portion of the loan portfolio through loan sales at $t = 0$, as in Gorton and Pennacchi (1995). In this case, the bank can increase the investment size through borrowing an amount of debt and selling a fraction of the loan portfolio, see Section 3.4.3.

At $t = 2$, the payoff of the bank's loan portfolio is realized. If the sum of the bank's portfolio return and proceeds from loan sales is below its liabilities, the bank defaults. Following the literature, I assume that upon failure, there is a fixed bankruptcy cost B.[5] Our main results would not change with a proportional bankruptcy cost.

The timing of the model is summarized as follows. At $t = 0$, the bank decides whether a fraction of the loan portfolio will be sold afterwards, and signs a contract with loan buyers. Then the bank raises funds by issuing debt to investors. Finally, the bank chooses to make the effort to screen the borrowers. At $t = 1$, the bank allocates the loans to the buyers according to the loan sales contract made at $t = 0$. At $t = 2$, the payoff of the bank's loan portfolio is realized. The bank pays back the investors if it succeeds. Otherwise, the bank defaults.

The timeline of the model is illustrated in Figure 3.1.

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[4] This allows me to omit the risk-shifting problem at $t = 1$. Without this assumption, the bank may not sell loans at $t = 1$ even though it promises to do so at $t = 0$, see Winton (1999) for a similar treatment.

[5] See James (1991) and Slovin et al. (1993) for the evidence of substantial direct and indirect costs of bank failure.

3.2.2 First-Best Effort Choice

As a benchmark, I first consider the optimal screening effort for a social planner. The social planner chooses the screening effort to maximize its expected return of the loan portfolio minus the screening cost. That is

$$\max_{0<q<1} \Pi = (\theta_B + (\theta_G - \theta_B)(\gamma + e))R + (1 - q)\epsilon R - c(e) \tag{3.1}$$

As I mentioned before, a borrower's probability of success depends upon the type of the borrower and the aggregate state. Therefore, the return of the bank's loan portfolio depends on the bank's screening effort and the aggregate state. Here the first term is the part of the loan portfolio that depends on the bank's screening effort. The second term is the part of the loan portfolio that depends on the aggregate state. The last term is the screening cost for the social planner. The F.O.C gives the first-best screening effort

$$e^* = \frac{(\theta_G - \theta_B)R}{c} \tag{3.2}$$

Clearly, as the difference of success probability between good loans and bad loans, $\theta_G - \theta_B$, is larger, or as the return of the loan conditional on success, R, is higher, the marginal benefit of screening effort increases, so the social planner will choose a higher level of screening effort.

3.2.3 The Bank Holds the Entire Loan Portfolio

In this section, I study the case that the bank holds the loan portfolio on its balance sheet until maturity. To finance its loan portfolio, the bank needs to borrow 1 unit of funds from investors. Let us use D to denote the face value of debt.

Firstly, to highlight the role of bank's insolvency risk, I impose the following assumption.

ASSUMPTION 3.1. $(\theta_B + (\theta_G - \theta_B)(\gamma + e^*))R < 1$

This assumption says that the bank will default in the low aggregate state, even if the bank chooses screening effort e^*. Under Assumption 3.1, the bank is exposed to the insolvency risk, and thus bank debt is risky. I also assume that the bank will not default in the high aggregate state.

After borrowing from the investors, the bank chooses its screening effort so as to maximize its expected profit as given by

$$\max_{0<q<1} \Pi = (1-q)[(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + \epsilon R - D] - c(e) \tag{3.3}$$

The first term is the bank's expected return when the bank succeeds. With probability $1-q$, the aggregate state is high, in which case the bank succeeds. Conditional on success, the return of the loan portfolio is $(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + (\theta_B + (\theta_G - \theta_B)(\gamma + e))R + \epsilon R$, and the payment to investors is D. The second term is the cost of screening.

The F.O.C of this problem yields

$$e_1 = \frac{(1-q)(\theta_G - \theta_B)R}{c} \tag{3.4}$$

as the optimal screening effort for the bank.

The following lemma shows that the bank's optimal screening effort is socially inefficient.

LEMMA 3.1. *If the bank holds the entire loan portfolio until maturity, as long as $q > 0$, the bank's privately optimal choice of screening effort is below the socially optimal level, i.e., $e_1 < e^*$.*

The under-provision of screening effort arises from the risk-shifting problem when bank debt is risky. The social planner values the payoff of the loan portfolio in all states. On the contrary, due to limited liability, the bank only values the payoff of the loan portfolio conditional on solvency. In the low aggregate state, the bank defaults and receives 0, in which case the investors seize the return of the loan portfolio. This implies that the surplus of screening is not fully captured by the bank. Since screening is unobservable and costly, the bank has no incentives to provide the socially optimal screening effort. This leads to the under-provision of screening effort. Moreover, this moral hazard problem is more severe when the probability of the low aggregate state is higher.

I now turn to the determination of the equilibrium face value of bank debt. Without deposit insurance, the expected value of the debt must be at least equal to investors' opportunity cost of the fund. Since the bank has insolvency risk, the promised repayment D must compensate investors for the risk that the debt may not be fully repaid. Investors can not observe the bank's screening effort, so the face value of the debt will be determined based on investors' conjecture of the bank's screening effort. Let e^{**} denote the investors' conjecture of bank's screening effort. The participation constraint of investors is

$$q[(\theta_B + (\theta_G - \theta_B)(\gamma + e^{**}))R - B] + (1-q)D = 1 \tag{3.5}$$

The first term is investors' expected payment if the bank's portfolio return is lower than its liabilities, conditional on the investors' belief that the bank will choose screening effort e^{**}. In this case, a fixed bankruptcy cost B is incurred, so investors receive less than the bank's portfolio return. The second term is investors' expected payment if bank's portfolio return exceeds its liabilities, in which case, the investors receive the full face value of debt.

In a rational equilibrium, investors' conjecture about the bank's screening effort must be consistent with the bank's actual choice of screening effort, i.e., $e_1 = e^{**}$. I can explicitly characterize the face value of bank debt.

$$D = \frac{1 + qB - q(\theta_G - \theta_B)(\gamma + \frac{(1-q)(\theta_G - \theta_B)R}{c}))R}{1-q} \tag{3.6}$$

Clearly, when the bank's default risk, q, is higher, investors require a higher interest rate to compensate for the risk of bank default.

3.2.4 The Bank Sells Loans

In this section, I study loan sales and the bank's screening incentives. First, I treat the bank's choice of loan sales as exogenously given, and explore the effects of loan sales on the bank's screening incentives. Later I will derive the bank's optimal choice of whether or not to sell loans in equilibrium.

In our model, loan sales are valuable to the bank due to the presence of bankruptcy cost. Compared with the case when the bank holds the entire loan portfolio, a safe cash flow generated by loan sales makes the bank less risky, thus minimizing the possibility of bankruptcy and the bankruptcy cost.

Before the bank raises debt from investors, the bank decides whether a fraction of the loan portfolio will be sold after loan originations. The bank commits to selling a portion of loans to the buyers at a price p. In other words, the bank funds the portfolio initially on its balance sheet, and then transfers a portion of loans to the buyers according to the loan sales contract.

The proceeds from loan sales are used to pay down on-balance sheet debt. Here I first assume that the bank has no private information about the loans. Thus the loans allocated to the buyers would be randomly chosen from the loan pool. The case with adverse selection will be discussed in Section 3.3.

I assume that outside loan buyers are competitive. This implies that the price of the loan will be equal to the expected value of the loan, given loan buyers' conjecture about bank's screening effort $e^{'}$. The price of the loan will be

$$p = (\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + (1-q)\epsilon R \tag{3.7}$$

The first term is determined by the bank's screening effort, while the second term is determined by the aggregate state. Intuitively, if the loan buyers expect the bank to choose a higher screening effort, they are willing to pay a higher price for the loan.

Suppose that the bank sells a proportion $s \leq 1$ of the entire loan portfolio. After borrowing from the investors, the bank chooses its screening effort so as to maximize its expected profit as given by

$$\begin{aligned}\max_{0<q<1} \Pi = {} & q \min\{sp + (1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R - D, 0\} \\ & + (1-q)[sp + (1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + (1-s)\epsilon R - D] - c(e)\end{aligned} \tag{3.8}$$

The first term is the bank's expected return when the aggregate state is low. In the bracket of the first term, sp is the proceeds from loan sales, and $(1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R$ is the return of the portion of the loan portfolio that remains on the bank's balance sheet. The second term is the bank's expected return when the aggregate state is high. The third term is the cost of screening. I have the following the result.

LEMMA 3.2. *If the bank chooses to sell loans, it will sell a portion s such that the bank's bankruptcy risk is eliminated, i.e.,* $sp + (1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R \geq 1$.

To understand Lemma 3.2, we can consider the opposite case that $sp + (1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R < 1$. If this is true, the bank will default in the low aggregate state. On the one hand, the risk-shifting problem that I discuss in the previous section still exists. On the other hand, loan sales generate a new incentive-dilution problem that I will show in the following sections. Therefore, loan sales with $sp + (1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R < 1$ can never be optimal for the bank.

With Lemma 3.2, we know that the bank will not default even if the aggregate state is low. Clearly, if the bank never defaults, the debt that the bank issues to investors becomes riskless. The face value of bank debt is

$$D = 1 \tag{3.9}$$

Therefore, we can simplify the bank's objective function as

$$\max_{0<q<1} \Pi = sp + (1-s)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + (1-s)\epsilon R - 1 - c(e)$$

The F.O.C of this problem yields

$$e_2 = \frac{(1-s)(\theta_G - \theta_B)R}{c} \tag{3.10}$$

as the optimal screening effort for the bank.

The following lemma shows that the bank's optimal screening effort when the bank sells a portion of the loan portfolio is below the socially optimal level.

LEMMA 3.3. *If the bank sells a portion s of the loan portfolio, as long as $s > 0$, the bank's privately optimal choice of screening effort is below the socially optimal level, i.e., $e_2 < e^*$.*

This lemma establishes the well-known result that loan sales dilute incentives. If the bank only retains a proportion $1-s$ of the loan portfolio, the bank has less skin in the game. Since the bank does not fully capture the benefits of screening, it will have insufficient incentives to screen loans diligently.

Clearly, the bank will try to minimize the negative incentive-dilution effect. The bank can choose the smallest s such that Lemma 3.2 is satisfied. We have the following result.

LEMMA 3.4. *If the bank sells loans, the optimal level of loan sales is $s^* = \frac{1-(\theta_B+(\theta_G-\theta_B)\gamma)R-\frac{(\theta_G-\theta_B)^2R^2}{c}}{(1-q)\epsilon R-\frac{(\theta_G-\theta_B)^2R^2}{c}}$.*

The key question is: do loan sales reduce the bank's screening incentives, compared with the case when the bank holds the entire loan portfolio? The next proposition shows that contrary to the conventional wisdom, the effect of loan sales on the bank's screening incentives can be positive.

PROPOSITION 3.1. *If and only if $s^* < q$, the bank's screening effort when the bank sells a portion s^* of the loan portfolio is greater than if the bank holds the entire loan portfolio.*

Proposition 3.1 establishes our key result that loan sales may not necessarily lead to a lax lending standard. The intuition of this result is as follows. On the one hand, if the bank sells loans, we have the classic moral hazard result: loan sales reduce the bank's incentives to screen the loans since the bank's return is less sensitive to its screening effort when the bank doesn't hold the entire loan portfolio. In extreme cases, if the bank sells the whole loan portfolio, the bank will choose a screening effort of 0. This negative incentive-dilution effect is on the bank's asset side, and has been extensively discussed in the literature on loan sales. On the other hand, if the bank can avoid bankruptcy risk through loan sales, the bank's risk-shifting problem is also eliminated. As shown in the previous section, the risk-shifting problem can distort the bank's screening effort downward. If loan sales reduce the bank's risk-shifting problem, it can improve its screening incentives. I refer to it as the risk-shifting reduction effect of loan sales. This positive effect is on the bank's liability side, which is missing in the existing literature. If $s^* < q$, the positive risk-shifting reduction effect is sufficiently high such that it dominates the negative incentive-dilution effect. Therefore, loan sales improve the bank's screening incentives.

We can also understand this result from the perspective of credit risk transfer. Loans sales can transfer the bank's non-controllable aggregate risk to outside loan buyers. This is beneficial since the aggregate risk damages the bank's screening incentives by generating a risk-shifting problem. However, when transferring the aggregate risk, the bank has to simultaneously transfer the risk that is controllable by the bank, which is bad for the bank's screening incentives. When the aggregate risk is sufficiently high, the benefit of transferring non-controllable aggregate risk outweighs the cost of transferring controllable risk.

I use a numerical example to illustrate Proposition 3.1. From Figure 3.2, we can see that in the blue region where q or R is relatively high, the bank's screening effort when the bank sells a portion s^* of the loan portfolio, is higher than the screening effort when the bank holds the entire loan. In the white region where q or R is relatively low, the bank's screening effort when the bank sells a portion s^* of the loan portfolio, is lower than the screening effort when the bank holds the entire loan. Figure 3.3 shows a similar pattern for q and γ.

The next proposition provides the results of comparative statics.

PROPOSITION 3.2. *Conditional on bank selling loans,*

(I) the higher the R or γ, the lower the portion of loans that will be sold.

(II) the higher the R or γ, the more likely the bank's screening effort when the bank sells a portion s^* of the loan portfolio is greater than if the bank holds the entire loan portfolio.

The intuition is as follows. For part (I) of Proposition 3.2, when R or γ increases, the sale price of the loan increases. So the bank is able to sell a smaller portion of the loan pools to avoid bankruptcy, which implies that s^* decreases. A lower s^* means that the incentive-dilution effect of loan sales is smaller. Therefore, the risk-shifting reduction effect is more likely to outweigh the incentive-dilution effect, which is part (II).

In the previous section, I compare the bank's screening effort when the bank holds the entire loan and when the bank sells a fraction of the loan portfolio. In this section, I take a further step to explore when the bank will choose to sell loans in equilibrium. By comparing the bank's expected profit under different schemes, I determine the conditions under which loan sales would increase bank value. The following proposition summarizes the results.

PROPOSITION 3.3. *In the equilibrium,*

(I) If $s^* < q$, the bank will sell a portion s^* of the loan portfolio. Compared with the case that the bank holds the entire loan portfolio, the bank's screening effort is improved by loan sales, i.e., $e_2 > e_1$.

(II) If $s^* > q$, and $(\theta_G - \theta_B)(e_1 - e_2)R + c(e_2) - c(e_1) < qB$, the bank will sell a portion s^* of the loan portfolio. Compared with the case that the bank holds the entire loan portfolio, the bank's screening effort is diluted by loan sales, i.e., $e_2 < e_1$.

(III) If $s^* > q$, and $(\theta_G - \theta_B)(e_1 - e_2)R + c(e_2) - c(e_1) > qB$, the bank will not sell loans.

For a bank with $s^* < q$, loan sales can both both reduce bankruptcy cost and improve the bank's screening incentives, so the bank will always choose to sell a portion of the loan portfolio. For a bank with $s^* > q$, it is more complicated. In this case, on the one hand, loan sales reduce bankruptcy cost, which is beneficial to the bank. On the other hand, they reduce the bank's screening incentives compared with the case that the bank holds the entire loan portfolio, which is costly to the bank. The bank trades off the benefit and cost of loan sales. When the bankruptcy cost is sufficiently high, the bank is willing to sell a portion of the loan portfolio even if the bank' screening incentives are diluted. When the bankruptcy cost is low, the bank chooses not to sell loans and bear the bankruptcy cost.

I use a numerical example to illustrate Proposition 3.3. From Figure 3.4, we can see that in the blue region where q or R are relatively high, the bank will choose to sell loans. In this region, the bank's screening incentives are improved by loan sales. In the red region where q or R are moderate, the bank will choose to sell loans. However, the bank's screening incentives are reduced by loan sales. In the white region where q or R are low, the bank will not sell loans. Figure 3.5 shows a similar pattern for q and γ.

3.3 Loan Sales with Strategic Adverse Selection

So far, I have treated the bank as having no private information of the quality of the loans, and thus the sold loans are randomly selected from the loan pool. I relax this assumption and consider how adverse selection affects bank's loan sales. I modify the benchmark model by supposing that after loan originations, the bank can privately observe the realized qualities (G or B) of the loans.[6] Thus the bank may have incentives to strategically allocate the bad loans to the investors. This means that loans buyers face an adverse selection problem, in addition to the moral hazard associated with the bank's screening effort.

Suppose that the bank commits to selling a portion s^* of the loan portfolio. There are two possible rational equilibrium, depending on the bank's screening effort e_2.

In the first equilibrium, given the bank's screening effort e_2, the amount of bad loans in the loan portfolio is less than the amount of loans to be sold, i.e., $1-\gamma-e_2 < s^*$. This implies that in addition to the bad loans, some good loans are allocated to the buyers. After loan sales, on the bank's balance sheet, there are $1-s^*$ good loans.

In the second equilibrium, given the bank's screening effort e_2, the amount of bad loans in the loan portfolio is greater than or equal to the amount of loans to be sold, i.e., $1-\gamma-e_2 \geq s^*$. This implies that all the loans allocated to the buyers are bad. After loan sales, on the bank's

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[6] In the words of Stein (2002), the information of loan's quality is soft information. The bank receives informative but non-verifiable signals about the loans. The information can not be credibly transmitted to outside buyers.

balance sheet, there are $1 - \gamma - e_2 - s^*$ bad loans, and $\gamma + e_2$ good loans.

The following lemma shows that only the second equilibrium is sustainable.

LEMMA 3.5. *If the bank can strategically allocate the bad loans to the buyers, in equilibrium, the amount of the bad loans in the bank's loan portfolio is greater than or equal to the amount of loans to be sold.*

To understand why the first equilibrium is not sustainable, we consider a deviation strategy for the bank. If $1 - \gamma - e_2 < s^*$, the amount of bad loans in the portfolio is less than the amount of loans to be sold, so the bank needs to allocate some good loans to the buyers. All the loans that remain on bank's balance sheet are good. Suppose that the bank deviates by choosing an effort $e_d < e_2$ such that $1 - \gamma - e_d = s^*$. With the deviation, all the loans remaining on the bank's balance sheet are still good, as in the case when the bank chooses e_2. Also note that since the price of loans has been predetermined at $t = 0$, the proceeds from loan sales is not affected by the deviation. However, since $e_d < e_2$, the bank's screening cost is lower. Therefore, the bank's expected profit is strictly higher with deviation, which suggests that the equilibrium with $1 - \gamma - e_2 < s^*$ is not sustainable.

As in the previous section, loan buyers s are willing to pay a price that is equal to the expected value of the loan. In equilibrium, loan buyers correctly anticipate that the loans to be sold are bad, so the price of the loan is

$$p = \theta_B R + (1 - q)\epsilon R$$

How would strategic adverse selection affect the bank's loan sales decision and screening effort? Intuitively, one would expect that adverse selection might damage the bank's ability to transfer risk. However, the next proposition shows the intuition is incorrect.

PROPOSITION 3.4. *Strategic adverse selection is irrelevant for the bank's loan sales decision and screening effort.*

The intuition of this result is as follows. The motive for a bank to sell loans is to transfer the aggregate risk to the outside buyers. As long as the bad loans and good loans have the same exposure to the aggregate risk, it is equally efficient for the bank to sell the bad loans or good loans from the perspective of risk transfer. Therefore, strategic adverse selection will not undermine the efficiency of the bank's loan sales.

It is interesting to compare my results with the standard adverse selection problem. The key difference is regarding the loan sales decision. In a standard adverse selection problem, the bank decides ex-post whether to sell loans. Ex-post selling choice generates the possibility of market breakdown because the bank can choose not to sell. In my model, on the contrary, the bank can commit to the amount of loans to be sold, so there is no risk of market breakdown.

3.4 Extensions

3.4.1 Capital Requirement

Until now, I have assumed that the bank is is fully financed with debt. Now I introduce the capital requirement. I assume that the regulator requires the bank to finances the loan portfolio with an amount of equity k and an amount of debt $1-k$, where k is exogenously determined by the regulator. I focus on the case that k is low such that the bank still fails in the low aggregate state.

Similar as before, we solve the F.O.C conditions for the bank under capital requirement. When the bank holds the entire loan portfolio,

$$e_1 = \frac{(1-q)(\theta_G - \theta_B)R}{c}$$

When the bank sells a portion s^* of the loan portfolio,

$$e_2 = \frac{(1-s^*)(\theta_G - \theta_B)R}{c}$$

Compared with the benchmark model, s^* is altered by the capital requirement. Now

$$s^* = \frac{1-k-(\theta_B+(\theta_G-\theta_B)\gamma)R - \frac{(\theta_G-\theta_B)^2R^2}{c}}{(1-q)\epsilon R - \frac{(\theta_G-\theta_B)^2R^2}{c}} \tag{3.11}$$

As in the benchmark model, if and only if $s^* < q$, bank's screening effort when the bank sells a portion of the loan portfolio is higher than if the bank holds the entire loan portfolio. The next proposition shows that under the capital requirement, the banks' screening incentives when the bank sells loans are improved, compared with the benchmark model.

PROPOSITION 3.5. *Under the capital requirement, the bank's screening effort when the bank* *sells a portion s^* of the loan portfolio is more likely to be greater than if the bank holds the entire loan portfolio. Conditional on the bank selling loans, the higher the k, the greater the bank's screening effort.*

This result is quite intuitive. Under the capital requirement, the bank borrows less from the investors. Therefore, the bank can sell a smaller portion of its loan portfolio to avoid the bankruptcy risk, which implies that the incentive-dilution effect is mitigated. This explains why under the capital requirement, the bank's screening effort when the bank sells a portion s^* of the loan portfolio is more likely to be greater than if the bank holds the entire loan portfolio. Moreover, as k is higher, the portion of the loan portfolio to be sold becomes smaller, so the bank's screening effort when the bank sell a portion s^* of the loan portfolio is greater.

3.4.2 Deposit Insurance

In this section, I study the bank's choice of loan sales when there is a flat deposit insurance. With a flat deposit insurance, the insurance fund will pay back the investors when the bank defaults on its debt. The interest rate demanded by the investors will compensate for the opportunity cost of funds, so

$$D = 1$$

I solve the F.O.C conditions for the bank with a flat deposit insurance,. When the bank holds the enitre loan portfolio,

$$e_1 = \frac{(1-q)(\theta_G - \theta_B)R}{c}$$

When the bank sells loans,

$$e_2 = \frac{(1-s^*)(\theta_G - \theta_B)R}{c}$$

We have the following proposition.

PROPOSITION 3.6. *The bank will not sell loans with a flat deposit insurance.*

The intuition is as follows. When there is no deposit insurance, investors will take into account the bankruptcy cost into the pricing of debt. Since the bank captures all the surplus, in the end, the bankruptcy cost is beared by the bank. Therefore, the bank has incentives to sell loans to avoid the bankruptcy cost. With a flat deposit insurance, bank's benefit from risk transfer disappears. Since the insurance fund pays back the investors when the bank defaults, investors will not care about the bankruptcy cost anymore. In this case, if the bank holds the entire loan portfolio, it can free-ride on the insurance fund. Therefore, the bank will never sell loans, which may be socially inefficient.

3.4.3 Other Motives of Loan Sales

Until now, I focus on the role of loan sales to transfer the bank's credit risk. Would the main results hold if the bank sells loans for other motives? In this section, I study the case that the banks sells loans to increase the investment size, or fund a new investment opportunity separately. I show that the results are robust as long as loan sales still help the bank to reduce the bankrupt risk.

Increase Investment Size

To study the case that loan sales allow the bank to increase it's investment size, I deviate from the benchmark model by assuming that bank's deposit base is fixed and bank's investment size is variable. Loan sales allow the bank to expand the funding source and have a larger investment size. In this case, loan sales are valuable to the bank because bank's investment is profitable. For simplicity, I assume that there is constant return to the investment as long as investment size is below I_m.

Suppose that bank's deposit base is 1. Before the bank extends loans, the bank determines the investment size I, funded by raising 1 from the depositors and selling a fraction of the loan portfolio s.

As before, I assume that outside loan buyers are competitive. Given loan buyers' conjecture about bank's screening effort $e^{'}$. The price of the loan will be

$$p = (\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + (1 - q)\epsilon R \tag{3.12}$$

If the bank sells a fraction s of the loan portfolio, it receives $sI[(\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + (1 - q)\epsilon R]$ from loan sales. The investment I is funded through deposit and loan sales. Therefore, we have

$$I - 1 = sI[(\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + (1 - q)\epsilon R] \tag{3.13}$$

After the bank sells loans, there are $(1 - s)I$ loans on bank's balance sheet.

If the bank doesn't sell loans, as before,

$$e_1 = \frac{(1-q)(\theta_G - \theta_B)R}{c} \tag{3.14}$$

is the optimal screening effort for the bank.

For the case that bank sells loans, I focus on the case that value of the loan portfolio remaining on bank's sheet is sufficiently high such that the bank will not default in the low aggregate state. That is,

$$(1-s)I(\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R > 1 \tag{3.15}$$

In this case, $D = 1$. The bank chooses its screening effort so as to maximize its expected profit as given by

$$\begin{aligned}\max_{0<q<1} \Pi &= q(1-s)I(\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R \\ &+ (1-q)(1-s)I(\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + (1-q)(1-s)I\epsilon R - 1 - Ic(e)\end{aligned} \tag{3.16}$$

The F.O.C of this problem yields

$$e_2 = \frac{(1-s)(\theta_G - \theta_B)R}{c} \tag{3.17}$$

as the optimal screening effort for the bank.

Clearly, when s is lower, bank's screening incentive is stronger. If the size of investment is I, we can solve s^* which satisfies

$$I - 1 = s^* I[(\theta_B + (\theta_G - \theta_B)(\gamma + \frac{(1-s^*)(\theta_G - \theta_B)R}{c}))R + (1-q)\epsilon R] \tag{3.18}$$

It is easy to show that when I is larger, s^* would be lower. Together with the assumption that investment is profitable, the bank will choose the investment size as I_m. As long as I_m is sufficiently large, the value of the loan portfolio $(1 - s^*)I_m$ on bank's balance can be greater than 1 even in the low aggregate state, and $e_2 > e_1$. This result is intuitive: when the bank sells loans and increase investment size, the bank obtains the NPV of the sold loans, which accrues to bank's asset side and makes the bank less risky. Therefore, the risk-shifting reduction effect still plays a role in this case and may improve bank's screening incentives.

New Investment Opportunity

Second, I consider the case that loan sales can allow the bank to fund a new investment opportunity. To focus on the different motives of loan sales, here I assume that there is no aggregate risk anymore, so a G loan always succeeds with probability θ_G, while a B loan succeeds with probability θ_B.

Now suppose that the bank has existed before $t = 0$. On the asset side of the bank's balance sheet, there is an asset which will mature at $t = 2$. The payoff of the asset is either Z with probability $1 - q$, or 0 with probability q. On the liability side of the bank's balance sheet, the face value of the preexisting debt is D_1. At $t = 0$, the bank can extend new loans to borrowers. It issues an amount 1 of debt to investors to finance its loan portfolio. I assume that the new debt holders are junior to the preexisting debt holders. At $t = 1$, a new investment opportunity appears. The new investment opportunity requires a fixed cost of 1, and will payoff $v > 1$ at $t = 2$. At $t = 2$, the payoff of the bank is realized. If bank's payoff is below its liabilities, the the bank defaults.

Here loan sales provide the bank with a cash flow prior to maturity of the loans. The bank can use the proceeds from loan sales to fund the new investment opportunity at $t = 1$. Without loan sales, the bank is not able to undertake the new investment.opportunity.[7]. I make an additional assumption.

ASSUMPTION 3.2. $\theta_G R < D_1 + 1$, $\theta_G R + v - 1 > D_1 + 1$.

Assumption 3.2 says that the bank will default when the payoff of the preexisting asset is 0 and the bank does not undertake the new investment opportunity. However, if the bank undertakes the new investment opportunity, the bank is solvent even if the payoff of the preexisting asset is 0.

I start with the case that the bank holds the loan portfolio until maturity. To finance its portfolio of loans, the bank needs to borrow 1 unit of funds from investors at $t = 0$. Let us use

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[7] Here I implicitly assume that the presence of imperfections such as asymmetric information and bank capital regulation prevent the bank from issuing new debt at $t = 1$.

D_2 to denote the face value of debt issued at $t = 1$.

The bank chooses its screening effort so as to maximize its expected profit as given by

$$\max_{0<q<1} \Pi = (1-q)[(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + Z - D_1 - D_2] - c(e) \tag{3.19}$$

The F.O.C of this problem yields

$$e_1 = \frac{(1-q)(\theta_G - \theta_B)R}{c} \tag{3.20}$$

as the optimal screening effort for the bank, which is exactly the same as the benchmark model.

Next I study the case when the bank sells loans to fund the new investment opportunity. The bank chooses its screening effort so as to maximize its expected profit as given by

$$\begin{aligned}\max_{0<q<1} \Pi = {} & q[(1-s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + v - D_1 - D_2] \\ & + (1-q)[(1-s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + v + Z - D_1 - D_2] - c(e) \end{aligned} \tag{3.21}$$

The F.O.C of this problem yields

$$e_1 = \frac{(1-s^*)(\theta_G - \theta_B)R}{c} \tag{3.22}$$

as the optimal screening effort for the bank. Here

$$s^* \;=\; \frac{\theta_B + (\theta_G - \theta_B)\gamma + \frac{(\theta_G-\theta_B)^2 R}{c} - \sqrt{(\theta_B + (\theta_G - \theta_B)\gamma + \frac{(\theta_G-\theta_B)^2 R}{c})^2 - 4\frac{(\theta_G-\theta_B)R}{cR}}}{2\frac{(\theta_G-\theta_B)R}{c}} \tag{3.23}$$

As long as $s^* < q$, the bank's screening effort when the bank sells a portion s^* of the loan portfolio is greater than if the bank holds the entire loan portfolio, similar as the benchmark model. More generally, I can show that for other motives of loan sales, such as liquidity management, as long as loan sales reduce the bank's bankruptcy risk, our main results still hold.

3.5 Conclusion

This chapter re-examines the classical issue of loan sales and banks' moral hazard. I explicitly model banks' own capital structures and highlight the role of banks' bankruptcy risk, which is a key departure from the existing literature. I show that if loan sales act as a risk-sharing device for banks, it can improve the banks' screening incentives under some conditions. In the model, banks finance their loan portfolios by issuing risky debt. Due to limited liability, banks are subject to a risk-shifting problem which leads to the under-provision of screening effort. The bank may sell loans to transfer the aggregate risk. On the one hand, loan sales reduce banks' skin in the game, thus diluting their screening incentives. On the other hand, loan sales lower banks' bankruptcy risk, alleviating the risk-shifting problem. The sign and the magnitude of the effect of loan sales on banks' moral hazard depend crucially on the relative weights of these two opposing effects. When a bank's bankruptcy risk is high, the positive risk-shifting reduction effect of loan sales dominates the negative incentive-dilution effect, thus loan sales might curb rather than exacerbate the bank's moral hazard problem, contrary to the conventional wisdom. I show that adverse selection will not undermine the efficiency of bank loan sales. I also study various extensions of the model to demonstrate that the main results of the model are robust.

3.6 Appendix

3.6.1 Figures

Figure 3.1: Timeline

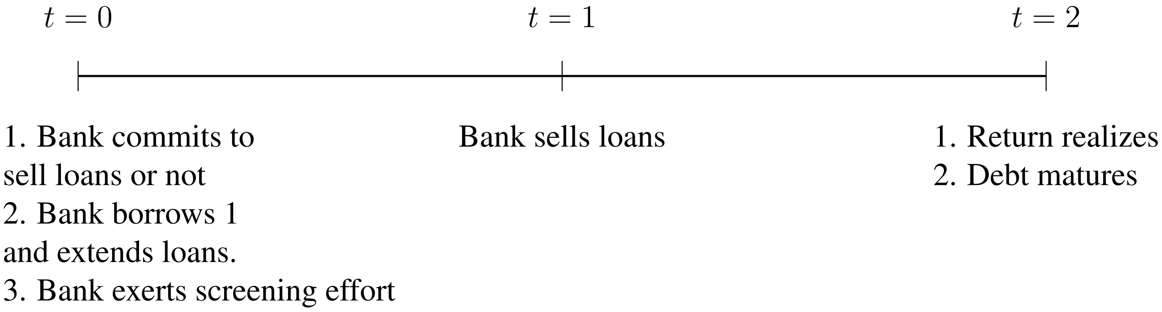
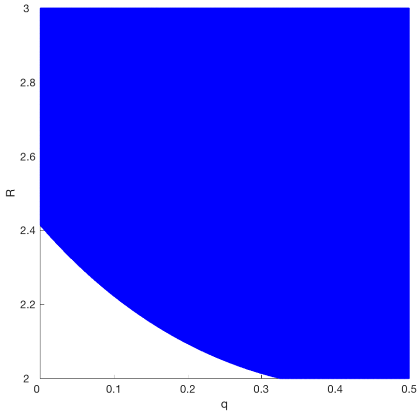
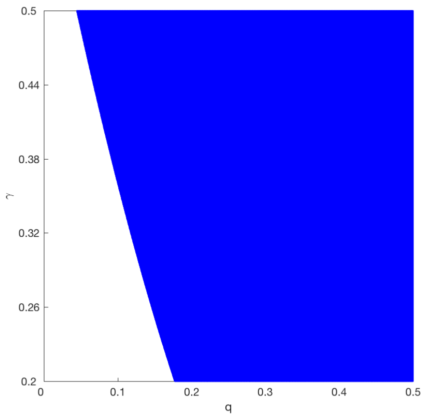


Figure 3.2: Bank's Screening Effort with Varing R



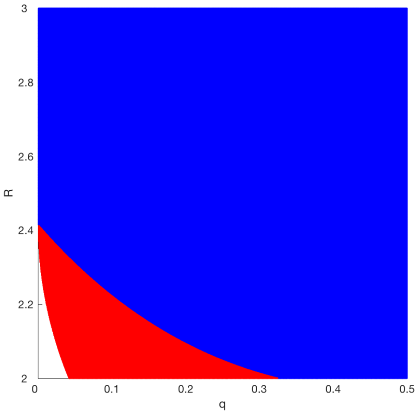
Note: The blue area is where the bank's screening effort is higher with loan sales; the white area is where the bank's screening effort is lower with loan sales.

Figure 3.3: Bank's Screening Effort with Varing γ



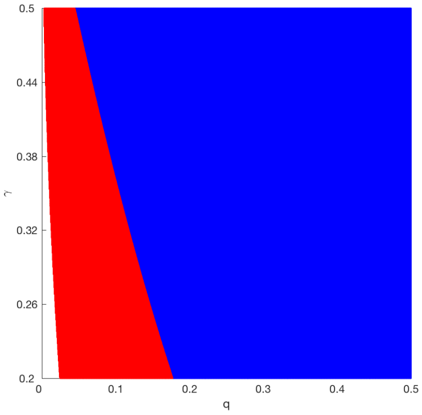
Note: The blue area is where the bank's screening effort is higher with loan sales; the white area is where the bank's screening effort is lower with loan sales.

Figure 3.4: Bank's Choice of Loan Sales with Varing R



Note: The blue area is where the bank chooses to sell loans and screening effort is higher; the red area is where the banks chooses to sell loans and screening effort is lower; the white area is where the bank chooses not to sell loans.

Figure 3.5: Bank's Choice of Loan Sales with Varing γ



Note: The blue area is where the bank chooses to sell loans and screening effort is higher; the red area is where the banks chooses to sell loans and screening effort is lower; the white area is where the bank chooses not to sell loans.

3.6.2 Proofs

Proof of Lemma 3.4

If $s^* < q$, $e_2 > e_1$. From equation 3.15, we have the price of the sold loans

$$p = (\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + (1-q)\epsilon R$$

Plug p into the non-bankruptcy condition, we have

$$(\theta_B + (\theta_G - \theta_B)(\gamma + e^{'}))R + s^*(1-q)\epsilon R = 1$$

In a rational equilibrium, loan buyers' conjecture about bank's screening effort must be consistent with bank's actual choice of screening effort, that is, $e_2 = e^{'}$. Plug the optimal screening effort e_2 into this condition, we have

$$s^* = \frac{1 - (\theta_B + (\theta_G - \theta_B)\gamma)R - \frac{(\theta_G - \theta_B)^2 R^2}{c}}{(1-q)\epsilon R - \frac{(\theta_G - \theta_B)^2 R^2}{c}}$$

So we have $s^* < q$ if and only if

$$\frac{1 - (\theta_B + (\theta_G - \theta_B)\gamma)R - \frac{(\theta_G - \theta_B)^2 R^2}{c}}{(1-q)\epsilon R - \frac{(\theta_G - \theta_B)^2 R^2}{c}} < q$$

Q.E.D.

Proof of Proposition 3.3

First, we prove if $\frac{1 - (\theta_B + (\theta_G - \theta_B)\gamma)R - \frac{(\theta_G - \theta_B)^2 R^2}{c}}{(1-q)\epsilon R - \frac{(\theta_G - \theta_B)^2 R^2}{c}} < q$, the bank will always choose to sell the loan. Bank's expected profit without loan sales and with loan sale is respectively

$$\Pi_1 = (\theta_B + (\theta_G - \theta_B)(\gamma + e_1))R + (1-q)\epsilon R - 1 - qB - c(e_1)$$

$$\Pi_2 = (\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R + (1-q)\epsilon R - 1 - c(e_2)$$

As stated in Proposition 3.1, if $s^* < q$, $e_2 > e_1$. Also we know that $e^* > e_2 > e_1$. By the definition of e^*, e^* maximizes

$$F = (\theta_B + (\theta_G - \theta_B)(\gamma + e))R - c(e)$$

That is,

$$\frac{\partial F}{\partial e} \mid_{e=e^*}= 0$$

Since $c(e)$ is a concave function, for $e < e^*$, we have

$$\frac{\partial F}{\partial e} \mid_{e<e^*}> 0$$

As $e^* > e_2 > e_1$, we have

$$(\theta_B+(\theta_G-\theta_B)(\gamma+e_1))R+(1-q)\epsilon R-c(e_1) < (\theta_B+(\theta_G-\theta_B)(\gamma+e_2))R+(1-q)\epsilon R-c(e_2)$$

Together with $qB > 0$, we have $\Pi_1 < \Pi_2$.

Next, we prove if $s^* \geq q$, the bank will choose to sell loans if and only if $(\theta_G - \theta_B)(e_1 - e_2)R + c(e_2) - c(e_1) < qB$.

If $s^* \geq q$, $e^* > e_1 > e_2$.

We have

$$(\theta_B+(\theta_G-\theta_B)(\gamma+e_1))R+(1-q)\epsilon R-c(e_1) > (\theta_B+(\theta_G-\theta_B)(\gamma+e_2))R+(1-q)\epsilon R-c(e_2)$$

To have $\Pi_1 < \Pi_2$, we need

$$(\theta_B+(\theta_G-\theta_B)(\gamma+e_1))R+(1-q)\epsilon R-c(e_1)-qB < (\theta_B+(\theta_G-\theta_B)(\gamma+e_2))R+(1-q)\epsilon R-c(e_2)$$

This implies $(\theta_G - \theta_B)(e_1 - e_2)R + c(e_2) - c(e_1) < qB$.

Q.E.D.

Proof of Proposition 3.4

First, given s^* and p, we can write bank's maximization program with adverse selection.

$$\begin{aligned}\max_{0<q<1} \Pi = {} & q[s^*p + (1-s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R - D] \\ & + (1-q)[s^*p + (1-s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e))R + (1-s)\epsilon R - D] - c(e)\end{aligned}$$

which is the same as without adverse selection. The F.O.C also remains the same:

$$e_2 = \frac{(1 - s^*)(\theta_G - \theta_B)R}{c}$$

There are two other conditions to determine s^*. The first is the price of loans

$$p = \theta_B R + (1 - q)\epsilon R$$

The second is the non-bankruptcy condition

$$s^* p + [(\gamma + e_2)\theta_G + (1 - \gamma - e_2 - s)\theta_B]R = 1$$

Combining these two conditions, we have

$$(\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R + s^*(1 - q)\epsilon R = 1$$

which is exactly the same as without adverse selection. Together with the same F.O.C, this implies that the solution e_2 and s^* must the be same.

Q.E.D.

Proof of Proposition 3.5

We just need to compare bank's expected profit without loan sales and with loan sales. Without loan sales,

$$\Pi_1 = (1 - q)[(\theta_B + (\theta_G - \theta_B)(\gamma + e_1))R + \epsilon R - 1] - c(e_1)$$

With loan sales,

$$\begin{aligned}\Pi_2 = q[s^* p + (1 - s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R - D] \\ + (1 - q)[s^* p + (1 - s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R + (1 - s)\epsilon R - D] - c(e_2)\end{aligned}$$

Since in equilibrium

$$s^* p + (1 - s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R - D = 1$$

We can rewrite Π_2 as

$$\Pi_2 = (1-q)[\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R] + (1-q)(1-s)\epsilon R - 1 - c(e_2)$$

By the definition of e_1, e_1 maximizes $(1-q)[(\theta_B + (\theta_G - \theta_B)(\gamma + e_1))R] - c(e_1)$, so

$$(1-q)[(\theta_B + (\theta_G - \theta_B)(\gamma + e_1))R] > (1-q)[s^*p + (1-s^*)(\theta_B + (\theta_G - \theta_B)(\gamma + e_2))R]$$

Moreover, $(1-q)(1-s^*)\epsilon R < (1-q)\epsilon R$, so we have $\Pi_2 < \Pi_1$

Q.E.D.

Bibliography

Acharya, V. V., Cooley, T. F., Richardson, M. P., and Walter, I. (2011). Market failures and regulatory failures: Lessons from past and present financial crises.

Acharya, V. V. and Richardson, M. (2009). Causes of the financial crisis. *Critical Review*, 21(2-3):195–210.

Adrian, T. and Shin, H. S. (2010). Liquidity and leverage. *Journal of financial intermediation*, 19(3):418–437.

Adrian, T. and Shin, H. S. (2011). Financial intermediary balance sheet management. *Annu. Rev. Financ. Econ.*, 3(1):289–307.

Aghion, P. and Howitt, P. W. (2009). *The economics of growth*. MIT press.

Ahnert, T., Chapman, J., et al. (2017). Asset encumbrance, bank funding and fragility. Technical report, European Systemic Risk Board.

Allen, F. and Gale, D. (1994). Limited market participation and volatility of asset prices. *The American Economic Review*, pages 933–955.

Asriyan, V. and Vanasco, V. (2014). Informed intermediation over the cycle. *Working Paper*.

Babihuga, R. and Spaltro, M. (2014). *Bank funding costs for international banks*. Number 14-71. International Monetary Fund.

BCBS (2013). Basel iii: The liquidity coverage ratio and liquidity risk monitoring tools. *Basel Committee on Banking Supervision, BIS*.

Beau, E., Hill, J., Hussain, T., and Nixon, D. (2014 Q4). Bank funding costs: what are they, what determines them and why do they matter? *Bank of England Quarterly Bulletin*.

Beck, T., Chen, T., Lin, C., and Song, F. M. (2016). Financial innovation: The bright and the dark sides. *Journal of Banking & Finance*, 72:28–51.

Berger, A. N. and Udell, G. F. (1990). Collateral, loan quality and bank risk. *Journal of Monetary Economics*, 25(1):21–42.

Bhattacharya, S., Plank, M., Strobl, G., and Zechner, J. (2002). Bank capital regulation with random audits. *Journal of Economic Dynamics and Control*, 26(7):1301–1321.

Biais, B., Rochet, J.-C., and Woolley, P. (2015). Dynamics of innovation and risk. *The Review of Financial Studies*, 28(5):1353.

Boissay, F., Collard, F., and Smets, F. (2016). Booms and banking crises. *Journal of Political Economy*, 124(2):489–538.

Boyd, J. H. and Nicoló, G. D. (2005). The theory of bank risk taking and competition revisited. *The Journal of Finance*, 60(3):1329–1343.

Boyd, J. H. and Prescott, E. C. (1986). Financial intermediary-coalitions. *Journal of Economic Theory*, 38(2):211–232.

Boz, E. and Mendoza, E. G. (2014). Financial innovation, the discovery of risk, and the us credit crisis. *Journal of Monetary Economics*, 62:1–22.

Brunnermeier, M. and Krishnamurthy, A. (2014). Liquidity mismatch. In *Risk Topography: Systemic Risk and Macro Modeling*. University of Chicago Press.

Bubb, R. and Kaufman, A. (2014). Securitization and moral hazard: Evidence from credit score cutoff rules. *Journal of Monetary Economics*, 63:1–18.

Caballero, R. J. and Farhi, E. (2013). A model of the safe asset mechanism (sam): Safety traps and economic policy. Technical report, National Bureau of Economic Research.

Calomiris, C. W. and Kahn, C. M. (1991). The role of demandable debt in structuring optimal banking arrangements. *The American Economic Review*, pages 497–513.

Carbó-Valverde, S., Marques-Ibanez, D., and Rodríguez-Fernández, F. (2012). Securitization, risk-transferring and financial instability: The case of spain. *Journal of International Money and Finance*, 31(1):80–101.

Cebenoyan, A. S. and Strahan, P. E. (2004). Risk management, capital structure and lending at banks. *Journal of Banking & Finance*, 28(1):19–43.

CGFS (2013). Asset encumbrance, financial reform and the demand for collateral assets. *Committee on the Global Financial System, BIS*, 49.

Chan, Y.-S. and Thakor, A. V. (1987). Collateral and competitive equilibria with moral hazard and private information. *The Journal of finance*, 42(2):345–363.

Chemla, G. and Hennessy, C. A. (2014). Skin in the game and moral hazard. *The Journal of Finance*, 69(4):1597–1641.

Chiaramonte, L. and Casu, B. (2013). The determinants of bank cds spreads: evidence from the financial crisis. *The European Journal of Finance*, 19(9):861–887.

Dahlgren, S. J. (2011). A new era of bank supervision. Remarks at the New York Bankers Association Financial Services Forum.

De Nederlandsche Bank (2016). Keeping encumbrance to a minimum. *Bank Newsletter, April 2016*.

Dell'Ariccia, G., Laeven, L., and Marquez, R. (2014). Real interest rates, leverage, and bank risk-taking. *Journal of Economic Theory*, 149:65 – 99. Financial Economics.

Demsetz, R. S. (2000). Bank loan sales: A new look at the motivations for secondary market activity. *Journal of Financial Research*, 23(2):197–222.

Dewatripont, M., Tirole, J., et al. (1994). The prudential regulation of banks. Technical report, ULB–Universite Libre de Bruxelles.

Di Filippo, M., Ranaldo, A., and Wrampelmeyer, J. (2016). Unsecured and secured funding. *Working Paper*.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *The review of economic studies*, 51(3):393–414.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of political economy*, 91(3):401–419.

Diamond, D. W. and Rajan, R. G. (2001). Liquidity risk, liquidity creation, and financial fragility: A theory of banking. *Journal of political Economy*, 109(2):287–327.

Donaldson, J. R., Gromb, D., and Piacentino, G. (2017). The paradox of pledgeability. *Working Paper*.

Drucker, S. and Puri, M. (2008). On loan sales, loan contracting, and lending relationships. *The Review of Financial Studies*, 22(7):2835–2872.

Dudley, W. C. (2014). Improving financial institution supervision – examining and addressing regulatory capture. Testimony before the Senate Committee on Banking, Housing, and Urban Affairs, Financial Institutions and Consumer Protection Subcommittee.

EBA (2014). Guidelines on disclosure of encumbered and unencumbered assets. *European Banking Authority/GL/2014/03*.

EBA (2016). Eba report on asset encumbrance. *European Banking Authority reports*.

EBA (2017). Eba risk dashboard. *European Banking Authority reports*.

Eisenbach, T. M., Haughwout, A., Hirtle, B., Kovner, A., Lucca, D. O., and Plosser, M. C. (2015). Supervising large, complex financial institutions: What do supervisors do? *FRB of New York Staff Report*.

Eisenbach, T. M., Lucca, D. O., and Townsend, R. M. (2016). The economics of bank supervision. *NBER Working Paper*.

ESRB (2013). Recommendations of the european systemic risk board of 20 december 2012 on funding of credit institutions. *ESRB reports*.

European Commission (2015). Commission implementing regulation (eu) 2015/79 of 18 december 2014. *Commission Implementing Regulation*.

Fama, E. F. (1985). What's different about banks? *Journal of monetary economics*, 15(1):29–39.

Favara, G. (2012). Agency problems and endogenous investment fluctuations. *The Review of Financial Studies*, 25(7):2301.

Fender, I. and Mitchell, J. (2009). Incentives and tranche retention in securitisation: a screening model.

Freixas, X., Laeven, L., and Peydró, J.-L. (2015). *Systemic Risk, Crises, and Macroprudential Regulation*. MIT Press.

Freixas, X. and Rochet, J.-C. (2008). *Microeconomics of banking*. MIT press.

Gai, T. A. K. A. P. and Chapman, J. (2017). Asset encumbrance, bank funding and fragility. *Working Paper*.

Gande, A. and Saunders, A. (2012). Are banks still special when there is a secondary market for loans? *The Journal of Finance*, 67(5):1649–1684.

Geithner, T. F. (2010). Remarks before the american enterprise institute on financial reform. Technical report.

Gennaioli, N., Shleifer, A., and Vishny, R. (2012). Neglected risks, financial innovation, and financial fragility. *Journal of Financial Economics*, 104(3):452–468.

Goldstein, I. and Pauzner, A. (2005). Demand–deposit contracts and the probability of bank runs. *the Journal of Finance*, 60(3):1293–1327.

Goodhart, C. A. E. and Lastra, R. M. (2010). Border problems. *Journal of International Economic Law*, 13(3):705.

Gorton, G., Lewellen, S., and Metrick, A. (2012). The safe-asset share. *The American Economic Review*, 102(3):101–106.

Gorton, G. and Ordoñez, G. (2014). Collateral crises. *American Economic Review*, 104(2):343–78.

Gorton, G. and Ordoñez, G. (2016). Good booms, bad booms. *NBER Working Paper*.

Gorton, G. B. and Pennacchi, G. G. (1995). Banks and loan sales marketing nonmarketable assets. *Journal of monetary Economics*, 35(3):389–411.

Gu, C., Mattesini, F., Monnet, C., and Wright, R. (2013). Endogenous credit cycles. *Journal of Political Economy*, 121(5):940–965.

Hasan, I., Liu, L., and Zhang, G. (2016). The determinants of global bank credit-default-swap spreads. *Journal of Financial Services Research*, 50(3):275–309.

Helberg, S. and Lindset, S. (2014). How do asset encumbrance and debt regulations affect bank capital and bond risk? *Journal of Banking & Finance*, 44:39–54.

IMF (2013). Changes in bank funding patterns and financial stability risks. *IMF Global Financial Stability Report*.

ISDA (2015). Isda margin survey 2015. *International Swaps and Derivatives Association*.

James, C. (1991). The losses realized in bank failures. *The Journal of Finance*, 46(4):1223–1242.

Jiang, W., Nelson, A. A., and Vytlacil, E. (2013). Securitization and loan performance: Ex ante and ex post relations in the mortgage market. *The Review of Financial Studies*, 27(2):454–483.

Juks, R. (2012). Asset encumbrance and its relevance for financial stability. *Sveriges Riksbank Economic Review*, page 3.

Julio, B., Kim, W., and Weisbach, M. (2007). What determines the structure of corporate debt issues? Technical report, National Bureau of Economic Research.

Kanagaretnam, K., Zhang, G., and Zhang, S. B. (2016). Cds pricing and accounting disclosures: Evidence from us bank holding corporations around the recent financial crisis. *Journal of Financial Stability*, 22:33–44.

Kane, E. J. (1988). Interaction of financial and regulatory innovation. *The American Economic Review*, 78(2):328–334.

Keeley, M. C. (1990). Deposit insurance, risk, and market power in banking. *The American Economic Review*, 80(5):1183–1200.

Keys, B. J., Mukherjee, T., Seru, A., and Vig, V. (2010). Did securitization lead to lax screening? evidence from subprime loans. *The Quarterly journal of economics*, 125(1):307–362.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2012). The aggregate demand for treasury debt. *Journal of Political Economy*, 120(2):233–267.

Kurlat, P. (2015). Liquidity as social expertise. *Working Paper*.

Laeven, L., Levine, R., and Michalopoulos, S. (2015). Financial innovation and endogenous growth. *Journal of Financial Intermediation*, 24(1):1 – 24.

Marshall, D. A. and Prescott, E. S. (2006). State-contingent bank regulation with unobserved actions and unobserved characteristics. *Journal of Economic Dynamics and Control*, 30(11):2015–2049.

Martin, A. (2008). Endogenous credit cycles. *Working Paper*.

Martinez-Miera, D. and Repullo, R. (2017). Search for yield. *Econometrica*, 85(2):351–378.

Matta, R. and Perotti, E. C. (2015). Insecure debt. *Working Paper*.

Matutes, C. and Vives, X. (1996). Competition for deposits, fragility, and insurance. *Journal of Financial Intermediation*, 5(2):184 – 216.

Miller, M. H. (1986). Financial innovation: The last twenty years and the next. *The Journal of Financial and Quantitative Analysis*, 21(4):459–471.

Minsky, H. (1986). *Stabilizing an Unstable Economy*. A Twentieth Century Fund report. Yale University Press.

Morrison, A. D. and White, L. (2005). Crises and capital requirements in banking. *The American Economic Review*, 95(5):1548–1572.

Morrison, A. D. and White, L. (2013). Reputational contagion and optimal regulatory forbearance. *Journal of Financial Economics*, 110(3):642 – 658.

Myerson, R. B. (2012). A model of moral-hazard credit cycles. *Journal of Political Economy*, 120(5):847–878.

Nini, G., Smith, D. C., and Sufi, A. (2009). Creditor control rights and firm investment policy. *Journal of Financial Economics*, 92(3):400–420.

Ordoñez, G. (2013). The asymmetric effects of financial frictions. *Journal of Political Economy*, 121(5):844–895.

Panetta, F. and Pozzolo, A. F. (2010). Why do banks securitize their assets? bank-level evidence from over one hundred countries. *Working paper*.

Parlour, C. A. and Plantin, G. (2008). Loan sales and relationship banking. *The Journal of Finance*, 63(3):1291–1314.

Pavel, C. A., Phillis, D., et al. (1987). Why commercial banks sell loans: An empirical analysis. *Economic Perspectives*, (May):3–14.

Pennacchi, G. G. (1988). Loan sales and the cost of bank capital. *The Journal of Finance*, 43(2):375–396.

Podpiera, J. and Ötker, M. I. (2010). *The fundamental determinants of credit default risk for European large complex financial institutions*. Number 10-153. International Monetary Fund.

Prescott, E. S. (2004). Auditing and bank capital regulation. *Working Paper*.

Purnanandam, A. (2010). Originate-to-distribute model and the subprime mortgage crisis. *The Review of Financial Studies*, 24(6):1881–1915.

Ramakrishnan, R. T. and Thakor, A. V. (1984). Information reliability and a theory of financial intermediation. *The Review of Economic Studies*, 51(3):415–432.

Reinhart, C. M. and Reinhart, V. R. (2010). After the fall. *Working Paper*.

Rochet, J.-C. (2008). *Why Are There So Many Banking Crises?: The Politics and Policy of Bank Regulation*. Princeton University Press.

Schularick, M. and Taylor, A. M. (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *American Economic Review*, 102(2):1029–61.

Silber, W. L. (1983). The process of financial innovation. *The American Economic Review*, 73(2):89–95.

Singh, M. (2010). Collateral, netting and systemic risk in the otc derivatives market. *IMF Working Paper WP/10/99*.

Slovin, M. B., Sushka, M. E., and Polonchek, J. A. (1993). The value of bank durability: Borrowers as bank stakeholders. *The Journal of Finance*, 48(1):247–266.

Smith, C. W. and Warner, J. B. (1979). On financial contracting: An analysis of bond covenants. *Journal of financial economics*, 7(2):117–161.

Stein, J. C. (2002). Information production and capital allocation: Decentralized versus hierarchical firms. *The journal of finance*, 57(5):1891–1921.

Stein, J. C. (2012). Monetary policy as financial stability regulation. *The Quarterly Journal of Economics*, 127(1):57–95.

Stein, J. C. (2013). Overheating in credit markets: origins, measurement, and policy responses. *speech at the "Restoring Household Financial Stability after the Great Recession: Why Household Balance Sheets Matter" research symposium*, 7.

Stulz, R. and Johnson, H. (1985). An analysis of secured debt. *Journal of financial Economics*, 14(4):501–521.

Suarez, J. (1994). Closure rules, market power and risk-taking in a dynamic model of bank behaviour. *Working Paper*.

Suarez, J. and Sussman, O. (1997). Endogenous cycles in a stiglitz–weiss economy. *Journal of Economic Theory*, 76(1):47 – 71.

Thakor, A. V. and Udell, G. F. (1991). Secured lending and default risk: equilibrium analysis, policy implications and empirical results. *The Economic Journal*, 101(406):458–472.

Tufano, P. (2003). Financial innovation. In George M. Constantinides, M. H. and Stulz, R. M., editors, *Corporate Finance*, volume 1, Part A of *Handbook of the Economics of Finance*, pages 307 – 335. Elsevier.

Van Rixtel, A. A. and Gasperini, G. (2013). Financial crises and bank funding: recent experience in the euro area. *BIS Working Papers 406*.

Vanasco, V. (2017). The downside of asset screening for market liquidity. *The Journal of Finance*, 72(5):1937–1982.

Veldkamp, L. L. (2005). Slow boom, sudden crash. *Journal of Economic Theory*, 124(2):230 – 257.

Winton, A. (1999). Don't put all your eggs in one basket? diversification and specialization in lending. *Working Paper*.

Yorulmazer, T. (2013). Has financial innovation made the world riskier? cds, regulatory arbitrage and systemic risk. *Working Paper*.