Essays on bank monitoring, regulation and competition

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Chapter 2

Foundations of Banking

Abstract

I present a unifying framework of banking in which banks both monitor their borrowers and provide liquidity to depositors. In this framework I review the role of several features of banks. I explain how diversification affects banks' monitoring incentives, which are particularly relevant for their role in lending. This asset-side perspective is quite prevalent in the banking literature, and is the main focus of this dissertation. I also analyze bank fragility issues that may lead to bank runs and regulatory resolutions designed to contain bank fragility. Moreover, I discuss the potential positive disciplining effect of (the threat of) fragility in mitigating moral hazard. In addition, this review discusses rationales for capital regulation and for banks to voluntarily hold capital.

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2.1 Introduction

One of the key objectives of this chapter is to understand the role of banks in monitoring borrowers (the asset side). Through monitoring and screening, banks resolve the inaccessibility of capital markets for information-intensive borrowers. Following this, regulatory issues, in particular bank fragility concerns, are addressed. These originate to a large extent from the mismatch between (opaque) assets and liquid deposits. This chapter concludes with some insights from the literature on bank capital and capital regulation.

I survey some core results of the modern banking literature in a unifying model of banking in which banks monitor their borrowers in the sense that they seek to contain borrowers' behavior. A unifying framework allows me not only to review the key contributions of financial intermediation literature and address some open questions (following several surveys, e.g. Bhattacharya, Boot, and Thakor (1998) and Gorton and Winton (2003)), but also to reveal some new connections between various functions that banks perform. To facilitate this, however, sometimes stronger assumptions are made. I organize this review along the following questions: *i*) How banks can commit to monitoring? *ii*) Why banks provide liquidity to their depositors? *iii*) How a combination of monitoring and liquidity provision may cause fragility? *iv*) How fragility could induce depositors to push banks into monitoring? And *v*) why bank capital and capital regulation are critical in committing banks to monitor?

In addition to monitoring, banks also supply liquidity to depositors. Early contributions describing the creation of liquidity include Bryant (1980) and Diamond and Dybvig (1983). Banks provide intertemporal insurance to their depositors. In particular, demand-deposit contracts give depositors the right to withdraw their deposits upon demand. Such liquid contracts could add value because liquidity needs are random and in a large population of depositors diversification therefore allows banks to invest some of these funds in long-term (illiquid) projects. In doing so, banks enable investors to participate in profitable long-term lending without giving up liquidity. Banks could then potentially offer to pay a higher interest rate on short-term deposits in return for a lower long-term rate on deposits compared to capital market investments. For risk-averse investors, this could increase utility. Following Jacklin and Bhattacharya (1988) and Von Thadden (1999), I discuss the conditions for such smoothing to be possible.

While liquidity provision seems to create value for depositors (and hence the bank), it also has drawbacks. In particular, the combination of liquidity provision (via the sequential service constraint) and illiquid and opaque loans could make banks prone to bank runs. That is, the threat of excessive withdrawals could, via anticipated losses on fire sales of assets, make depositors run on their banks in order to retrieve their funds before default occurs. Such (costly) bank runs could provide a rationale for bank regulation, and deposit insurance in particular. I focus on two regulatory resolutions: suspension of convertibility and deposit insurance.

However, following Calomiris and Kahn (1991), a threat of a bank run may also have positive implications. That is, it may exert pressure on banks to follow safe strategies, and/or monitor their borrowers more rigorously. Such pressure may not be strong enough and/or (credible) deposit insurance – as an ultimate remedy to the bank run problem – may have removed it all together. In this case, bank capital could become even more important. In particular, bank capital could act as a commitment for depositors (or the deposit insurer) that their bank will truly monitor its borrowers. Such commitment might be in the self interest of banks, and thus banks may voluntarily choose positive levels of capital. If banks do not fully internalize the cost of a bank run, the regulator may have to impose capital requirements on banks.

I also reconsider the effect of deposit insurance on banks' monitoring incentives and on the probability of bank runs. I show that deposit insurance may subject banks to moral hazard. In particular, following the analysis of Merton (1977) I show that banks lower the level of monitoring if deposit insurance becomes rather generous.

The chapter is organized as follows. Section 2.2 focuses on the role of banks in monitoring. In Section 2.3, I focus on bank fragility stemming from the liquidity provision role of banks. Section 2.4 describes how the sequential service constraint and the liquidity of deposits may work in favor of bank monitoring; that is, they may commit banks to monitoring. In Section 2.5, I analyze the importance of bank capital and capital regulation. Section 2.6 concludes the chapter.

2.2 The Role of Banks in Monitoring

I now highlight and discuss the key conclusions of the literature on the existence of financial intermediaries. A bank's role in monitoring and screening borrowers is central to this literature. Monitoring serves to lower informational asymmetries between investors and borrowers. In particular, following Freixas and Rochet (1999), bank monitoring can be seen as information gathering as in Leland and Pyle (1977), Ramakrishnan and Thakor (1984), and Allen (1990). In this case, banks act on behalf of investors to acquire information about borrowers. Banks either observe the quality of the borrower or verify the cash flows of the borrower (see Townsend (1979) and Krasa and Villamil (1992)).

In addition, monitoring might denote an action of a bank against a deviating borrower as in Diamond (1984). In Holmstrom and Tirole (1997) bank monitoring contains opportunistic behavior. Townsend (1979) focuses on the role of banks and other monitors in auditing borrowers.

Several empirical studies provide evidence on the positive impact that a bank relationship might have on a borrower. James (1987) identifies a positive stock price response to the announcement of a new bank credit arrangement. Building on this, Lummer and McConnell (1989) distinguish between new bank loans and renewals and show that renewals have a positive announcement effect but new bank loans do not. Several other studies, however, show no significant difference between initiations of loans and loan renewals (see Slovin, Johnson, and Glascock (1992), Best and Zhang (1993) and Billett, Flannery, and Garfinkel

(1995)).[1]

I proceed as follows. I first specify a general framework that allows me to capture the core contributions to the literature on bank monitoring. Second, I extend the model to analyze the role of diversification. Third, I relate the analysis to the financial intermediation literature that points to the value of diversification in reducing monitoring costs (Leland and Pyle (1977) and Ramakrishnan and Thakor (1984)). Fourth, I explain the role of financial intermediaries in qualitative asset transformation.

2.2.1 Model specification

Here I present my basic model, which I will expand and modify in each section to study the problem at hand. All agents in the model – banks, borrowers, and depositors – are risk neutral.

The basic characteristics of a borrower are as follows. At $t = 0$, a borrower undertakes a project that demands \$1 of investment. Because the borrower has no initial funds, he must borrow from a bank. Monitoring occurs at $t = 1$. At $t = 2$, the project yields R in the case of success and \$0 in the case of failure.

The bank's main role is to monitor the borrower. A bank incurs a cost c_M to monitor the borrower. Although monitoring is costly for the bank, it increases the quality of the borrower's project. In particular, if monitored, the borrower's project becomes a good project that succeeds with probability p_G; if not monitored, the borrower's project becomes bad and it only succeeds with probability p_B, where $\Delta p \equiv p_G - p_B > 0$.[2]

The bank and depositors can invest in a risk-free asset with a risk-free return r_F. I assume that the expected return of a good project net of monitoring costs is higher than the risk-free return, whereas the expected return of a bad project is lower; that is,

$$p_G R - c_M > r_F > p_B R. \tag{2.1}$$

A bank is financed with deposits. For now, there is no deposit insurance. Also capital is not important. The bank promises to depositors a gross interest rate r_D, where $r_D \geq r_F$. I assume that the bank is a monopolist that seeks to capture all rents. Summarizing, the timeline is as follows. At $t = 0$, the bank raises funds from depositors and lends to the borrower. At $t = 1$, the bank monitors its borrower and, at $t = 2$, payoffs are realized and depositors are repaid. Initially I abstain from deposit insurance; see Figure 2.1.

[1]More recent evidence suggests that the importance of bank loan agreements is declining (see André, Mathieu, and Zhang (2001) and Fields et al. (2006)). However, loan agreements seem to keep their value for small firms, poorly performing firms, in times of greater economic uncertainty, and in banking systems with high quality lenders (see also Boscaljon and Ho (2005)).

[2]This captures the role that banks play in relationship banking: banks invest in borrower-specific knowledge that might be beneficial to their borrowers; see Boot and Thakor (2000) and Ongena and Smith (2000) for reviews of relationship banking.

$t = 0$:	$t = 1$:	$t = 2$:
♠ The bank gathers funds from depositors and lends to borrower(s).	♠ The bank can monitor its borrower(s).	♠ Payoffs are realized.

Figure 2.1: The basic sequence of events

2.2.2 Preliminary discussion: Monitoring incentives

I first analyze the incentives of a bank to monitor its borrower. That is, I compute the profit of the bank conditional on monitoring and compare this with what the bank earns without monitoring.

Conditional on monitoring, the bank's profit is computed as follows. Bank monitoring costs c_M but increases the quality of the borrower's project. In particular, the borrower undertakes a good project that succeeds with probability p_G. If the borrower succeeds, the monopolistic bank takes rents R but it must repay the deposit rate r_D at $t = 2$. If the borrower fails, the bank gains zero profit and also fails to repay its depositors. The profit of the bank conditional on monitoring is

$$\Pi_M(r_D) = p_G[R - r_D] - c_M. \tag{2.2}$$

If the bank does not monitor, it saves the cost of monitoring. However, now the borrower undertakes a bad project and hence only succeeds with probability p_B. The bank's profit conditional on the absence of monitoring is

$$\Pi_{NM}(r_D) = p_B[R - r_D]. \tag{2.3}$$

Because bad projects have a negative NPV, a bank cannot operate if it abstains from monitoring. Depositors will anticipate this and will not provide funding. That is, depositors would demand a return r_D, such that the anticipated return $p_B r_D$ equals the return r_F that they require; that is, $r_D = \frac{r_F}{p_B}$. However, with these costs of deposits the bank's profit is negative; that is,

$$\Pi_{NM}(\frac{r_F}{p_B}) = p_B R - r_F,$$

which is negative due to the condition in (2.1). Hence, the bank can only operate if it convinces depositors that it will monitor its borrower. A bank has an incentive to monitor if $\Pi_M(r_D) > \Pi_{NM}(r_D)$. Using (2.2) and (2.3), one needs

$$p_G[R - r_D] - c_M > p_B[R - r_D]. \tag{2.4}$$

At the same time, depositors demand a return r_D such that their anticipated return $p_G r_D$ equals the return r_F; that is, $r_D = \frac{r_F}{p_G}$. Insert this into (2.4) to see that deposit taking and lending is only possible if

$$c_M \leq \bar{c}_M, \text{ where } \bar{c}_M \equiv \Delta p[R - \frac{r_F}{p_G}]. \tag{2.5}$$

The condition in (2.5) shows that the bank is only willing to finance the borrower if the cost of monitoring is not too high. Borrowers with high costs of monitoring (i.e., $c_M > \bar{c}_M$) therefore stay without funds even though they could undertake profitable projects (as guaranteed by the condition in (2.1)). The intuition for this is that a bank cannot commit to monitor such a borrower if the cost of monitoring is too high. In the absence of monitoring, the borrower undertakes an unprofitable project. Depositors anticipate this and are unwilling to finance such a bank. Hence, the bank cannot afford to finance such a borrower.

The reason why a borrower with (potentially) profitable projects can stay without bank financing deserves further explanation. Because monitoring is not contractible, the bank should be incentivized correctly, such that monitoring is also beneficial for the bank. However, if the cost of monitoring is high, this may be difficult. In this case, the bank may prefer to stop monitoring (and spare the cost c_M) and gamble on the project. If the borrower succeeds, the bank gains; in the case of a failure, depositors lose.

I follow the banking literature and present several ways how banks commit to monitoring. I start with the role of diversification. Financing several borrowers at the same time and diversifying allows the bank to better commit to monitoring.

2.2.3 Diversified intermediaries

One of the main characteristics of financial intermediaries is that they raise funds from many depositors and lend to many borrowers. In the following simplified framework I analyze how diversification affects a bank's incentives to monitor its borrowers. A key result is that a diversified bank can easily commit to monitoring.

I allow for diversification as follows. The bank lends \$1 of funds in total to N equally sized borrowers, such that each borrows $\frac{1}{N}$ with a return of $\frac{R}{N}$. For a more general distribution, see Tirole (2006, p. 158). As before, p_B is small, such that the bad project is negative NPV.

I distinguish between two cases. In the first case, projects are perfectly correlated. A bank that finances N borrowers then receives in total $p_G[N\frac{R}{N} - r_D] - c_M$ if it monitors (which is the same as in (2.2)) and $p_B[N\frac{R}{N} - r_D]$ if it stops monitoring its borrowers (the same as (2.3)).

However, if borrowers' returns are independent, the situation changes. I now establish that a bank is then induced to monitor more. Assume for now that the bank is solvent as long as at least one borrower succeeds. It is easy to see that the bank now succeeds with a higher probability $p_G(N) = 1 - [1 - p_G]^N$ in the case of monitoring and $p_B(N) = 1 - [1 - p_B]^N$ in the absence of monitoring, where $p_B(N) > p_B$ and $p'_G(N) > 0$ and $p'_B(N) > 0$, than without diversification. The expected return of each borrower conditional on monitoring vs. no monitoring is the same as without diversification; that is, R vs. $p_B R$. However, a diversified bank succeeds more often even if it abstains from monitoring. That is, it has to repay its depositors with probability $p(N)$. That is, in expectation it repays to depositors $p(N)r_D$.

Hence, in the case of independent borrowers' returns, the incentive constraint for the bank to monitor its borrowers changes. The following inequality has to be satisfied,

$$p_G R - p_G(N)r_D - c_M > p_B R - p_B(N)r_D. \tag{2.6}$$

Note that the left side of (2.6) describes the profit of the bank in the case of monitoring. Hence the bank receives $p_G \frac{R}{N}$ on each borrower; hence, in total $p_G R$. However, it has to repay depositors, which in expectations cost $p_G(N)r_D$, and incurs monitoring cost c_M. The right side of (2.6) is the expected profit if the bank deviates and stops monitoring. In expectations, the bank receives $\frac{p_B R}{N}$ on each borrower; hence in total $p_B R$. The bank now incurs no monitoring cost and repays r_D to depositors with probability $p_B(N)$.

Rearranging (2.6) shows that the bank monitors the borrowers if

$$c_M < \bar{c}_M(N), \text{ where } \bar{c}_M(N) \equiv \bar{c}_M + [\frac{p_B(N)}{p_G(N)} - \frac{p_B}{p_G}]r_F, \tag{2.7}$$

and $\bar{c}_M$ is as defined in (2.5). I can now show the following proposition.

Proposition 2.1. *Diversification enables the bank to finance borrowers for which a cost of monitoring is high; that is, $\bar{c}_M(N) > \bar{c}_M$.*

The intuition for Proposition 2.1 is the following. Note that diversification does not change a bank's expected return on its borrowers. However, a well-diversified bank succeeds with higher probability in repaying its depositors. This then contains the risk-shifting incentives of a bank. In particular, now the bank instead of depositors must internalize a larger part of the losses if one of its borrowers fails. Hence, the bank is incentivized more to monitor its borrowers.

Diamond (1984) shows that completely diversified financial intermediary can easily commit to monitoring (see Section 2.2.5 for further discussion). Proposition 2.1 replicates this result. In particular, $\bar{c}_M(N = \infty) = \Delta p R$; hence, (2.1) guarantees that $c_M < \bar{c}_M(N = \infty)$ always holds. That is, the bank can always commit to monitoring if it is completely diversified.

Proposition 2.1 has the following empirical implication. It predicts that a better diversified bank might be willing to finance more opaque borrowers – that is, borrowers that demand higher monitoring (i.e., small, more opaque borrowers). Empirical evidence on this aspect is inconclusive, however. Different lending technologies differently affect banks' abilities to lend to opaque borrowers. Large banks seem to be better at gathering hard information through transaction technologies such as factoring, leasing, small business credit scoring (see Berger, Rosen, and Udell (2007) and Berger and Udell (2006), whereas small banks are better at gathering soft information through relationship lending (see Stein (2002) and Berger et al.

(2005)).

Now I can extend the analysis a bit further to give predictions on how increased competition for deposits would change the incentive of a bank to monitor. If competition for deposits increases, a bank may have to offer depositors a higher deposit rate. A simple way to analyze the effects of higher competition for deposits is to observe the effect of an increase in r_F.

Corollary 2.1. *An increase in competition (via higher r_F) lowers the monitoring incentives of a bank.*

Corollary 2.1 replicates the analysis of Keeley (1990). The intuition is as follows. As competition for deposits increases, the bank expects to earn lower rents, hence lowering the attractiveness of its marginal borrowers. In effect this means that a bank has lower incentives to incur monitoring costs in order to increase its success probability. That is, lowering bank rents makes monitoring less valuable.

The following corollary connects the effects of diversification and competition.

Corollary 2.2. *Diversification is (even) more effective if competition for deposits is high (high r_F).*

Corollary 2.2 stems from two observations of Corollary 2.1 and Proposition 2.1. First, if competition for deposits is high, the risk-shifting behavior of a bank is more pronounced (see Corollary 2.1). Second, diversification reduces risk shifting because it increases the success probability of a bank. That is, a bank better internalizes the costs of less monitoring (see Proposition 2.1). Hence, diversification that contains risk shifting has the highest effect if risk shifting is high, that is, if competition is high. In contrast, if competition for deposits is low, the risk-shifting behavior of a bank (i.e., lowering monitoring) is relatively limited and diversification has a lower effect.

Up to my knowledge this result has not yet been derived. Winton (1997) establishes a reversed relation between diversification and competition. He argues that bank owners have less incentives to engage in competition if a bigger bank becomes more diversified. In particular, higher competition brings additional market share and additional diversification which benefits mostly debtholders. Corollary 2.2 shows that diversification is especially valuable if competition between banks is high because a diversified bank can commit to monitoring. This contradicts Besanko and Thakor (1993) who argue that higher competition may induce banks to select risky, less diversified portfolio. Note, however, that their result depends on the presence of deposit insurance. Without deposit insurance, a bank in a competitive banking system can not raise deposits without being diversified. Thus, competition in this case forces banks to diversify via a market discipline mechanism.

The implications of Corollary 2.1 and Corollary 2.2 are immediate. Competition may undermine a bank's incentive to monitor. Diversification then helps because it mitigates moral hazard.

I have presented a very simplified model to explain the bank's role in monitoring. Banks that pool many borrowers together and thus diversify are better at committing to monitoring their borrowers. In the next section I link the main insights from my simple model of bank monitoring to literature on banks' existence. Central to this literature is that bank monitoring contains information asymmetries between firms and investors.

2.2.4 Information acquisition: Intermediaries as information sellers

I now review the contributions that focus on the role of banks as information producers. In this view, agents endogenously join together and form a bank because this allows for more efficient information production than each individual agent could achieve on his own.

Broadly speaking, one could argue that banks mediate information asymmetries between firms and investors. Normally, firms have more information about the prospects of their projects than investors. Especially if investors are small, they have little incentive to incur monitoring costs in order to lower information asymmetries. Banks, however, pool a large number of investors together and as such could be delegated information producers.

The cost advantages that banks possibly achieve in information acquisition stem not only from pooling together funds from small investors (some type of scale economies), but also could be skill related (e.g. benefits of specialization). In addition, banks could possibly reuse information across time and across different borrowers better than individual agents could (see Chan, Greenbaum, and Thakor (1986)).

Leland and Pyle (1977) were the first to rationalize banks as mediators of information asymmetries. They applied insights from the (then) emerging field of information economics to financial intermediation; see Akerlof (1970), Spence (1973) and Rothschild and Stiglitz (1976). In their analysis, entrepreneurs differ in the profitability of their projects. Risk-averse entrepreneurs prefer borrowing funds to self investing; however, borrowing might be limited due to information asymmetries. In particular, because investors cannot determine the profitability of entrepreneurs, they charge entrepreneurs a high lemon cost of financing. That is, charging the actuarially fair average cost is not sustainable because this would induce an adverse selection problem with only risky entrepreneurs raising funds at this average rate. Leland and Pyle (1977) argue that the "good" entrepreneurs choose to (partially) self finance to separate themselves from bad risks. Building on this, Leland and Pyle (1977) suggest that good entrepreneurs may form a coalition to lower the costs of such separation. Diamond (1984) expands this reasoning by showing that potential diversification in the coalition could lower the costs of this separation even further.

Ramakrishnan and Thakor (1984) explain the information acquisition function of financial institutions. They focus on the incentive contract between an investor as a risk-averse principal and risk-averse agents that gather information about the prospects of borrowers; that is, they screen firms. Ramakrishnan and Thakor (1984) show that diversification among information-producing agents may help reduce the agency problem between the principal and information-producing agents. As long as the projects of the firms are uncorrelated and agents can observe their respective efforts (no moral hazard between agents), the formation of a coalition lowers the agency cost per agent.

Ramakrishnan and Thakor (1984) argue that two conditions must be satisfied for financial intermediation to occur; that is, the formation of a coalition of information-producing agents. First, the projects should be diversifiable (i.e., the correlation should not be too high). Second, sufficiently many projects should exist; that is, sufficient diversification should be possible. In this case, the total agency costs of the financial intermediary become small compared to the sum of total agency costs of individual entrepreneurs.[3]

Allen (1990) shows that a financial intermediary might be better at selling information than an individual agent. This is because agents on their own may be forced to leave some rents in order to commit to truthful reporting of information. A coalition of agents in a financial intermediary can better commit to truthful reporting and hence extract additional rents from information selling.

The financial intermediary as described above could be viewed as a pure brokerage institution that produces information for resale. Examples are analysts providing financial advice on investments and credit rating agencies that screen and certify firms, and bond issues.

In summary, agents that produce and resell information may have incentives to form coalitions. I have reviewed several contributions that discuss such endogenous formation of financial intermediaries and their role as information producers. The scope of these papers is quite broad and may be applied to many different types of financial intermediaries. In fact, with the increasing importance of fee business in banking, such brokerage rather than the asset-transformation role is gaining importance. However, depository financial institutions involving asset transformation are (still) of considerable importance. The next chapter focuses on such institutions and, in particular, on the asset transformation role that they perform.

2.2.5 Asset transformation

Banks not only produce information but they also act as asset transformers. They provide for transformation of maturity, liquidity, and risk between their assets and liabilities. In particular, banks fund risky borrowers with low-risk deposits. Analyzing this asset transformation role also illuminates why debt contracts may be an optimal contract between banks and depositors and between banks and borrowers.

Diamond (1984) provides the following explanation of the asset transformation role of banks. Without banks, depositors could lend funds directly to borrowers. Doing so, depositors should monitor borrowers to guarantee repayments of the loans. This, however, may

[3] Both Diamond (1984) and Ramakrishnan and Thakor (1984) predict that banks would be of infinite size. In reality, several small banks exist as well. Millon and Thakor (1985) show that the underlying assumption of Ramakrishnan and Thakor's model is that agents costlessly observe the efforts of other agents in the coalition. If the efforts in the coalition are observable only at a cost, several finite financial institutions may appear.

result in several inefficiencies. First, monitoring may be duplicated. Second, depositors may free ride on each other, such that at the end nobody monitors. A bank that gathers funds from depositors and lends them to borrowers resolves these monitoring problems. Although the bank still has to monitor borrowers, Diamond (1984) shows that depositors do not need to monitor a well-diversified bank. He shows that writing a standard debt contract between depositors and a well-diversified bank may guarantee bank monitoring. With this he elegantly solves the problem of who monitors the bank – in his view, nobody needs to monitor a well-diversified bank.

The rationale for why diversification guarantees bank monitoring is the following. Diamond (1984) adds the possibility of non-pecuniary punishment to the standard debt contract between depositors and the bank.[4] In particular, if the bank breaches its contractual obligations and fails to repay depositors, it is punished. Punishment may be an instrument that helps induce the bank to always monitor the borrowers. A dark side of punishment is that an (undiversified) bank may fail even if it monitors the borrower. In this case, punishment is costly for a bank. However, a well-diversified bank that monitors will never fail and costly punishment will never be realized. The sole threat of punishment is enough to incentivize a well-diversified bank to monitor. Hence, punishment is a costless device to induce a well-diversified bank to monitor.

Despite its unquestionable importance, Diamond's analysis has some shortcomings. In particular, the existence of non-pecuniary punishments seems to be unrealistic. While a literal interpretation is far-fetched – banks neither physically punish their defaulted borrowers nor put them in jail – a more realistic interpretation such as the loss of reputation as a mechanism of non-pecuniary punishment also has some difficulties. In particular, investors can hardly fine-tune the loss of reputation to the final outcome of the returns of the bank. However, this is necessary to commit the bank to truthfully report its returns while minimizing the cost of punishment. Moreover, Diamond's analysis suggests that intermediaries should be infinite, which does not seem realistic.

Several other contributions complement Diamond (1984) and further justify the existence of a debt contract. Townsend (1979) and Gale and Hellwig (1985) use a costly state verification approach to justify the existence of the standard debt contract. If it is costly to monitor the performance of borrowers, banks design their lending contracts to minimize monitoring costs. Townsend (1979) and Gale and Hellwig (1985) show that conditioning monitoring on default is an optimal strategy. This leads to a debt contract in which equal payments are made in non-default. A few assumptions are that banks are limited to deterministic monitoring and borrowers are risk neutral. In other words, they show that a standard debt contract minimizes the monitoring cost. In addition, the bank should monitor more if the firm performs badly.

Another rationale for the use of debt contracts is given by Gorton and Pennacchi (1990).

[4]In Diamond (1984), the punishment is a non-pecuniary penalty such as the loss of reputation or physical punishment.

In Gorton and Pennacchi's contribution, the role of a financial intermediary is to design securities that split the cash flows of the underlying assets into securities of different informational content. In their setting, debt contracts are used to protect uninformed traders on the capital markets. They show that firms optimally divide their cash flows into two securities, equity and debt. Uninformed traders protect themselves by buying a security with low informational content; that is, debt security. In contrast, informed traders buy equity contract that contains a lot of information about firm profitability. This is reminiscent of later work on optimal security design by Boot and Thakor (1997) and DeMarzo and Duffie (1999).

To summarize, financial intermediation occurs because markets may be unable to resolve information asymmetries. The various contributions discussed above consider various types of informational frictions and present rationales for different forms of financial intermediaries such as banks, investment banks, credit-rating agencies, and mutual funds.

2.3 Bank Fragility and Regulation

Another feature that distinguishes banks from other firms is that they provide liquidity to their depositors. Liquidity provision is intrinsically linked to the sequential service constraint (SSC) in demand deposits. A feature that could make liquidity provision beneficial is that banks pool together large group of deposits and insure depositors against shocks in their consumption needs. Banks can invest part of the gathered funds in liquid assets (to cover the stochastic early consumption need of depositors) and another part in illiquid loans. They then use the liquid assets to repay depositors with early consumption needs while depositors with late consumption needs are repayed with illiquid loans. Having many depositors makes this liquidity need rather predictable in the aggregate. Yet, liquidity provision also makes banks intrinsically fragile institutions. That is, if many depositors unexpectedly withdraw their funds for reasons other than liquidity needs, a bank might have to liquidate its illiquid loans at possibly high costs.

In this section I first evaluate the benefits of liquidity provision as put forward by Diamond and Dybvig (1983). Key in Diamond and Dybvig is the possibility of a sunspot bank run. I also evaluate two regulatory mechanisms that prevent bank runs: deposit insurance and limitations on convertibility.

2.3.1 Liquidity provision

Following Diamond and Dybvig (1983), I use the following simple model. Depositors are risk-averse and initially identical. Each depositor invests his endowment of \$1 at $t = 0$. At $t = 1$, he finds out whether he must consume immediately or must wait on consumption until $t = 2$. With the short-term return r_{D1} and the long-term return r_D, consumption at $t = 1$ brings him utility $U(r_{D1})$. If a depositor must wait on consumption until $t = 2$, he obtains utility $U(r_D)$. For simplicity, I assume that the depositor's utility function has a constant

$t = 0$:	$t = 1$:	$t = 2$:
♠ The bank gathers funds from depositors and invests in long-term projects.	♠ Depositors may have a liquidity need. ♠ The bank liquidates some long-term projects to repay early withdrawals.	♠ Payoffs are realized.

Figure 2.2: The sequence of events accounting for depositors' liquidity needs

intertemporal relative risk aversion:

$$U'(r) = r^{-a}, \text{ and } U(r) = \frac{r^{1-a}}{1-a},$$

where $a > 1$.[5] The probability of an early consumption need is ρ and the probability of late consumption is $[1-\rho]$. Probabilities are independently distributed among depositors. Hence, the expected utility of a depositor is

$$u(r_{D1}, r_D) = \rho U(r_{D1}) + [1-\rho]U(r_D). \tag{2.8}$$

There exist only one type of (long-term) project to invest in. Investments are made at $t = 0$. The (long-term) project payoff is R at $t = 2$ per \$1 of invested funds. Early liquidation, however, is possible. If the project is prematurely liquidated, it returns only the nominal invested funds; see Figure 2.2.

I first analyze a situation of autarky in which depositors directly invest in the project (finance the borrower). With probability ρ depositors must consume early; that is, at $t = 1$. This forces them to liquidate their investments, realizing each a return of \$1. With probability $[1-\rho]$ they consume late. In this case, they receive a return R. A depositor's expected utility with such direct investment is (use (2.8))

$$U_A = \frac{\rho}{1-a} + \frac{1-\rho}{1-a}R^{1-a}. \tag{2.9}$$

When there is only one investment opportunity, a trade between depositors cannot improve the outcome in autarky. This is because everybody invests in the same type of project and trade cannot occur. This is different if depositors can invest in projects of different types. Then trade occurs between depositors that have a short-term project but a long-term liquidity need and depositors with a long-term project but a short-term liquidity need. The option to trade then increases depositors' utilities (see Bhattacharya and Gale (1987) and Von Thadden (1997)).

Now I compare autarky with the outcome that a bank can provide. For the moment, I assume that the bank only performs liquidity provision ignoring asset-side monitoring. The

[5]The assumption of $a > 1$ is common in the literature (see Diamond and Dybvig (1983) and Von Thadden (1999)). It guarantees that the liquidity provision role of a bank is valuable.

bank's added value thus should come completely from its role in liquidity provision. A bank promises its depositors the deposit rate r_{D1} for early withdrawals and r_D for late withdrawals. Although initially the bank invests all its funds in (long-term) projects, it must liquidate the proportion ρr_{D1} of its investments to repay early depositors. The proportion $1 - \rho r_{D1}$ of investments is not liquidated and yields a final return R.

The bank solves the following optimization problem:

$$\Pi^* = \max_{r_{D1}, r_D} [1 - \rho r_{D1}]R - [1 - \rho]r_D \tag{2.10}$$

$$s.t.$$

$$\rho U(r_{D1}) + [1 - \rho]U(r_D) \geq U_A. \tag{2.11}$$

The bank maximizes its expected profit in (2.10) under the condition that the incentive constraint in (2.11) is satisfied. In particular, the bank must offer depositors at least the utility U_A that they can obtain in autarky (see (2.9)).

In equilibrium, a bank offers $\{r^*_{D1}, r^*_D\}$, which solves (2.10), where $1 < r^*_{D1} < r^*_D < R$. The bank makes positive profits, that is, in equilibrium $\Pi^* > 0$. This shows that banks create value for depositors through liquidity provision. More specifically, banks provide intertemporal insurance for depositors. That is, intertemporarily risk-averse depositors value intertemporarily smoothed payoffs. Put another way, in expected value sense the depositors' utility increases if the bank subsidizes depositors with early consumption needs at the expense of depositors with late consumption needs. This replicates Diamond and Dybvig (1983). In Diamond and Dybvig (1983), however, banks maximize the depositors' utilities whereas in my case banks maximize their own profits. That is, banks may achieve equal utility for depositors compared to autarky and at the same time realize some profits.

The literature includes several follow-up studies extending the findings of Diamond and Dybvig (1983). Jacklin (1987) shows that if deposit contracts are allowed to be traded at $t = 1$ this would unravel the bank's added value; that is, in such a case carefully designed equity contracts providing dividends in the interim period could provide just as much liquidity provision as a demand-deposit contract.

In response to this critique, Bhattacharya and Gale (1987) and Von Thadden (1997) argue that, in addition to liquidity provision, banks also transform the maturities of assets. In particular, allowing for a second, short-term investment opportunity, they show that banks better allocate funds between short-term and long-term assets providing for liquidity *and* maturity transformation superior to what markets can achieve.

The rationale why banks provide better intertemporal insurance and maturity transformation than capital markets deserves further attention. With capital markets, depositors cannot commit to the level of price at which assets will be traded. Consequently, the optimal allocation between short-term and long-term assets is not an equilibrium outcome. In particular, if depositors select the optimal allocation, each depositor has an opportunity for a valuable deviation. That is, a depositor can invest more in a long-term and less in a short-term asset than in the optimal allocation. By doing this, the depositor can gain in trade, after the price is formed on the market. In contrast, a bank can commit to the socially optimal allocation because it can commit ex-ante to the fixed payoffs of depositors.

Several other contributions further highlight the role of liquidity provision. Von Thadden (1997) shows that the liquidity provision and the monitoring function of banks interact and should not be viewed separately. Pooling of intermediation functions may reduce moral hazard problems and enhance bank stability by mediating the liquidity problems of demand-deposit contracts.

Allen and Gale (1997) use a standard overlapping generations model to show that financial intermediaries provide for better intertemporal insurance than capital markets. More specifically, people cannot insure against a bad outcome ex ante; that is, before they are born. This makes capital markets incomplete such that underinvestment in safe assets occurs. Financial intermediaries can smooth the returns by accumulating reserves of safe assets and this may lead to a Pareto efficient outcome.

So far, I have used the word *liquidity* in the context of Diamond and Dybvig (1983). In particular, an asset is considered liquid as long as agents can choose when to use it (intertemporarily) for consumption when they would like to do so. In contrast, Holmstrom and Tirole (1998) provide for a slightly different definition of liquidity. In their view, instruments are liquid if they allow intertemporal transformation of welfare. Holmstrom and Tirole (1998) argue that banks act as coordinators of the use of scarce liquidity. That is, banks redistribute liquidity from firms that have excess liquidity to firms that need liquidity.

Several distinct notions of liquidity might be the reason why empirical research on bank liquidity creation is scarce. Kashyap, Rajan, and Stein (2002) find evidence that banks provide liquidity both on the liability side (via demand deposits) as well as on the asset side via loan commitments. To the extent that deposit withdrawals and commitment takedowns are imperfectly correlated, banks create synergies in combining both functions.

Deep and Schaefer (2004) and Berger and Bouwman (2007) attempt to directly measure liquidity creation by banks. Deep and Schaefer (2004) only consider on–balance sheet items. They compute the liquidity transformation gap as the difference between liquid liabilities and assets held by a bank, scaled by its total assets. Using this measure they show that liquidity transformation of the U.S. banking industry is, at best, modest. However, Berger and Bouwman (2007) include off–balance sheet items in their analysis and obtain a reversed result. They estimate that the U.S. banking industry creates \$2.5 of liquidity per \$1 of capital. They also find that bank liquidity creation has increased substantially in the last decade. Nevertheless, these studies on liquidity creation are still very incomplete. For example, Berger and Bouwman (2007) do not capture the liquidity created by non-banking vehicles (e.g., ABCP conduits).

To summarize, several papers highlight banks as liquidity providers. Future research should develop testable hypotheses pinpointing the exact role that banks play in liquidity provision. In the next section, I turn to the fragility that a combination of liquidity provision and investing in opaque assets may bring.

2.3.2 Sunspot bank runs vs. information-based bank runs

So far, I have presented a rather positive perspective on banks and in a sense on bank stability as well. In the view of Diamond (1984) and Ramakrishnan and Thakor (1984), banks can completely diversify and hence they never fail (see Section 2.2). However, this assumption is frequently violated in reality. That is, banks cannot completely diversify themselves and hence default risk may exist. In the context of Diamond and Dybvig (1983), bank activity is more at risk. The combination of opaque assets and liquid (withdrawable on demand) deposits could expose banks to costly runs. I now first discuss the potential fragility of banks stemming from banks' liquidity provision function. Second, I turn to an information-based rationale for bank runs; namely, averse information about a bank's loans that may trigger a bank run.

I first focus on a purely liquidity-driven bank run as first described by Diamond and Dybvig (1983). In terms of this model, if "many" depositors withdraw early a bank may have to liquidate more projects than anticipated. Because early liquidation is costly (assets need to be liquidated forgoing returns) and early withdrawals have a subsidized rate, late depositors suffer. With sufficiently high unexpected early withdrawals, late depositors might be better off withdrawing their funds prematurely as well. Even worse, trying to beat the crowd by being first in line is becoming an increasingly attractive option when many other early withdrawals are anticipated. This triggers what is known as a sunspot bank run.

The optimization problem in (2.10) has two equilibria. In the first, only a proportion ρ of the depositors withdraw early, and the others withdraw late. In the second, Pareto inferior equilibrium, all depositors withdraw early.

A prevalent criticism of sunspot bank runs is that they lack a trigger mechanism. Sunspot bank runs in Diamond and Dybvig (1983) are not correlated with the economic variables. Empirical findings contradict this. Empirical studies persistently show that bank runs are a consequence of deterioration of bank quality reflected in different economic indicators; for example, increasing small business failure rates (see Gorton (1988) and Demirgüç-Kunt and Detragiache (2002)). I respond to this criticism first by reviewing several contributions in the literature that describe the notion of the informational bank run (see Chari and Jagannathan (1988) and Jacklin and Bhattacharya (1988)). In Section 2.4, I extend the model by analyzing the potential disciplining role that the threat of a bank run could have.

Banks are characterized both by liquidity provision *and* by having opaque assets. In particular, giving credit to monitoring-intensive borrowers makes banks opaque on the asset side (see Morgan (2002)). A combination of opaque assets and liquid deposits makes banks sensitive to what is called information-based bank runs. Chari and Jagannathan (1988) and Jacklin and Bhattacharya (1988) analyze such information-induced bank runs. In their setting, a group of depositors observe the risk of a bank and, when they observe (too) high risk, they withdraw early. Other depositors, however, observe only the amount of the withdrawals (i.e., the line in front of the bank), but not the underlying information of bank asset quality. Hence, they do not know whether early withdrawals are a consequence of early liquidity needs or are information based. Consequently, information-driven bank runs and also sunspot bank runs can both occur as equilibrium events.

In a related model, Goldstein and Pauzner (2005) connect the probability of a bank run to underlying economic fundamentals. In their model, the beliefs of investors are determined by economic fundamentals. That is, economic fundamentals do not directly induce withdrawals, but instead serve as a device that coordinates the beliefs of investors on a particular outcome. They show that inefficient (i.e., sunspot) bank runs occur more often at a bank that offers higher short-term interest rates; that is, at banks that offer more intertemporal risk sharing. A bank will then weight the benefits of risk sharing with the drawback of inducing an inefficient bank run in determining the level of liquidity provision for its depositors.

To summarize, financial intermediation theory argues that bank runs may either be pure sunspot phenomena or be information based. In both cases, bank runs are costly events that may provide a rationale for bank regulation.

2.3.3 Cost of bank runs and regulatory resolutions

The banking sector is considered special because of the externalities that banks could impose on the economy at large. A bank run imposes externalities and possibly negatively affects social welfare for several reasons. First, a bank run may potentially spread and provoke a systemic bank crisis. Second, bank failures can produce a sharp monetary contraction and induce a recession (see Bernanke (1983) for an argument that banking crises deepened the severity of the Great Depression). Third, the failure of banks may reduce the supply of bank loans, which is especially detrimental to small- and medium-sized business financing (see Hubbard, Kuttner, and Palia (2002)). A total collapse of a banking system might even cause a breakdown of the payment system and impair trade.

Empirical research confirms that the costs of bank crises are high. However, no agreement exists on how costly crises are. First, in cross-country studies, Hoggarth, Reis, and Saporta (2002) assess the costs of banking instability at 15 to 20% of annual GDP. Second, Bordo, Eichengreen, Klingebiel, and Martinez-Peria (2001) extend their analysis over the past 120 years of financial history to show that the frequency of crises has been rising. They assess the output losses of a crises at 6 to 8% of an annual GDP for a single banking crisis, but well over 10% if a banking crisis is accompanied by a currency crisis. In any case, these estimates confirm that banking crises are costly.

The broad economic importance of bank stability and considerable costs of bank instability to the economy at large justify the existence of extensive banking regulation. There are two main resolutions to costly bank runs: suspension of convertibility and deposit insurance.

Suspension of convertibility seems to be the optimal response in a case in which the liquidity shocks are i.i.d. among depositors. In this case, the bank only repays an expected proportion of depositors in the first period. Announcing this, and assuming an infinitely large bank, provides perfect resolution. In particular, suspension of convertibility precludes losses because it prevents excessive early withdrawals, which would otherwise lead to firesales. Depositors anticipate that there will be no losses and are comfortable with leaving their funds in the bank. Consequently, only depositors with early liquidity needs raise their funds.

Suspension of convertibility becomes more problematic if liquidity shocks are partially correlated (and/or not fully diversified). In this case, suspension of convertibility induces suboptimal liquidity provision because not all depositors with an early liquidity need are able to withdraw their funds (see Diamond and Dybvig (1983)). In the case of information-based bank runs, matters are more complicated. Suspension of convertibility may again lead to a suboptimal liquidity provision (see Chari and Jagannathan (1988)).

If the implicit costs of suspension of convertibility are high, deposit insurance may become a preferred regulatory policy. Credible deposit insurance eliminates bank runs. Excessive early withdrawals are then backed by government bonds and taxed. However, deposit insurance is *not* socially costless. The cost of deposit insurance stems from the deadweight costs that taxation brings. In a richer setting, either regulatory intervention could also have an impact on the given problem between a bank and investors.

Gorton and Pennacchi (1990) justify the existence of deposit insurance in another way. In their view, deposit insurance is valuable because it protects uninformed agents (i.e., depositors), from being abused from the informed traders that hold bank equity.

To summarize, deposit insurance is an optimal regulatory policy if the deadweight costs of taxation are lower than the costs of suboptimal liquidity provision that the suspension of convertibility could bring. In this section, I have presented a view in which bank runs are purely negative phenomena and regulation is needed to prevent them. In the next section, however, I present an argument why (the threat of) bank runs might serve a useful economic function. In particular, the threat of a bank run could discipline banks to behave prudently.

2.4 Is There Something Good about the SSC?

So far, the liquidity of deposits via the sequential service constraint (SSC) was shown to have drawbacks; that is, it may cause bank runs. Why then does the SSC exist and, more specifically, what could be the positive role of the SSC? This section shows that the SSC may act as a threat that commits banks to monitoring.

Liquidity provision and the sequential service constraint may now play a valuable role.

2.4.1 Analysis

I now analyze a situation in which depositors can monitor their banks and pressure them to behave prudently. In particular, depositors may make a run on the bank after obtaining a negative signal, and this may be damaging for the bank. Such a prospect could discipline the bank.

$t = 0$:	$t = 1$:	$t = 2$:
♠ The bank gathers funds from depositors and lends to a borrower.	♠ The bank can monitor its borrower. ♠ Depositors obtain a signal about bank monitoring. ♠ Depositors can threaten to run on the bank and force it to invest in a transparent monitoring technology.	♠ Payoffs are realized.

Figure 2.3: Sequence of events with a bank run as a threat

I assume that there is no deposit insurance. This is obviously important; otherwise, no depositors would choose to run. Depositors are risk neutral.[6] With probability α, all depositors obtain a (costless) signal at $t = 1$. With probability $1 - \alpha$, depositors receive no signal. The signal perfectly reveals whether the bank has monitored its borrower. If the signal shows no monitoring, depositors run on the bank. Calomiris and Kahn (1991) model a bank run as liquidation of the bank. In contrast, I allow for a less punishing role of a bank run. I assume that depositors that run on the bank may be persuaded to leave their funds at the bank.

In particular, the bank can restore the confidence of depositors by making its monitoring technology transparent. In this case, bank monitoring is contractible; however, the transparent monitoring technology is less effective. That is, in the case of the transparent monitoring technology, the success probability p_T of the borrower's project is lower than the success probability of a good project, but higher than the success probability of a bad project; that is, $p_G > p_T > p_B$. Figure 2.3 depicts the sequence of events.

Resolution of a bank run in this way seems to better match reality. More specifically, in the case of a bank run usually the regulator (or acquiring bank) steps in. The regulator may force the troubled bank to become transparent (i.e., to invest in the transparent monitoring technology) such that monitoring of the bank may be easily controlled. This may mean that the bank can only use verifiable hard data in its monitoring technology but has to disregard unverifiable soft information about its borrowers. Hence, the transparent monitoring technology is verifiable but is less valuable for borrowers.

The bank profit, conditional on monitoring, see (2.2), is left unchanged. Conditional on no monitoring, the bank profit is left unchanged as well, see (2.3), if depositors receive no signal. This happens with probability $1-\alpha$. However, with probability α depositors receive a negative signal. In this case, the bank profit is lower. That is, depositors threaten to run on the bank which forces it to invest in the transparent monitoring technology. In this case, a borrower's project differs from a good project only in its success probability; that is, p_T is lower than p_G. Hence, (2.3) becomes

$$\Pi_{NM} = [1-\alpha]p_B[R - r_D] + \alpha\{p_T[R - r_D] - c_M\}. \tag{2.12}$$

[6]To maintain focus, I do not include random liquidity needs of depositors as analyzed in Section 2.3.

The incentive constraint in (2.4) now becomes (use (2.2) and (2.12))

$$p_G[R - r_D] - c_M \geq [1 - \alpha]p_B[R - r_D] + \alpha\{p_T[R - r_D] - c_M\}. \tag{2.13}$$

Note that, as long as the condition in (2.13) is satisfied, the bank always monitors its borrower. Anticipating this, depositors demand a return $r_D = \frac{r_F}{p_G}$. Combining this with (2.13) establishes that the bank monitors if

$$c_M < \tilde{c}_M \text{ where } \tilde{c}_M \equiv \bar{c}_M + \frac{\alpha}{1-\alpha}[p_G - p_T][R - \frac{r_F}{p_G}], \tag{2.14}$$

where $\bar{c}_M$ is as given in (2.5). I can now show the following result.

Proposition 2.2. *Building on a threat of a bank run strictly* increases *the threshold $\tilde{c}_M$ of monitoring costs below which financing is available; that is, $\tilde{c}_M > \bar{c}_M$.*

This result shows that the threat of a bank run also allows the bank to finance a borrower that has relatively high costs of monitoring. Such a borrower is left without funding in the absence of such a bank run threat.

In the model so far, banks always behave prudently (the incentive constraint in (2.13) is satisfied). Depositors never run on the bank even though they could do so. That is, a bank run only acts as a threat but it never materializes. I now enrich the analysis by allowing depositors to observe the monitoring of their bank only at a certain cost c_D. I also make the following assumption:

Assumption 2.1. *$p_T < 2p_B$.*

Assumption 2.1 guarantees that investing in a transparent monitoring technology is not an attractive option. In particular, it is never so attractive that depositors would automatically (i.e., without observing monitoring of their bank) force the bank to invest in the transparent monitoring technology.

It is easy to see that, for high monitoring costs $c_M > \bar{c}_M$, there exists no Nash equilibrium in pure strategies with monitoring (for low monitoring costs $c_M \leq \bar{c}_M$, Section 2.2.2 shows that the bank always monitors). That is, if depositors always "observed" the bank, the bank would behave prudently and monitor its borrower. Knowing that, depositors would refrain from "observing" the bank to save on c_D. However, then anticipating this, the bank would stop monitoring. As a consequence, no pure strategy equilibrium with monitoring would exist.

I can show the following result.

Proposition 2.3. *For low monitoring costs (i.e., $c_M \leq \bar{c}_M$), the bank always monitors and there is no bank run. For high monitoring costs (i.e., $c_M > \bar{c}_M$), the following equilibrium in mixed strategies exists. A bank monitors its borrower with probability β and it refrains from monitoring its borrower with probability $1 - \beta$. Depositors observe the monitoring of their bank with probability α and do not observe it with probability $1 - \alpha$.*

When depositors invest in observing the monitoring choice of the bank, this not only induces the bank to monitor (Proposition 2.3) but also introduces the possibility of bank runs. I now determine the probability of a bank run. A bank run occurs if a bank does not monitor its borrower (with probability $[1-\beta]$) and depositors observe this (with probability α). Hence, the probability of a bank run is

$$p_{BR} = [1-\beta]\alpha. \tag{2.15}$$

The proof of Proposition 2.3 also shows that depositors only run if they receive a negative signal. If they receive no signal, they prefer to stay in a bank. That is, Assumption 2.1 guarantees that depositors cannot profit from a bank run without observing bank behavior.

I can now show the following result.

Corollary 2.3. *Increasing the cost of bank monitoring, c_M, and/or the cost of depositors' observing the bank, c_D, increases the probability of a bank run.*

Increasing the cost of bank monitoring, c_M, increases the probability of a bank run because the higher costs of bank monitoring negatively affect a bank's incentives to monitor, which induces depositors to invest in observing monitoring of their bank; that is, they "observe" more often (α increases). This increased pressure from depositors restores banks' incentives to monitor. In fact, the bank monitors with the same probability as before (i.e., β is independent of c_M). Yet, depositors more frequently spot risky behavior of their bank. Hence, a bank run occurs more often.

Increasing the costs to depositors of c_D for observing bank behavior augments the probability of a bank run through two channels. First, depositors may be less willing to "observe" the bank. The bank anticipates this and monitors less. Lower monitoring increases the probability of a bank run. Second, depositors anticipate that the bank monitors less and they demand higher returns. These higher returns induce depositors to "observe" the bank more, which again leads to more bank runs.

Proposition 2.2 above shows that demand deposits can act as a disciplining device, as in Calomiris and Kahn (1991). They argue that demand deposits serve as a threat for managers to behave in the interest of depositors. In particular, in their analysis demand deposits deter managers from absconding with the funds of the bank. More specifically, demand deposits induce depositors to check whether the bank monitors its borrowers. This is valuable because depositors can vote with their feet (i.e., run), and in doing so bring down the bank. Calomiris and Kahn (1991) also show that having a larger number of depositors augments the accuracy of depositors' actions if their signals are imperfectly correlated.

Diamond and Rajan (2000) justify why banks combine monitoring of their borrowers with a liquidity provision to depositors. They claim that it is difficult to lend to the borrower, which is indispensable for the project that he is undertaking. If such a borrower cannot commit to staying with the project, he may hold up the bank. Anticipating this, the bank can only lend a limited amount. The relationship bank may partially solve this problem by gathering specific knowledge related to the project that the borrower undertakes. In this case, if the borrower leaves, the relationship bank may overtake and continue the project instead of the borrower. However, a new problem arises. If struck by a liquidity need, the relationship bank may have difficulties in obtaining funds to the full value of its loan. This is because the relationship bank may now hold up investors due to its specific knowledge related to the project. Diamond and Rajan (2000) show that withdrawable demand deposits prevent this renegotiation problem. In particular, depositors successfully threaten the bank with withdrawal in the case of any renegotiation.[7]

In Chapter 7, I provide another rationale for why banks combine liquid demand deposits with lending to borrowers that need monitoring. Following Jensen (1986), I show that demand deposits may commit banks to monitoring. In particular, withdrawals on demand deposits could force banks to liquidate some of their borrowers early to repay debt and, in doing so, limit debt financing in later periods. This alleviates moral hazard. In addition, demand deposits, contrary to straight short-term and long-term debt, help commit the bank not to overleverage itself and this commits the bank to monitoring. I show that banks prefer demand deposits if the cost of early liquidation of borrowers is intermediate and if bank monitoring is costly.

Proposition 2.3 and Corollary 2.3 explicitly model the occurrence of a bank run in a mixed strategy Nash equilibrium. This allows for the identification of parameters in the economy (i.e., the cost of monitoring the borrower and the cost of "observing" the bank's action) that have an impact on the probability of a bank run. This is related to the approach taken by Goldstein and Pauzner (2005). Whereas Goldstein and Pauzner (2005) as well as Chari and Jagannathan (1988) connect the probability of a bank run to an exogenous event (the state of the economy or a signal about the bank's action), this analysis endogenously determines the probability that depositors "observe" the bank's action, which subsequently affects the probability of a bank run.

Although the threat of a bank run may be viable, the theoretical banking literature is not yet conclusive on the exact mechanism that triggers a bank run. In the following section I present a short inroad to the analysis of this question.

2.4.2 Sequential service constraint: Further thoughts

I now present a more in-depth analysis of the role of the SSC. In particular, the SSC and the observed pattern of withdrawals provide for a type of information aggregation among depositors. This is important because this type of informational aggregation may on the one hand be inefficient and induce bank runs, yet on the other hand may be efficient in resolving free-riding in the monitoring of the banking depositors.

Instructive is the bank run on the UK bank Northern Rock that occurred in September

[7]Despite the benefit of demand deposits, Diamond and Rajan (2001) show that a level of capital is valuable because it limits bankruptcy costs. Therefore, a bank selects its optimal capital structure by weighting the benefits of liquidity creation and the enforcement of borrowers' repayment with the costs of bankruptcy.

2007. The Treasury Committee in its report (House of Commons (2008)) analyzes the causes and consequences of the run on Northern Rock. Interestingly, the lending side of Northern Rock before the run seemed quite solid. The regulator (Financial Service Authority) also allowed Northern Rock to adopt the advanced approach of risk measurement under the Basel II capital accord. As Mervyn King, the Governor of Bank of England stated: "What I would say about Northern Rock (and this is the tragedy of Northern Rock) is that most of the staff [...] did an excellent job in appraising the loans that they were making, and that they monitored very carefully and they did not lend money to people who should not be borrowing from them. The lending side was handled extremely well."

The main cause of a bank run on Northern Rock was the improper structure of its liabilities. Northern Rock was heavily financed on the capital markets, with a substantial maturity mismatch. It was the credit squeeze on capital markets that drove Northern Rock illiquid. When it became public that Northern Rock had liquidity problems and that it had to arrange a support facility at the Bank of England, a bank run was triggered. One interpretation is that information about the unwillingness of informed investors to provide financing triggered the bank run of less informed, small depositors. This is related to the work of Ó Gráda and White (2002) who analyze bank runs in 1854 and 1857 and argue that the bank run triggered by informed market participants in 1857 had much graver consequences than the bank run triggered by less wealthy, less experience – uninformed – depositors in 1854. My analysis addresses the following questions that these examples provoke: *i*) what can increase the precision of a bank run; and *ii*) how can a bank run be halted?

I model a sequential withdrawal of depositors as an informational cascade following Bikhchandani, Hirshleifer, and Welch (1992). In particular, each depositor, in addition to monitoring the bank on his own, also observes the actions of depositors in the line in front of him. These actions reveal the information of other depositors and may trigger an informational cascade. An informational cascade denotes a situation in which a depositor may decide on his action (i.e., to withdraw or not) entirely on the basis of the actions of his predecessors regardless of his own signal. This analysis points to the main drawback of the sequential service constraint: depositors may optimally choose to disregard their own information and in doing so trigger bank runs even though the bank is sound. This could make information aggregation inefficient.

By modeling the withdrawal of deposits as a cascade, I obtain a few new insights. I show that the sequential service constraint allows for cheaper monitoring of a bank. That is, it suffices for only a few depositors to monitor the bank, and the SSC makes it optimal for a few to monitor and hence resolves the free-rider problem among depositors. Others may then simply follow their actions. Thus monitoring by a few is enough to provide incentives to the bank to behave safely. Moreover, monitoring by a few also presents the drawback of the sequential service constraint: inefficient aggregation of information via cascades. In particular, depositors may rely completely on the actions of their predecessors, disregarding their own information about the quality of the bank.

Interestingly, I show that borrowing from depositors with an exogenous liquidity need may limit the loss of information due to the cascading effect. That is, a liquidity need lowers the information content of the withdrawals of depositors early in line. More specifically, if the depositor at the front of the line withdraws, this might be either because he has obtained a negative signal about the bank's quality, or because this depositor simply has a liquidity need. Thus, liquidity needs reduce the "stigma fraction" of withdrawals. This partially limits the herding behavior of depositors and improves the precision of bank runs.

Several contributions aim to explain bank runs as a consequence of an informational cascade. Yorulmazer (2003) applies the same model to explain the occurrence of bank runs on safe banks. He shows that completely eliminating bank runs may create costs. In particular, the demand-deposit contract that eliminates bank runs must discourage late depositors from withdrawing early even if they obtain a negative signal about the bank's quality. This means that short-term returns must be sufficiently small. Although this may prevent bank runs, it limits the intertemporal insurance function of the bank. More specifically, an intertemporally averse depositor values the most demand-deposit contracts of comparable early and late returns. In the case of a run-proof demand-deposit contract, however, the early return has to be substantially smaller than the late return.

The main difference between Yorulmazer (2003) and this analysis is in the observability of the type of depositors. In Yorulmazer (2003), depositors may observe whether depositors in line are late or early depositors. In my model, types of depositors are not observed. Hence, it is not known whether depositors withdraw due to their liquidity needs or due to the signal about the bank's quality. This contributes some noise to the informational cascade.

The closest paper to my analysis is Gu (2007). In his model bank runs are similarly triggered by the herding behavior of depositors. In particular, a depositor's decision to withdraw depends on both his signal about the bank's quality and the withdrawal decisions of other depositors. He shows that deposit contracts that allow for bank runs can be optimal because the bad bank might be liquidated before it invests in bad projects. My analysis generalizes Gu (2007) by showing that withdrawals motivated by liquidity needs could "confuse" the inference of depositors from previous withdrawals and be beneficial. In particular, when liquidity needs are common, depositors put a higher weight on their own signal about the bank's quality and less eagerly draw inferences from withdrawals by other depositors. This partially limits herding and could improve the precision of bank runs.

The observation that withdrawals based on liquidity needs may actually improve the precision of a bank run is in contrast with the existing literature in which a bank run occurs as a consequence of (excessive) simultaneous withdrawals by uninformed depositors. Diamond and Dybvig (1983) argue that liquidity needs may trigger a sunspot bank run. Chari and Jagannathan (1988) consider both informed and sunspot bank runs. They show that withdrawals due to liquidity needs might be mistakenly considered a consequence of negative information about the bank and may trigger a run of uninformed depositors. In their model, however, uninformed depositors obtain no signal whereas informed depositors perfectly observe bank monitoring. Hence, there is no role for beneficial pooling of information that my analysis predicts. That is, I consider a setting where depositors' signals are not perfectly informative; hence, depositors benefit from the informational content of the history of withdrawals.

Chen (1999) stresses that the first-come, first-serve rule that the SSC contains creates a negative payoff externality among depositors. In particular, if a depositor withdraws after everybody else has already withdrawn, he may receive very small returns. In this model, informed depositors can withdraw early based on their signals about the quality of the bank. Uninformed depositors cannot evaluate the quality of the bank directly. To limit the negative payoff externality, they nevertheless withdraw soon based on other less precise measures, such as bankruptcy of other banks. Consequently, bank runs may be triggered by noisier information of uninformed depositors and this is socially costly. Chen (1999) proposes that deposit insurance should cover only losses to uninformed depositors but not losses to informed depositors. In this analysis, noise in the form of a potential liquidity need does not distort the signal of each depositor. It distorts information about the actions of the other depositors. In this case, noise is beneficial and it increases the precision of bank runs and may therefore be valuable.[8]

I proceed as follows. First, I analyze the case in which depositors have no liquidity needs. Hence, they withdraw only on the basis of their signal. Second, I focus on the case with a liquidity need. In particular, if a depositor is struck by a liquidity need, he must withdraw regardless of his signal.

The following stylized model captures the key characteristics of the sequential service constraint. The bank may be either good or bad. The bank is good if it monitors its borrowers. In this case, it is optimal for depositors to keep their deposits in the bank. The bank is bad if it does not monitor its borrowers. In this case it is optimal for depositors to prematurely withdraw their deposits. However, depositors cannot directly observe the quality of the bank. Each depositor obtains a costless signal about the bank's quality. More specifically, the signal is symmetric and informative in the sense that a depositor obtains a positive signal with probability $\Phi > \frac{1}{2}$ and a negative signal with probability $1 - \Phi$ if the bank is good. If the bank is bad, a depositor obtains a negative signal with probability Φ and a positive signal with probability $1 - \Phi$. Hence, a depositor can only imprecisely anticipate a bank's quality from his signal. The signals that depositors receive are independent.[9] Additionally, a depositor observes withdrawals (or no withdrawals) of his predecessors. This gives him additional but imprecise information about the signals about

[8] This relates to the observation of the theory of informational cascades that it is more beneficial for society if agents rely on their own information than if they follow the actions of others; see Bikhchandani, Hirshleifer, and Welch (1992) and Bikhchandani, Hirshleifer, and Welch (1998).

[9] Kelly and Ó Gráda (2000) argue that the rumors about bank stability spread through social networks. Using correlated instead of independent signals of subsequent depositors would allow for this effect. However, this extension is left for future work. Iyer and Puri (2007) stress that not only social networks are important but also the strength of the bank-depositor relationship. This suggests that depositors with more precise information about their bank run less willingly.

the bank's quality that other depositors have received.

This setting allows for the occurrence of several informational cascades. For example, an informational cascade starts if the first two depositors do not withdraw. In this case, the subsequent depositors do not withdraw regardless of their signals. A different informational cascade starts if the first two depositors obtain a negative signal and withdraw. In this case, the third depositor observing these withdrawals withdraws irrespective of his own signal. All the subsequent depositors withdraw as well and an informational cascade starts. In this case, an informational cascade resembles a bank run. That is, one of the key characteristics of a bank run is that depositors withdraw simply because of the long line in front of the bank and regardless of their own knowledge about the bank's quality.

Representing a bank run as an informational cascade points to the following problem. Bank runs may not necessarily happen to bad banks and they may also happen to good banks. I now compute the probability that a bank run occurs if the bank is good. First, I compute the probability that the first two depositors in line withdraw. With probability $[1-\Phi]^2$, both depositors mistakenly receive a negative signal. With probability $\Phi[1-\Phi]$, the first depositor receives a positive signal and the second depositor receives a negative signal. In this case, the second depositor anticipates that the first depositor has received a positive signal. Due to his negative signal, he cannot make any assessment of the quality of the bank. Hence, he flips the coin and withdraws with probability $\frac{1}{2}$. That is, both depositors mistakenly withdraw if

$$\Phi_M \equiv [1-\Phi]^2 + \frac{\Phi}{2}[1-\Phi]. \tag{2.16}$$

Interestingly, if the first two depositors withdraw, the third depositor and all subsequent depositors withdraw regardless of their signals. That is, even though the third depositor obtains a positive signal, he anticipates that the first depositor has obtained a negative signal. Because the second depositor has also withdrawn, the third depositors anticipates that the bank is more likely bad than good and withdraws. Subsequent depositors withdraw as well.

Now I compute the probability of a bank run on a good bank. The bank run occurs if the first two depositors withdraw. If the first two depositors correctly leave their funds in the bank, which happens with probability

$$\Phi_C \equiv \Phi^2 + \frac{\Phi}{2}[1-\Phi], \tag{2.17}$$

the bank run does not occur. Moreover, in this case, all the subsequent depositors leave their funds in the bank. However, if only one of the two depositors, withdraws which happens with probability

$$\Phi_{MC} \equiv \Phi[1-\Phi], \tag{2.18}$$

the cascade does not start (see Table 2.1). The third depositor gains no additional information from the actions of the first two. Hence, the whole game starts from scratch; in particular, the bank run starts with probability Φ_{WW} if the third and fourth depositors

	Good bank	Bad bank
Both stay → All stay	Φ_C	Φ_M
One stays, one withdraws	Φ_{MC}	Φ_{MC}
Both withdraw → Bank run	Φ_M	Φ_C

Table 2.1: The probabilities of various actions that the first two depositors may take (to withdraw or stay in the bank) in the absence a liquidity need

withdraw. In sum, the probability that a bank run on a good bank starts is

$$Pr(BR, G) = \Phi_M + \Phi_{MC}\Phi_M + \Phi_{MC}^2\Phi_M + \ldots = \frac{\Phi_M}{1 - \Phi_{MC}}. \tag{2.19}$$

Inserting (2.16) and (2.18) into (2.19) yields

$$Pr(BR, G) = \frac{[2 - \Phi][1 - \Phi]}{2[1 - \Phi + \Phi^2]}. \tag{2.20}$$

I compute the probability of a bank run on a bad bank as follows. A bank run on a bad bank occurs if the first two depositors correctly withdraw, which occurs with probability Φ_C. A bank run may also occur if only one of the first two depositors withdraws (with probability Φ_{MC}). In this case, the third and fourth depositors again rely only on their signals. A bank run on a bad bank occurs with probability

$$Pr(BR, B) = \Phi_C + \Phi_{MC}\Phi_C + \Phi_{MC}^2\Phi_C + \ldots = \frac{\Phi_C}{1 - \Phi_{MC}}. \tag{2.21}$$

Inserting (2.17) and (2.18) into (2.21) yields

$$Pr(BR, B) = \frac{\Phi^2 + \frac{\Phi}{2}[1 - \Phi]}{1 - \Phi[1 - \Phi]}. \tag{2.22}$$

Now the main part of the analysis of the SSC starts. I allow for a liquidity need. That is, with small probability $\epsilon \rightarrow 0$ a depositor may have a liquidity need. Conditional on having a liquidity need, a depositor must withdraw (early with probability $\frac{1}{2}$ or late with probability $\frac{1}{2}$) regardless of his signal. Such a liquidity need introduces noise into the information content of withdrawals. In particular, a depositor cannot anticipate with certainty that the withdrawals are triggered by negative signals. They may be triggered by the liquidity needs of depositors.

Now I compute the probability of a bank run on a good bank in the presence of a liquidity need. In the presence of a liquidity need, the first two depositors withdraw less often than without a liquidity need (see (2.16)). That is, the first two depositors only withdraw if they both mistakenly receive negative signals, which happens with probability $[1 - \Phi]^2$. Upon observing the first depositor to withdraw, the second depositor may stay in the bank if he receives a positive signal. This is because the second depositor relies more on his own signal knowing that the withdrawal of the first depositor may well be liquidity-driven. Hence, the probability that the first two depositors mistakenly withdraw is lower than (2.16); that is,

$$\bar{\Phi}_M \equiv [1-\Phi]^2. \tag{2.23}$$

If the first two depositors withdraw, the third depositor and all subsequent depositors withdraw regardless of their signals and a bank run starts.

The bank run occurs if the first two depositors withdraw. If the first two depositors leave their funds in the bank, a bank run does not occur. This happens only if they both correctly receive a positive signal; that is, with the probability

$$\bar{\Phi}_C \equiv \Phi^2. \tag{2.24}$$

However, if only one of the two depositors withdraws, which happens with probability

$$\bar{\Phi}_{MC} \equiv 2\Phi[1-\Phi], \tag{2.25}$$

the cascade does not start (see Table 2.2). The third depositor gains no additional information from the actions of the first two. Hence, the whole game starts from scratch. Thus, the probability that a bank run on a good bank occurs in the presence of a liquidity need is

$$\bar{Pr}(BR, G) = \bar{\Phi}_M + \bar{\Phi}_{MC}\bar{\Phi}_M + \bar{\Phi}_{MC}^2\bar{\Phi}_M + \ldots = \frac{\bar{\Phi}_M}{1-\bar{\Phi}_{MC}}. \tag{2.26}$$

Inserting (2.23) and (2.25) into (2.26) yields the probability of a bank run on a good bank

$$\bar{Pr}(BR, G) = \frac{[1-\Phi]^2}{1-2\Phi[1-\Phi]}. \tag{2.27}$$

In the same way, I compute the probability of a bank run on a bad bank

$$\bar{Pr}(BR, B) = \bar{\Phi}_C + \bar{\Phi}_{MC}\bar{\Phi}_C + \bar{\Phi}_{MC}^2\bar{\Phi}_C + \ldots = \frac{\bar{\Phi}_C}{1-\bar{\Phi}_{MC}}. \tag{2.28}$$

Inserting (2.24) and (2.25) into (2.28) yields

$$\bar{Pr}(BR, B) = \frac{\Phi^2}{1-2\Phi[1-\Phi]}. \tag{2.29}$$

I can now show the following result.

Proposition 2.4. *The presence of a liquidity need lowers the probability of a bank run on a good bank and increases the probability of a bank run on a bad bank.*

The intuition for Proposition 2.4 is the following. Adding noise – a probability of a liquidity need – lowers the information content of the actions of previous depositors. In particular, depositors cannot observe whether previous withdrawals are liquidity- or information-driven.

	Good bank	Bad bank
Both stay → All stay	$\bar{\Phi}_C$	$\bar{\Phi}_M$
One stays, one withdraws	$\bar{\Phi}_{MC}$	$\bar{\Phi}_{MC}$
Both withdraw → Bank run	$\bar{\Phi}_M$	$\bar{\Phi}_C$

Table 2.2: The probabilities of various actions that the first two depositors may take (to withdraw or stay in the bank) in the presence of a liquidity need

This induces each depositor to rely more on his own signal and leads to less herding and consequently to better information aggregation. Figure 2.4 graphically shows that introducing noise into the actions of depositors reduces the probability of a bank run on a good bank and increases the probability of a bank run on a bad bank.

Observe that the probabilities of a bank run in the case of a liquidity need given in (2.26) and (2.29) do not depend on the size of the liquidity need ϵ. This is because I have assumed that a liquidity need occurs with a small probability ($\epsilon \rightarrow 0$). Alternatively, I could allow for a higher probability of a liquidity need (higher ϵ). In this case, the information content of previous withdrawals may even be lower and each depositor would rely more on his own signal. Consequently, a bank run would start only after several withdrawals occur in a row.

Interestingly, a release of a small amount of new information may halt a bank run. Note that if information released contains the information content of two subsequent withdrawals, the subsequent depositor again follows his own signal. This shows that purely sunspot bank runs might be stopped by early intervention. A release of new information or backing by more informative investors suffices. Ó Gráda and White (2002) confirm this by showing that the sunspot bank run in 1854 was successfully stopped by intervention of more informed investors.

Although a liquidity need improves the precision of a bank run, it also introduces a drawback. That is, with a liquidity need the bank run starts later. In particular, more depositors should observe the bank before a bank run starts. This is costlier and may create a free-rider problem if observing the bank is costly. However, this would make the analysis more complex and it is left for further work.

The main implication of the analysis in this section is the following. Recall that, with the possibility of a liquidity shock, withdrawals may occur because of negative signals about the quality of the bank *or* due to liquidity needs of depositors. Such noise decreases the probability of a bank run on a good bank and increases the probability of a bank run on a bad bank. This shows that the sequential service constraint induces better aggregation of information if depositors may be hit by an exogenous liquidity shock.

Despite this potential effectiveness of "depository discipline," the prevalence of deposit insurance poses some questions regarding the relevance of this mechanism. In the following section, capital and capital regulation are introduced as potential alternative (and more realistic) mechanisms.

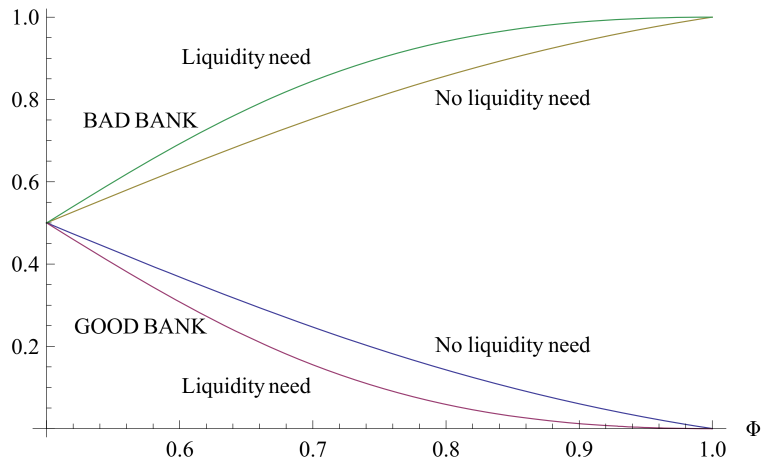

Figure 2.4: The probability of a bank run on a good bank (and on a bad bank) as a function of precision of a signal (in the case of a liquidity need and in the absence of a liquidity need)

2.5 Bank Capital

In this section I focus on an alternative mechanism that commits banks to monitoring. Banks can commit to monitoring by raising sufficient amounts of capital. This suggests that it could be privately optimal for a bank to be well capitalized. In this context I also discuss the recent work of Allen, Carletti, and Marquez (2007), which analyzes precisely this issue. An important caveat is that banks may not internalize the cost of a bank run sufficiently. In this case, capital regulation may be necessary.

2.5.1 Bank capital

Now I analyze the monitoring incentives of a bank that is financed with deposits and bank capital. I follow the work of Allen, Carletti, and Marquez (2007) to show that banks may voluntarily hold capital. In particular, capital induces banks to monitor their loans and hence credibly communicates to borrowers that banks will monitor. This is valuable for borrowers and hence can improve the profitability of the banks. I connect the level of bank capital (i.e., the level of capital) with the strength of the borrower (i.e., the size of the collateral).

I now expand the model that was introduced in Section 2.2.1 along the lines of Holmstrom and Tirole (1997) in two directions. First, I allow for bank capital. The bank collects the proportion k of the total funds needed from the providers of bank capital at a cost r_E per unit. The proportion $[1-k]$ it collects from depositors at a cost r_D. Capital is more costly than deposits; that is, $r_E > r_D$.[10] Second, I denote the strength of the borrower by the size of his collateral A, where $A < r_F$. That is, if the borrower fails, the bank and in particular

[10]See Holmstrom and Tirole (1997) and Diamond and Rajan (2000) for explicit models of why the cost of capital might be higher than the cost of deposits. Note that this assumption bypasses the question *how* capital is raised, including potential adverse selection problems, as in Myers and Majluf (1984), or moral hazard problems, as in Thakor (1990).

$t = 0$:

♠ The bank gathers funds from depositors and capital providers and lends to a borrower.

$t = 1$:

♠ The bank can monitor its borrower.

♠ Depositors obtain a signal about bank monitoring.

♠ Depositors can run on the bank and force it to invest in a transparent monitoring technology.

$t = 2$:

♠ Payoffs are realized.

♠ If necessary depositors seize a collateral.

Figure 2.5: Sequence of events accounting for bank capital and collateral

its depositors are still able to size at least A. See Figure 2.5.

If depositors anticipate bank monitoring, they demand

$$p_H r_D + [1 - p_H]A = r_F,$$

which yields

$$r_D = \frac{r_F - [1 - p_G]A}{p_G}. \tag{2.30}$$

Because the bank finances the investment with $1 - k$ deposits, it pays out to depositors $r_D[1 - k]$ in the case of success. It also incurs the cost of capital financing kr_E.[11] The expected profit of the bank conditional on monitoring its borrower is

$$\Pi_M = p_G\{R - r_D[1 - k]\} - c_M - kr_E. \tag{2.31}$$

The expected profit of the bank conditional on not monitoring its borrower is

$$\Pi_{NM} = p_B\{R - r_D[1 - k]\} - kr_E, \tag{2.32}$$

where I have assumed that depositors anticipate that the bank will monitor. The bank monitors if (2.31) is higher than (2.32). That is,

$$p_G\{R - r_D[1 - k]\} - c_M - kr_E \geq p_B\{R - r_D[1 - k]\} - kr_E. \tag{2.33}$$

I can now show the following result.

Proposition 2.5. *A borrower with high collateral (i.e., $A > \bar{A}$) can borrow from banks. A borrower with low collateral (i.e., $A \leq \bar{A}$) cannot obtain a bank loan, where*

$$\bar{A} \equiv \frac{r_F}{1 - p_G} - \frac{p_G}{[1 - p_G][1 - k]}[R - \frac{c_M}{\Delta p}]. \tag{2.34}$$

The intuition for Proposition 2.5 is the following. On the one hand, if the borrower with low collateral fails, the bank and its depositors receive only low returns from his collateral. Anticipating this, depositors demand a relatively high deposit rate. However, a high deposit

[11] Note that kr_E reflects the cost of outside equity.

rate lowers the bank profit and consequently the bank cannot commit to monitoring. Hence, the borrower with low collateral cannot obtain a bank loan. On the other hand, if the borrower with high collateral fails, the bank and depositors still receive decent returns. Consequently, depositors demand low returns and the bank anticipating high profits can commit to monitoring.

Proposition 2.5 partially replicates Holmstrom and Tirole (1997). Holmstrom and Tirole (1997) further extend the analysis to include the possibility of issuing direct debt. They show that undercapitalized borrowers (i.e., those with low levels of collateral) cannot obtain finance at all, whereas reasonably capitalized borrowers (i.e., those with intermediate levels of collateral) borrow from banks and well-capitalized borrowers can issue direct debt. In my model above, I have precluded the option of direct debt by assuming that a borrower with direct debt would always decide on a bad project due to his high private benefits. If the level of private benefits is sufficiently small, a borrower with high collateral could issue direct debt, which would replicate the result of Holmstrom and Tirole (1997).

I can now show the following proposition.

Proposition 2.6. *A better capitalized bank can lend to a borrower with lower collateral (i.e.,* $\frac{\partial \bar{A}}{\partial k} < 0$*). A borrower with low collateral (i.e.,* $A < \bar{A}(k=0)$*) can only borrow from a bank with the minimum level of capital*

$$k^* = 1 - \frac{p_G[R - \frac{c_M}{\Delta p}]}{r_F - [1-p_G]A}. \tag{2.35}$$

Proposition 2.6 shows that the level of capital of the bank is important if the bank wishes to finance a borrower with low levels of collateral. This is because a well-capitalized bank has its own capital at stake and this induces it to monitor even a borrower with low levels of collateral.

The next corollary shows that interbank competition affects the minimum level of bank capital.

Corollary 2.4. *The bank needs more capital if competition for deposits increases (i.e.,* $\frac{\partial k^*}{\partial r_F} > 0$*).*

The intuition for Corollary 2.4 stems from the negative effect of competition on bank rents. Because competition undermines the bank's expected profits, the bank is less incentivized to monitor its borrower. The only way that it can reestablish monitoring incentives and attract depositors is by holding more capital.

Proposition 2.6 and Corollary 2.4 follow the work of Allen, Carletti, and Marquez (2007) by showing that banks may choose to voluntarily hold positive levels of capital and that these positive levels of capital increase with competition. However, they go even further in their analysis. They show that banks may even hold more capital than is socially optimal if competition between banks is high. This is because banks use capital to commit to monitoring in order to better compete for borrowers. In particular, monitoring is valuable for borrowers because it increases borrowers' success probability. If competition for borrowers is high, banks would like to commit to high levels of monitoring (as Corollary 2.4 also shows). However, higher competition lowers bank rents and makes it increasingly difficult for banks to commit to monitoring. This is why banks use high levels of capital. Bank capital commits them to high monitoring despite strong competition.

The empirical literature confirms that banks often hold considerably higher levels of capital than prescribed by the regulator (see Flannery and Rangan (2004) and Calem and Rob (1999)).

Boot and Greenbaum (1993) and Gehrig and Jost (1995) show that banks may use not only financial capital, but also reputational capital, to enforce credibility in their own monitoring. Boot and Greenbaum (1993) show that reputation allows banks to lower their market-determined funding costs. Such reputational benefits encourage banks to monitor and are especially important if competition between banks is high. They also show that deposit insurance fixes future funding costs for banks and, in doing so, destroys the funding-related benefits of reputation.

Above I have explained the incentive role of bank capital in which bank capital serves as an incentive mechanism for bank monitoring. Calem and Rob (1999) point to another role of capital. In their view, capital acts as a buffer against bank losses. More specifically, banks hold excessive capital to assure that they satisfy the capital requirements demanded by the regulator even if they are hit by a solvency shock. In the intertemporal model, they show that the relation between bank capital and its risk is a U-shaped curve. Banks with the lowest levels of capital are the riskiest. Then bank risk declines with bank capital. At higher levels of capital, however, bank risk starts increasing again. Calem and Rob (1999) also point to the influence of market pressure (i.e., pricing of the uninsured depositors) on prudent bank behavior.

Peura and Keppo (2006) assume that banks can only recapitalize at a delay. If the losses exceed the capital buffer, banks may be driven to liquidation. Their model, calibrated to the data of U.S. banks, reasonably well predicts why banks hold excessive capital.

2.5.2 Bank capital and bank runs

Now I combine bank capital with the possibility of a bank run. I observe how bank capital affects the possibility of a bank run. I modify the model in the previous section by introducing the possibility that depositors at a cost c_D observe whether a bank monitors its borrower (see Section 2.4). For simplicity, I set the borrower's collateral to zero.

The bank now has two options. It may raise sufficient capital and always monitor its borrower. In this case, depositors are safe and they do not need to observe a bank's behavior. Alternatively, the bank may hold lower levels of capital. In this case, Proposition 2.3 shows that, when depositors observe the bank at cost c_D, the bank only monitors its borrower with certain probability. However, this then may lead to a bank run.

I can now show the following.

Proposition 2.7. *If capital is not too costly (i.e., $r_E < \bar{r}_E$), the bank raises k^* capital and monitors. If capital is costly, however, (i.e., $r_E \geq \bar{r}_E$), the bank finances entirely with deposits and follows a random monitoring strategy, where*

$$\bar{r}_E \equiv r_F + \frac{c_D[p_G - p_B]}{p_T - p_B}. \tag{2.36}$$

Proposition 2.7 shows that bank capital – as discussed by Allen, Carletti, and Marquez (2007) – and the threat of a bank run as discussed by Calomiris and Kahn (1991) act as complementary mechanisms that commit the bank to monitoring. The bank decides on the cheaper one; that is, the bank weights the cost of capital with the cost of a potential bank run. If capital is relatively costly, the bank uses as little capital as possible. However, if a bank run becomes more probable, the expected cost of a bank run increases and the bank may prefer to raise capital.

Proposition 2.7 also connects the characteristics of depositors with the level of bank capital (note that (2.36) is increasing in c_D). The empirical prediction is the following. Banks use less capital if they finance from depositors with a low cost of observing the bank. That is, banks that use a lot of interbank lending (where the cost of observing is low) would stick to the regulatory-prescribed capital requirements. However, banks may use capital significantly above the regulatory-prescribed levels of capital if they finance from depositors with a high cost of observing the bank.

Several contributions in the literature jointly describe and compare the use of bank capital and demand deposits. Diamond and Rajan (2000) claim that, if borrowers' returns are certain, demand deposits are an optimal contract because they prevent borrowers and a relationship bank from holding up its depositors. However, if borrowers' returns are uncertain, a bank may become insolvent, which would trigger a bank run and costly fire sales. Capital is then seen as a buffer against potential losses. Banks set their capital by trading the lower cost of bankruptcy with lower liquidity creation, and the lower ability to force a borrower's repayment.

Dowd (2000) points to the tradeoff between liquidity provision of demand deposits and additional stability that bank capital provides. He expands Diamond and Dybvig's model. In addition to depositors, he allows for agents that provide bank capital. He shows that banks would choose capital on their own to cushion losses and prevent bankruptcy.

Chapter 3 shows that higher levels of capital are value enhancing for the banking industry as a whole because they weed out inefficient banks and make room for efficient banks. Interestingly, banks may want the regulator to impose higher than socially optimal levels of capital. This is because high capital requirements by weeding out inefficient banks may provide more space for efficient banks and therefore may be preferred by the average bank.

2.5.3 Capital regulation

A bank run may be costly for the economy as a whole (see Section 2.3.3). For example, a bank run may spread to other banks. Considering Proposition 2.7, this points to the following problem. A bank maximizing its own profit may not fully consider this externality of a bank run. Hence, banks may on average raise too little capital compared to the welfare optimal value. Consequently, the regulator may have an incentive to impose capital requirements on banks in order to limit the probability of a bank run. Observe from Proposition 2.6 that banks will always monitor (and hence be safe) if the regulator demands that banks raise more capital than k^*. In this case, each bank has sufficient capital at stake. This induces it to high levels of monitoring with a positive impact on bank stability.

The literature offers a highly divergent view on the influence of capital regulation on banks' risk-taking and on the overall risk of the banking system (for a review, see Santos (2001) and VanHoose (2006)). In the approach in which banks are considered as pure portfolio managers, Kim and Santomero (1988) show that only risk-adjusted capital regulation is effective. If capital requirements are independent of risk, a bank replaces safe assets with risky ones. In addition, the analysis by Kim and Santomero (1988) holds only if a bank's losses are not constrained by a limited liability clause. Rochet (1992) appropriately considers the limited liability of a bank. He shows that, for low levels of capital, the bank relies on its limited liability and chooses a portfolio with maximum risk and minimum diversification. As a response, Rochet (1992) suggests an additional regulation of a minimum level of capital regardless of the risk and the size of a bank.

Diamond and Rajan (2001) show that an increase in capital requirements may force the bank to liquidate some borrowers, which may increase a bank's risk. It may also result in spillover effects among borrowers. In particular, the liquidation threat that higher capital requirements introduce may result in a credit crunch for a cash-poor borrowers and smaller loan repayments for cash-rich borrowers.

A study that points to a detrimental intertemporal effect of tightening capital requirements is Blum (1999). He shows that a bank that expects an increase in capital requirements in the future might have an incentive to immediately become riskier. This is because a unit of capital is worth more if capital requirements are tight. One way of increasing capital in the future is to boost profits by immediately adopting riskier strategies. Besanko and Kanatas (1996) show that increasing capital requirements augments the proportion of outside ownership and lowers the proportion of inside (managerial) ownership. Consequently, managers employ less effort in assuring bank stability and banks may become less stable.

Chapter 3 allows for the heterogeneity of banks. Banks differ in the qualities of their monitoring technologies. I analyze more in depth the linkages between competition and capital regulation. In particular, I show that competition may increase the effectiveness of capital regulation for high quality banks. In particular, high-quality banks would respond more to increases in capital requirements. I highlight the potential danger of capital regulation. Capital regulation may be less effective when needed the most: that is, for low-quality banks. Low-quality banks would raise monitoring only a little as a response to an increase in capital requirements.

Another potential danger of capital requirements may be adverse macroeconomic effects. Blum and Hellwig (1995) prove that capital adequacy regulation may act procyclically. That is, in the case of an economic downturn, firms often renege on servicing their debt obligations. Banks suffer losses. In order to fulfill capital requirements, they have to cut back on lending, which may further depress the economy. Risk-adjusted capital regulation (such as that proposed by the Basel II accord) may act even more procyclically, because bank risk increases in economic downturns (see Borio (2003) and Gordy and Howells (2006)).

2.5.4 Deposit insurance reconsidered

In spite of some exceptions, capital regulation generally has a positive effect on bank monitoring and reduces the probability of bank runs. Deposit insurance, however, may work in the other direction.

In Section 2.3.3, I argued that bank runs may be prevented by the introduction of deposit insurance. Now I highlight the drawback that deposit insurance has on banks' incentives to behave prudently. In particular, I extend the model of an information-based bank run to incorporate the effect of deposit insurance. I show that deposit insurance undermines banks' monitoring incentives. Interestingly, I show that deposit insurance contains the probability of a bank run if a borrower is risky on average, but increases the probability of a bank run if a borrower is safe on average.

I consider a situation in which the regulator repays a proportion of δ promised returns in the case of a bank failure. Hence, depositors receive their promised return with probability $\bar{p}_G = p_G + [1 - p_G]\delta$ in the case of a good project and $\bar{p}_B = p_B + [1 - p_B]\delta$ in the case of a bad project. A run on a bank (that forces it into investment in a transparent monitoring technology) also brings $\{p_T + [1 - p_T]\delta\}r_D \equiv \bar{p}_T r_D$ instead of $p_T r_D$ to depositors.

I can now show the following result.

Lemma 2.1. *More generous deposit insurance increases a bank's risk (i.e., $\frac{\partial \beta}{\partial \delta} < 0$).*

The intuition for Lemma 2.1 stems from the impact of deposit insurance on depositors. Insured depositors have lower incentives to observe the bank. The bank anticipates this and takes advantage by lowering the level of monitoring.

This lemma builds on the huge body of literature that describes the pro-risk effect of deposit insurance. Merton (1977) assesses the value of deposit insurance for a bank using option valuation methodology. In particular, he shows an isomorphic structure between deposit insurance and the put option on the bank asset value with a strike price equal to the promised maturity value of bank debt. He predicts that deposit insurance is more valuable for a bank the riskier the bank is, assuming that the deposit insurance premium is insensitive to a bank's risk. Consequently, under flat-rate deposit insurance, banks may be inclined to follow risky strategies.

In Chapter 3 I point to the cross-subsidization effect of deposit insurance. In particular, in the presence of deposit insurance, which makes the deposit rate insensible to a bank's risk, good banks subsidize bad banks. I show that the introduction of higher capital requirements limits the distortion of deposit insurance.

A direct solution to the distortions of deposit insurance seems to be to adjust the deposit insurance premium to a bank's risk. However, Chan, Greenbaum, and Thakor (1992) show that fairly priced deposit insurance cannot be implemented in a competitive banking system due to information problems. Fairly priced deposit insurance can only be implemented if banks are subsidized through deposit insurance.

Gropp and Vesala (2004), however, present a rather positive view of deposit insurance. They claim that a bank might behave more safely in the presence of carefully designed explicit deposit insurance. They argue that deposit insurance that is limited only to depositors commits the regulator not to bail out other creditors, such as large creditors or holders of subordinated debt.

Now I explore the impact of deposit insurance on the probability of a bank run.

Proposition 2.8. *Increasing the coverage of deposit insurance augments the probability of a bank run if a borrower is safe on average (i.e., for $p_G > \bar{p}_G$), but lowers the probability of a bank run if a borrower is risky on average (i.e., for $p_G \leq \bar{p}_G$).*

Proposition 2.8 stems from two effects of deposit insurance. First, deposit insurance increases bank risk taking; that is, banks monitor less. If a borrower is safe on average, this effect prevails and increasing the coverage of deposit insurance negatively affects the probability of a bank run. However, the opposite effect of deposit insurance is at work as well. Deposit insurance guarantees the promised returns to depositors. Consequently, depositors have no incentives to monitor their bank. However, then they cannot spot risky bank behavior and there are no bank runs. This opposite effect prevails if a borrower is risky on average. In this case, depositors gain a lot when deposit insurance is introduced and it is less valuable to make a run on a bank.

Proposition 2.8 shows that deposit insurance may be detrimental for the stability of a well developed banking system (in which borrowers are safe on average) but may increase the stability of a less-developed banking system (in which borrowers are risky on average).

Proposition 2.8 complements the empirical study by Demirgüç-Kunt and Detragiache (2002). They show that, in countries with explicit deposit insurance, banks are more prone to bank runs and the possibility of a bank run is increasing in the coverage of deposit insurance premiums. This shows that deposit insurance might work exactly in the opposite way it is intended to.

This section shows that banks may commit to high monitoring on their own using high levels of capital. Sometimes, however, this is not enough. That is, banks may not fully internalize the costs of several externalities that bank runs may bring. Consequently, banks may use too little capital. Capital regulation may then help to restore prudent behavior. If deposit insurance exists, banks' risk-taking may be even more problematic. Capital regulation in the presence of deposit insurance seems crucial.

2.6 Conclusion

This chapter has reviewed some fundamental features of banking in a unifying framework. This allows for a condensed presentation of key insights of the modern banking literature. In addition, it offers some new insights and connections between several insights from the literature.

I start with an ambitious goal to answer the question of why banks are better in monitoring borrowers. In Section 2.2, I first show that banks that pool together many borrowers (with uncorrelated returns) have higher incentives to monitor. I relate this result to several contributions in the financial intermediation literature. In Section 2.3, I discuss liquidity provision, which in combination with opaque bank loans makes banks inherently unstable. I describe the possibility of sunspot and information-based bank runs. I also focus on stability-oriented bank regulation that aims at preventing bank crises. The threat of a bank run may, however, have a positive role; that is, it could exert pressure on banks to behave prudently.

Finally, I turn to the role of capital and capital regulation. Banks may hold capital on their own to commit themselves to high(er) monitoring. If this effect is insufficient, the regulator may impose capital requirements on banks. Although the literature is not conclusive, capital and capital requirements in general induce more bank monitoring. Interestingly, one of the insights coming from the survey in this chapter is that deposit insurance may increase the probability of a bank run in a well-developed banking system but decrease it in a less-developed banking systems.

2.7 Appendix

Proof of Proposition 2.1

Because $p_G > p_B$, one can easily show that $\frac{p_B(N)}{p_G(N)}$ is increasing in N for $N \geq 1$ and is therefore higher than $\frac{p_B}{p_G}$ for $N > 1$. ■

Proof of Corollary 2.1

Rewrite (2.7) to obtain $\bar{c}_M(N) = [R - r_F]\frac{p_G(N)-p_B(N)}{p_G(N)}$. Note that $\frac{\partial \bar{c}_M(N)}{\partial r_F}$ is negative. ■

Proof of Corollary 2.2

Use the definition in (2.7) to compute $\frac{\partial^2 \bar{c}_M(N)}{\partial r_F \partial N} = \frac{\partial}{\partial N}[\frac{p_B(N)}{p_G(N)}]$, which is positive. ■

Proof of Proposition 2.2

Use (2.14) to see that $\frac{\partial \tilde{c}_M}{\partial \alpha} < 0$. ■

Proof of Proposition 2.3

For $c_M \leq \bar{c}_M$, the bank always monitors (see (2.5)) and there is no bank run. For $c_M > \bar{c}_M$, the following analysis applies. If a depositor observes the level of a bank's monitoring, he expects to obtain

$$V_O = \beta p_G r_D + [1-\beta] p_T r_D - c_D. \tag{2.37}$$

That is, with probability β, the bank monitors and a depositor expects $p_G r_D$. With probability $1-\beta$, the bank does not monitor and a depositor withdraws early and receives $p_T r_D$. A depositor also incurs the cost of observing the level of a bank's monitoring c_D.

If a depositor does not observe the level of a bank's monitoring, he expects

$$V_{NO} = \beta p_G r_D + [1-\beta] p_B r_D. \tag{2.38}$$

That is, with probability β, the bank monitors and a depositor expects $p_G r_D$. With probability $1-\beta$, the bank does not monitor. However, a depositor does not observe this. Hence, he does not withdraw funds and he receives $p_B r_D$.

In equilibrium, probability β is such that depositors are indifferent between observing bank's behavior or not. That is, (2.37) equals (2.38); that is,

$$\beta p_G r_D + [1-\beta] p_T r_D - c_D = \beta p_G r_D + [1-\beta] p_B r_D.$$

Rearranging yields

$$[1-\beta][p_T - p_B] r_D = c_D. \tag{2.39}$$

In equilibrium, probability α is such that the bank is indifferent between monitoring and not monitoring; that is, (2.13) is satisfied with equality. In addition, depositors can directly invest in borrowers, which yields the following condition on the promised deposit rate r_D at $t = 2$,

$$r_F = \{\beta p_G + [1-\beta] p_B\} r_D. \tag{2.40}$$

Solving (2.39) and (2.40) shows that the bank monitors its borrowers with probability

$$\beta = 1 - \frac{c_D p_G}{c_D[p_G - p_B] + r_F[p_T - p_B]}, \tag{2.41}$$

and that the depositor demands a deposit rate of

$$r_D = \frac{r_F}{p_G} + \frac{c_D[p_G - p_B]}{p_G[p_T - p_B]}. \tag{2.42}$$

The probability that the depositor monitors its bank is (use (2.13))

$$\alpha = \frac{[p_G - p_B][R - r_D] - c_M}{[p_T - p_B][R - r_D] - c_M}. \tag{2.43}$$

Depositors would run on the bank *without* observing its monitoring if

$$\beta p_G r_D + [1 - \beta] p_B r_D > p_T r_D. \tag{2.44}$$

The condition in (2.44) can be rewritten as $\beta > \frac{p_T - p_B}{p_G - p_B}$. Note from (2.41) that $\beta > \frac{p_B}{p_G - p_B}$. This and Assumption 2.1 guarantee that the condition in (2.44) is always satisfied. This concludes the proof. ■

Proof of Corollary 2.3

Use (2.41) to see that $\frac{\partial \beta}{\partial c_D} < 0$. Insert (2.42) into (2.43) to see that $\frac{\partial \alpha}{\partial c_D} > 0$. Combine this with (2.15) to see that $\frac{\partial p_{BR}}{\partial c_D} > 0$.

Observe from (2.13) that $R > r_D$, otherwise the bank's profit is negative. Use (2.43) to see that $\frac{\partial \alpha}{\partial c_M} > 0$. Combine this with (2.15) to see that $\frac{\partial p_{BR}}{\partial c_M} > 0$. ■

Proof of Proposition 2.4

Subtract (2.20) from (2.27) and (2.22) from (2.29) to obtain

$$\bar{Pr}(BR, G) - Pr(BR, G) = -[\bar{Pr}(BR, B) - Pr(BR, B)] = \frac{\Phi[1 - \Phi][1 - 2\Phi]}{2[1 - \Phi + \Phi^2]\{[1 - \Phi]^2 + \Phi^2\}}. \tag{2.45}$$

Observe that (2.45) is negative because the signal is informative; that is, $\Phi > \frac{1}{2}$. ■

Proof of Corollary 2.4

Differentiating (2.35) yields $\frac{\partial k^*}{\partial r_F} = \frac{p_G}{r_F^2}[R - \frac{c_M}{\Delta p}]$, which is positive because of the condition in (2.1). ■

Proof of Proposition 2.5

Insert (2.30) into (2.33) and solve for A from $\Pi_M = \Pi_{NM}$ to obtain (2.34). ■

Proof of Proposition 2.6

If the condition in (2.5) is satisfied, the bank does not need to raise costly capital to commit to monitoring. Hence, $k^* = 0$. However, if $c_M \geq \bar{c}_M$, the bank must hold sufficiently high capital to commit to monitoring. That is, the condition in (2.33) is satisfied and must be satisfied with equality because capital is costly. Solve (2.33) for k to obtain (2.35). ■

Proof of Proposition 2.7

Observe from (2.31) that the profit of the bank increases with k as long as $r_E < \bar{r}_E$ where

$$\bar{r}_E \equiv p_G r_D. \tag{2.46}$$

Insert (2.42) into (2.46) to obtain (2.36). ■

Proof of Lemma 2.1

Replacing p_B, p_G, and p_T with $\bar{p}_B$, $\bar{p}_G$, and $\bar{p}_T$ in (2.41) and (2.42) one obtains

$$\begin{aligned} \beta &= 1 - \frac{c_D \bar{p}_G}{c_D[\bar{p}_G - \bar{p}_B] + r_F[\bar{p}_T - \bar{p}_B]}, \\ r_D &= \frac{r_F}{\bar{p}_G} + \frac{c_D[\bar{p}_G - \bar{p}_B]}{\bar{p}_G[\bar{p}_T - \bar{p}_B]}. \end{aligned} \tag{2.47}$$

Rearrange (2.47) to obtain

$$\beta = 1 - \frac{c_D\{p_G + [1 - p_G]\delta\}}{c_D[p_G - p_B] + r_F[p_T - p_B]} \frac{1}{1 - \delta}.$$

Observe that $\frac{\partial \beta}{\partial \delta} < 0$. ■

Proof of Proposition 2.8

For $p_G = 1$, observe that neither r_D nor α depends on δ. Hence, due to Lemma 2.1, $\frac{\partial p_{BR}}{\partial \delta} > 0$ for $p_G = 1$. Observe that r_D at $p_G = 1$ must be smaller than R. This yields the condition

$$r_F + \frac{c_D[1 - p_B]}{p_T - p_B} < R.$$

For $p_G < 1$, we have $\frac{\partial \alpha}{\partial \delta} < 0$. Now note that

$$\frac{\partial r_D}{\partial p_G} = \frac{1}{p_G^2}\{-r_F + \frac{c_D p_B}{p_T - p_B}\} < \frac{1}{p_G^2}\{-r_F + \frac{p_B}{1 - p_B}[R - r_F]\} < 0.$$

Observe that for $p_G \to p_B$ the deposit rate r_D increases above R. At the point where p_G is such that r_D approaches R, the negative effect of δ on α is extremely high and prevails over its effect on β. Hence, there exists $\bar{p}_G$ such that for $p_G > \bar{p}_G$ I have $\frac{\partial p_{BR}}{\partial \delta} > 0$ and for $p_G \leq \bar{p}_G$ I have $\frac{\partial p_{BR}}{\partial \delta} \leq 0$. ■