An Inquiry into Regulatory Margin Calls for Financial Institutions

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Contents

List of Abbreviations

AIG	American International Group
BCBS	Basel Committee on Banking Supervision
BIS	Bank for International Settlements
CDS	credit default swap
CFTC	Commodity Futures Trading Commission
CoCo	contingent convertible bond
CoVaR	conditional value at risk
FSB	Financial Stability Board
GDP	gross domestic product
IMF	International Monetary Fund
IOSCO	International Organization of Securities Commissions
LFI	large financial institution
LHS	left hand side
RHS	right hand side
SEC	Securities and Exchange Commission
SIFI	systemically important financial institution
SNB	Swiss National Bank
TARGET2	Trans-European Automated Real-time Gross Settlement Express Transfer System
TARP	Troubled Asset Relief Program
U.S.	United States (of America)

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Variables

a	risk-free asset
c	cost
d	deposit
e	equity
f	debt
i	investment cost
k	condition
l	loan
m	mode
p	probability of a state
q	probability of a condition
r	return on second period loan
s	state
t	date
v	return on first period loan
$\mathcal{A}$	strategy (always unrestricted safe mode)
$\mathcal{B}$	strategy (always safe mode with restriction in downturn)
$\mathcal{C}$	strategy (unrestricted safe mode in $t = 0$, risky mode in $s = b$)
$\mathcal{D}$	strategy (restricted safe mode in $t = 0$, risky mode in $s = b$)
$\mathcal{E}$	strategy (risky mode in $t = 0$, failure mode in $s = b$)
$\mathcal{F}$	failure mode
$\mathcal{N}$	non-lending mode
$\mathcal{P}$	price of credit default swap
$\mathcal{R}$	risky mode
$\mathcal{S}$	safe mode
$\mathcal{SR}$	safe mode in $t = 0$, risky mode in $s = b$
$\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}$	safe mode given condition is good, risky mode given condition is bad
$\mathcal{V}$	market value of large financial institution

$\mathcal{X}$	strategy (non-lending mode in $t = 0$ and in $s = b$)
$\mathcal{Y}$	strategy (non-lending mode in $t = 0$ and risky mode in $s = b$)
$\mathbb{A}$	strategy (unrestricted safe mode for $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$)
$\mathbb{B}$	strategy (restricted safe mode for $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$)
$\mathbb{C}_b$	strategy in bad condition (unrestricted risky mode for $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$)
$\mathbb{C}_g$	strategy in good condition (restricted safe mode for $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}$)
$\mathbb{D}_b$	strategy in bad condition (potentially restricted risky mode for $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}$)
$\mathbb{D}_g$	strategy in good condition (unrestricted risky mode for $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$)
$\mathbb{E}$	strategy (failure mode)
α	probability of default
δ	face value of deposits
ε	value of equity
η	liquidity coverage ratio
κ	regulatory capital ratio
λ	banker's share of bank profits
μ	mean of loan returns
ξ	factor
π	banker's expected profit
ρ	recovery rate
σ	standard deviation
φ	face value of debt
ϕ	expected profit of loans
ψ	factor
ω	cash flow
Δ	liquidity risk

Indices

b	bad (state or condition)
fb	first best
g	good (state or condition)
h	high
j	index
l	low
max	upper limit
mc	margin call
min	lower limit
$*$	optimum

Chapter 1

Introduction and Overview

1.1 Introduction

The world financial crisis from 2007 to 2009 has once more revealed the fragility of the financial system. Although we have gained much experience with financial crises in the past decades and centuries, risks to financial stability were mostly neglected in the run up to the crisis. The Federal Reserve Chairman, Ben Bernanke, stated in spring 2007 that financial markets were stable enough to absorb losses in the subprime mortgage market, so that spillover effects were unlikely to occur (Bernanke, 2007). Around the same time, the International Monetary Fund (IMF) also argued that the developments in the United States' (U.S.) housing market were U.S. specific so that the slowdown of the U.S. economy would have no major global impact (IMF, 2007). In retrospect, these developments constituted the starting point for the deepest global recession in the post-war period. Several bailouts of financial institutions had to be undertaken in many countries. Europe ran into a sovereign debt crisis which continues to this day. Aiming to stabilize the financial system, central banks executed excessive liquidity programs. Lowering the interest rates to close to zero, they had to access unconventional tools to further ease monetary policy. Hence a lively debate has ensued on how to make the financial system more resilient.

The financial system is generally prone to risks. It allocates resources and risks between creditors and debtors via both financial intermediaries, like banks and other financial institutions, and financial markets (Allen and Gale, 2001). From a macroeconomic perspective, the defaulting of financial institutions will only constitute a problem if this leads to financial instability. Although a single defaulting institution might impose huge losses on its investors, such a default can still be efficient in terms of welfare. This may be the case if the rescue costs for society exceed investors' losses. In contrast, if the financial system as a whole is in distress, negative welfare effects will accrue due to negative externalities. For instance, investors may face uncertainty about the solvency of all financial institutions and may thus provide less funds. In consequence, even solvent financial institutions might face difficulties refinancing their investments. In this case, they will have to cut back lending so that investments in the real economy might decline, which might lead to a slowdown of economic growth. Financial instability, and its impact on the real economy, thus provide a reason for regulatory intervention.

Regulation aims to prevent financial crises by reducing the risks which imperil the stability of the financial system. Following the joint proposal by the IMF, the Bank for International Settlements (BIS) and the Financial Stability Board (FSB), we define this so called *systemic risk* as "the disruption to the flow of financial services that is (i) caused by an impairment of all or parts of the financial system; and (ii) has the potential to have serious negative consequences for the real economy" (IMF *et al.*, 2009, p. 5). In this thesis, we focus on the origins of these impairments, which are the risks of either contagion or a common shock.

Contagion effects will occur if the default of a single institution drives other financial institutions into distress. This contagion might be caused by several types of direct and indirect linkages between financial institutions. The most direct link will exist if institutions invest in other institutions. In this case, all linked institutions have to bear the losses of their investments in a defaulting institution. If these losses become too large, so that the linked institutions are themselves unable to pay off their own investors, contagion will emerge (Allen and Gale, 2000). However, contagion might also occur in the absence of such direct linkages. If financial institutions have invested in similar assets or markets to those of the defaulting institution, market participants might adjust their expectations regarding the solvency of the other institutions as well. If this shift in expectations implies overly high refinancing costs, these institutions might become distressed as well (Freixas *et al.*, 2000a). All of these types of contagion effects can be visualized by the typical chain reaction of dominoes. If all dominoes stand in line and the first domino is toppled, this will lead to a chain reaction and all the other dominoes will topple as well. Moreover, depending on the composition of the dominoes (or the structure of the financial system) cascading defaults may occur. This will be the case if each domino tile knocks down more than just one domino.

In contrast, a *common shock* will emerge if several banks are simultaneously in distress. Making use of the domino analogy again, such a shock might emerge if an earthquake shakes the surface on which the dominoes are standing. If several domino tiles topple at the same time, a common shock has hit. Obviously, such a shock might additionally impose contagion effects as well. Transferring this picture onto the financial system, business cycle fluctuations might shake financial institutions. If these fluctuations become sufficiently large, so that many companies of a business-cycle sensitive sector face difficulties in repaying their loans, all financial institutions lending to this sector will have to bear losses at the same time. If these losses are too large, more than one bank might default at the same time.[1] Financial institutions might be incentivized to foster the likelihood of a common shock by investing in the same assets if this increases their likelihood of governmental support in distress. The anticipation of governmental support allows financial institutions to increase their risk taking. In this case a common shock might also emerge endogenously (Acharya, 2009).

While several trigger of contagion effects have been identified, the literature on common shocks is still in its infancy. From a regulatory perspective, the risk of common shocks might, however, be even more crucial, as regulatory agencies have no time to build up walls to protect the remaining dominoes, which have not been hit by the shock, from being toppled. As common shocks might cause an even more severe decline in economic performance than contagion effects, the analysis in this thesis focuses on minimizing the probability of common shocks resulting from business cycle fluctuations.

The world financial crisis can be considered as a combination of both contagion effects and common shocks. While the origin of this crisis was rooted in the U.S. subprime mortgage market, the myopic use of financial engineering, the build-up of financial sector imbalances and an increasingly interconnected financial system amplified this crisis and resulted in devastating effects and international distress. Globally low interest rates, caused by an expansionary monetary policy in the U.S. and a savings glut in Asia, incentivized investors to search for more profitable investment opportunities. This search for yield increased the riskiness of asset portfolios. Simultaneously, new investment products emerged which claimed to reduce risks by pooling different assets. The demand for these securities, such as asset backed securities and collateralized debt obligations, increased tremendously in the last decade (IMF, 2009). However, the securitization process only led to a misperception of risks, as the risks of the pooled assets were de facto more correlated than expected.

When subprime loans defaulted, several contagion effects emerged. Investors lost confidence in both securities and their underlying assets. In order to limit their

[1] Admati and Hellwig (2013, p. 47) argue that the absence of banking crises between the 1940s and 1970s can be explained by low business cycle volatility, among other things.

losses, they sold a large portion of their assets. Due to mark-to-market accounting rules these fire sales resulted in a common shock for several financial institutions. In September 2008, the bankruptcy of Lehman Brothers, one of the largest investment banks in the U.S., fueled a loss of confidence in their counterparties from investors. Money market funds withdrew their funds and interbank markets froze. Refinancing became difficult, so that central banks had to step in with large liquidity programs. Nevertheless, financial institutions hoarded liquidity at the central banks instead of granting loans. Credit decreased sharply, resulting in a worldwide recession.

Regulation also had its stake in these developments. It tolerated a housing price bubble in many countries as well as increasing global current-account imbalances, and failed to notice gross capital flows. In the run up to the crisis, gross capital flows grew excessively between Europe and the U.S. although net capital flows remained fairly stable. By borrowing and investing funds in the U.S. at the same time, European financial institutions were highly exposed to financial markets abroad.[2] Probably the largest regulatory failures were the weakening of capital requirements prior to the crisis and the misjudgment of the impact of Lehman Brothers' bankruptcy on the stability of the financial system during the world financial crisis. As equity shares declined sharply, financial institutions possessed too few buffers to absorb the various financial shocks.[3]

In the aftermath of the world financial crisis, policy makers, professionals and scholars alike came forward with proposals on how to improve regulation in order to reduce systemic risk. These proposals either aim to reduce systemic risk prior to or during a financial crisis. The most widely discussed regulatory measures of *financial crisis prevention* are capital requirements and liquidity requirements. Both serve to build up buffers to make these institutions less prone to shocks. Several *crisis management* measures have been suggested to prevent contagion effects in case a financial crisis still occurs. These measures comprise ways to recapitalize financial institutions in distress and increase investors' confidence in the stability of the remaining financial institutions. Although several interdependencies exist, the two types of regulatory measures are usually analyzed separately.

[2]Shin (2012) therefore considers this global banking glut to be the true culprit of the overly loose credit conditions in the U.S.

[3]For a more detailed overview about the origins of and the developments during the world financial crisis, see e.g. Acharya *et al.* (2009c). Reinhart and Rogoff (2009b) put this crisis in a broader historical perspective and point out that most financial crises are caused by some kind of excessive (short-term) debt financing. Rajan (2010) argues that the origin of the increase in granting highly risky loans is the educational inequality in the U.S. In order to compensate the resulting income inequality, the government fostered loans to people who had too little income.

At present, many countries implement banking regulations based on the recommendations of the Basel Committee on Banking Supervision (BCBS). These recommendations are drafted in the Basel Accords. The first Basel Accord was formed in 1988 in response to the liquidation of the German Herstatt Bank in 1974, the largest failure of a financial institution in the post-war period until then. It demanded that banks finance a certain share of their risky investments with equity and disclosed reserves (BCBS, 1988). As the international financial system has changed significantly in the last decades, the Basel Accord was adjusted in 2006 to incorporate risks resulting from an increased interconnectedness of the financial system. The Basel II Accord increased banks' information disclosure and implemented a more risk-sensitive capital ratio (BCBS, 2006). In consequence, banks disproportionally invested in low-risk assets, like AAA-securities. In the world financial crisis, these assets turned out to be riskier than expected. The Basel III Accord tries to incorporate this experience by including several fine-tuning measures such as countercyclical capital buffers and a leverage ratio, as well as liquidity requirements (BCBS, 2011b).

These recent adjustments of the Basel Accord in particular are considered as highly complex and a major challenge for regulatory agencies. Even if these agencies are able to collect all relevant information from banks, they might face difficulties in assessing the information in time. Therefore, Haldane and Madouros (2012) and Hellwig (2010), among others, call for a reduction of the complexity of regulatory measures. Based on this idea, Hakenes and Schnabel (2013) show that overly complex regulation might also be the consequence of regulators being caught out by sophisticated banks. Facing informational advantages, banks are incentivized to use complex arguments in order to persuade regulators to implement the regulatory measures which serve them best. As regulators are unwilling to admit their inability to understand the argument, this might result in a socially undesirable and unduly low level of regulatory intervention.

Despite these arguments, only a few suggestions have been made on how to reduce regulatory complexity until now. The most prominent example is Admati *et al.* (2013), who call for a simple, risk-*un*weighted capital ratio of 30% in normal times and 20% in times of distress. Like the Basel Accord, this proposal can be classified as a financial crisis prevention measure, as it builds up buffers against potential losses.

In this thesis we will have a closer look at another regulatory measure which is both a simple rule and considers interdependencies of crisis prevention and crisis management measures. The *regulatory margin call* proposed by Hart and Zingales (2011) combines capital requirements with an obligatory regulatory intervention if a financial institution nevertheless turns out to be in distress. In detail, Hart and Zingales suggest a two stage trigger mechanism based on market participants' expectations regarding institutions' probability of default. As a proxy for these expectations the authors consider the price of credit default swap (CDS) contracts written on the respective financial institution. A CDS is a bilateral contract between a seller of protection and a protection buyer, according to which the protection buyer pays a fee to the protection seller in order to receive a payment if a stipulated credit event materializes, e.g. a default. If market participants regard the probability of default as high, they will buy CDS contracts to protect themselves against a potential default. According to Hart and Zingales, each time the CDS price exceeds 100 basis points for more than 30 days, the financial institution has to raise additional equity (make a margin call) in a predetermined time. If the CDS price remains above the threshold, as the institution is either unable or unwilling to raise more equity, the regulator is forced to perform a stress test. If this stress test confirms the risk to financial stability, the regulator has to take over, replace the management and wipe out shareholders.

Although the margin call has received some attention in the literature, an in-depth analysis of this proposal has not been carried out. This thesis therefore sets out to provide a profound theoretical analysis of the effectiveness of this regulatory proposal based on two points of criticism. These are the impact of the margin call on financial institutions' investment decisions and the impact of asymmetric information on the pricing in the CDS market.

Hart and Zingales claim that their margin call is a free lunch as it imposes no restriction on investing in projects with a positive net present value. We challenge this statement and aim to identify the de facto determinants which constitute financial institutions' investment decisions. In order to compare our results with their findings, we answer this first research question with a two-period partial equilibrium model that is quite similar to their model.

As the margin call is based on expectations about the future development of financial institutions, it constitutes a counterproposal to the Basel III Accord which is based on banks' balance sheets and thus on information about past performance. In a second step, we thus aim to compare the margin call with the main measures of the Basel III Accord to identify which regulatory measure achieves financial stability at the lowest cost in terms of lowest deadweight loss resulting from inefficient bank lending.

The analysis of the margin call is based on the assumption that all market participants possess the same information regarding the financial institution. However, financial institutions typically hold private information, so that market participants might be unable to observe the institutions' risk taking. Therefore, we close our analysis by studying the impact of asymmetric information on the effectiveness of the margin call.

1.2 Overview

We analyze the effectiveness of the margin call in the following chapters, based on the two points of criticism identified above. In this section, we will present the structure of the thesis and will summarize the findings of each respective chapter.

Chapter 2: Literature Survey

This chapter surveys the literature on regulatory measures and their ability to minimize systemic risk. It is striking that a standard definition of systemic risk is lacking. The largest strand of the literature solely focuses on the risk of different contagion effects. In contrast, this thesis understands systemic risk in a broader sense comprising all kinds of risks which could lead to an instability of the financial system and which would impose negative effects on the real economy. In consequence, we explicitly include the risk of common shocks. This latter aspect has not received much attention until the seminal work by Acharya (2009), who explains why common shocks might accrue endogenously. As the world financial crisis resulted from a combination of both contagion effects and common shocks, as well as the interdependence of both, it is essential to consider potential sources of common shocks as well when searching for adequate regulatory measures.

Regulatory measures to minimize systemic risk can be divided into two categories. They aim to either prevent the materialization of systemic risk prior to financial crises, or manage the spread of systemic risk on the financial system when it has materialized. It is widely acknowledged that the two types of regulatory measures might impose feedback effects on each other. While explicit or implicit guarantees might lead to increased risk taking in the run up to the next crisis (see e.g. Claessens *et al.*, 2001b), risk-weighted capital requirements might cause fire sales (see e.g. Kashyap *et al.*, 2008). However, these interdependencies are usually not explicitly considered when determining the impact of regulatory measures on financial stability.

There are only a few regulatory measures that take into account interdependencies between prevention measures and management measures. Contingent convertible bonds (CoCos) aim to build up buffers in normal times, which can be drawn down in times of distress. These bonds will be converted into equity once a predetermined scenario takes place and may thus reduce losses. Consequently, CoCos aim to reduce governmental support in a crisis but may not be eligible to cover all losses. We therefore focus on the seminal proposal by Hart and Zingales (2011), which is a regulatory margin call. This mechanism defines capital requirements for large financial institutions (LFIs) as an approach to prevent financial crises ex ante. Moreover, it determines how these institutions will be managed if a crisis nevertheless occurs. Hart and Zingales argue that the expectation of a predetermined rescue mechanism incentivizes financial institutions to reduce their risk taking ex ante. As this proposal is rather new, we conclude that an in-depth theoretical analysis of the margin call is needed to identify potential limitations of this approach with respect to financial stability and bank lending, and to compare it with the regulatory measures currently in place.

Chapter 3: A Review of the Margin Call

We start our analysis by presenting the regulatory margin call following the analysis of Hart and Zingales (2011). The margin call is outstanding as it explicitly combines crisis prevention and management measures. Moreover, it constitutes an attempt to reduce the complexity of financial regulation by focusing on the price of CDS contracts as the key figure that comprises information on institutions' assets and liabilities and which is observable by all market participants. As market participants write CDS contracts on both banks and LFIs, this regulatory measure can be applied not only to banks, but to all financial institutions on which CDS contracts exist.

The aim of this margin call is to reduce LFIs' incentive to boost leverage, which increases the probability of default. The literature identifies several reasons why financial institutions prefer debt over equity. In the presence of explicit or implicit guarantees, debtholders demand lower interest rates on debt as they expect to receive their payment even if the institution is in distress. Moreover, several countries promote debt financing by granting tax advantages. Hart and Zingales consider a third advantage, which is the reduction of agency costs resulting from an incomplete contract problem. These costs might occur if the manager exhibits an informational advantage vis-à-vis investors. In this case, equity financing enables the manager to renegotiate or even refuse repayments to shareholders after the investment is made. Issuing debt mitigates this incentive and commits the manager to use his skills on behalf of investors.

Although Hart and Zingales suggest a margin call that is triggered each time the CDS price exceeds 100 basis points for more than 30 days, their analysis is based on a threshold of zero basis points. They find that their margin call limits the leverage of the LFI so that systemic risk will not materialize. Moreover, they claim that their proposal will not hamper the LFI from investing in new projects if their net present value is positive. Identifying an arithmetic error in their analysis, we arrive at a different conclusion. The LFI will only invest in new projects if their funding liquidity is positive, not just their net present value. The funding liquidity comprises the amount an institution is able to pledge against its investment projects. As the manager of the LFI will receive a share of the LFI's returns, equity financing leads to a lower funding liquidity than debt financing. Accordingly, the implementation of the margin call will restrict new investments if the funding liquidity with equity financing turns out to be too low. Based on this analysis, we derive the three research questions which will be analyzed in the following chapters of this thesis.

Chapter 4: Bank Lending and Financial Stability over the Business Cycle

The theoretical model by Hart and Zingales (2011) lacks a fully-fledged intertemporal analysis of the LFI's investment decision. Based on the observation that the funding liquidity plays a crucial role for investment decisions, we build a two-period model to evaluate the impact of the funding liquidity on all investment decisions over the business cycle. The model presented in this chapter is an extended and slightly modified version of Bucher *et al.* (2013).

Our model resembles that of Hart and Zingales, but focuses on banks instead of LFIs by considering debt in the form of demandable deposits. This limitation allows for a comparison of the margin call with regulatory measures that solely apply to banks. In order to focus on the impact of the funding liquidity on the trade-off between financial stability and efficient bank lending, in this chapter we restrict our attention to deposits as the only source of external financing. Therefore, this model serves as a workhorse model which we will adjust in the following chapters according to the needs of the remaining research questions.

Empirically, Jordà *et al.* (2011) detect a correlation between bank lending and the business cycle. Most articles argue that bank lending might affect the business cycle, while the reversed causality has not, as yet, attracted much attention. We start to fill this gap by analyzing the impact of the volatility of business cycles on banks' ability to grant loans. Therefore, we focus on threats to financial stability which will occur if banks' risk taking hampers the absorption of common shocks resulting from business cycle fluctuations.

Considering a representative forward-looking banker, we analyze his investment and risk taking decisions given that stochastic business cycle fluctuations will emerge in the future. If a downturn materializes, banks' assets will yield a lower cash flow compared with an upswing and banks' internal funds decline. Moreover, the economic prediction in the downturn is quite poor, so that pledging against prospective earnings to obtain external funds might be insufficient to finance new investments. This will be the case if banks prefer a safe capital structure that enables them to pay off investors independently from economic conditions. Banks thus have to use internal funds to co-finance new loans. Depending on the extent of business cycle fluctuations and therefore the extent of banks' liquidity risks, the funding gap might be too large or the amount of internal capital too low, so that bank lending will be restricted in the downturn. Anticipating a potential restriction in the future, banks are incentivized to increase their internal capital and thus their lending ability in an economic downturn. This will be feasible if they increase the value of their assets, i.e. if they increase their credit supply today. In consequence, bank lending becomes procyclical, as banks overinvest in good times in order to reduce the underinvestment in bad times. If, however, the cost of excessive bank lending becomes too large, banks will prefer to gamble for resurrection to increase their funding liquidity in the downturn. In this case they issue more deposits and the capital structure becomes risky. Financial instability will thus occur if the economy slides into a recession, as banks' returns are too low to compensate their depositors. Moreover, liquidity risks might be so large that banks anticipate a large debt overhang in the downturn and thus put financial stability at risk straight away. We are thus able to explain procyclical lending, a secular trend in granting loans or a curtailing of loans, depending on the extent of liquidity risks in the economy.

Chapter 5: Bank Lending and Financial Stability with External Equity

In order to analyze the impact of regulatory measures on financial stability and bank lending, we have to extend the model of Chapter 4 by considering the possibility of raising external equity. This chapter thus serves as a preparation for the comparison of the margin call with different regulatory instruments of the Basel III Accord. Moreover, we add an interesting twist in the specification of the business cycle by assuming that banks' loans are nonperforming in the downturn, i.e. they cannot be paid off within the stipulated time. Therefore, banks possess no internal funds at that time, but will roll over these loans to pledge against an expected lower return, which will materialize at the end of the next period. We thus capture a scenario which is quite often observable in the run up to a recession.

These model modifications only slightly change the results. As in Chapter 4, the driving factors behind a bank's ability to grant loans in the downturn remain the funding liquidity of these loans and the cash flow which materializes in the downturn. Raising equity allows banks to maintain a safe capital structure, even for larger liquidity risks. However, due to financial frictions, bankers are able to extract rents when raising equity. The funding liquidity of equity financing is thus lower than that of debt financing. Accordingly, bank lending will again be restricted in the downturn if banks choose a safe capital structure. If the liquidity risks increase, granting loans might be heavily restricted so that banks prefer to impose a threat to financial stability by gambling for resurrection. We identify the same lending patterns as in Chapter 4 with one exception. As loans are nonperforming in the downturn, their return will only materialize if investors do not run on the bank in the recession. Due to this modification, the secular trend of the business cycle becomes more pronounced.

Chapter 6: Comparison of Regulatory Measures

Having determined the benchmark model in Chapter 5, we are now in a position to compare the regulatory margin call with the instruments in the Basel III Accord, with respect to their trade-off between financial stability and efficient bank lending. We find that they all increase financial stability for certain liquidity risks but differ in their impact on bank lending.

We consider the three main measures of the Basel III Accord, which are risk-weighted capital requirements, countercyclical capital buffer requirements and the liquidity coverage ratio. As long as the regulator possesses the same information regarding the volatility of the business cycle, she imposes no excessive regulatory measure. Hence all requirements will only restrict issuing deposits if banks choose a risky capital structure. Imposing any regulatory measure will reduce the funding liquidity of the risky capital structure and will thus lead to a restriction on bank lending. Therefore, banks' expected return when choosing a risky capital structure declines. In comparison, choosing a safe capital structure thus becomes more beneficial for certain liquidity risks and financial stability increases. However, as the safe capital structure is also associated with a restriction on bank lending, financial stability can only be achieved at the cost of inefficient bank lending.

The regulatory measures discussed in this chapter differ in their restriction on issuing deposits. Both a liquidity coverage ratio of more than 100%, as the Basel

III Accord suggests, and a margin call with a threshold of zero basis points, as Hart and Zingales consider in their theoretical analysis, would fully prevent banks from choosing a risky capital structure. However, we have shown already in Chapter 4 that for sufficiently large liquidity risks banks are unable to grant loans with a safe capital structure. For these risks, imposing a liquidity coverage ratio or a regulatory margin call would result in a severe credit crunch. A lower liquidity coverage ratio or a higher threshold for the margin call would dampen this effect on bank lending but would tolerate a certain degree of systemic risk.

Moreover, we exemplify the impact of asymmetric information, with the help of countercyclical capital buffer requirements. Given that the regulator possesses less information, we assume that she imposes an unduly strong countercyclical capital buffer. If the liquidity risks in the economy are fairly low, banks will only need a small share of equity funds to maintain a safe capital structure. Although bankers would prefer to raise more equity funds in order to increase their rent extraction, shareholders would be unwilling to provide more funds due to rather low expected returns. Imposing a large capital ratio in normal times would therefore imply that banks were unable to fulfill these requirements and would thus grant no loans at all. Hence, strong countercyclical capital buffer requirements might result in a disintermediation as they impose a cutback in lending without increasing financial stability. Without specifying the impact of asymmetric information for all regulatory measures, we argue that similar effects may occur for these measures as well.

Chapter 7: Margin Call with Asymmetric Information

Financial institutions typically possess more information regarding the risks in their balance sheets than investors and regulatory agencies. Regulatory intervention might therefore become a shot in the dark. This chapter analyzes the impact of markets' lack of information about the value of banks' assets and banks' risk taking on the effectiveness of the margin call. Such a modification allows us to explain why banks are swamped with liquidity, which allows them to grant loans excessively. Moreover, we identify that banks might be incentivized to disguise their risks. In this case, the effectiveness of regulatory measures like the margin call might be hampered.

As the dynamic analysis will not yield any additional information, we focus in this chapter on banks' investment and portfolio decisions in an economic downturn. In this case, bank loans are again nonperforming. Banks will thus only collect any earnings if they roll over these loans. In contrast to Chapters 5 and 6, we assume that banks gained additional information regarding the return on these nonperforming loans by monitoring them in the past. Hence they are able to assess the value of these assets while market participants can only form expectations on their returns. Investors will therefore either overstate or understate the value of banks' assets. Providing funds based on their expected return, investors might provide either too little or too much funding, depending on which type of misperception prevails. As long as the lack of information is solely related to the value of banks' assets, this will only lead to a different allocation of banks' returns between bankers and shareholders. If, however, investors are additionally unable to determine banks' risk taking, depositors will provide too little or too much funding as well. If banks choose a risky capital structure while investors expect a safe capital structure, banks will receive excess liquidity. As they know that they will pay off less to investors, marginal investment costs of granting loans decline and bank lending becomes excessive. This overinvestment differs from the overinvestment we identified in the dynamic analysis of the previous chapters. While the latter coincides with a safe capital structure, the overinvestment in this chapter imposes a threat to financial stability as it goes along with a risky capital structure.

In this chapter we implement the original proposal by Hart and Zingales, i.e. we consider a margin call which will be triggered if the CDS price exceeds 100 basis points. Accordingly, we allow for financial instability to occur with a probability of one percent given that the bank run will destroy the value of all assets. Due to markets' lack of information about the value of banks' assets, we find, however, that the margin call might be unable to prevent financial instability even if the probability of a common shock is clearly above one percent. Moreover, we identify similar unwanted effects as for the countercyclical capital buffer discussed in Chapter 6. For certain liquidity risks, a disintermediation will occur, as implementing the margin call will cut back lending without increasing financial stability.

Chapter 8: Conclusion and Outlook

In this chapter we summarize the main findings of this thesis. Suggesting a simple rule which considers interdependencies between crisis prevention and management measures, the regulatory margin call by Hart and Zingales (2011) stimulates the debate on whether to return to less complex regulation. Focusing on the trade-off between financial stability and efficient bank lending, we identified that the margin call is no free lunch and might turn out to be ineffective when banks possess private information. However, we obtained similar results for the regulatory measures of the Basel III Accord. Although a way to ensure the proper functioning of the CDS market needs to be determined, we conclude that the margin call should receive more attention in today's regulation as it may perform better in identifying new sources of systemic risk which have not been considered by the current regulation. Moreover, the margin call is applicable to all financial institutions on which CDS contracts exist.

Nevertheless, this analysis can only be seen as a first step towards evaluating the margin call and potential interdependencies between crisis prevention and crisis management measures. We thus close this chapter with an overview of further research questions in this field.

Chapter 2

Literature Survey

There is a growing literature on how to reduce systemic risk both prior to and during a financial crisis. Especially in response to the world financial crisis, several proposals have been submitted to identify and minimize systemic risk. These proposals focus predominantly on financial crisis prevention. Although it is indisputable that interdependencies between financial crisis prevention and management measures exist, the two aspects are usually analyzed separately. However, there are first attempts which aim to incorporate the impact of these interdependencies. Up to now, the regulatory margin call by Hart and Zingales (2011) is the only measure which explicitly combines financial crisis prevention and management measures. As this proposal is, moreover, outstanding in other respects, we will argue in this chapter that the margin call needs to be analyzed in more detail.

2.1 Introduction

The world financial crisis has shown again quite plainly that the materialization of systemic risk can have a major impact on the financial system and the real economy. Depending on the empirical approach, gross domestic product (GDP) tends to decline on average by 9-20% during financial crises.[1] Regulators aim to prevent these effects on economic growth. Therefore, they attempt to minimize systemic risk, both prior to and during financial crises, by regulatory intervention. In order to achieve this goal, it is, however, essential to identify and measure all different types of systemic risk.

[1]See Hoggarth *et al.* (2002) as well as Reinhart and Rogoff (2009a) for detailed analyses on financial crises costs.

In this chapter we present an overview of the literature on minimizing systemic risk. It becomes apparent that a uniform definition of systemic risk and its potential triggers is missing. As a result, diverse proposals on measuring systemic risk and improving financial stability have been made. These proposals can be classified in two strands. The first strand aims to reduce systemic risk prior to financial crises. The main focus of this literature is on the design of capital and liquidity requirements. Other suggestions deal with deposit insurance or capital controls. The second strand seeks to limit systemic risk during a financial crisis. These crisis management measures comprise government guarantees as well as different recapitalization schemes. While the former can be implemented immediately, the latter demand a somewhat longer preparation.

In recent decades, a tendency towards more comprehensive regulatory frameworks emerged. Regulators aimed to account for as many types of systemic risk as possible, which resulted in regulatory frameworks that have been extended by several fine-tuning instruments. In the U.S., this trend resulted in the Dodd-Frank Wall Street Reform and Consumer Protection Act (henceforth Dodd-Frank Act). The complexity of this act is, inter alia, indicated by the fact that it covers more than 2,300 pages. Clearly, comprehensive regulatory frameworks pose a challenge for regulatory agencies. First, it might be difficult to identify potential externalities of all different regulatory instruments. Second, all relevant information has to be collected and assessed in a timely manner (Danielsson *et al.*, 2005). A central question is thus whether a return to less complex regulation, as suggested by Haldane and Madouros (2012) and Hellwig (2010), might be more beneficial.

Although interdependencies between the two types of regulatory intervention are widely acknowledged in the literature, they are mostly not considered in the analysis of these measures. First attempts to capture this link are CoCos and the regulatory margin call by Hart and Zingales (2011). While CoCos are primarily a preventive buffer, which can be converted into equity to absorb shocks in bad times, the margin call explicitly combines crisis prevention and crisis management measures. Therefore, this proposal is eligible to identify interdependencies between the two types of regulatory intervention.

In this chapter we show that the regulatory margin call has several advantageous features, compared with other proposals. It captures the interdependency between crisis prevention and management by forcing the regulator to commit herself ex ante to a specific intervention in times of distress. Moreover, it is a simple rule which can be easily observed by both investors and regulatory agencies. As the margin call is based on the CDS price, we will argue that it might be feasible to capture different types of systemic risk. Finally, this rule can be applied not only to banks but to all financial institutions which are considered to be systemically important. Therefore the margin call will take center stage in this thesis.

This chapter proceeds as follows. Section 2.2 presents the literature on identifying and measuring systemic risk. Proposals on how to reduce systemic risk prior to financial crises are surveyed in Section 2.3, while suggestions on how to improve financial crisis management are discussed in Section 2.4. Section 2.5 identifies the missing link between these strands of literature and argues that it is worthwhile to analyze the regulatory margin call in more detail. Section 2.6 concludes and provides an outlook on the research focus of this thesis.

2.2 Systemic Risk

Following IMF *et al.* (2009) we perceive systemic risk as any impairment that causes financial instability by limiting the functioning of an essential part of the financial system so that the real economy may be seriously damaged. As argued in Chapter 1, we thus regard the risk of both contagion and common shock to be equally important.

This definition differs from the perception of systemic risk prior to and during the world financial crisis. A large strand of the literature employs systemic risk as synonymous with contagion, see e.g. Rochet and Tirole (1996), Schoenmaker and Oosterloo (2005), Adrian and Brunnermeier (2008) or Haldane (2009). Other papers consider merely a specific aspect of systemic risk. For instance, Bartholomew and Whalen (1995) define systemic risk as the probability of an unexpected loss of confidence, whereas Mishkin (1995) regards it as a breakdown of the financial market's informational function.

Closer to our definition is the survey by de Bandt and Hartmann (2002), who distinguish between a narrow and a broad sense of systemic risk.[2] Whereas they denote the narrow sense as the risk of contagion, the broad sense captures the risk of a common shock. Due to the developments during the world financial crisis, we are, however, more in line with Acharya (2009), who treats common shocks not as subordinated but as a coequal type of systemic risk.

[2]This survey has recently been updated in de Bandt *et al.* (2009).

2.2.1 Types

In the following section we survey the literature on the different types of systemic risk. We first present different triggers of contagion , and then turn to the literature on common shocks, which is still in its infancy. Identifying different types of systemic risk might be crucial for the choice of regulatory measure, as the optimal choice might differ depending on the type of systemic risk that is prevailing in the economy.

Contagion

Financial contagion might occur via either direct or indirect linkages between financial institutions. While business relations result in direct linkages, financial institutions might be also indirectly linked by operating in the same markets, such as the interbank market, asset markets or foreign exchange markets. Several triggers of contagion for both types of linkages have been identified in the literature.

The seminal paper on direct contagion is by Allen and Gale (2000). They show that the failure of one bank might cause financial instability if banks are linked via overlapping claims. A liquidity shock might force a bank to sell its assets prematurely. If the decline in value of this bank is too large, it will have to default on its investors' claims, i.e. on the claims of other banks. Contagion will only occur if the loss of these claims lowers the value of other banks to such an extent that it results in a default on their claims as well. Allen and Gale find that the network structure determines the financial system's ability to absorb shocks. Within a complete claim structure, in which all banks are mutually connected, idiosyncratic shocks can be absorbed by the financial system. However, in an incomplete structure, directly linked banks are less able to absorb large liquidity shocks, so that contagion might emerge. These findings inspired a growing literature on financial contagion and financial networks in general.[3]

Considering asymmetric information, different triggers of direct contagion have been identified. Dasgupta (2004) argues that banks do not fully insure their liquidity risks in the presence of incomplete information about regional asset returns. Accordingly, contagion may still be feasible in a complete network structure. Credit lines might be a further trigger for contagion (Freixas *et al.*, 2000b). If banks grant credit lines to ensure their uncertain liquidity needs, this allows depositors to withdraw from insolvent institutions. In consequence, parts of the resulting losses are transfered to other banks. Depositors may reduce their lack of information by collecting information about the banks' fundamentals. Hasman and Samartín (2008)

[3] See Summer (2013) for an overview of financial contagion in network models.

show that this may prevent contagion of solvent banks in an incomplete market structure.

Abstracting from the symmetric network in Allen and Gale (2000), Gai and Kapadia (2010) analyze networks with an arbitrary structure. While connectivity is beneficial due to risk sharing, it may lead to widespread effects if contagion nevertheless emerges. They find that the amplification of a shock is driven by its location within the financial system.

Besides trading with each other via the interbank market, banks are also indirectly connected when operating in this market. Due to incomplete information, an illiquid but solvent bank might be unable to refinance itself via the interbank market as other institutions are unwilling to provide liquidity. If this bank defaults, it may entail changes in depositors' money demand and may lead to herding behavior (Banerjee, 1992). Excessive withdrawals from other banks occur, either because depositors regard their bank as similar to the failing bank (information contagion),[4] or because of pure panic.[5] Rochet and Tirole (1996) find that government intervention in the interbank market, e.g. in the form of implicit insurance via the discount window of the central bank, may be a further trigger for contagion. In the presence of such interventions, banks are less incentivized to monitor their interbank market investments.[6] Accordingly, the riskiness of these investments may increase and may cause insolvencies in the banking sector.

Indirect contagion may likewise arise if banks operate in the same asset markets. Although the model by Kiyotaki and Moore (1997) discusses firms, the analyzed effects can be assigned to the banking system as well. In a dynamic model, they show how small, sector-specific technology shocks can cause large persistent fluctuations in output and asset prices via firms' borrowing contraints. These fluctuations can trigger spillover effects to other sectors where the shock might be amplified. In another setting, Diamond and Rajan (2005) analyze the interdependency between illiquidity and insolvency, which may cause a contagion spiral. Banks invest in projects which might be delayed but still productive. If the share of delayed investment projects is too large, banks face problems trying to satisfy depositors' claims. In order to overcome illiquidity, banks are thus forced to liquidate some of their projects. Consequently, the average productivity of these projects declines, which might cause the insolvency of some banks. Anticipating these insolvencies, depositors might run

[4]For further analyses of information contagion see e.g. Chari and Jagannathan (1988), Iori *et al.* (2006), Acharya and Yorulmazer (2008b) and Allen *et al.* (2012).

[5]Aharony and Swary (1996) and Docking *et al.* (1997) find that the empirical evidence for such pure contagion is rare.

[6]For a theoretical analysis of the disciplinary effect of debt, see Myers (1977).

on their banks prematurely. Therefore, banks have to liquidate even more projects and the average productivity shrinks even further. The amplification of both effects might thus result in a collapse of the entire banking sector. A similar reinforcing effect between assets' market liquidity and banks' funding liquidity is identified by Brunnermeier and Pedersen (2009).

Currency crises may also trigger indirect contagion effects in the financial sector. Miller (1996) shows that the financial sector will be in distress if speculative attacks in the foreign exchange market are financed by withdrawing funds prematurely. Anticipating distress in foreign exchange markets may even incentivize depositors to withdraw their funds before a currency crisis takes place (Goldfajn and Valdés, 1997). According to the third generation of currency crises, increasing capital inflows lead to over-borrowing in foreign currency and over-lending in national currency.[7] The depreciation during a currency crisis will thus erode banks' balance sheets so that national banks become distressed as well (Corsetti *et al.*, 1999; Chang and Velasco, 2000).[8]

Empirical studies identify either the risk of contagion within specific markets or the channel through which contagion spreads. Analyzing U.S. bank failures between 1880 and 1936, Schoenmaker (1996) confirms the existence of contagion risks in the banking system. In contrast, Sheldon and Maurer (1998) find little evidence for these risks in the Swiss banking system between 1987 and 1995, when investigating national interbank credits. Upper (2011) compares several studies that focus on the probability and potential extent of contagion in the interbank market prior to the world financial crisis. Although contagion risks are considered to be quite low, Upper finds that these studies differ with respect to the extent of potential contagion effects. In a recent study on the interbank market covering the period of the world financial crisis, Memmel and Sachs (2013) find that contagion risks have been declining since 2008.

Financial institutions handle their transactions via settlement systems, and those of their customers via payment systems. As both systems transfer large volumes daily, the default of a single institution might have a major impact on all of its trading partners (Kahn and Roberds, 1998). Some studies analyze whether the risk of contagion via these direct linkages depends on the design of these systems. While in a gross settlement system all transactions have to be paid directly, in a net system

[7]The other two generations of currency crises do not explicitly consider the impact of speculative attacks on the financial sector. While the first generation explains speculative attacks by excessive debt (Krugman, 1979), the second generation analyzes the impact of self-fulfilling prophecies (Obstfeld, 1986).

[8]For an overview about the literature on further contagion channels see Upper (2011).

only the balance of a certain period, e.g. a day, has to be settled.[9] The empirical evidence of contagion in net settlement systems is, however, mixed. Humphrey (1986) provides evidence that in the U.S. net settlement systems might increase systemic risk, whereas Angelini *et al.* (1996) do not find such indication for Italy. In the euro area, most transactions are settled via the Trans-European Automated Real-time Gross Settlement Express Transfer System (TARGET2). Such gross settlement systems reduce the probability that a financial institution is unable to settle its transactions (Borio and Van den Bergh, 1993).

For several contagion channels identified above, the literature provides empirical evidence. Derviz and Podpiera (2007) investigate the specific relation between the domestic bank shareholders and foreign subsidy managers within multinational banks. They show that lending contagion due to these direct linkages emerged in 19 out of 31 cases. Bekaert *et al.* (2011) identify information contagion as the major channel of the world financial crisis. After the bankruptcy of Lehman Brothers, investors reassessed the vulnerability of other markets. They argue that the different extents of contagion depend on the weakness of the respective domestic factors in each country. Focusing on the world financial crisis as well, Didier *et al.* (2010) and Ahrend and Goujard (2014) give evidence for asset price contagion. While Didier *et al.* (2010) exhibits this channel for equity markets, the findings by Ahrend and Goujard (2014) indicate that bond markets have been a trigger for contagion as well. In contrast, Calomiris and Mason (1997) find that although the Chicago banking crisis of June 1932 entailed immense uncertainty about assets' quality, asset market contagion did not take place. The failure of insolvent banks had only a small effect on solvent banks. Evidence for a liquidity channel during the world financial crisis is provided by Longstaff (2010), who analyzes the impact of CDO markets on the financial system.

Summing up, this section shows that the literature on contagion triggers is manifold. These findings inspired several diverse proposals on how to reduce systemic risk, as we will see below.

Common Shock

De Nicolò and Kwast (2002) identify an increased correlation of stock returns among large and complex financial institutions during the 1990s. Although this indicates an increased probability of a simultaneous default of several financial institutions,

[9]See Leinonen and Soramäki (2003) for a more detailed description of the differences between these systems.

common shocks as another type of systemic risk did not receive much attention until the world financial crisis.

The seminal theoretical contribution to the analysis of common shocks is provided by Acharya (2009). He analyzes banks' incentives to invest in similar assets or industries. The default of a bank generates two types of externalities for the remaining banks in the financial system. First, the surviving banks have to pay higher interest rates on their debt, as the overall debt supply in the market declines. Second, banks benefit from the default in the sense that they are able to hire the staff of the defaulting institution. These new staff generate economies of scale so that banks' monitoring costs decline, which increases their expected return. Given that the negative externalities prevail, banks prefer to survive only if other banks survive as well. Accordingly, they choose to increase the co-movements of their risks. If institutions are large, essential or unique, these incentives become even higher as the extent of negative externalities increases. Although highly positive correlations constitute the optimal individual solution, they result in an increasing endogenous systemic risk of a common shock.

Endogenous common shocks might also occur for other reasons. Banks are incentivized to correlate their risks to actually increase the severity of a financial crisis, so that the possibility that the regulator bails them out to ensure financial stability increases (Acharya and Yorulmazer, 2007). Moreover, banks may increase their leverage in expectation of expansionary monetary policy in times of distress (Diamond and Rajan, 2009) or in expectation of other governmental intervention (Farhi and Tirole, 2012).

Up to now, empirical studies have focused on co-movements between banking crises and business cycles. Based on a data set which covers the past 140 years, Jordà *et al.* (2011) identify a close relationship between the severity of a recession and the extent of a credit boom in the run up to a recession. Although these findings do not indicate a specific causality, it is often argued that banking crises entail a negative impact on the real economy, see e.g. Bernanke (1983), Kaminsky and Reinhart (1999), Demirgüç-Kunt *et al.* (2006) and Altunbas *et al.* (2011). Dell'Ariccia *et al.* (2008) confirm this causality by comparing sectors that are highly dependent on external finance with sectors to which external finance is less important. They find that during a financial crisis credit supply declines to a larger extent in sectors that have to raise more external funds. This can be explained by the increase in external financing costs. Even if the other sectors are unaffected by the crisis, the overall effect on the real economy thus turns out to be negative. According to Dell'Ariccia *et al.* (2008), this effect is even more pronounced for developing countries and for countries with little access to foreign capital markets. However, determining the output losses during banking crises, Hoggarth *et al.* (2002) do not find any significant differences between developed and developing countries.

There is also evidence for a reversed causality. Gorton (1988) concludes, from an analysis of depositors' behavior over 100 years, that bank panics are systematic events which emerge in response to sufficiently large recessions. Observing business failures, depositors reassess their expectations about the prospective returns of their investments. Depending on their expected return, they might be incentivized to withdraw their deposits prematurely. If this behavior is optimal for a large share of depositors, the common shock thus caused on banks will result in a financial crisis.

Common shock and its interdependency with contagion effects impose a huge threat to the stability of the financial system, as the world financial crisis has illustrated. Accordingly, understanding the triggers of common shocks and identifying the causalities between banking crises and recessions are just two important task for today's researchers. While Acharya (2009) argues that bank behavior might increase the likelihood of a common shock, we will show in this thesis that the risk of a common shock might also have an impact on banks' investment decisions.

2.2.2 Measurement

The effectiveness of regulatory intervention depends, to a large extent, on the ability to identify systemic risk and measure financial institutions' contribution to it. Although regulators have to find appropriate indicators for both contagion and common shocks, up to now the focus on the literature has been on contagion. In particular, the literature focuses on identifying systemically important financial institutions (SIFI), i.e. institutions whose default will cause financial instability. Detecting these institutions enables regulatory agencies to impose additional regulatory measures to reduce systemic risk, as we will show in Section 2.3.

One relevant factor of systemic importance is the size of an institution. The default of a large institution might impose such a negative impact on the financial system that regulators consider it necessary to bail out this institution to maintain financial stability. These institutions are considered to be too big to fail.[10] Moore and Zhou (2012) confirm that size is an important factor for measuring systemic risk, but they find that its impact is nonlinear. There is no additional impact of banks with a size larger than 20 billion U.S. dollars. Estimating the impact of large institutions on common shocks, Lehar (2005) however gives evidence that larger and

[10] Another problem resulting from the size of an institution is that it might be too big to rescue, as observed in Iceland in 2008 and in Ireland in 2009.

more profitable institutions contribute less to systemic risk. This result indicates that optimal measuring of systemic risk might differ depending on the cause of systemic risk.

There are several other factors which determine the systemic importance of an institution. Based on these factors, several proposals have been made to measure banks' contributions to the overall systemic risk.

Adrian and Brunnermeier (2008) build their proposal on a standard risk measure in finance. The value at risk is a measure that captures the probability of a minimum loss of a certain portfolio within a specified time horizon. Based on this concept they develop a conditional value at risk (CoVaR). The CoVaR determines the value at risk of a single institution conditional on the distress of other financial institutions. Adrian and Brunnermeier interpret the difference between both measures as the institution's contribution to systemic risk.

Tarashev *et al.* (2009) suggest an assessment of each institution's contribution to systemic risk by determining the Shapley value, which is a standard solution method in cooperative game theory. The Shapley value identifies an institution's systemic risk based on the additional risk it generates by joining all feasible coalitions, i.e. in this context all feasible linkages with other financial institutions. Tarashev and Drehmann (2013) extend this approach by splitting the risks equally between borrowers and lenders. Both approaches are built on the Shapley value and the same definition of systemic risk. However, an empirical estimation of the tow measures gives two different conclusions regarding the systemic importance of several financial institutions. Consequently, this result points to the general problem regulators face when choosing an adequate concept to identify SIFIs.

More broadly, Haldane (2009) suggests measuring contagion based on the interconnectedness of each institution within the financial system. Analyzing CDS spreads, Barth and Schnabel (2013) empirically support that interconnectedness, correlation among financial institutions and the economic context, i.e. whether the financial system is already in distress, are better indicators than the size of an institution. In a similar vein, Zhou (2010) develops a systemic impact index which ranks banks based on the number of simultaneous bank failures in the financial system after their default. Moreover, Acharya *et al.* (2010) propose the assessment of the systemic expected shortfall, which indicates how much an institution is prone to being undercapitalized if the overall financial system is undercapitalized.

The price of CDS contracts is considered to be an eligible indicator of an institution's individual probability of default, see e.g. Hull *et al.* (2004); Blanco *et al.* (2005); Acharya and Johnson (2007); Marsh and Wagner (2012); Zhang and Zhang

(2013).[11] Comparing different high-frequency indicators, Rodríguez-Moreno and Peña (2012) find that CDS prices are not only preferable to detect individual risks, but also aggregate risks. Likewise, Belke and Gokus (2011) find that the volatility of CDS is a suitable measure for identifying the overall risk of the financial system, as volatility tends to be higher in times of financial crises and lower otherwise. Based on similar notions, Huang *et al.* (2009) suggest a systemic risk indicator based on CDS spreads and co-movements in banks' equity returns.

The literature has developed diverse proposals to measure systemic risk. Identifying the most suitable approach is a difficult task which constitutes a field of research in itself. In Europe, several new agencies have been created to reveal systemic risk in the financial system. While the European System of Financial Supervisors is responsible for microprudential supervision, the European Systemic Risk Board together with the European Central Bank is in charge of macroprudential oversight. Although identifying all types of systemic risk is of importance for the effectiveness of regulatory intervention, this is beyond the scope of this thesis.

2.3 Financial Crisis Prevention

Regulatory frameworks aim to reduce systemic risk prior to financial crises. The most widespread framework is the Basel Accord. As the Basel II Accord had not been implemented in most countries when the world financial crisis started, it is hard to tell whether this agreement would have been able to reduce systemic risk. However, the Basel II Accord received substantial criticism even prior to its implementation. Consequently, several suggestions were made in the course of the crisis on how to improve the Basel II Accord and increase banks' ability to absorb shocks in the future. The bulk of these proposals concentrate on capital and liquidity requirements, which have partially been considered in the Basel III Accord. Additionally, there is a debate on adjusting other instruments such as deposit insurance or capital controls. In this section, we concentrate on these measures and do not develop a more general discussion on whether to minimize systemic risk with a separate banking system.[12]

[11] For an analysis on contagion risk via the CDS market and banks' risk taking behavior see Heyde and Neyer (2010).

[12] For a discussion on separate banking systems see e.g. Blum (2012), Burghof (2012), Krahnen (2013) andLang and Schröder (2013).

2.3.1 Capital and Liquidity Requirements

The capital requirements of the Basel II Accord have been criticized for not considering banks' contributions to systemic risk. Among others, Acharya *et al.* (2009b) and Brunnermeier *et al.* (2009) thus demand a surcharge on capital requirements for systemically important banks.

Suggestions for the design of such a surcharge build on the indicators to measure systemic risk presented above. Many economists propose tying capital requirements to the institution's size, see e.g. Boyd and Jagannathan (2009), Hubbard (2009) and Squam Lake Working Group (2009c). This may diminish banks' incentive to become too big to fail and will increase the ability to absorb shocks for those banks which are already too large. Focusing on the ability to propagate shocks, Dietrich and Vollmer (2009) suggest imposing larger capital requirements on multinational banks than on cross-border financial services. Although subsidiaries are beneficial in creating more liquidity, multinational banks inefficiently allocate this liquidity across their subsidiaries so that local shocks can be transferred into aggregate shocks.[13] Another approach is to define the surcharge based on the time it would take to close the institution. Such "funeral plans" or "living wills" have been brought into the debate by Kashyap (2009) and the Squam Lake Working Group (2009b).[14]

The BCBS decided to close this regulatory gap by imposing additional loss absorbency requirements on global systemically important banks in the range of 1-2.5% (BCBS, 2013). Following IMF *et al.* (2009), the BCBS identifies these banks based on their size, interconnectedness and lack of readily available substitutes for the services they provide. Moreover, the BCBS takes into account banks' global activities and their complexity. The latter captures the idea presented above that regulators might face difficulties in liquidating certain banks.

The risk-weighted capital requirements of the Basel II Accord have furthermore been criticized for their procyclical effect on bank lending and economic growth, see e.g. Mulder and Montfort (2000), Ferri *et al.* (2001) or Repullo and Suarez (2008).[15] In an economic upswing, risks are considered to be low. Risk-weighted capital requirements are thus lower and ease banks' refinancing costs. Banks increase their lending, which might reinforce economic growth. On the contrary, risks are expected to be larger in an economic downturn. As banks face larger refinancing costs they

[13]The implementation of the Dodd-Frank Act considers the importance of foreign banking organizations by forcing them to generate an intermediate holding company for their activities in the U.S., which can be directly regulated (Federal Reserve System, 2014).

[14]See Rajan (2009) for an similar plan requiring each institution to create a concept for how to close the institution within a weekend.

[15]Allen and Saunders (2004) provide a survey on procyclicality and the impact of business cycle fluctuations on credit risks, operational risks and market risks.

have to cut back lending, so that economic growth might decline. Moreover, banks might also aim to countervail these additional costs by increased risk taking.

Some suggestions have been made on how to counteract these effects. Kashyap *et al.* (2008) recommend imposing higher capital reserves in a boom, which can be used as an additional buffer in a recession. Other determinants for these countercyclical capital requirements could be asset growth rates (Goodhart, 2008), leverage, maturity mismatches, credit and asset prices (Brunnermeier *et al.*, 2009), or credit growth and bank profits (Repullo and Suarez, 2013). Besides reducing output fluctuations, N'Diaye (2009) argues that countercyclical capital requirements may also support monetary policy, as fewer interest rate adjustments are needed.

Incorporating this criticism, countercyclical capital requirements became part of the Basel III Accord. Such a buffer can be implemented by national regulators either on the national level or applying only to specific banks or products within a range of 0-2.5% (BCBS, 2011b). Switzerland is the first country to impose a countercyclical capital buffer. Since September 2013, additional capital requirements of 1% apply to all mortgage loans taken out in Switzerland.

A third point of criticism with respect to risk-weighted capital requirements is their dependence on external ratings. During the world financial crisis, confidence in the quality of these ratings has substantially declined. Moreover, unexpected downgrades are considered to have triggered contagion by reducing investors' confidence and by forcing some investors to change their portfolios based on standards that limit their risk taking. Sy (2009) thus favors higher capital requirements for institutions that are identified, via stress tests, to be vulnerable to a rating downgrade. In order to restore confidence, Hubbard (2009) recommends agreeing on international standards and increasing disclosure.[16] A further problem constitutes rating agencies' conflict of interest. They are paid by the same financial institutions whose products they are rating, so they are incentivized to rate benevolently. This tendency is amplified by institutions' ability to shop around. Accordingly, they will hire the rating agency which provides the best rating. Searching for this best rating could be prevented by assigning each institution or product to one agency (Altman *et al.*, 2010). A conflict of interest may also arise due to other activities such as counseling. Therefore, the International Organization of Securities Commissions suggests a mandatory registration for rating agencies, whereby they have to confirm that such conflicts of interest do not exist (IOSCO, 2008).

[16] See Carvajal *et al.* (2009), Caprio *et al.* (2008) and Barth *et al.* (2004) for how transparency and disclosure can lead to risk reduction.

These issues have only been considered to some extent in the Basel III Accord. Transparency is increased as regulatory agencies have to provide more detailed information of their ratings (BCBS, 2011b).

The Basel III Accord has additionally been extended by liquidity requirements. The world financial crisis led to a curtailing in liquidity provision which severely hampered the functioning of the financial system. To increase financial institutions' ability to absorb liquidity shocks, two types of liquidity requirements have been implemented. The liquidity coverage ratio aims to ensure that banks survive a predefined stress scenario for a certain length of time, so that regulators will have time to react if a crisis occurs. In detail, this ratio is defined as stock of high quality liquid assets over net cash outflows over a 30-day time period and has to be larger than one. The net stable funding ratio has a long-term horizon of one year. Its aim is to reduce banks' incentive of short-term financing, by demanding that a share of long-term investments has to be covered by stable funding sources (BCBS, 2010).

In contrast to the literature on capital requirements, the literature on liquidity requirements focuses on analyzing their effectiveness and not on how to adjust these measures. Farhi and Tirole (2012) show that liquidity requirements are suitable to reduce banks' incentives to collectively increase their maturity mismatch and liquidity risk. Hong *et al.* (2013) compare the impact of the liquidity coverage ratio and the net stable funding ratio on banks' probability of default. They find that while the net stable funding ratio decreases the probability of default, the liquidity coverage ratio encourages liquidity hoarding. On an aggregate level, this causes illiquidity and thus increases the probability of default. Ratnovski (2013) argues that liquidity requirements will result in increased refinancing risks if this measure hampers the hedging of liquidity risks via another channel. Instead of enlarging their liquidity buffer to reduce liquidity risk, banks may also increase transparency about their solvency. If investors are able to observe banks' solvency, their liquidity demand will decline and banks will be less exposed to liquidity risks. Ratnovski therefore argues that liquidity requirements should either be accompanied by measures that generate more transparency, or by measures that reduce the risk of large refinancing needs, like the net stable funding ratio.

Focusing on the liquidity coverage ratio, Perotti and Suarez (2011) find that this measure works as a tax, which either is totally ineffective or imposes dead weight costs. They prefer a Pigovian tax as the liquidity coverage ratio is least binding when banks' incentive for excessive credit is large. De Nicolò *et al.* (2014) analyze the effect of a liquidity coverage ratio when implemented in a system that already comprises both capital requirements and deposit insurance. They show that liquidity requirements have a negative impact on both banks' efficiency to perform maturity transformation and on welfare. In order to fulfill the liquidity requirements, banks have to either use retained earnings or lower their indebtedness. Both alternatives hamper maturity transformation and will result in a cutback in lending. As liquidity is provided by the central bank, Bindseil and Lamoot (2011) argue more generally that an interaction of central bank and regulatory agency is substantial for the effectiveness of a liquidity coverage ratio.

A fundamental problem of the Basel Accords is that they solely apply to banks. All other financial institutions, such as bank holding companies or insurance companies, are not subject to this regulatory framework (Coates and Scharfstein, 2009). In order to circumvent higher costs resulting from regulatory intervention, risks are thus shifted outside the banking sector, e.g. to the insurance sector. The case of American International Group (AIG) illustrates that these risks may nevertheless constitute a threat to the banking sector. Risk shifting can thus increase systemic risk in the form of counterparty credit risks, see e.g. Hellwig (1995, 1998), Allen and Carletti (2006) and Allen and Gale (2007).

Boyd and Jagannathan (2009) propose to reduce these risk shifting incentives by enlarging the term "bank" to all institutions which either have transactionable liabilities or risky assets funded by liquid debt liabilities. In a similar vein, Carvajal *et al.* (2009) recommend extending regulation to all financial institutions which perform financial activities on a leveraged basis, while Hubbard (2009) suggests applying it to all institutions that are able to receive funds from the lender of last resort.

We can conclude that several attempts have been made to increase financial stability by imposing new crisis prevention measures. Empirical evidence on the effectiveness of these measures is obviously missing, to date, as these requirements have not been fully implemented as yet. Consequently, it will be up to further research to determine whether the adjustments in the regulatory framework make the financial system more resistant to systemic risk. However, the increased complexity forms a challenge for regulatory agencies. Assessing all information in time and identifying interdependencies among the diverse measures are difficult tasks. Whether regulation has to become more comprehensive, to cope with changes in the financial system, remains questionable. However, expanding regulatory intervention to other financial institutions besides banks seems to be a reasonable extension. In this thesis, we will thus focus on a regulatory measure which can be applied to other financial institutions as well.

2.3.2 Further Measures

In order to give a broader picture of crisis prevention measures, we briefly comment on both deposit insurance and capital controls. These two instruments have been applied during the world financial crisis, but they will be less relevant for the following analysis of this thesis.

Deposit Insurance

In response to the Great Depression, many countries implemented a deposit insurance.[17] Its aim is to support small depositors, who are unable to optimally monitor financial institutions, against default (Cordella and Yeyati, 2002).

A deposit insurance is considered to be advantageous in preventing bank runs à la Diamond and Dybvig (1983). Such a bank run will occur if depositors expect that other depositors will run on the bank. As this implies that they will not receive any payoff in the future, they will also run on the bank, although they do not face any liquidity need. Analyzing the impact of a deposit insurance on different governmental bailout options, Philippon and Schnabl (2013) moreover find that it is able to reduce the costs of all analyzed alternatives.

However, a deposit insurance also generates negative externalities. Depositors monitor their banks less intensively, as they do not have to fear losing their funds because potential losses are covered by the deposit insurance. This loss of market discipline enables banks to increase their risk taking and thus their profits. Moreover, a deposit insurance will result in an increased leverage, as raising short-term funds becomes less costly (Caprio *et al.*, 2008). Acharya *et al.* (2009a) argue that such a change in the leverage composition increases systemic risk, as short-term markets freeze more quickly in response to expectation changes. Without explicitly considering either of these two arguments, Demirgüç-Kunt and Detragiache (2002) give evidence that deposit insurance increases the probability of a financial crisis.

Several proposals have been made regarding how to reduce these negative externalities. Chan *et al.* (1992) recommend an incentive-compatible, risk-sensitive deposit insurance to counteract private information and moral hazard. In order to prevent a risk understatement from institutions aiming to pay lower premiums, they suggest tying capital requirements inversely to deposit insurance premiums. Thus, institutions are incentivized to disclose their risks correctly, as understating their risks lowers their premium but increases the costs of higher capital require-

[17] Demirgüç-Kunt *et al.* (2008) give an overview about the 87 countries which had implemented deposit insurance systems by 2003.

ments.[18] In order to reduce banks' incentive to use short-term financing, Perotti and Suarez (2009b) suggest a Pigouvian tax depending on the institution's contribution to systemic risk. Moreover, depositors' incentive to monitor can be increased by limiting the coverage of insurances not only per account but also per depositor, and by excluding certain kinds of deposits from the insurances, such as foreign-currency deposits (Demirgüç-Kunt *et al.*, 2008). Acharya *et al.* (2012) propose counteracting creditors' lack of monitoring resulting from the deposit insurance by a two-tier capital requirement. Besides a core capital requirement comparable with the Basel Accords, banks should face an additional requirement which has to be invested in treasuries or similar assets. This capital will accrue to the regulator instead of the bank's creditors if the bank failed. Banks therefore bear part of the costs of a financial crisis.

In the aftermath of the world financial crisis, European regulators increased their deposit insurances to maintain investors' confidence in the financial system and thus to reduce the probability of bank runs. Based on the Directive 2009/14/EC of the European Parliament and of the Council, its implementation proceeded in two steps. In 2009 the deposit insurance increased to 50,000 and by the end of 2010 to 100,000 euros. However, whether deposit insurance is a suitable instrument to reduce systemic risk prior to financial crises remains questionable.

Capital Controls

In the past, capital controls have primarily been implemented in developing countries to protect domestic capital markets from speculative capital flows, which might constitute a channel for currency and/or banking crises as described in Section 2.2. During the world financial crisis, this instrument has been discussed again for both emerging markets (Ostry *et al.*, 2010) and developed countries (Vella *et al.*, 2012). While Iceland has implemented capital controls on capital outflows, Cyprus has applied them to domestic transactions as well. In Europe, capital controls are currently also discussed in the form of a financial transaction tax. This is a tax on short-term capital flows based on the idea of Tobin (1978).[19]

Empirical studies mostly find negative effects of capital controls or, more precisely, a positive effect on welfare when capital controls are reduced. An exception is Chile's effective implementation of capital controls during the 1990s (Edwards, 1999). Although Bordo *et al.* (2001) show that lowering capital controls increases

[18] An overview of the literature dealing with the incentive problems of mispriced premiums is given by Beck *et al.* (2007).

[19] For a discussion of advantages and disadvantages of the Tobin tax, see e.g. Eichengreen (1999).

the probability of both currency and banking crises, Demirgüç-Kunt and Detragiache (1998) show that this effect appears only in the short-run and will only be pronounced if the institutional environment is weak. The long-run effect is clearly positive due to an increase in efficiency resulting from more competition (Claessens *et al.*, 2001a). Although opening financial markets increases the interconnectedness of financial institutions, and thus systemic risk, Brusco and Castiglionesi (2007) argue that welfare increases as the benefit of liquidity coinsurance outweighs the costs of increased risk taking. Kaminsky (2005) surveys the findings on macroeconomic consequences of capital controls since the 1970s. She argues that capital controls create large costs in the long run. As domestic financial institutions are protected, inefficiencies increase, which results in lower economic growth. A removal of capital controls might instead result in higher transparency and improved corporate governance.[20]

To sum up, in the past capital controls have generally been considered to be ineligible as a crisis prevention measure. This view has changed, to some extent, during the world financial crisis (IMF, 2012). However, as their resulting costs may be substantial, capital controls should only be applied on a short-term basis.

2.4 Financial Crisis Management

Despite adequate financial crisis prevention, financial distress may still occur leading to difficulties for financial institutions in recapitalizing themselves via the market. Fire sales may emerge and may trigger contagion (Gorton and Huang, 2004). Ensuring financial stability may thus only be feasible with regulatory intervention. As taxpayers' costs can be substantial, it is necessary to determine a strategy that supports the financial system at the lowest cost.

Unlike Kobayashi (2003) and Diamond (2001), who employ the term recapitalization to mean only measures that influence the reproduction of institutions' liabilities, i.e. debt and equity, we apply a broader definition. Following Laeven and Valencia (2008), as well as Hoshi and Kashyap (2010), we perceive all governmental measures preventing a financial institution's insolvency as recapitalization. We thereby widen the tools of financial crisis management to those which may also affect the asset side of banks' balance sheets, such as government guarantees, asset purchases or changes in accounting standards.

In this section, we examine the costs and benefits of measures undertaken in the world financial crisis. As these measures apply to single defaulting institutions,

[20] For an analysis of potential costs on the microeconomic level see Forbes (2005).

crisis management predominantly takes place at the national level.[21] We distinguish between crisis management measures that were implemented immediately and those which faced an implementation lag. Government guarantees belong to the former category. As regulators first have to assess all relevant information of the defaulting institution, both "bad banks" and nationalization are part of the latter category.

2.4.1 Immediate Measures

At the beginning of a financial crisis, governments might aim to increase investors' confidence in order to avoid information contagion or pure panics. Moreover, they may seek to stabilize SIFIs whose default would cause systemic effects. Government guarantees constitute an instrument that can be applied immediately. Predominantly, government guarantees are granted on bank liabilities. These can apply either to the whole banking sector, e.g. in the form of deposit insurance, or to single institutions; e.g. Hypo Real Estate Holding AG in 2008. Furthermore, guarantees may also apply to banks' assets. In this case, troubled assets remain with the banks but the government caps their potential losses. Between November 2008 and March 2009, Citigroup, Bank of America, ING, Royal Bank of Scotland and Lloyds Banking Group received such asset guarantees from their respective national governments (Panetta *et al.*, 2009).

The advantage of government guarantees is that they can be applied immediately, as the government does not have to provide liquidity at once, if at all (Ingves and Lind, 1997). They stabilize the payment system whose efficiency is usually endangered during crises by exceptionally high uncertainty in the financial market (Claessens *et al.*, 2001b).

Despite their stabilizing function, guarantees create several negative externalities. As government guarantees on bank liabilities during a crisis are comparable to a deposit insurance prior to a crisis, similar effects may arise. Guarantees diminish debt's disciplinary function as debtors are less incentivized to monitor their creditors (Acharya and Franks, 2009). Moreover, costs of short-term debt decline when anticipating government guarantees, so that banks increase their risk taking (Chaney and Thakor, 1985). Hakenes and Schnabel (2010) argue that this applies only to competitors, and not to the protected banks. Government guarantees expand the market share of protected banks. As competition thus increases for competitors, their margins decline, which induces competitors to take increased risk. Besides

[21] Although international solutions would be the best way to prevent regulatory arbitrage, agreeing on how to finance these measures might constitute a problem. Praet and Nguyen (2008) provide an analysis on burden-sharing principles and burden-sharing rules.

these effects, the anticipation of government guarantees might induce a further effect, which is unlikely to occur in response to a deposit insurance. Banks may correlate their risks to increase the probability of being rescued, as governments will only intervene if the financial system as a whole is at risk. This correlation of risks increases systemic risk already ex ante (Acharya and Yorulmazer, 2007). In the long run, government guarantees thus drive up the rescue costs of the next financial crisis (Claessens *et al.*, 2001b).

Asset guarantees are usually not granted directly at the beginning of a crisis, but after other intervention measures failed to serve their purpose. As with guarantees on bank liabilities, asset guarantees might increase risk taking. Moreover, they incentivize banks to become systemically important. An appropriate design and a successful exit strategy are thus also crucial for the effectiveness of these guarantees (Panetta *et al.*, 2009).

To overcome negative externalities of government guarantees, Landier and Ueda (2009) propose that only partial guarantees should be granted. If it is feasible to identify the minimum amount of guarantees needed to stabilize the financial system, both taxpayers' costs as well as risk taking incentives will be reduced. As this is, however, difficult to achieve, Acharya and Richardson (2009) recommend obliging institutions to pay back all accessed guarantees after their situation has improved. Such a design could diminish banks' incentives to take unsound risk.

The empirical evidence on the effectiveness of government guarantees granted in the past is predominantly negative. Laeven and Valencia (2008) provide no evidence that guarantees lead to a shortening of financial crises. Analyzing 42 banking crises prior to the world financial crisis, Laeven and Valencia (2012) show that the effect of blanket guarantees on bank liabilities is short lived and limited, as they do not apply to non-residents who might still withdraw they funds. Kane and Klingebiel (2004) cannot confirm any stabilizing effect in a smaller sample of 12 banking crises. Analyzing bank failures in several countries over three decades, Honohan and Klingebiel (2000) provide evidence for banks' excessive risk taking in response to government guarantees. Gropp *et al.* (2014) examine the removal of government guarantees for German savings banks in 2001 and identify both a reduction in risk taking and a shift away from short-term financing.

Considering the world financial crisis, Grande *et al.* (2011) find that government guarantees have been effective in avoiding a credit crunch and in resuming bank funding, but caused distortions in borrowing costs. A similar mixed result is identified by Aït-Sahalia *et al.* (2012). They provide evidence that the announcement of guarantees had a positive impact during the subprime crisis but a negative effect when the crisis became global, due to fear of regulatory arbitrage and disruptive cross-border flows.

We can conclude that government guarantees are regularly applied during financial crises despite their negative long-term effects. It is crucial to examine whether negative externalities can be reduced by changing the conditions of these guarantees. As governments cannot credibly commit themselves not to grant guarantees in times of distress, identifying appropriate crisis prevention measures thus becomes even more important.

2.4.2 Gradual Measures

In contrast to government guarantees, other crisis management measures have an implementation lag. We distinguish between measures that apply to banks' asset side and those that are effective on their liabilities side. While purchasing assets allows the removal of toxic assets from the asset side, capital injections, in the form of debt or equity, provide additional liquidity which is operative on the liabilities side.

Asset Purchases

During financial crises banks may face illiquidity problems due to toxic assets on their balance sheets. Assets will turn out to be toxic either if their price declines significantly or if they become non-tradable.[22] In both cases, banks might be unable to receive sufficient liquidity to fulfill investors' liquidity demand. Governments can provide liquidity by purchasing banks' toxic assets. Asset purchases might be offered either to all banks, such as the U.S. Troubled Asset Relief Program (TARP), or to certain financial institutions. In the world financial crisis, AIG, UBS, Lloyds Banking Group, Royal Bank of Scotland, WestLB and Hypo Real Estate Holding AG, among others, received liquidity via direct asset purchases from their respective governments.

Asset purchases are beneficial as they ease banks' refinancing opportunities via the market. After a sufficient amount of toxic assets are removed from banks' balance sheets, the remaining bank is considered to be healthy and will face fewer difficulties in finding new investors. As a result, asset purchases may also facilitate bank lending (Hauck *et al.*, 2011). Holmes (2009) also argues that asset purchases will generate

[22] Diamond and Rajan (2011) provide a further explanation of why banks might be reluctant to sell their assets. They argue that when banks have uncertain liquidity needs, they prefer to risk insolvency, as these losses are partly borne by their investors. Selling assets to build up a liquidity buffer, however, lowers their return when asset prices are too low.

specialization effects if toxic assets are transferred to a so called "bad bank". While the bad bank centers on managing and selling toxic assets, the remaining good bank is able to return to its day-to-day business.

The challenges with respect to asset purchases are to ensure banks' participation and to determine an adequate price for the toxic assets in times of high uncertainty. Governments aim to purchase assets at the lowest possible price to reduce taxpayers' costs. However, banks will not sell their assets if the price is so low that becoming insolvent constitutes lower losses. They might even demand a mark-up when selling their assets due to stigma costs (Corbett and Mitchell, 2000). Mitchell (2001) argue that asset purchases might not be applicable to all banks. If assets' returns crucially depend on the banker's skills, these assets should be left with the bank.[23] Finally, anticipating that governments buy out toxic assets might again increase risk taking prior to financial crises (Claessens *et al.*, 2001b).

The success of this crisis management instrument thus heavily depends on the conditions of the asset purchases. The easiest way to achieve banks' participation is to make asset purchases obligatory for all banks. However, this may impose large costs for the government. Corbett and Mitchell (2000) thus suggest that the government should credibly threaten to punish banks for not participating, in case they have to be recapitalized afterwards. Banks will be incentivized to participate in the asset purchase if the price for toxic assets is sufficiently large. Therefore, Ingves and Lind (1997) and Uhlig (2010) recommend buying toxic assets above the current market price. This transaction remains beneficial for the government as long as asset prices stay below their respective fundamental price, which is however also difficult to determine in times of distress (Hoshi and Kashyap, 2010).

In order to circumvent asset pricing in advance, van Suntum and Ilgmann (2013) propose to swap toxic assets temporarily against government bonds. After winding up some of the assets, the remaining assets will be repurchased when their value covers the nominal value of transferred assets. Such a design allows liquidity provision without relieving banks of all potential losses. This may antagonize increased risk taking.[24] Banks' participation in this design might, however, only be ensured under compulsion. Comparing different bad bank schemes, Hauck *et al.* (2011) find that the appropriate design depends on the transfer payment which is needed to ensure banks' participation. While an outright sale will be beneficial if the transfer payment is low, a repurchase agreement is advantageous otherwise.

[23]For a theoretical analysis of such relationship lending see Diamond and Rajan (2001a,b). Elyasiani and Goldberg (2004) provide a further overview of the relationship lending literature.

[24]A similar effect may be obtained by buying out only a share of toxic assets (Berglöf and Roland, 1995).

A public bad bank is considered to be superior to a private one as they have a longer decision horizon. Public bad banks can thus wait until toxic assets recover and may even generate profits (Bergström *et al.*, 2003). Incorporating relationship lending, Ingves and Lind (1997), however, recommend implementing a bad bank that is only partially owned by the government and that employs the manager of the concerned bank to save knowledge regarding the toxic assets.

Historical experience on asset purchases has not been very positive. Laeven and Valencia (2008) explain the failure of bad banks as being due to enormous political and legal regimentations, which resulted in substantial inefficiencies. During the world financial crisis, TARP was ineffective, as financial institutions refused to participate (Panetta *et al.*, 2009). Prior to this crisis, only the bad banks created during the Swedish banking crisis have formed an exception. According to Laeven and Valencia (2008), their success resulted from the fact that the Swedish government imposed almost no constraints on the bad banks regarding how to manage the toxic assets.

Even now, some of the bad banks installed during the world financial crisis have not been resolved. However, some asset purchases have already been successful. Besides fulfilling its stabilizing function by providing liquidity, some bad banks materialized substantial returns for their respective governments. In 2012, the Federal Reserve Bank of New York announced that Maiden Lane II LLC and Maiden Lane III LLC, the bad banks that were created to purchase toxic assets from AIG, have been resolved with a return of 2.8 billion U.S. dollars and 6.6 billion U.S. dollars, respectively (Federal Reserve Bank of New York, 2012b,c).[25] UBS repurchased their shares from the Swiss National Bank (SNB) in November 2013, which lead to a return for the latter of nearly 3.8 billion U.S. dollars (SNB, 2013b). The bad bank designs of the U.S. and Switzerland show some similarities. Both AIG and UBS would have participated in potential losses of their respective bad banks. Moreover, financial experts determined a price for the toxic assets which would have prevailed under normal market conditions (SNB, 2009; Federal Reserve Bank of New York, 2012a).

Summing up, the design of asset purchases and the pricing of toxic assets is crucial for the effectiveness of this crisis management measure. First evidence from the world financial crisis indicates, that this instrument has been effectively imple-

[25]The first Maiden Lane LLC has been created to facilitate the merger of the bank holding company JPMorgen Chase & Co. with the investment bank Bear Stearns. It prevented contagion resulting from Bear Stearns' failure and materialize a return of nearly 800 million U.S. dollars (Federal Reserve Bank of New York, 2012a).

mented. However, the implementation lag of asset purchases is rather long, so that it has to be accompanied by other measures.

Capital Injections

Besides asset purchases, the government can provide liquidity directly via different types of capital injections, such as credit lines, preferred stocks or common stocks. During the world financial crisis, all forms of capital injections were used. As nationalization via common stocks constitutes the most severe intervention in the market, governments first started to grant credit lines, e.g. for AIG in September 2009 (Panetta *et al.*, 2009). The advantage of subordinated debt is that it prevents governmental interventions in the decision making process and solely aims to stabilize the financial system (Nakaso, 2001). However, the crisis became so severe that governments nationalized several institutions either in parts or as a whole. Prominent examples are the Federal National Mortgage Association (Fannie Mae), Federal Home Loan Mortgage Corporation (Freddy Mac), Northern Rock, Royal Bank of Scotland, Lloyds Banking Group, Dexia Group, Fortis Bank Nederland, Kaupthing Bank, Landsbanki, IKB Deutsche Industriebank AG and Hypo Real Estate Holding AG.

In contrast to the governmental measures discussed so far, a credible announcement of nationalization is beneficial in reducing managers' risk taking, as such behavior increases the probability of losing their jobs in the long run (Richardson, 2009). Nationalization provides an opportunity for regulators to restructure and split institutions which are considered to be too big to fail (Roubini, 2009).[26] Focusing on rescuing these large banks, Wilson and Wu (2010) show that liquidity provision via common stocks is superior to buying toxic assets or providing preferred stocks, in terms of achieving efficient bank lending.[27]

Despite its ability to reduce systemic risk, nationalization forms a very strong interference in the market system and will result in an increase in the fiscal budget. Nationalized banks furthermore tend to be poorly governed. One explanation is that they might lose specific human capital, as skilled managers either leave voluntarily or are replaced (Richardson, 2009). Acharya *et al.* (2011, p. 147) state that even if granting of loans is not disrupted, nationalization might crowd out private credit and will thus be less efficient.

[26] The first split up of a large and complex financial institution during the world financial crisis was ING. In the course of the crisis, Dexia Group, Fortis Bank Nederland and WestLB, among others, have been split up as well.

[27] Common stocks will also not be inferior to the other recapitalization schemes if banks face a debt overhang (Wilson, 2012).

Several theoretical contributions focus on whether capital injections in general are a suitable management measure. Comparing different recapitalization schemes, Tirole (2012) argues that the government should purchase the weakest legacy assets to clean up the market, provide capital injections for banks which possess intermediate-quality assets and leave the strongest assets in the market. With this mixture, adverse selection can be reduced to the point where the market is able to rebound. Bhattacharya and Nyborg (2013) find that capital injections based on stocks will be more beneficial than asset purchases if banks differ in their debt overhang and if screening enables the regulator to provide bank-specific interventions. In contrast to asset purchases, these capital injections allow for participation in banks' returns. In a similar vein, Philippon and Schnabl (2013) show that capital injections, against preferred stocks plus warrants, reduce opportunistic behavior. As the government participates in banks' returns, these injections are only beneficial for banks in distress. Competitors benefit from other banks' receiving capital injections, as this increases financial stability. In order to counteract free-riding, Philippon and Schnabl (2013) suggest that government intervention should be conditional on there being a sufficient number of participating banks. The optimal ex-post intervention might also depend on the prevailing type of systemic risk. While liquidity provision via credit lines is more beneficial in preventing the spread of contagion, common shocks might be better counteracted by other types of capital injection (Georg, 2013).

Empirical evidence on capital injections is mixed. Analyzing the Japanese banking crisis, Giannetti and Simonov (2013) find that capital injections allow banks to grant more credit to firms that might boost economic growth. Laeven and Valencia (2013b) support these findings for a broader sample of 50 countries. However, Hoggarth *et al.* (2004) show for the Norwegian and South Korean crisis that nationalization prolongs the cutback in lending in the aftermath of a crisis. Based on a data set that covers more than a hundred countries, Barth *et al.* (2004) find a negative correlation between government ownership and banks' efficiency as well as their stability. Therefore, they advise that the nationalization period should be kept as short as possible. This is in line with Richardson (2009) who favors nationalization only as an intermediate step to give the regulator additional time to evaluate toxic assets before they are sold to a bad bank. In the world financial crisis, this combination has, for instance, been applied to Northern Rock and Hypo Real Estate Holding AG. Surveying more than 140 banking crises in the past three decades, Laeven and Valencia (2013a) show that whereas nationalization is equally common in advanced and developing economies, they differ with respect to other crisis management measures. Empirical evidence on the long-term effects of the different capital injections that have recently been undertaken are, however, not feasible yet.

We can recapitulate that capital injections are a further measurement to provide banks with liquidity and thus reduce financial instability in times of distress. Among all types of capital injections, nationalization is the strongest interference in the financial system. However, it appears that there is no one-size-fits-all-strategy to provide banks with liquidity. More research is thus needed to identify the long-term effects of the measures undertaken in the world financial crisis and how these interventions might adjust banks' behavior in the future.

2.5 Missing Links

Although financial crisis prevention and management have predominantly been analyzed separately, interdependencies are widely acknowledged. The anticipation of certain crisis management measures might increase banks' risk taking prior to a crisis and thereby systemic risk. Likewise, the implementation of a specific crisis prevention measure, such as risk-weighted capital requirements, might impose a threat to financial stability, e.g. in the form of fire sales. It is thus essential to consider these interdependencies when aiming to minimize systemic risk.

Researchers have only recently started to address these links. Acharya and Yorulmazer (2008a) analyze the impact of capital injections on banks' risk taking prior to a crisis. They find that herding behavior will be reduced if the regulator commits herself to provide liquidity to surviving banks instead of providing liquidity to distressed banks. Surviving banks may then use the liquidity to buy out the underpriced assets of distressed banks. Accordingly, banks are less incentivized to correlate their risks with those of their competitors. Dewatripont and Freixas (2011) examine both crisis prevention and management measures. They suggest issuing contingent securities ex ante so that investors bear a share of banks' risk taking in times of distress. This instrument should be complemented by a prompt corrective action plan ex post if a crisis still occurs.

In the following sections, we discuss two further proposals, both of which entail an automatic recapitalization mechanism, in more detail. These are CoCos and the regulatory margin call proposed by Hart and Zingales (2011).[28] The former allows banks to convert debt into equity in times of distress, which increases their ability

[28]It could be argued that deposit insurances also constitute a combined measure as institutions are forced to place money ex ante in order to be able to pay off depositors in times of distress. However, in this thesis we regard deposit insurances as a prevention instrument, since an active management component is missing.

to bear losses; the latter, however, allows to cover all potential losses by an adequate crisis management measure.

2.5.1 Contingent Convertible Bonds

CoCos are a form of debt that will convert into equity in times of distress if certain predetermined criteria are met. The conversion allows banks to receive an additional buffer to bear losses in times of distress, during which raising equity would be rather difficult. Accordingly, banks' probability of default, and thereby the risk of contagion effects, declines (Landier and Ueda, 2009). This type of bond was first suggested by Wall (1989) in the form of a put option on subordinated debt. In the aftermath of the world financial crisis, CoCos received more attention, as they may be used to fulfill the capital requirements of the Basel III Accord. From the first issuance by Lloyds Banking Group in 2009, until 2013, CoCos amounting to 70 billion U.S. dollars were issued (Avdjiev *et al.*, 2013).

Brunnermeier *et al.* (2009) regard CoCos as beneficial as they help to accomplish a debt overhang without losing debt's disciplinary function. Pennacchi (2010) shows that CoCos lead to less risk taking than subordinated debt, independent of their specifications. In comparison with equity, issuing Cocos creates lower information-based costs (Landier and Ueda, 2009). Flannery (2010) therefore argues that banks are less incentivized to circumvent these costs by shifting their activities off-balance sheet. CoCos are also advantageous from the social perspective, as a larger share of the losses is born by investors instead of taxpayers (Squam Lake Working Group, 2009a).

Depending on the conversion ratio, CoCos might, however, be prone to manipulations from both their holders and shareholders. The conversion ratio defines how many equity shares holders of CoCos will receive after the conversion. Albul *et al.* (2010) find that stock price manipulations will be avoided if the conversion ratio lies within a certain range. However, Sundaresan and Wang (2010) show that if manipulation is entirely eliminated by an appropriate conversion scheme, CoCos will lose their strength in reducing banks' risk taking incentives.

Depending on the contract, the conversion from debt to equity can be triggered either mechanically, e.g. based on market characteristics, or on a discretionary basis, i.e. based on the regulator's judgment. Flannery (2010) suggests a market-based trigger on common stocks while the regulator determines only basic attributes of the contract, such as the trigger point or whether all converted bonds have to be replaced. In order to counteract manipulation, Calomiris and Herring (2013) likewise favor a market trigger based on a 90 days moving average of a market equity ratio.

As manipulation of a long-term average is rather costly, speculation is less likely to occur. In contrast, Squam Lake Working Group (2009a) recommend a dual trigger that combines market information and the regulator's judgment. A conversion will thus only take place if covenants of the debt contract are violated and if the regulator additionally confirms that a systemic crisis is prevailing. This mechanism ensures that banks can become insolvent in normal times. In a similar vein, McDonald (2013) supports a dual trigger based on the institution's stock price and an index that comprises all financial institutions. According to this approach, conversion will only occur if several financial institutions are in distress; otherwise an institution may still default. Hilscher and Raviv (2012) find that the conversion trigger is important to determine the optimal conversion rate. However, an adequate specification of the conversion rate has a larger impact on risk taking than the trigger.

The Basel III Accord aims not only to increase the quantity but also the quality of bank capital. Accordingly, CoCos can only be applied to fulfill capital requirements if certain specifications are satisfied. One of these specifications is that the trigger is based on a judgment by the relevant authority. This authority has to confirm that without the conversion either a write-off of the bank or public capital injections are needed (BCBS, 2011a).

Summing up, CoCos may be a suitable regulatory measure that considers interdependencies between crisis prevention and crisis management. If adequately designed, they might reduce systemic risk in the financial system. However, they only form a supplementary instrument in the regulatory framework, as banks might not be able to raise enough debt in form of CoCos to cover all potential losses. In the following section, we will therefore focus on an instrument that might be applied as a substitute for the Basel III Accord.

2.5.2 Regulatory Margin Call

The modifications of the Basel Accords exhibit a tendency towards more complex regulation. In order to strike a new path, Hart and Zingales (2011) propose a simple rule which additionally constitutes a seminal attempt to reduce systemic risk resulting from interdependencies between crisis prevention and crisis management measures.

In detail, Hart and Zingales suggest a two-stage trigger mechanism based on market participants' expectations regarding an institution's probability of default. As the CDS market is the leading market with respect to information discovery (see Subsection 2.2.2), they perceive the price of CDS contracts written on a financial institution to be an eligible indicator for its probability of default. Accordingly, the margin call will be triggered each time the CDS price exceeds a certain threshold. Observing the developments in the CDS market prior to the world financial crisis, Hart and Zingales view an average of 100 basis points in the last 30 days to be a suitable threshold. If the margin call is triggered, the financial institution has to raise equity in a predetermined time. The additional equity will serve as a buffer against potential losses and will thus lead to a decline in the CDS price. If the institution is, however, unable to raise enough equity, so that the CDS price stays above the threshold, the regulator commits herself to intervene. She will perform a stress test to identify whether the institution is actually at risk or whether the CDS price increased for other reasons. If the stress test confirms market participants' expectations, the regulator will take over the financial institution and replace its manager with a receiver. Additionally, shareholders will be wiped out while creditors will face a haircut of at least 20 percent. Creditors are thus supposed to be incentivized to reveal the true probability of default. Afterwards the receiver will either close the institution or recapitalize it by an initial public offering. If the stress test indicates that the institution is not at risk, the regulator will have to confirm this result by injecting funds into the institution. Hence regulatory forbearance will be reduced. Moreover, the stress test will reduce the probability of a "bear raid", i.e. betting on a self-fulfilling default.

In contrast to the Basel Accords, the margin call can be applied to all financial institutions on which CDS contracts exist. This is a major advantage, as Arnold *et al.* (2012) find that systemic risk is, to a large extent, originated by non-banks. One example from the world financial crisis was money market funds, which were highly risky at that time (Kacperczyk and Schnabl, 2013). Moreover, the margin call builds on forward-looking data, while the capital requirements of the Basel Accords are based on balance sheet data and therefore on past developments. As the CDS price contains all kinds of information, it might thus be more suitable to detect potential threats to financial stability that have so far not been explicitly implemented in the regulatory framework. Finally, the margin call is a simple rule which is easily observable by both investors and the regulator.

The effectiveness of the margin call, however, crucially depends on the functioning of the CDS market. Although the design of the margin call is intended to reduce price manipulations, market imperfections might still arise, e.g. due to asymmetric information. A further downside is that financial institutions might prefer to sell a share of their risky portfolios rather than raising new equity. Depending on the amount that needs to be sold to lower the CDS price, fire sales might emerge, imposing a threat to financial stability (Hanson *et al.*, 2011; Hilscher and Raviv, 2012).

In addition, the margin call might be exposed to legal problems. While the margin call is implementable in the U.S. as the Dodd-Frank Act allows for such a wipeout, it might not be compatible with national legislation in other countries, e.g. with the property rights in Article 14 of the Basic Law for the Federal Constitution of the Federal Republic of Germany.

Despite potential disadvantages, the margin call by Hart and Zingales (2011) constitutes a seminal approach to take into account interdependencies between crisis prevention and crisis management measures. However, this proposal raises several questions which we will identify below. These questions determine the course of the investigation of this thesis.

2.6 The Road Ahead

The literature on systemic risk is widespread. Based on different definitions, several proposals have been made regarding systemic risk reduction, both prior to and during financial crises. Although crisis prevention and crisis management measures might impose negative externalities when working together, these have mostly been neglected when searching for an appropriate regulatory framework. Analyzing interdependencies between crisis prevention and management measures is thus an important field of research when searching for an adequate regulatory framework.

This thesis sets out to contribute to this field of research by providing an in-depth analysis of the regulatory margin call. Hart and Zingales (2011) analyze the impact of their proposal on financial stability and efficient bank lending in a dynamic framework. They claim that the margin call is a free lunch as it imposes no restriction on investing in new projects that possess a positive net present value. As this result contradicts the findings of the literature on regulation, we challenge this statement and raise three research questions.

Focusing on the trade-off between financial stability and efficient bank lending, we will first shed light on financial institutions' intertemporal investment decisions. In a second step, we will compare the margin call with the main instruments of the Basel III Accord in order to identify whether the margin call is more suitable than the current regulatory framework. Finally, we will observe the functioning of the CDS market and determine the effectiveness of the margin call when financial institutions possess private information about the quality of their investments.

Chapter 3

A Review of the Margin Call

In this chapter we analyze the margin call proposed by Hart and Zingales (2011), which constitutes a seminal attempt to combine financial crisis prevention and management measures. Large financial institutions (LFIs) will have to increase their equity if the market evaluates an increased probability of default measured by the CDS price. If an institution is unable to raise additional equity, the regulator will take over, wipe out existing shareholders and liquidate the institution. Hart and Zingales argue that this margin call is able to increase financial stability without restricting investment. Identifying an arithmetic error in their argument, we arrive at a different conclusion. Based on this finding we develop the research questions of this thesis.

3.1 Introduction

In order to illustrate the effectiveness of their regulatory margin call, Hart and Zingales analyze the investment decisions of a representative LFI over the business cycle. As the LFI's returns depend crucially on the business cycle, this model serves to capture systemic risk in the form of common shocks resulting from business cycle fluctuations. If economic conditions worsen, the LFI yields lower returns and might be unable to satisfy its liabilities. A common shock will materialize if the representative LFI is in distress. However, Hart and Zingales present a different interpretation of the LF. They consider the financial intermediary to be a SIFI. Hence they argue that their proposal aims to prevent the risk of contagion effects that might emerge due to the SIFI's direct or indirect linkages. Defining systemic importance based on the size of an institution, they suggest applying the margin call on all institutions exhibiting an asset volume of more than 200 billion U.S. dollars.

Generally such a proposal allows the margin call to be applied not only on banks but on all financial institutions that are considered to be systemically important. This might also include insurance companies like AIG, which received the largest bailout by the U.S. government during the world financial crisis in order to maintain financial stability.

Independent of the interpretation of the type of systemic risk, we find that the margin call will effectively reduce financial institutions' risk taking and thus the probability of a bankruptcy caused by business cycle fluctuations. By forcing the institution to raise additional equity in an economic downturn, it possesses enough funds to pay off debtholders, independent of the future state of the economy. However, we arrive at a different conclusion with respect to the impact on investment. While Hart and Zingales argue that their margin call is a free lunch, we find that new investments crucially depend on their funding liquidity. If this funding liquidity is lower in the case of equity financing, the margin call might have an impact on investment decisions. Based on these findings we will argue that an in-depth analysis of the margin call is needed to identify potential strengths and weaknesses.

In the following section, we will analyze the impact of the margin call on the basis of Hart and Zingales (2011) but with a slightly modified setup that neglects nonessential specifications of the model. This setup is presented in Section 3.2. We solve the model in Section 3.3 in two steps. First, we identify the optimal LFI behavior in the absence of any regulatory measure. Afterwards, we show that the margin call will avoid a bankruptcy at all times if the threshold is set to zero. Section 3.4 discusses limitations of the model. It comprises a robustness check conducted by Hart and Zingales. Identifying a mistake in their argument, we derive three research questions, which we set out to analyze in the next chapters of this thesis. Section 3.5 concludes.

3.2 Setup

3.2.1 Agents and Technologies

We consider a manager who runs an LFI that exists for two more periods and three dates, $t = 0, 1, 2$. The institution holds an investment project financed in the past. Until $t = 0$, the LFI possesses only equity and thus no outstanding claims. Without changing the institution's liability structure, shareholders will receive a payoff depending on the materialized returns of the investment project.

The investment returns materialize at the end of the second period and depend crucially on the state of the economy, as Figure 3.1 depicts. At date $t = 1$, the

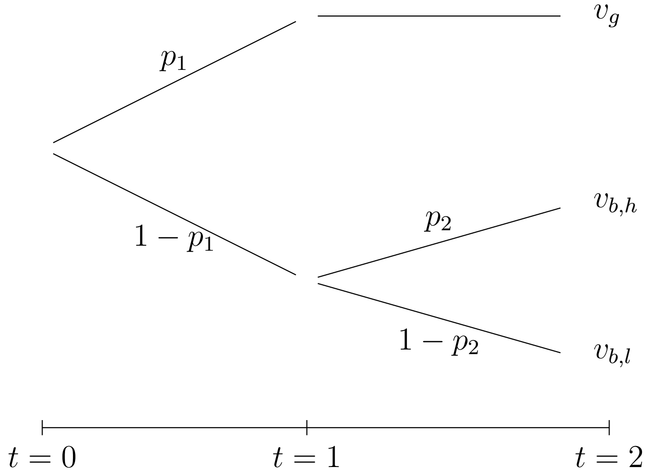

Figure 3.1: Investment earnings

economy is either in an upswing or experiences a downturn. With probability p_1 the economy is in a "good" situation, $s = g$, so that the investment will yield a certain and high return v_g at the end of the second period. If, however, the economy is in a "bad" situation, $s = b$, at $t = 1$, which occurs with probability $1-p_1$, the investment will remain risky while its expected return will be lower than in the good situation. In this downturn, the economy will either recover or will run into a recession at $t = 2$. With probability p_2 the investment will be quite successful so that a return $v_{b,h} < v_g$ materializes. However, with probability $1-p_2$ the investment will yield a low return $v_{b,l} \in [0, v_{b,h})$.[1] The mean μ thus satisfies $\mu := p_1 v_g + (1-p_1)[p_2 v_{b,h} + (1-p_2) v_{b,l}] > 1$.

Shareholders might be incentivized to sell their equity shares before returns materialize. As the manager possesses no funds on his own, he has to raise additional funds at the beginning of the first period to buy back equity shares. He therefore becomes a shareholder himself. In order to buy back equity shares, he has to issue debt from investors who are unrestricted in funds. These debtholders, among whom there is perfect competition, have access to a risk-free storage technology. Hence they will only provide funding if their expected payoff covers their opportunity costs. Moreover, debtholders do not face any liquidity needs at $t = 1$ so they are patient until the end of the second period. All agents are risk neutral and have a discount rate of zero.

[1] Hart and Zingales distinguish two different scenarios for the upswing as well. As this distinction is, however, irrelevant for the analysis, we will henceforth neglect this aspect.

3.2.2 Contracting Friction and Capital Structure

We consider an incomplete contract problem à la Hart and Moore (1994). At the beginning of the first period, the manager may raise funds from debtholders in the amount of f_0 with a face value φ_0 in order to comply with shareholders' demand to buy back equity shares. However, as the manager's skills are required to collect the full value of the investment, the relationship between the manager and investors suffers from an incomplete contract problem. Exhibiting an informational advantage vis-à-vis investors, the manager can threaten to withhold his skills. This enables him to renegotiate or even refuse repayments to debtholders as well as shareholders after the investment decision is made.

Issuing debt mitigates this incentive and commits the manager to use his skills on behalf of investors. As debt is senior to equity, debtholders would immediately sue the manager if he tried to renegotiate the debt's face value. In consequence, the institution would become bankrupt and all remaining values would be shared among debtholders. However, a bankruptcy will also occur if the institution's investment turns out to be too poor to repay the face value φ_0. If the investment is risky, issuing debt might thus lead to a bankruptcy, even if the manager applies his skills.[2]

A bankruptcy will be avoided, if the LFI possesses a sufficient amount of equity. As the value of equity is linked to the value of the institution, shareholders will receive lower payments if banks are less profitable. Equity thus serve as a buffer for bad times. The downside of equity is that they cannot discipline the manager like debt. By threatening to withhold his skills the manager renegotiates and demands a share, λ, of the institution's net profits (after satisfying debtholders' claims) as compensation for his commitment. In consequence, shareholders will only receive a share $1-\lambda$ of the institution's net profits when the investment's return materializes.

As shareholders are unable to circumvent the manager's renegotiation, they are incentivized to increase their payoff by changing the institution's capital structure. If they call for induced debt, the manager will have to use this capital at the beginning of the first period to buy back equity shares. Issuing debt reduces the expected profit of the institution at the end of the second period. However, shareholders bear only the fraction $1 - \lambda$ of this loss of return, while receiving the whole amount of debt when selling their equity shares. Accordingly, shareholders boost the leverage of the institution as high as possible. As the manager receives these equity shares in the buyback, he becomes a shareholder of the LFI. He is therefore always incentivized to apply his skills to achieve the full value of the investment. As employing his skills

[2] This assumption constitutes an analogy to the idea of solving the hold-up problem by issuing demandable deposits (Diamond and Rajan, 2001b).

is costless for the banker, he will apply his skills as long as the expected profit of the investment is positive.[3]

The face value of debt issued at $t = 0$, φ_0, determines the institution's capital structure. We can distinguish two modes of operation $m_0 = \{\mathcal{S}, \mathcal{R}\}$. If the face value is relatively small, so that the LFI is always able to repay this face value independent of the state of the economy, the institution will operate in the "safe" mode, $\mathcal{S}$. The institution will operate in the "risky" mode, $\mathcal{R}$, if the face value is larger than at least one feasible return, i.e. at least larger than $v_{b,l}$. In this case a bankruptcy will occur each time the return on the investment project is lower than the face value of debt.

3.3 LFI Behavior

In order to determine the ex ante and ex post effects of the margin call, we start by identifying the LFI's optimal behavior without any regulation in place. Afterwards, we assume a regulator imposes the margin call on the LFI.

3.3.1 Benchmark

At the beginning of the first period, shareholders aim to maximize the market value of the LFI, $\mathcal{V}_0$. This value determines the profit they are able to extract from the institution. Without issuing any debt, the manager receives the share, λ, of the investment's profit, which materializes at $t = 2$. The institution's market value at $t = 0$ is thus given by

$$\mathcal{V}_0 = (1-\lambda)\left[p_1 v_g + (1-p_1)p_{2,b}v_{b,h} + (1-p_1)(1-p_{2,b})v_{b,l}\right] = (1-\lambda)\mu. \tag{3.1}$$

Issuing debt allows shareholders to extract a larger amount of the LFI. Suppose, the LFI operates in the safe mode, $\mathcal{S}$, by issuing debt with a face value lower than the investment's return in the recession ($\varphi_0 \leq v_{b,l}$). The LFI is thus able to pay off debtholders, independent of the state of the economy at $t = 2$. Accordingly, debtholders expect to receive this face value with certainty and do not insist on a premium, i.e. they are willing to provide an amount of debt f_0 equivalent to the face value. The market value of the LFI in the safe mode $\mathcal{V}_0^{\mathcal{S}}$ thus comprises the

[3] Note that Hart and Zingales did not apply the most intuitive approach to model shareholders' bargaining power. In the proceeding chapters we will thus only adopt some aspects of their framework. By neglecting the idea of active shareholders, we will leave the bargaining power with the manager.

expected profit of equity and the expected return on debt:

$$\mathcal{V}_0^{\mathcal{S}} = (1-\lambda)\left[\mu - \varphi_0\right] + \varphi_0 = \mathcal{V}_0 + \lambda\varphi_0. \tag{3.2}$$

It follows from equation (3.2) that the market value $\mathcal{V}_0^{\mathcal{S}}$ increases with the face value of debt. Shareholders thus receive the highest payoff, if the manager issues debt with a face value of $\varphi_0^{\mathcal{S}} = v_{b,l}$.

Suppose the LFI operates in the risky mode $\mathcal{R}$. This will be the case if at least one return feasible at $t = 2$ is too low to pay off debtholders. In this mode, the manager may issue debt with a face value up to the highest return on the investment, v_g. In this particular case, debtholders will only receive the face value if the economy is in an upswing at $t = 1$. In the following analysis of the margin call it is, however, useful to determine shareholders' decisions given that the face value is restricted to $\varphi_0 \in (v_{b,l}, v_{b,h}]$ as explained below. Debtholders will receive the face value at the end of the second period if the return on the investment exceeds this face value. If, however, the economy is in recession at $t = 2$, they will only receive the materialized return $v_{b,l}$, which is lower than the face value φ_0. Note that this is not a typical bank run, in which all values of the financial institution are destroyed, as Hart and Zingales abstract from systemic debt like deposits or other short-term funds. Instead the LFI will be liquidated and all values shared among debtholders. Debtholders will provide funds if the expected payoff covers their investment costs. Therefore, the manager is able to issue the amount of debt, f_0, which satisfies

$$f_0 = \left[p_1 + (1-p_1)p_{2,b}\right]\varphi_0 + (1-p_1)(1-p_{2,b})v_{b,l}. \tag{3.3}$$

The market value of the LFI in the risky mode is thus given by

$$\begin{aligned}\mathcal{V}_0^{\mathcal{R}} &= (1-\lambda)\left[p_1(v_g - \varphi_0) + (1-p_1)p_{2,b}(v_{b,h} - \varphi_0) + (1-p_1)(1-p_{2,b})(v_{b,l} - v_{b,l})\right] \\ &\quad + \varphi_0 \\ &= \mathcal{V}_0 + \lambda f_0. \end{aligned} \tag{3.4}$$

It follows from equations (3.3) and (3.4) that the market value when operating in the risky mode, $\mathcal{V}_0^{\mathcal{R}}$, i.e. the amount shareholders are able to extract from the institution at the beginning of the first period, increases with the amount of debt, f_0, and therefore with the face value of debt, φ_0. Accordingly, shareholders will demand to issue the largest amount of debt feasible, which corresponds to a face value of $\varphi_0 = v_{b,h}$.

In the absence of our additional restriction of the face value up to $v_{b,h}$, the face value is restricted to v_g when operating in the risky mode. As the argument remains unchanged, we can conclude that shareholders will choose a capital structure with the highest leverage feasible to increase their profits. In this case, the manager will have to offer a face value of $\varphi_0 = v_g$. Note that this implies that the manager has to buy back all equity shares. However, he expects to receive no profit at $t = 2$, as, independent of the state of the economy, all returns will have to be used to pay off debtholders.[4]

The comparison of the institution's market values in both modes given by equations (3.2) and (3.4) shows that shareholders will always prefer the risky mode, $\mathcal{R}$, over the safe mode, $\mathcal{S}$. If a regulator aims to prevent the default of the LFI with a probability of one, he thus has to prevent the risky mode, $\mathcal{R}$. This limits the face value of debt to $\varphi_0^{\mathcal{S}} = v_{b,l}$. In the following subsection we will see that the margin call proposed by Hart and Zingales will yield the same result with respect to preventing the default at all times. However, it increases the market value to a level above $\mathcal{V}_0^{\mathcal{S}}$.

3.3.2 Regulation

Following Hart and Zingales (2011), we analyze the impact of the margin call in two steps. First, we determine the amount of debt an LFI will issue under the margin call if the state of the economy is observable and verifiable for all agents. Afterwards, we argue that a margin call based on the CDS price will yield the same result if the state of the economy is observable for market participants but not verifiable for the regulator.

In order to reduce complexity, Hart and Zingales analytically discuss a margin call that aims to prevent a bankruptcy at all times. This implies that the margin call is triggered each time the CDS price becomes positive. Obviously, such a design is only intended to illustrate the mechanism of the proposal. If the CDS price were not allowed to be positive without triggering a margin call, a trade in CDS would not be profitable at all and the CDS price would lose its function as a suitable indicator of the institution's probability of default.

Verifiable State of the Economy

In the first step, we assume that the regulator is able to verify the state of the economy. She will trigger the margin call if there is a positive probability at $t = 1$

[4] To ensure that the manager will nevertheless use his skills, shareholders might reimburse him with a small compensation for his effort.

that the LFI might be unable to repay the face value of debt. If the LFI is unable to issue a sufficient amount of equity at $t = 1$ to reduce the probability of default to zero, the LFI will be taken over by the regulator. In this case, shareholders will be wiped out, debtholders receive a haircut and the manager will be replaced without receiving any compensation.

Suppose the manager issues debt at $t = 0$ with a face value of $\varphi_0 \in (v_{b,l}, v_{b,h}]$. If the economy is in an upswing at $t = 1$, the margin call is not triggered as debt is not at risk. However, if the economy is in a downturn at the end of the first period, debt will default with probability $1 - p_2$. In this case, the margin call is triggered and the manager has to raise $\varphi_0 - v_{b,l}$ in the form of equity $e_{1,b}$ to prevent the takeover. These funds will be invested in a risk-free asset $a_{1,b}$ with a zero net return. However, shareholders are only willing to provide this amount of equity if their expected payoff in the downturn remains nonnegative, i.e. if

$$e_{1,b} \leq (1 - \lambda)p_2 \left(v_{b,h} + a_{1,b} - \varphi_0\right) \tag{3.5}$$

holds. Alternatively, the LFI could reduce the CDS price by selling a share of their risky assets. As the investment returns, however, crucially depend on the manager's skills, relationship lending prevents the possibility of such fire sales. Note that a face value larger than $v_{b,h}$ would result in an immediate takeover by the regulator at $t = 0$, as shareholders would be unwilling to provide additional equity in the downturn due to a negative expected profit.

It follows from (3.5), that the LFI can only prevent the takeover if the face value of the first period's debt satisfies[5]

$$\varphi_0 \leq v_{b,l} + (1 - \lambda)p_2 \left(v_{b,h} - v_{b,l}\right) =: \varphi^{\mathcal{S}}_{0,mc}. \tag{3.6}$$

Compared with the face value of the safe mode without a margin call in place, $\varphi^{\mathcal{S}}_0 = v_{b,l}$, we can already conclude that the margin call ensures the stability of the LFI and additionally allows for a higher face value, $\varphi^{\mathcal{S}}_{0,mc} > \varphi^{\mathcal{S}}_0$. In this case, the market value of the LFI is thus again given by the value of equity and the value of debt

$$\begin{aligned} \mathcal{V}^{\mathcal{S}}_{0,mc} &= (1 - \lambda)\left[\mu + (1 - p_1)a_{1,b} - \varphi_0\right] - (1 - p_1)e_{1,b} + \varphi_0 \\ &= \mathcal{V}_0 + \lambda p_1 \varphi_0 + \lambda(1 - p_1)v_{b,l}. \end{aligned} \tag{3.7}$$

[5]Technically, this upper limit is determined by inserting $e_{1,b} = a_{1,b} = \varphi_0 - v_{b,l}$ in (3.5).

As shareholders seek to maximize their profit, they will demand to offer the highest face value feasible so that (3.6) holds with equality. Inserting this upper limit results in a market value of

$$\mathcal{V}_{0,mc}^{\mathcal{S}} = \mathcal{V}_0 + \lambda v_{b,l} + p_1 \lambda (1-\lambda) p_2 \left(v_{b,h} - v_{b,l}\right). \tag{3.8}$$

Comparing equation (3.8) with (3.2), i.e. the market value of the safe mode given that no margin call is in place, we can conclude that the margin call leads to a larger market value than a restriction of the face value up to $v_{b,l}$. With the margin call in place, the manager receives a lower payoff, as a larger face value of debt decreases the LFI's profits at $t = 2$. Independent of the state of the economy, issuing debt decreases the manager's profit by $\lambda v_{b,l}$ and thus increases the market value. In contrast to operating in the safe mode, the additional amount of debt due to a margin call in place imposes a second effect on the market value. The face value $\varphi_{0,mc}^{\mathcal{S}} > \varphi_0^{\mathcal{S}}$ will furthermore reduce the manager's profit in the upswing. The last term of equation (3.8) thus captures the expected decrease in the manager's payoff as the face value increases by $(1-\lambda)p_2 \left(v_{b,h} - v_{b,l}\right)$. With the probability p_1, the economy will be in an upswing, which implies that the manager's profit declines by the share λ of this additional face value so that the market value increases. Note that if the economy recovers from the downturn, the manager's profit will remain unchanged as shareholders have to issue equity to cover the difference between $\varphi_{0,mc}^{\mathcal{S}}$ and $v_{b,l}$.

Non-verifiable State of the Economy

In the second step, we assume that only market participants observe the state of the economy. The regulator is unable to verify the state of the economy and she imposes a margin call based on the LFI's credit default swap price instead. If the economy is in an upswing, the institution is not at risk and no market participant will buy a CDS. This behavior might change if the economy is in a downturn at the end of the first period. Debtholders expect a haircut if the LFI is taken over by the regulator. If the face value of debt is larger than $v_{b,l} + a_{1,b}$, a bankruptcy will occur if the economy is not recovering at the end of the second period. Debtholders will therefore buy CDS contracts to insure themselves against the potential losses of the haircut.[6] As the demand for CDS increases, the price exceeds zero. Accordingly, the margin call is triggered so that the LFI has to issue additional equity in order to prevent a

[6]As long as an insurance policy is fairly priced, buying this insurance will only make sense if debtholders are risk averse, at least to a certain degree. Considering risk aversion in the general set up will however only increase complexity without changing the results qualitatively.

takeover. If the face value of debt is small or the LFI raises a sufficient number of equity shares, debtholders will expect to receive the face value independent of the state of the economy at $t = 2$. They have thus no incentive to buy any CDS contract and the CDS price equals zero. We can conclude:

Proposition 3.1 (Hart and Zingales, 2011, p. 468). *Suppose that the state of the economy is observable but not verifiable. If $\varphi_0 \leq \varphi_{0,mc}^{\mathcal{S}}$, then the equilibrium price of a CDS will be greater than zero iff the economy is in a downturn at $t = 1$ and iff the LFI raises less equity than $\varphi_0 - v_{b,l}$.*

Suppose the regulator relies on the CDS price. In this case, a margin call will only occur if the economic conditions turn out to be bad at the end of the first period and if shareholders did not provide a sufficient amount of funds to prevent a potential bankruptcy at $t = 2$. The CDS price thus seems to be an appropriate indicator to detect potential default risks. This result enables us to determine shareholders' optimal behavior at $t = 0$.

We identified above that issuing debt with a face value up to $\varphi_{0,mc}^{\mathcal{S}}$ will never result in a takeover. Suppose the face value is larger than $\varphi_{0,mc}^{\mathcal{S}}$. In this case, debtholders anticipate already at $t = 0$ a potential default at the end of the first period. They will therefore buy CDS contracts and the margin call will occur at $t = 0$. In order to prevent a wipeout in the first period, shareholders will thus never call for a face value larger than $\varphi_{0,mc}^{\mathcal{S}}$.

Suppose the face value is lower than $\varphi_{0,mc}^{\mathcal{S}}$. In this case, shareholders will benefit from selling more equity shares in the first period. It is therefore beneficial to increase the institution's leverage up to the highest value feasible. We can thus conclude:

Proposition 3.2 (Hart and Zingales, 2011, p. 470). *With the margin call in place, shareholders will choose a face value $\varphi_0 = \varphi_{0,mc}^{\mathcal{S}}$ at $t = 0$ and will permit the manager to issue equity in the amount of $e_{1,b} = \varphi_{0,mc}^{\mathcal{S}} - v_{b,l}$ iff the economy is in a downturn at $t = 1$. A margin call therefore never occurs and bankruptcy is avoided with probability one. The second best is achieved.*

Implementing a margin call will only yield the second best outcome, as a face value of $\varphi_{0,mc}^{\mathcal{S}} < v_g$ will maintain a positive payoff for the manager, although he faces no costs in collecting the full value of the investment, see equation (3.8). Hence welfare would increase if a larger market value were achieved, while avoiding a bankruptcy at all times.

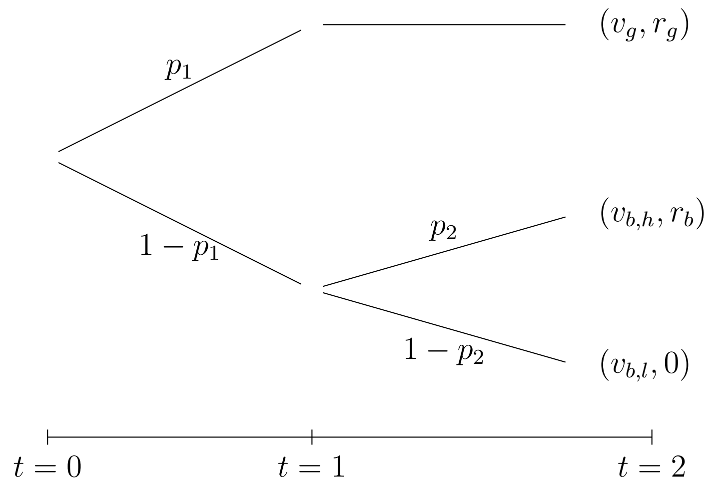

Figure 3.2: Investment earnings of first and second period loans
Note: At the end nodes, the first entry refers to the investment project financed in the past and the second entry to the investment project of the second period.

3.4 Discussion

3.4.1 Robustness

In this subsection we reassess one of the robustness checks of Hart and Zingales (2011). We focus on the impact of the margin call on the institution's ability to invest in new projects at the beginning of the second period. Identifying a mistake in their argument, we arrive at a different conclusion with respect to the institution's investment decision.

For simplicity, the second period project is fully correlated with the existing investment project. If the economy is in an upswing at $t = 1$, a second project would yield a high return, r_g, at the end of the second period, as Figure 3.2 depicts. However, the return on the second period investment will be risky if the economic conditions turn out to be bad. A recovery will lead to a return $r_b < r_g$, while a worsening of the economic conditions will imply that the investment projects defaults entirely.

The LFI may only invest in this second project if the manager is able to raise a sufficient amount of funds to finance the investment costs $i_{1,s}$. As the margin call is in place, the LFI has to ensure its solvency, independent of the state of the economy. Therefore, issuing debt $f_{1,s}$ will only be feasible if the face value $\varphi_{1,s}$ can be paid off independent of the economic condition at $t = 2$. As the LFI has no incentive to induce a margin call at $t = 0$, we can again restrict our analysis to a face value in the first period of $\varphi_0 \in (v_{b,l}, v_{b,h}]$. Shareholders will provide fresh equity $e_{1,s}$, if the expected additional return covers their investment costs.

We solve this investment decision by backward induction. In the first step we determine the LFI's optimal behavior in the second period for both the upswing and the downturn. Given these results we are then able to identify its optimal decision in the first period.

Suppose the economy is in an upswing at $t = 1$, which enables the LFI to repay the face value of first period debt φ_0 with certainty. If the manager has the approval of shareholders, he will raise equity $e_{1,g}$ and debt $f_{1,g}$ to cover the costs of the second investment project $i_{1,g}$ and to invest the remainder $a_{1,g}$ in the risk-free asset. The LFI's budget constraint at $t = 1$ thus reads

$$i_{1,g} + a_{1,g} = f_{1,g} + e_{1,g}. \tag{3.9}$$

Due to the margin call, the LFI must repay the face value of debt, i.e. $f_{1,g} = \varphi_{1,g}$. Without investing in the second project, shareholders' expected profit at the end of the second period amounts to $(1 - \lambda)[v_g - \varphi_0]$. As the expected profit with the second investment project will increase to $(1 - \lambda)[v_g + r_g + a_{1,g} - \varphi_0 - \varphi_{1,g}]$, they are therefore willing to provide equity up to

$$e_{1,g} \leq (1 - \lambda)[r_g + a_{1,g} - \varphi_{1,g}]. \tag{3.10}$$

Inserting the budget constraint (3.9) and the face value of debt in equation (3.10) yields

$$e_{1,g} \leq \frac{1 - \lambda}{\lambda}[r_g - i_{1,g}]. \tag{3.11}$$

Shareholders will thus approve the second investment and provide fresh funds if the net present value of the second investment project, $r_g - i_{1,g}$, is positive. The manager also seeks to invest in the second project, as this provides him with an additional profit of $\lambda[r_g + e_{1,g} - i_{1,g}]$. He receives the share λ of the second project's return, r_g. Moreover, if the remaining share $e_{1,g} - i_{1,g}$ is invested in the risk-free asset, $a_{1,g}$, he benefits from these additional returns as well. As the manager benefits from the investment returns without facing any investment costs or private costs, he would invest in any project with a nonnegative return r_g. However, shareholders will only permit the investment if the net present value, $r_g - i_{1,g}$, is positive. We can thus conclude that a project with a negative net present value will never be undertaken if the economy is in an upswing at $t = 1$.

Suppose the economy is in a downturn at $t = 1$. In this case, the face value of first period debt, φ_0, is too large and the margin call is triggered. In order to prevent the takeover, shareholders have to provide at least equity in the amount of

$\varphi_0 - v_{b,l}$, which will be invested in the risk-free asset. Should shareholders approve the second investment project, the manager will raise equity, $e_{1,b}$, and debt, $f_{1,b}$, to cover the costs of the second investment project, $i_{1,b}$, and to invest the remainder $a_{1,b}$ in the risk-free asset. The LFI's budget constraint thus reads

$$i_{1,b} + a_{1,b} = f_{1,b} + e_{1,b}. \tag{3.12}$$

In order to prevent a second margin call, the manager has to invest the whole amount of debt in the risk-free asset. Otherwise, the LFI might be unable to repay the face value $\varphi_{1,b}$ at $t = 2$. Shareholder will provide funds for the second investment project, if their expected return covers at least their investment costs, i.e. if

$$e_{1,b} \leq (1 - \lambda)[p_2(v_{b,h} + r_b) + (1 - p_2)v_{b,l} + a_{1,b} - \varphi_0 - \varphi_{1,b}]. \tag{3.13}$$

Inserting the budget constraint (3.12) and the face value of debt in equation (3.13) yields that shareholders are willing to provide equity up to

$$e_{1,b} \leq \frac{1 - \lambda}{\lambda}[p_2(v_{b,h} + r_b) + (1 - p_2)v_{b,l} - i_{1,b} - \varphi_0]. \tag{3.14}$$

The second investment will, however, only be undertaken if the amount of equity is sufficient to cover the investment costs and to prevent the takeover, i.e. if $e_{1,b} \geq i_{1,b} + \varphi_0 - v_{b,l}$. Considering this solvency constraint in (3.14) restricts the face value of first period debt to[7]

$$\varphi_0 \leq v_{b,l} + (1 - \lambda)p_2(v_{b,h} + r_b - v_{b,l}) - i_{1,b}. \tag{3.15}$$

As shareholders prefer the largest face value feasible, it follows that both (3.14) and (3.15) will hold with equality. Without investing in the second project, the manager's expected profit is $\lambda p_2(v_{b,h} - v_{b,l})$. As the investment is solely financed by equity, it yields a larger expected profit $\lambda p_2(v_{b,h} + r_b - v_{b,l})$. The manager would thus invest in any project with a positive net present value, i.e. as long as $p_2 r_b > 0$ holds. Shareholders will never agree to an investment with a negative net present value $p_2 r_b - i_{1,b}$. Therefore, we can conclude that an investment with a negative net present value is never undertaken.

In the first period, shareholders compare the expected market value of the LFI with and without the additional investment. They will only approve an investment in the downturn if this implies a larger market value at $t = 0$. Equations (3.15)

[7] Note that this result deviates from the result obtained in equation (9) by Hart and Zingales (2011, p. 476), which is $\varphi_0 \leq v_{b,l} + (1 - \lambda)[p_2(v_{b,h} + r_b - v_{b,l}) - i_{1,b}]$.

and (3.6) show that the market value of the LFI will only increase in the second investment project in the downturn if the funding liquidity of this project is positive. As the second investment project in the downturn will solely be financed by equity, the funding liquidity is determined by the amount shareholders are willing to provide. As the share λ of the expected profit will remain with the manager, shareholders will thus only agree to invest, if the funding liquidity is larger than their investment costs, i.e. if $(1-\lambda)p_2 r_b > i_{1,b}$. As this imposes a tighter restriction on the investment decision than a positive net present value, we can conclude:

Proposition 3.3. *With a margin call in place, no investment with a negative net present value will be undertaken. The LFI will invest in a project with a positive net present value, iff the funding liquidity is positive, i.e. iff* $(1-\lambda)p_2 r_b > i_{1,b}$.

Proof. Omitted. □

This proposition deviates from the respective proposition of Hart and Zingales (2011, p. 476) with respect to the institution's investment decision. We find that the investment decision is not based on the net present value of the second project but on its funding liquidity, i.e. the amount that can be pledged against this project. As long as the manager receives a share $\lambda > 0$ of the investment's profits, the funding liquidity will differ from the net present value. Hence a project will not be financed if its funding liquidity is negative, although its net present value is positive. These findings leave room for several research questions, which will be presented in the following subsection.

3.4.2 Further Research

Proposition 3.3 indicates that regulators might face a trade-off between financial stability and efficient bank lending. While the margin call is able to achieve financial stability, the LFI might be unable to finance investment projects with a positive net present value, which are desirable from a welfare perspective. We identified that this will be the case if the funding liquidity of equity financing is too low to cover the investment costs. Based on these findings, we pose three research questions, which will be answered in the next chapters of this thesis.

Identifying that the funding liquidity of the second investment project plays a crucial role, the first research question is whether the funding liquidity of the first investment project will have a similar effect on the first investment decision and how this might affect the LFI's intertemporal investment decision. Hart and Zingales consider an LFI whose investment decision for the first project was made in a previous period. Analyzing the complete intertemporal investment decision, we will show, in Chapter 4, that the first period's funding liquidity will determine the institution's capital structure in the first period and thus its ability to refinance second period investments. Moreover, Hart and Zingales consider returns, v_s, which are already reduced by the amount of systemic debt. A return below the face value of debt only leads to a closure of the institution after paying off all materialized returns to debtholders. From a regulatory perspective it is, however, more important to capture the risks resulting from institutions being unable to pay off their systemic debt. Issuing demandable deposits will lead to a bank run if the institution is unable to pay off the promised face value.[8] In contrast to a simple closure, such a bank run will destroy all values. We will see, in Chapter 4, that the possibility of a bank run will additionally affect the institution's intertemporal investment decision.

In contrast to the findings of Hart and Zingales, we have shown that the margin call might increase financial stability at the cost of a cutback in financing profitable investment projects. Therefore the margin call might result in a trade-off between financial stability and efficient bank lending similar to any other regulatory measure. The second research question is thus whether this trade-off is less severe under a margin call than under the regulatory measures of the Basel III Accord. In detail, we compare the margin call with the three main measures of the Basel III Accord, i.e. risk-weighted capital requirements, countercyclical capital buffer requirements and the liquidity coverage ratio. In Chapter 5 we have to modify the framework. Chapter 4 neglects the possibility of external equity so that we have to allow for this second type of financing before we are able to compare all four measures in Chapter 6.

Finally, the third research question discussed in this thesis is whether information asymmetry between the banker and all other market participants impairs the effectiveness of the margin call. Regulators might be unable to observe the state of the economy and thus to identify the risks of the institution's capital structure. Hart and Zingales argue that their two-step trigger mechanism leads to a CDS price that reflects the true probability of default. As a takeover occurs only after the CDS price has exceeded the predetermined threshold *and* the stress test has confirmed the probability of default, initiating a self-fulfilling default by increasing the CDS price is not a profitable strategy for market participants. Moreover, creditors will face a haircut once the LFI is chaired by the receiver. They are thus incentivized to

[8]Bank runs are not restricted to deposits but might emerge by issuing any other short-term funding, such as repurchase agreements (Martin *et al.*, 2014). Considering deposits, however, allows us to compare the margin call with bank regulation measures.

publicize their information about the institution, as the haircut will be prevented if the LFI is able to raise additional equity.

This argument of Hart and Zingales is based on two crucial assumptions. First, both shareholders and debtholders possess the same information on the investment projects as the manager, and second, the stress test is able to identify all potential risks. While dropping any of these assumptions will have significant consequences for the effectiveness of the margin call, we will henceforth only focus on asymmetric information. If accompanying the investment projects allows the manager to obtain a more profound knowledge concerning the projects' probability to default, asymmetric information will emerge. Given that the manager has an informational advantage over the LFI's investors with respect to the projects returns, investors might be unable to identify whether the institution is at risk. We will therefore analyze the impact of asymmetric information on the effectiveness of the margin call in Chapter 7. Nevertheless, the effectiveness of stress test scenarios is a likewise important topic. The example of the Franco-Belgian bank Dexia has shown that this is not an easy task at all. In July 2011, the European Banking Authority attested to Dexia being one of the safest banks. This was three months before Dexia asked for a bailout due to its large exposure to Greece. As stress test scenarios depend heavily on individual characteristics of an institution, there is no one-size-fits-all strategy. Identifying appropriate stress test scenarios is thus beyond the scope of this thesis.

3.5 Conclusion

The regulatory margin call by Hart and Zingales (2011) constitutes a first step to combine the regulatory measures of crisis prevention and crisis management. Although crisis management measures will never be in action as the LFI never defaults ex post, anticipating these measures is sufficient to affect the institution's behavior ex ante.

Following the analysis of Hart and Zingales, the margin call seems to be a suitable approach to achieve financial stability. However, in contrast to the findings of Hart and Zingales, we have demonstrated that, like all other regulatory measures, the margin call comes at the cost of inefficiencies in financing profitable investment projects. The reason is that a restriction in the amount of debt reduces an investment's funding liquidity. As the manager is able to extract a share of the institution's profit, he cannot pledge against the full value of the project if it is co-financed with equity. If shareholders' expected profit is too low to cover the investment costs, projects with a positive net present value will thus not be undertaken.

Based on the analysis of the margin call, we derived three research questions, which will be answered in the following chapters. First, in Chapter 4, we shed light on the impact of the funding liquidity of all investment projects for the intertemporal investment decision. Second, we evaluate under which conditions the margin call is more suitable than other bank regulation measures to ease the trade-off between financial stability and efficient bank lending. By considering figures that capture the market information of the expected probabilities of default instead of focusing on ex post information given in institutions' balance sheets, the margin call was designed as a counterproposal to Basel III.[9] After adjusting the framework accordingly in Chapter 5, we compare the margin call with the three main measures of the Basel III Accord in Chapter 6. Finally, we highlight the impact of asymmetric information on the effectiveness of the margin call in Chapter 7.

[9]The first working paper version of this article was available in April, 2009.

Chapter 4

Bank Lending and Financial Stability over the Business Cycle

In this chapter we present a two-period model, which captures the link between bank lending and the business cycle.[1] Focusing on the impact of real volatility on the dynamics of bank lending and the stability of the banking sector, we abstract from potential feedback effects of bank lending on the business cycle. Considering a forward-looking banker, we are able to determine different lending patterns over the cycle, depending on the liquidity risks in the economy and therefore the bank's funding liquidity. While some patterns are accompanied by a safe capital structure, the banker might be incentivized to put the stability of the bank at risk if liquidity risks in the economy are too high. We identify procyclical lending, a secular trend in granting loans or a curtailing of loans. This model serves as a basis for the analysis of the margin call conducted in the following chapters. It will be modified according to the needs of each research question.

4.1 Introduction

We concluded in the last chapter that the funding liquidity of new investment projects plays a crucial role for financial institutions' investment decisions. Even if an investment project has a positive net present value, it will not be undertaken if the funding liquidity of these investments is negative. As this argument holds for all investment decisions, in this chapter, we analyze the impact of the funding liquidity

[1] The findings of this chapter have been published as Bucher *et al.* (2013). However, for the purpose of this thesis, this chapter comprises a slightly modified version of the model.

on investment decisions in a dynamic framework. In contrast to Hart and Zingales, we thus explicitly consider the intertemporal aspects of the investment decisions over the business cycle.

The link between credit cycles and business cycles has attracted much attention during the world financial crisis. According to Jordà *et al.* (2011), a close relationship between the severity of a recession and the extent of a credit boom in the run up to the recession is observable for many recessions in the past 140 years. As a mutual occurrence of financial crises and deep and lasting recessions is quite likely, identifying the underlying causality, and thus potential risks to financial stability, is an important task for today's researchers.

Whereas the direction of causality between financial and real activities is still disputed, some explanations exist as to why instabilities in financial markets cause business cycles. The financial instability hypothesis argues that after a period of prolonged prosperity speculative euphoria might emerge, providing the basis for excessive bank lending. An increase in the riskiness of investments may then shift the economy from a good to a bad equilibrium (Minsky, 1986). However, before the recent financial crisis, this knowledge was not considered in consensus macroeconomic models. As these models were unable to explain this crisis, the financial instability hypothesis has received more attention recently (Vercelli, 2009; Davidson, 2008; Whalen, 2008). In order to explain and predict financial crises, recent macroeconomic models like Gertler and Kiyotaki (2010), Christiano *et al.* (2010) and Cúrdia and Woodford (2008), among others, returned to focus more strongly on financial frictions. However, these models are still unable to fully explain phenomena like excessive credit growth and bank failures.

In this chapter, we add a reason why expectations about business cycle fluctuations affect bank lending.[2] Reconciling rational behavior with certain implications of Minsky's financial instability hypothesis, we identify liquidity risks resulting from real volatilities as a driving factor for the bank's ability to raise funding. Exhibiting an informational advantage vis-à-vis investors, contractual frictions hamper the banker's ability to pledge against the full value of investments. Depending on the extent of these funding problems, we determine different lending patterns over the business cycle: procyclical lending, a secular trend in granting loans or a curtailing of loans. Neglecting feedback effects of bank lending on business cycle fluctuations, we thus shed light on the reversed causality, which has not received much attention until now.

[2] Our argument holds for both LFIs and banks. Aiming to compare the margin call with the measures of the Basel III Accord (which solely apply to banks) later, we have chosen to focus on banks in the chapter.

A forward-looking banker seeks to balance expected returns and losses, which vary with business cycle movements, over time. If a downturn occurs, liquidity risks will materialize. In this case, bank assets yield a lower cash flow compared with an economic upswing, so that the bank's internal capital declines. Moreover, the economic prediction in the downturn is rather poor so that pledging against prospective earnings to raise external funds will be insufficient to finance banks' investments. Hence the relation between internal capital and the bank's funding liquidity of new loans determines the restriction of bank lending in a downturn. Banks may be incentivized to increase internal capital, and so their ability to grant loans in the downturn, by an excessive credit supply in the run-up to the recession. If the cash flow in the downturn is, however, insensitive to banks' ability to grant loans, they will start to gamble for resurrection. This behavior will result in a bank run if the recession is prolonged. Moreover, an outright failure in the downturn will occur if the performance of existing loans is so poor that the bank is unable to refinance the existing debt overhang at that time.

The chapter is organized as follows. Section 4.2 presents the setup of the model. This model is solved by backward induction in Section 4.3, i.e. we first identify the banker's optimal behavior in the second period, and take these results as given to determine his optimal strategy over the business cycle. In Section 4.4 we comment on the robustness of the major changes compared with the baseline model of the previous chapter, and on potential implications for financial stability and bank regulation. Section 4.5 concludes this chapter.

4.2 Setup

4.2.1 Agents and Technologies

Analyzing bank lending over the business cycle, we consider a representative bank that exists for two periods and three dates, $t = 0, 1, 2$. At the beginning of each period, at date $t = 0$ and $t = 1$, the banker who runs the bank decides on the bank's capital structure and its portfolio. He raises funds d_t from depositors, invests a_t in a short-term asset and grants loans in the amount of l_t. While the short-term asset is risk-free and generates a zero net return in each period, loan earnings are risky and depend crucially on the state of the economy, as Figure 4.1 illustrates.

The model depicts different paths of the business cycle. At the end of the first period, two states are feasible. The economy will be either in an upswing, which occurs with probability p_1, or experiencing a downturn. If economic conditions are benign at $t = 1$, the economic upswing will continue until $t = 2$ with probability $p_{2,g}$

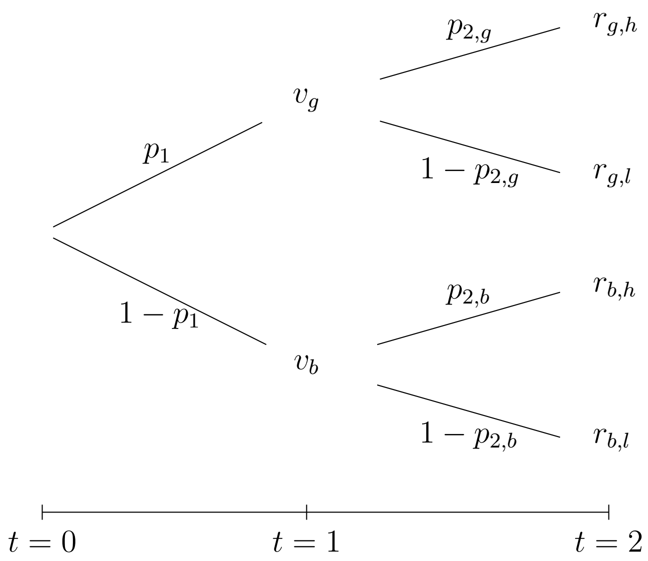

Figure 4.1: Loan earnings of first and second period loans (per unit)

so that a boom materializes. With probability $1 - p_{2,g}$ the upswing will cool-down. Likewise, the economy will either recover from the downturn with probability $p_{2,b}$ or will run into a recession at the end of the second period.

At $t = 1$, loans granted at $t = 0$ yield a high return v_g if the economy is in an upswing and a lower return $v_b \in (0, v_g)$ if a downturn emerges.[3] If the economy is benign, loans granted at $t = 1$ are very productive at the end of the second period. In this "good" situation, $s = g$, the bank expects a high return $r_{g,h}$ in the boom and a mediocre return $r_{g,l} < r_{g,h}$ in the cool-down at $t = 2$. However, if a downturn occurs at $t = 1$, the situation turns out to be "bad", $s = b$. In this case, second period loans will yield $r_{b,h} < r_{g,l}$ if the economy recovers until $t = 2$ and $r_{b,l} \in (0, 1)$ if the recovery holds off. Assuming $p_1 v_g > 1$ and $p_{2,b} r_{b,h} > 1$ ensures that first and second period loans maintain a positive net return ex ante, i.e. before they are granted.

It is useful to characterize both first and second period loan returns by both their mean, μ, at the date of origination, and their risks. Considering a mean preserving spread, changes in risks will not affect loans' expected return and we obtain[4]

$$\mu_1 := p_1 v_g + (1 - p_1)\, v_b, \qquad \Delta_1 := v_g - v_b, \tag{4.1}$$

$$\mu_{2,s} := p_{2,s} r_{s,h} + (1 - p_{2,s})\, r_{s,l}, \qquad \Delta_{2,s} := r_{s,h} - r_{s,l}. \tag{4.2}$$

[3]Unless otherwise stated, all returns are per unit.

[4]For given probabilities p_1 and $p_{2,s}$, there are linear relationships between our risk measures Δ_1 and $\Delta_{2,s}$ and the respective standard deviations σ_1 and $\sigma_{2,s}$ according to $\sigma_1 = \Delta_1 \sqrt{p_1(1 - p_1)}$ and $\sigma_{2,s} = \Delta_2 \sqrt{p_2(1 - p_2)}$.

This allows us to compare the effects of varying magnitudes of business cycles. An increase in the expected return on loans entails better overall conditions of the economy in the respective period or state. If the riskiness of loans increases, the bank expects lower returns in the downturn, cool-down or recession. Accordingly, business cycle fluctuations increase.[5] Given the definitions of Δ_1 and $\Delta_{2,s}$, we can rewrite loan earnings as follows[6]

$$v_g = \mu_1 + (1 - p_1)\,\Delta_1, \qquad r_{s,h} = \mu_{2,s} + (1 - p_{2,s})\,\Delta_{2,s}, \tag{4.3}$$

$$v_b = \mu_1 - p_1\Delta_1, \qquad r_{s,l} = \mu_{2,s} - p_{2,s}\Delta_{2,s}. \tag{4.4}$$

The banker's skills are required to collect the full value of loans. If the banker refuses to apply his skills, investors will be unable to collect any earnings from their investments. However, the granting of loans is associated with non-pecuniary costs for the banker. These costs follow an increasing and convex function, c, of the loan volume, l_t, with $c(0) = c'(0) = 0$. This can be motivated as follows. The banker first starts to grant loans to customers who demand only little involvement, e.g. as their project is well characterized or as there exists a long bank customer relationship. After granting less costly loans, he adds more complex, and thus more demanding, projects, so that each additional loan granted increases his private costs disproportionately.[7] As risk-free assets require nearly no effort from the banker, we normalize these costs to zero.

At $t = 0$ the banker possesses no funds of his own, so that granting loans is only feasible by raising deposits. Having access to a risk-free storage technology, depositors will only provide funds if their expected net return is nonnegative. As all other agents, depositors have no time preference. They will thus patiently wait for their repayment if this is at least as beneficial as an early withdrawal. There is perfect competition among these depositors, who are unrestricted in funds. The banker seeks to maximize his expected profit. All agents are risk neutral.

4.2.2 Contracting Friction and Capital Structure

We consider the same incomplete contract problem as in Chapter 3. Accordingly, we can likewise conclude that issuing demandable deposits with a face value, δ_t,

[5]Considering persistent and mean reverting shocks, our model captures a feature that is standard in macroeconomic models (cf. Aghion *et al.*, 2010).

[6]As $v_b > 0$ and $r_{s,l} > 0$, the liquidity risks are restricted to $\Delta_1 < \frac{\mu_1}{p_1}$ and $\Delta_{2,s} < \frac{\mu_{2,s}}{p_{2,s}}$, respectively.

[7]Note that, in contrast to Chapter 3, these private costs explain why the banker should be compensated by participating in the bank's returns.

		Upswing	Downturn
safe	$m_0 = \mathcal{S}$	no bank run	no bank run
risky	$m_0 = \mathcal{R}$	no bank run	bank run
failure	$m_0 = \mathcal{F}$	bank closed	bank closed

(a) at $t = 0$

		Boom / Recovery	Cool-down / Recession
safe	$m_{1,s} = \mathcal{S}$	no bank run	no bank run
risky	$m_{1,s} = \mathcal{R}$	no bank run	bank run
failure	$m_{1,s} = \mathcal{F}$	bank closed	bank closed

(b) at $t = 1$

Table 4.1: Modes of operation

eliminates the banker's incentive of renegotiating or even refusing payments and commits him to use his skills on behalf of investors. The face value of deposits captures the amount the banker promises to pay depositors at the end of the period. The difference between this face value, δ_t, and the funds provided by depositors, d_t, captures the interest on deposits. Bankers need to promise a nonnegative interest to obtain funding. If the banker tried to renegotiate repayments to depositors, depositors would immediately run on the bank so that all values would be destroyed. However, a bank run will also occur each time depositors expect loan earnings to be too low to cover their claims. Hence, while deposits serve as a commitment device for the banker, the downside is that risky assets originate bankruptcy risks even if the banker applies his skills.[8] Issuing equity would allow the banker to protect himself against these fluctuations in loan earnings.[9]

The banker is free to choose the face value of deposits so that we can distinguish between three modes of operation, m_t, for each period (see Figure 4.1). In the "safe" mode, $\mathcal{S}$, the banker promises to pay a face value of deposits, δ_t, which is smaller than the bank's returns in the worst possible state of the business cycle, i.e. smaller than v_b and $r_{s,l}$, respectively. Accordingly, depositors will receive this face value at the payment next date with certainty. The bank's capital structure is safe and a bank run will never occur. In this mode, the expected profits of loans in the first and second period are given by

$$\phi_0^{\mathcal{S}}(l_0) = (\mu_1 - 1)\, l_0 - c(l_0), \qquad \phi_{1,s}^{\mathcal{S}}(l_{1,s}) = (\mu_{2,s} - 1)\, l_{1,s} - c(l_{1,s}). \tag{4.5}$$

A larger face value implies that depositors will only be compensated if loan returns are sufficiently high. In this case, the banker operates in the "risky" mode, $\mathcal{R}$, by choosing a risky capital structure. If loans materialize a lower return as a downturn, cool-down or recession occurs, depositors will run on the bank and all values will be

[8] A full-fledged analysis of the underlying hold-up problem based on first-principles is provided by Diamond and Rajan (2000, 2001b), who show that deposits mitigate this problem but come at the cost of financial fragility.

[9] We will, however, abstract from this possibility until Chapter 5.

destroyed. Accordingly, the expected profits of loans are lower and given by

$$\phi_0^{\mathcal{R}}(l_0) = (p_1 v_g - 1)\, l_0 - c\,(l_0)\,, \qquad \phi_{1,s}^{\mathcal{R}}(l_{1,s}) = (p_{2,s} r_{s,h} - 1)\, l_{1,s} - c\,(l_{1,s})\,. \tag{4.6}$$

The banker will declare bankruptcy at $t = 1$ and will operate in the "failure" mode, $\mathcal{F}$, if he is unable to satisfy existing claims irrespective of the state of the economy.

Efficient loan volumes are characterized by expected marginal revenues equaling marginal costs, which comprise both investment costs and private lending costs. We refer to the efficient loan volumes as first best. Hence the first best loan volume of first period loans l_0^{fb} is given by $\phi_0^{\mathcal{S}\,\prime}\left(l_0^{\text{fb}}\right) = 0$, while the first best loan volume of second period loans $l_{1,s}^{\text{fb}}$ is defined by $\phi_{1,s}^{\mathcal{S}\,\prime}\left(l_{1,s}^{\text{fb}}\right) = 0$.

4.3 Bank Behavior

In this section we determine the subgame perfect equilibrium of the model. The banker maximizes his expected profit by choosing the bank's portfolio and the face value of deposits. This profit materializes at the end of each period as loan earnings and asset returns, net of the payments to depositors and the banker's costs of managing the loan portfolio. We specify the respective budget constraints and objective functions for both periods and explore the banker's optimal strategy over the business cycle.[10] Applying backward induction, we first analyze the banker's optimal behavior in the second period for each state feasible. Afterwards, we turn to the first stage.

4.3.1 Second Period

At the beginning of the second period, the economy is either in an upswing or experiencing a downturn. At this date, first period loans materialize a return $v_s l_0$ and the risk-free asset yields a_0. Both returns will be used to pay off depositors the face value, δ_0, so that the available cash flow is $v_s l_0 + a_0 - \delta_0$. We can thus define $\omega_{1,s} := \frac{v_s l_0 + a_0 - \delta_0}{l_0} \lesseqgtr 0$ as the banker's cash flow per unit of loans granted at $t = 0$. If the cash flow, $\omega_{1,s} l_0$, is positive, it captures the amount of internal capital available to the banker to co-finance second period loans. A negative cash flow, however, implies that the banker has to use a share of fresh funds raised at $t = 1$ to pay off the existing debt overhang.

[10]Following Mas-Colell *et al.* (1995, p. 228) we define the banker's strategy as the complete contingent plan for all possible distinguishable circumstances in which he is called upon to move.

Unless the banker operates in the failure mode, $m_{1,s} = \mathcal{F}$, which results in an immediate bank closure, his optimization problem at $t = 1$ reads

$$\max_{l_{1,s},a_{1,s},\delta_{1,s}\in\mathbb{R}^+} \pi_{1,s} = E\left[\max\left\{r_{s,j}l_{1,s} + a_{1,s} - \delta_{1,s}, 0\right\}\right] - c\left(l_{1,s}\right) \tag{4.7}$$

$$\text{s. t.} \quad l_{1,s} + a_{1,s} = \omega_{1,s}l_0 + d_{1,s}, \tag{4.8}$$

$$d_{1,s} = \begin{cases} \delta_{1,s} & \text{if} \quad m_{1,s} = \mathcal{S}: \ \delta_{1,s} \leq r_{s,l}l_{1,s} + a_{1,s}, \\ p_{2,s}\delta_{1,s} & \text{if} \quad m_{1,s} = \mathcal{R}: \ \delta_{1,s} \in \left(r_{s,l}l_{1,s} + a_{1,s}, r_{s,h}l_{1,s} + a_{1,s}\right], \end{cases} \tag{4.9}$$

with $j = \{h, l\}$. Equation (4.8) reflects the bank's budget constraint at $t = 1$. The banker grants second period loans, $l_{1,s}$, and invests $a_{1,s}$ in the risk-free asset. These investments are refinanced externally by new deposits, $d_{1,s}$. If the current cash flow, $\omega_{1,s}l_0$, is positive, funding will also be provided internally, whereas deposits will have to refinance the debt overhang if $\omega_{1,s}l_0$ is negative. The link between the amount of second period deposits, $d_{1,s}$, and the face value of these deposits, $\delta_{1,s}$, is specified in (4.9). If the banker operates in the safe mode, $\mathcal{S}$, deposits are always repaid, irrespective of the state at $t = 2$. Hence depositors do not ask for a premium but provide deposits, $d_{1,s}$, equal to the face value, $\delta_{1,s}$. However, if the banker operates in the risky mode, $\mathcal{R}$, depositors will only provide deposits equal to their expected payoff. As they will receive the face value only if second period loans materialize a high return, $r_{s,h}$, which occurs with probability p_2, they will provide less funds. The difference between the face value and the amount of deposits thus captures the premium that depositors receive in order to compensate for the potential loss in case the return is too low so that a bank run occurs. Finally, equation (4.7) shows the banker's expected profit, $\pi_{1,s}$, at the beginning of the second period. The banker will obtain the bank's profits at the end of this period, net of depositors' claims and his non-pecuniary costs of managing second period loans. Due to limited liability, the expected pecuniary profit is nonnegative.

Suppose the banker operates in the safe mode, $m_{1,s} = \mathcal{S}$. In this case, the risk-free asset will always exactly cover its investment costs so that the banker is indifferent with respect to this asset. However, it follows from (4.9) that this mode is only feasible for a sufficiently low face value of deposits. Considering this restriction on deposits yields that bank lending will be restricted according to

$$\left[1 - r_{s,l}\right] l_{1,s} \leq \omega_{1,s}l_0. \tag{4.10}$$

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">cash flow ($\omega_{1,s}l_0$)</td></tr>
<tr><td>+</td><td>−</td></tr>
<tr><td rowspan="2">funding liquidity ($r_{s,l}-1$)</td><td>+</td><td>$l_{1,s}$ unrestricted</td><td>lower bound $l_{1,s}^{\min}$</td></tr>
<tr><td>−</td><td>upper bound $l_{1,s}^{\max}$</td><td>safe mode unavailable</td></tr>
</table>

Table 4.2: Cash flow and funding liquidity in the safe mode at $t = 1$

Whether this restriction on bank lending is binding depends on first period loans cash flow, $\omega_{1,s}l_0$, and the funding liquidity, $r_{s,l} - 1$, per unit of second period loans. If the cash flow is positive, the banker is able to use the internal capital to co-finance second period loans. A negative cash flow, however, demands that the banker will have to raise additional funds at $t = 1$ to cover the existing debt overhang. As long as the banker operates in the safe mode, he can issue deposits up to $r_{s,l}l_{1,s} + a_{1,s}$. If $r_{s,l} > 1$, the funding liquidity of second period loans will be positive and the excess liquidity can, for instance, be used to cover a debt overhang. However, $r_{s,l} < 1$ implies that the bank has to fill the funding gap, $1 - r_{s,l}$, by co-financing second period loans with internal capital. This will only be feasible if first period loans materialize a positive cash flow at $t = 1$.

Accordingly, four different scenarios might occur. These are illustrated in Figure 4.2. If both first period loans yield a positive cash flow and second period loans can be financed by issuing deposits only, bank lending will not be restricted. The banker will face an upper bound, $l_{1,s}^{\max}$, on bank lending, if the cash flow is positive while the funding liquidity of second period loans is negative. In this case, the loan volume granted at $t = 0$ determines the materialized cash flow and therefore the banker's ability to co-finance second period loans. This results in an intertemporal link between granting loans in the first and second periods. Analogously, bank lending will be restricted by a lower bound if the funding liquidity of second period loans is positive while the cash flow is negative. The banker will have to grant at least loans in the amount of $l_{1,s}^{\min}$ to ensure that he will receive sufficient funds to cover the existing debt overhang. Finally, the safe mode is not feasible if both first period loans' cash flow and second period loans' funding liquidity are negative.

Recall from equation (4.4) that $r_{s,l}$ decreases in $\Delta_{2,s}$. Accordingly, an increase in the risk level, $\Delta_{2,s}$, leads to a decline in the funding liquidity of the second period loans. The same argument applies for first period loans. We will show below that the funding liquidity in the first period when operating in the safe mode depends on v_b, which decreases in Δ_1. This is why we henceforth refer to the risks considered in this model as liquidity risks.

Suppose the banker operates in the risky mode, $m_{1,s} = \mathcal{R}$. Compared with the safe mode this allows the banker to increase the face value of deposits, $\delta_{2,s}$, up to

$r_{s,h}l_{1,s} + a_{1,s}$. Depositors will receive this face value only if the economic condition turns out to be prosperous, i.e. if either a boom or a recovery materializes at $t = 2$. As these situations occur with probability $p_{2,s}$, depositors are only willing to provide funding up to $p_{2,s}\delta_{2,s}$. Therefore, bank lending is restricted to

$$[p_{2,s}r_{s,h} - 1]l_{1,s} \geq -\omega_{1,b}l_0 + (1 - p_2)a_{1,b}. \tag{4.11}$$

This restriction again depends on first period loans' cash flow and second period loans' funding liquidity. Since we only consider investment projects with a positive net present value, it follows that $p_{2,b}r_{b,h} > 1$. The funding liquidity of second period loans, $p_{2,s}r_{s,h} - 1$, is thus always positive when operating in the risky mode. Co-financing via internal capital is therefore unnecessary. However, bank lending may be restricted by a lower bound if the cash flow of first period loans is negative. The downside of the risky mode is that an increase in the face value of deposits will lead to a bank run if the economy is either in a cool-down or in a recession. Accordingly, lending per unit is less profitable in the risky mode. Moreover, a bank run will also destroy the value of the risk-free asset. Therefore the banker will never invest in this asset when operating in the risky mode, due to its negative expected profit, $p_2 - 1$.

Suppose the banker operates in the failure mode, $m_{1,s} = \mathcal{F}$. This will be the case if the banker increases the face value of deposits, $\delta_{2,s}$, above $r_{s,h}l_{1,s} + a_{1,s}$. As depositors are certain that this face value will never be paid off, they will run on the bank straight away at $t = 1$. In consequence, all values are already destroyed at this date and the banker receives no compensation at all.

Comparing the resulting expected profits of all modes if the economy is in an upswing at $t = 1$, i.e. in the good state $s = g$, we obtain:

Lemma 4.1. *If the economy is in an upswing at date $t = 1$, the banker's optimal decision on the mode of operation, $m_{1,g}$, and bank lending, $l_{1,g}$, will have the following properties:*

$$m^*_{1,g} = \mathcal{S}, \quad l^*_{1,g} = l^{fb}_{1,b} \quad \forall\ l_0. \tag{4.12}$$

Proof. See appendix. □

Due to high (expected) profits of first and second period loans, the banker will always operate in the safe mode if the economic conditions are benign at $t = 1$. As expected returns of second period loans in the cool-down, $r_{g,l}$, are higher than in the recovery, $r_{b,h}$, the funding liquidity of second period loans will always be positive, even if the banker operates in the safe mode. Moreover, the high returns, $v_g l_0$, of first period loans yield a positive cash flow at $t = 1$.[11] In consequence, bank lending in the safe mode is never restricted and the banker grants loans according to the first best. As this behavior implies the largest expected return feasible, the banker will never prefer any other mode over the safe mode if the economy is in an upswing.

Analogously, we compare the resulting expected profits of all modes feasible if the economy is in a downturn at $t = 1$, i.e. in the bad state $s = b$, and obtain:

Lemma 4.2. *If the economy is in a downturn at date* $t = 1$*, the banker's decision on the mode of operation,* $m_{1,b}$*, and bank lending,* $l_{1,b}$*, will have the following properties:*

- *Given* $\omega_{1,b} \geq 0$*, then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{fb}_{1,b} & \text{if } \; l_0 \geq \frac{1-r_{b,l}}{\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{max}_1 & \text{if } \; l_0 \in [l^{min}_0, \frac{1-r_{b,l}}{\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} = \mathcal{R}, & l^*_{1,b} = l^{\mathcal{R}}_1 < l^{fb}_{1,b} & \text{if } \; l_0 < l^{min}_0, \end{array} \tag{4.13}$$

- *Given* $\omega_{1,b} < 0$*, then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{R}, & l^*_{1,b} = l^{\mathcal{R}}_1 < l^{fb}_{1,b} & \text{if } \; l_0 \leq l^{max}_0, \\ m^*_{1,b} = \mathcal{F}, & l^*_{1,b} = 0 & \text{if } \; l_0 > l^{max}_0, \end{array} \tag{4.14}$$

with $l^{max}_0 := -\frac{\phi^{\mathcal{R}}_{1,b}(l^{\mathcal{R}}_1)}{\omega_{1,b}}$ *and* $l^{max}_1 := \frac{\omega_{1,b}}{1-r_{b,l}} l_0$ *while* l^{min}_0 *is implicitly defined by*

$$\phi^{\mathcal{S}}_{1,b}\left(l^{max}_1(l_0)\right) = \phi^{\mathcal{R}}_{1,b}\left(l^{\mathcal{R}}_1\right). \tag{4.15}$$

Proof. See appendix. □

As long as first period's cash flow is positive as $\omega_{1,b} > 0$, and increase in first period loans increases the bank's internal capital. In this scenario, all three modes are available in the downturn at $t = 1$. However, second period loans' negative funding liquidity imposes a financial constraint, $l^{\max}_1$, when operating in the safe mode, $\mathcal{S}$. This constraint will not become binding if first period loans are sufficiently large. In this case, first period's cash flow is high enough to co-finance the first best loan volume, $l^{\text{fb}}_{1,b}$. Therefore the banker grants more loans and expects a larger expected return per unit of loans, compared with the risky mode, $\mathcal{R}$, so that he will always prefer the safe mode over the risky mode and the failure mode, $\mathcal{F}$. However, if first period loans are lower, the restriction on bank lending becomes binding. The banker thus compares the expected loss resulting from the restriction in the safe

[11]The formal proof of this statement is given in the appendix.

mode with the expected loss due to lower per unit returns in the risky mode. As long as first period loans are sufficiently large, the reduction in expected profits due to the constraint is comparatively low. Hence the banker still prefers the safe mode over the risky mode for all loan volumes above $l_0^{\min}$. If first period loans are too low to co-finance enough loans in the second period, operating in the risky mode leads to a higher expected profit. Accordingly, the banker will prefer the risky mode, $\mathcal{R}$, over the safe mode, $\mathcal{S}$, if first period loans are lower than $l_0^{\min}$. This threshold crucially depends on the funding liquidity of second period loans. If the liquidity risk of second period loans, $\Delta_{2,b}$, increases, the funding gap, $1 - r_{b,l} = 1 - \mu_{2,b} + p_{2,b}\Delta_{2,b}$, becomes larger and the restriction on bank lending in the safe mode, $l_1^{\max}$, tightens. Consequently, the banker has to co-finance a larger share by internal capital, which will only be sufficient if he granted enough first period loans, see the left hand side (LHS) of equation (4.15). At the same time, the expected return on second period loans, $r_{b,l}$, which might be destroyed in a bank run, declines, so that the expected profit of the risky mode as given by the right hand side (RHS) of equation (4.15) increases. The threshold $l_0^{\min}$, which leads to the banker being indifferent about whether to use the safe or the risky mode, thus increases with the size of the liquidity risk of second period loans.

If first period's cash flow is negative as $\omega_{1,b} < 0$, the safe mode is not feasible due to the negative funding liquidity of second period loans. The banker can thus only choose between the risky and failure modes. As long as second period returns are sufficiently large to offset the negative cash flow, the banker prefers the risky mode, $\mathcal{R}$, over the failure mode, $\mathcal{F}$. However, if the loan volume granted in the first period is too high, so that the expected profit of the risky mode turns out to be negative, the banker chooses the failure more over the risky mode. This is the case for all loan volumes larger than $l_0^{\max}$. As argued above, the expected profit of second period loans, $\phi_{1,b}^{\mathcal{R}}\left(l_1^{\mathcal{R}}\right)$, increases with the liquidity risk $\Delta_{2,b}$. In consequence, the banker is able to refinance a larger debt overhang in the downturn so that the threshold $l_0^{\max}$ increases with the liquidity risk of second period loans.

4.3.2 First Period

After determining the banker's optimal behavior with respect to the bank's portfolio and risk taking at $t = 1$ for a given l_0, we are now able to derive the banker's optimal decision at the beginning of the first period, and therefore his optimal strategy over the business cycle. As in the preceding section, we first clarify the banker's optimization problem. Following that we discuss the resulting optimal behavior.

Unless the banker operates in the failure mode, $\mathcal{F}$, which leads to a bank closure immediately at $t = 0$, his optimization problem at the beginning of the first period reads

$$\max_{l_0, a_0, \delta_0 \in \mathbb{R}^+} \pi_0 = p_1 \pi_{1,g}(l^*_{1,g}) + (1 - p_1)\, \pi_{1,b}(l^*_{1,b}) - c(l_0) \tag{4.16}$$

$$\text{s.t.} \;\; l_0 + a_0 = d_0, \tag{4.17}$$

$$d_0 = \begin{cases} \delta_0 & \text{if} \;\; m_0 = \mathcal{S} : \;\; m^*_{1,b} \neq \mathcal{F} \\ p_1 \delta_0 & \text{if} \;\; m_0 = \mathcal{R} : \;\; m^*_{1,b} = \mathcal{F} \end{cases} . \tag{4.18}$$

At $t = 0$ the banker anticipates his future optimal behavior when maximizing his expected profit, π_0, at $t = 0$. As in the second stage, he again has to consider the budget constraint given in equation (4.17). As the banker possesses no internal capital in the first period, all investments, i.e. loans, l_0, and risk-free assets, a_0, have to be financed by deposits, d_0. Equation (4.18) indicates that the amount of external funds depends again on the mode of operation. As depositors are able to anticipate the interrelation of first period loans and the respective optimal mode in the different states at $t = 1$, they will not demand a premium and will provide funds in an amount equal to the face value, δ_0, if they expect a repayment of this face value with certainty at $t = 1$. In this case, the bank operates in the safe mode, $m_0 = \mathcal{S}$, at $t = 0$. We obtained, in Lemma 4.1, that a closure will never occur once the economy is in an upswing at $t = 1$. However, the banker will have to operate in the failure mode in the downturn at $t = 1$, if the face value of first period deposits is so high that the negative cash flow in the downturn cannot be compensated by granting second period loans. In this case the banker will operate in the risky mode, $m_0 = \mathcal{R}$, at $t = 0$, as he will have to close the bank in the downturn at $t = 1$. Depositors will provide external funds up to $p_1 \delta_0$, as they expect to be repaid only in an upswing, which occurs with probability p_1. The difference between d_0 and δ_0 thus again depicts the premium the banker has to pay to receive funds from investors. The banker aims to maximize his expected profit, π_0, at the beginning of the first period given by equation (4.16). With probability p_1 the economy is in an upswing at $t = 1$ so that the banker will obtain $\pi^*_{1,g}$, implicitly defined by Lemma 4.1. If the economy is in the downturn, which occurs with probability $1 - p_1$, the banker's expected profit is $\pi^*_{1,b}$, which is specified based on the findings of Lemma 4.2. Moreover, the banker has to bear private costs $c(l_0)$ for granting first period loans, l_0.

As in the second stage, we are now able to identify the banker's behavior given the subgame-perfect modes at $t = 1$. As the banker will always operate in the safe mode, $m^*_{1,g} = \mathcal{S}$, once the economy is in an upswing, we only have to distinguish three different combinations of modes over the business cycle, depending on the mode in the first period and in the downturn at $t = 1$. These mode combinations can be put in a strict order.

Suppose, the banker operates in the safe mode in both the first and second period, i.e. $m_0 = m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. As the expected profit of investing in the risk-free asset is zero, the banker is again indifferent with respect to this investment. Recall from the second stage that the safe mode is feasible in the downturn only if the first period's cash flow, $\omega_{1,b}l_0 = v_b l_0 + a_0 - \delta_0$, is positive. Inserting (4.18) and the budget constraint (4.17), the cash flow reads

$$\omega_{1,b}l_0 = (v_b - 1)l_0. \tag{4.19}$$

Since the return on first period loans in the downturn, v_b, decreases in the liquidity risk, Δ_1, a positive cash flow will only materialize for lower liquidity risks. As the restriction on the face value of deposits is less tight for lower liquidity risks, depositors will always provide sufficient funding so that bank lending is not restricted in the first period. However, bank lending in the downturn will be restricted to

$$l_1^{\max} = \frac{\mu_1 - p_1\Delta_1 - 1}{1 - \mu_{2,b} + p_{2,b}\Delta_{2,b}} l_0 =: \psi l_0. \tag{4.20}$$

The bank's ability to grant loans in the downturn up to $l_1^{\max}$ crucially depends on first period loans. An increase in l_0 will loosen the restriction in the downturn. The factor ψ measures how much more loans are refinanceable in the downturn by increasing the loan volume granted in the first period. This leeway decreases with the liquidity risks of both periods, Δ_1 and $\Delta_{2,b}$. As argued above, an increase in the liquidity risk of first period loans, Δ_1, leads to a decrease in the first period's cash flow in the downturn, while an increase in the liquidity risk of first period loans, $\Delta_{2,b}$, increases the funding gap of second period loans.

If the restriction in the downturn is binding, the banker is thus incentivized to overinvest in the first period in order to loosen the restriction in the following period and therefore to reduce the underinvestment in the downturn at $t = 1$. He compares expected losses from granting loans above the first best in the first period with expected gains resulting from granting more loans in the downturn. As long as the liquidity risks are not too large, the restriction, and therefore the potential overinvestment, deviates only slightly from the first best. If the liquidity risks are larger, ψ will decrease and the restriction in the downturn will become tighter.

Increasing first period loans thus has a weaker impact on the banker's ability to grant loans in the downturn.

Suppose, the banker operates in the safe mode in the first period, but in risky mode once the economy is in the downturn at $t = 1$, i.e. $m = \mathcal{SR}$. We can conclude from Lemma 4.2 that the banker is unrestricted in granting loans in the downturn when operating in the risky mode. However, first period loans will materialize a negative cash flow if their liquidity risk becomes too large. In consequence, the banker's expected profit of this combined mode will only be positive if first period loans are not too large. Granting loans in the first period is thus restricted to

$$-[\mu_1 - p_1\Delta_1 - 1]l_0 \leq \phi^{\mathcal{R}}_{1,b}\left(l^{\mathcal{R}}_1\right). \tag{4.21}$$

If the first period's cash flow in the downturn, $\omega_{1,b} = \mu_1 - p_1\Delta_1 - 1$, turns out to be negative, the banker will have to refinance the existing debt overhang by pledging against second period loans. Accordingly, a larger liquidity risk will result in a tighter restriction on bank lending in the first period.

As bank lending is not restricted in the downturn, the volume of loans, l_0, granted in the first period will have no impact on granting loans in the second period. However, as a bank run occurs if the economy does not recover from the downturn until $t = 2$, the expected profit of second period loans is lower compared with the safe mode. In consequence the banker will grant loans according to $l^{\mathcal{R}}_1 < l^{\text{fb}}_{1,b}$ so that expected marginal returns in the risky mode equal marginal costs.

Finally, the banker will operate in the combined mode, $m = \mathcal{RF}$, if he chooses the risky mode in the first period and the failure mode in the downturn. In this case, the banker will only receive a payoff from both first and second period loans if the economy is in an upswing at $t = 1$. As the closure leads to a lower expected profit from granting first period loans, the banker will grant less loans compared with the first best, i.e. $l^{\mathcal{R}}_0 < l^{\text{fb}}_0$. However, the larger the liquidity risk of first period loans, the less value is destroyed in the downturn, so that the marginal return on first period loans increases. Accordingly, this underinvestment will become less pronounced, if the liquidity risk, Δ_1, increases. Moreover, the banker never invests in the risk-free asset as its expected profit becomes negative when operating in the risky mode in the first period.

We do not have to consider the possibility that the banker operates in the failure mode immediately at $t = 0$. Due to $p_1 v_g > 1$, granting loans in the first period is always beneficial. Comparing the expected profits of the different combinations of modes feasible, we obtain:

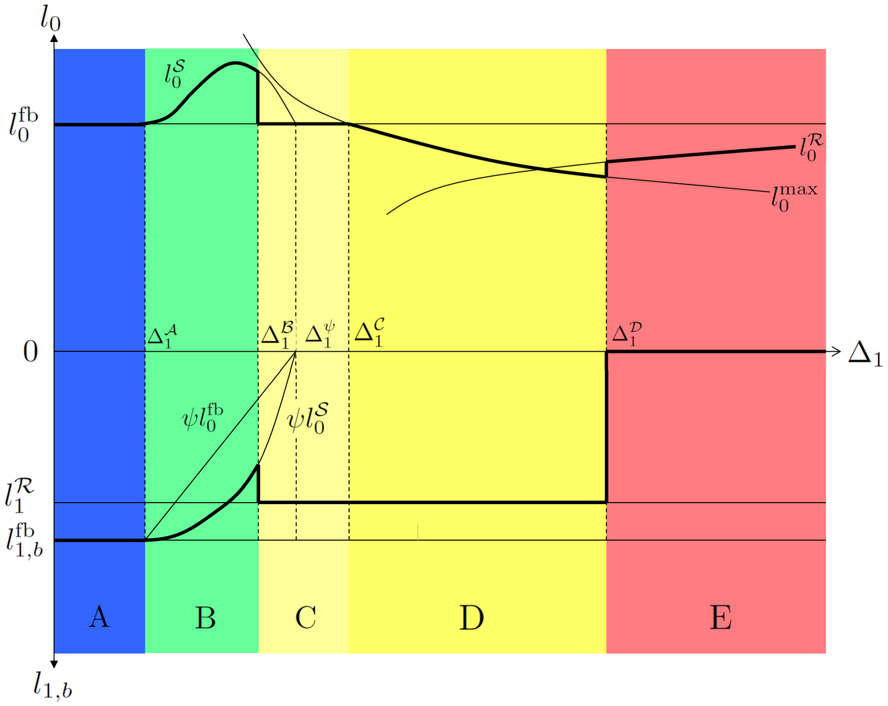

Figure 4.2: Optimal lending and capital structure decision at $t = 0$ and in the bad situation at $t = 1$ for a given $\Delta_{2,b}$

Proposition 4.3. *For $\Delta_1 < \frac{\mu_1}{p_1}$, the banker's optimal decisions on the mode of operation, m, and bank lending, l_t, at $t = 0$ and $t = 1$ have the following properties:*

$$\begin{array}{lllll}
\mathcal{A}: & m^* = \mathcal{SS}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if } \Delta_1 \leq \Delta_1^{\mathcal{A}}, \\
\mathcal{B}: & m^* = \mathcal{SS}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \text{if } \Delta_1 \in \left(\Delta_1^{\mathcal{A}}, \Delta_1^{\mathcal{B}}\right], \\
\mathcal{C}: & m^* = \mathcal{SR}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_1^{\mathcal{R}} < l_{1,b}^{fb} & \text{if } \Delta_1 \in \left(\Delta_1^{\mathcal{B}}, \Delta_1^{\mathcal{C}}\right], \\
\mathcal{D}: & m^* = \mathcal{SR}, & l_0^* = l_0^{max} < l_0^{fb}, & l_{1,b}^* = l_1^{\mathcal{R}} < l_{1,b}^{fb} & \text{if } \Delta_1 \in \left(\Delta_1^{\mathcal{C}}, \Delta_1^{\mathcal{D}}\right], \\
\mathcal{E}: & m^* = \mathcal{RF}, & l_0^* = l_0^{\mathcal{R}} < l_0^{fb}, & l_{1,b}^* = 0 & \text{if } \Delta_1 > \Delta_1^{\mathcal{D}},
\end{array}$$

with all critical values being defined in the appendix.

Proof. See appendix. □

The proposition states that the banker's optimal strategy over the business cycle depends crucially on the liquidity risks in the economy, i.e. on Δ_1 and $\Delta_{2,b}$. Figure 4.2 illustrates the optimal lending patterns subject to the liquidity risk of first period loans, Δ_1. We will comment on the impact of second period loans' liquidity risk, $\Delta_{2,b}$, only nontechnically as they predominantly affect the size of the thresholds determining a switch from one strategy to another. In the upper quadrant we display first period loans, whereas in the lower quadrant we depict second period loans if the economy is in a downturn at $t = 1$.[12] In both quadrants the thick line highlights the optimal loan volume depending on the liquidity risk of first period loans. Changes in this liquidity risk, Δ_1, do not alter the first best loan volume, l_0^{fb}, due to the mean preserving spread. Likewise, changes in $\Delta_{2,b}$ will not affect the first best loan volume, $l_{1,b}^{\text{fb}}$. A deviation of the thick lines from the first best loan volumes identifies a less efficient bank lending structure, which is prevailing in the green, yellow and red areas. While in the green area, B, the lending structure is only inefficient, both yellow areas, C and D, as well as the red area, E, identify a combination of inefficient bank lending and bank instability.[13] The light yellow area, C, depicts an optimal bank lending behavior in the first period and a less efficient bank lending behavior in the second period, which will lead to bank run at the end of the second period if the economy does not recover. Due to a restriction of first period loans, the dark yellow area, D, identifies a less efficient bank lending compared with the light yellow area, as bank lending is also restricted in the first period. However, the probability of default remains unchanged. The red area, E, identifies an increased risk taking, which results in a bank run during the downturn at $t = 1$.

If the liquidity risks in the economy Δ_1 and $\Delta_{2,b}$ are very low or if l_0^{fb} is large relative to $l_{1,b}^{\text{fb}}$ so that $\Delta_1 \leq \Delta_1^{\mathcal{A}}$, the restriction in the downturn on second period loans when operating in the safe mode is not binding and the banker is able to operate according to strategy $\mathcal{A}$. This is the preferred strategy from a welfare perspective as the bank is not at risk and bank lending is not restricted.

If the liquidity risks increase so that $\Delta_1 \in (\Delta_1^{\mathcal{A}}, \Delta_1^{\mathcal{B}}]$, the restriction in the downturn when operating in the safe mode becomes binding. Although the restriction will impose a deadweight loss, liquidity risks are still rather low, so that operating in the safe mode in both periods is prosperous enough to ensure the stability of the bank. According to strategy $\mathcal{B}$, the banker will overinvest in comparatively good times in the first period to reduce the potential underinvest in the downturn, so that a procyclical lending pattern emerges. Figure 4.2 depicts that the overinvestment in the first period mitigates the financial constraint in the downturn. If the banker grants loans according to the first best in the first period, the restriction in the downturn is given by ψl_0^{fb}. An increase in first period loans above the first

[12]We neglect second period loans in the upswing at $t = 1$, as in this situation the banker always operates in the safe mode and grants loans according to the first best independent of the liquidity risks in the economy.

[13]Stability refers to the absence of any deadweight loss at the dates, which will occur if, due to a bank run, not all loan earnings can be collected.

best loosens the restriction in the downturn to $\psi l_0^{\mathcal{S}}$. The upper quadrant illustrates that an increase in the liquidity risk, Δ_1, does not always amplify first period's overinvestment, $l_0^{\mathcal{S}}$. For smaller liquidity risks the efficiency loss in the first period is easily compensated by efficiency gains in the downturn and the overinvestment in first period loans becomes more pronounced. An increase in liquidity risks, however, tightens the financial constraint in the downturn so that the impact of first period loans on the banker's ability to grant loans decreases. Accordingly, overinvesting in the first period becomes too costly for larger liquidity risks. The overinvestment will be less distinct while the restriction on bank lending in the downturn, and therefore the underinvestment, becomes stronger. Note that the anticipation of a restriction on bank lending by a forward-looking banker is causal for the expansionary bank lending in the first period. This lending behavior could be interpreted as excessive credit supply. However, as we explicitly neglect feedback effects, this pattern cannot be interpreted as a bubble, which later bursts. Whether a downturn materializes depends on exogenous factors and thus not on the banker's investment decision. Moreover, it is important that the procyclicality does not induce any threat to the stability of the bank, as a bank run will never occur when choosing strategy $\mathcal{B}$.

Liquidity risks in the range of $\Delta_1 \in (\Delta_1^{\mathcal{B}}, \Delta_1^{\mathcal{D}}]$ imply rather high losses of deviating from first best loans volumes both in the first period and in the downturn at $t = 1$, when choosing strategy $\mathcal{B}$. In consequence, the banker prefers to operate in the risky mode once the economy is in the downturn at $t = 1$. Pursuing this strategy, $\mathcal{C}$, enables him to increase bank lending in the downturn. Although these values will be destroyed if the economy is in recession at $t = 2$, the expected profit of strategy $\mathcal{C}$ is sufficiently higher than that of strategy $\mathcal{B}$. While the liquidity risk in the first period, Δ_1, has no impact on the optimal loan volume, $l_1^{\mathcal{R}}$, it increases in $\Delta_{2,b}$. This implies larger returns when the economy recovers from the downturn, so that the threshold, $\Delta_1^{\mathcal{B}}$, will be lower, the higher the liquidity risk of second period loans is in the downturn. However, an increase in the liquidity risk of first period loans might impose a restriction on first period loans. If the cash flow in the downturn turns out to be negative, granting loans according to the first best might result in a substantial debt overhang in the downturn. In order to prevent a bank run at $t = 1$, bank lending in the first period is restricted to $l_0^{\max}$. Therefore the banker is able to signal the bank's credibility to repay first period deposits independent of the state of the economy. The restriction on bank lending becomes binding for all $\Delta_1 > \Delta_1^{\mathcal{C}}$ so that the banker will operate according to strategy $\mathcal{D}$ for all $\Delta_1 \in (\Delta_1^{\mathcal{C}}, \Delta_1^{\mathcal{D}}]$. This threshold is again affected by the liquidity risk of second period loans. An increase in $\Delta_{2,b}$ will allow the banker to pledge more against the bank's returns if the economy recovers from the downturn at $t = 1$. Therefore the banker can refinance a higher debt overhang without losing debtholders' confidence in the bank's solvency at $t = 1$, and $l_0^{\max}$ increases. Depending on the relation between first and second period loans, granting loans might follow a positive secular trend. In contrast to strategy $\mathcal{B}$, this pattern cannot be described as excessive lending, as the banker underinvests both in the first period and in the downturn. However, the causality remains unchanged. The anticipation of high liquidity risks in the second period incentivizes a forward-looking banker to underinvest in the first period in order to be able to survive the downturn. If a bank run materializes at the end of the second period it is thus not caused by the bank lending behavior and most interestingly not the result of a bursting bubble.

If the liquidity risks are very high, so that $\Delta_1 > \Delta_1^{\mathcal{D}}$, the banker's optimal strategy is to operate in the risky mode in the first period. In this situation, expected profits of operating in the safe mode and granting loans according to $l_0^{\max}$ are rather low. Operating in the risky mode allows the banker to increase the expected return on first period loans by increasing bank lending to $l_0^{\mathcal{R}}$. This behavior, however, will result in a bank closure if the economic conditions turn out to be bad at $t = 1$. If first period loans' liquidity risk, Δ_1, is sufficiently large, only small values will be destroyed in this bank run, so that it is more beneficial for the banker to increase bank lending in the first period, rather than surviving the second period in the case of an economic downturn.

4.4 Discussion

4.4.1 Robustness

In this section, we will comment on the main differences compared with the model of Hart and Zingales (2011). Besides considering the intertemporal dimension of investment decisions, our model differs with respect to the type of debt and the agent responsible for the bank's investment decisions.

Following the original idea of Diamond and Rajan (2000, 2001b) we leave the investment decision with the banker. Accordingly, the banker ensures that investors' participation constraint is satisfied with equality. He will therefore raise deposits in an amount equal to depositors' expected payoff. In consequence, all profits remain with the banker. However, whether the profits remain with the banker, as in this chapter, or with shareholders, as in Chapter 3, is not the driving factor for the bank's lending decision. This decision is primarily driven by the liquidity risks, which determine the funding liquidity of first and second period loans. If the funding liquidity is too low, the banker might be unable to grant any loans at all. This corresponds to our findings in Proposition 3.3.

Considering systemic or non-systemic debt only has a minor impact on the bank's lending decision. In this chapter we explicitly consider systemic debt in the form of deposits. If the bank operates in the safe mode, depositors will always receive the face value of deposits, independent of the economic conditions. Operating in the risky mode implies a face value that may not be able to be repaid. Accordingly depositors will run on the bank each time economic conditions are too poor to pay off the face value. In consequence, investors will provide less capital than the face value of deposits if the banker operates in the risky mode. In contrast, Chapter 3 considers non-systemic debt. As debtholders are unable to withdraw their capital prematurely, i.e. before the end of the period, a bank run will not occur if investors observe that the bank is unable to repay the full value of debt. If the banker chooses a risky capital structure and the economic conditions turn out to be poor, the materialized lower bank return will therefore be distributed among all debtholders. Nevertheless, the decision to provide capital is comparable for debtholders and depositors. Both groups of investors decide based on the expected profit of their investment, but as debtholders expect a payoff in the case of bankruptcy, they provide more funds. In consequence, a restriction on bank lending when choosing a safe capital structure might occur independent of the type of debt being considered. This restriction will become binding if both external and internal capital are unwilling or unable to provide enough funding, i.e. if the funding liquidity is too low.

Extending the framework of Chapter 3 by considering the investment decision of first period loans does not alter the bank's lending decision significantly. Granting loans in the first period still depends on first period loans' funding liquidity. However, this extension enables us to identify an intertemporal link in bank lending over the business cycle. If second period loans' funding liquidity is too low, the banker will be able to co-finance second period loans when the materialized cash flow of first period loans is sufficiently large.

We reduce complexity of the model by assuming that economic conditions in the upswing dominate those in the downturn. In consequence, both the materialized cash flow of first period's investments and the funding liquidity of second period loans are sufficiently high, so that bank lending is never restricted when operating in the safe mode. If, however, the returns of second period loans are not ranked according to $r_{g,h} > r_{g,l} > r_{b,h} > r_{b,l}$, the argument of our model still remains unchanged. In the first period, the banker aims to maximize his expected overall profit, taking into account potential effects for his ability to grant loans in the second period. Suppose bank lending is restricted in the upswing and in the downturn to the same extent. In this case, the banker will again balance expected losses of an overinvestment in the first period with expected gains from a lower underinvestment in the second period. If an overinvestment in the first period will loosen the restriction on bank lending in both the upswing and the downturn, an overinvestment becomes even more profitable. If the restrictions in the upswing and in the downturn differ, the banker will again consider the impact of first period loans on both restrictions, and weigh them based on the probability for both scenarios. Focusing on the impact of first period lending on granting loans in the downturn is thus not crucial for our results.

4.4.2 Implications for Financial Stability and Bank Regulation

The dynamic interdependencies between current and future lending and the decision to issue deposits have particular implications for financial stability and bank regulation. Considering the bank in this model as representative and the risks as macroeconomic or systemic risks, we analyze the impact of potential common shocks. A bank run in this model is thus understood as a financial crisis that occurs in response to the materialization of a common shock.

Depending on the extent of business cycle fluctuations, we are able to identify varying lending patterns over the business cycle, corresponding to what we observe in different countries. Bank lending becomes procyclical if both types of liquidity risks are neither too small nor too large, i.e. if recessions are relatively weak. Compared to the first best, bank lending is thus excessive in good times, but falls short if economic conditions worsen. However, this excessive credit supply does not cause financial fragility, which may resemble the situation in advanced economies, at least for mild recessions. The procyclical lending pattern we identify here differs from other explanations in the literature, such as Kiyotaki and Moore (1997), for two reasons. First, procyclical lending occurs as the forward-looking banker seeks to loosen potential restrictions in the future when anticipating an economic downturn. Second, and most importantly, procyclicality in our model does not refer to varying degrees of lending restrictions being less severe in prosperous times as financial constraints are less tight. Instead, if the banker chooses a procyclical lending pattern, he will overinvest by granting loans above the first best.

If liquidity risks are more pronounced, bank lending follows a different pattern. Once the economy slows down, the banker will gamble for resurrection by choosing a fragile capital structure in order to increase bank lending. However, putting the bank's stability at risk implies a financial crisis if the economic recovery is delayed. This implies that the banker will still underinvest in a recession, but to a lower extent compared with a safe capital structure. First period loans will only have an impact on the banker's ability to grant second period loans, as these loans can be solely financed by external capital. However, bank lending may be restricted in the first period in order to prevent a financial crisis in an economic downturn. Although bank lending is never excessive, the risky capital structure will result in a financial crisis if the recession's recovery holds off. In contrast to other explanations, this result is driven by a reversed direction of causality. The financial crisis in our model is not caused by an excessive credit expansion in the run up to the crisis. Instead, anticipating a potential crisis in the future induces more cautious behavior from the banker with respect to bank lending and increases risk taking in the run up to a recession. If the crisis becomes more likely, banks start to gamble for resurrection and put their stability at risk. This pattern might explain some aspects of financial crises in emerging countries as, on average, they face stronger recessions than advanced economies.

Very strong recessions are rather likely for less developed countries. For these larger liquidity risks, our model predicts an even more fragile banking system as banks will fail even in a temporary economic downturn. They will underinvest in the first period in order to benefit if the economic conditions are benign. Again the direction of causality is reversed to what is mostly argued, as anticipating a strongly volatile real economy causes this lending and risk taking pattern.

The conflict of interest between investors and the banker results in a trade-off between financial stability and efficient bank lending. This raises the question of whether and how a regulator should act. As our results are constraint efficient, imposing a regulation will not lead to a Pareto improvement. This may only be achieved by stabilizing the real economy, i.e. with the help of a credible macroeconomic policy. In the following chapters we will, however, argue that the regulator has a strong preference for maintaining financial stability. Considering that financial crises are associated with large welfare costs, the regulator seeks to prevent excessive risk taking. In order to verify that the trade-off is also prevailing for the margin call, and to compare its impact on financial stability and bank lending with other regulatory measures, we will first have to extend this framework by allowing for equity financing as well.

4.5 Conclusion

In this chapter, we have evaluated the impact of real economic volatility on bank lending and financial stability. It is quite likely that feedback effects from the banking sector to the business cycle will emerge. By abstracting from these effects we, however, put forward a reversed causality between bank lending and liquidity risks, which has not received much attention until now.

Analyzing the lending behavior of a forward-looking banker, we are able to identify different lending patterns over the business cycle, which depend on the magnitude of liquidity risks in the economy. Opposed to much of the current literature, these credit cycles are neither necessarily causal for real economic fluctuations, nor the result of any irrational or reckless behavior. Anticipating an economic downturn, forward-looking banks may instead seek to smooth potential losses arising from liquidity shortages over the business cycle. Hence procyclical lending will occur if the benefits of loosening liquidity constraints in the future outweigh the costs of deviating from the first best investment decision today. If the overall costs associated with this lending pattern become too large, banks will prefer different patterns, which impose a threat to financial stability. Depending on the magnitude of liquidity risks, a bank run might occur either early or late. Again, anticipating a deep recession, and therefore a bank run, might induce either a secular trend in bank lending or, if risks are more pronounced, a pure curtailing of credits.

From a policy perspective, the possibility of such a reversed causality may have major implications. Considering the bank in this model as a representative bank, a bank run can be understood as a financial crisis that occurs in response to a common shock.

The results in this chapter reinforce the argument of the previous chapter. Banks do not base their lending decisions on the net present value, but on the funding liquidity, which depends on the liquidity risks in the economy. Accordingly, the impact of the margin call may be more complex than suggested by Hart and Zingales (2011). In order to compare the impact of their proposal with some measures of the Basel III Accord, we will first modify this model in the next chapter by considering the possibility of external equity financing in both periods.

Chapter 5

Bank Lending and Financial Stability with External Equity

This chapter provides the benchmark model for the comparison of the margin call with the main measures of the Basel III Accord, which we will undertake in Chapter 6. In order to identify the extent of the trade-off between financial stability and bank lending for each regulatory measure, we modify the framework of Chapter 4 by explicitly considering the possibility of raising external equity. We adjust the business cycle scenario in order to focus on the downturn, in which the effectiveness of regulatory measures is especially important. Moreover, we add an interesting twist to the business cycle by analyzing the impact of nonperforming loans in an economic downturn. As in the previous chapter, we determine similar lending patterns depending on the funding liquidity of first and second period loans.

5.1 Introduction

Hart and Zingales (2011) conclude that their proposal will never affect banks' lending decisions. Identifying that this result holds only for a positive funding liquidity, we aim to analyze the impact of the margin call on financial stability and bank lending in more detail by explicitly allowing for a negative funding liquidity. Therefore we are able to specify the result of Proposition 3.3.

The margin call and the regulatory measures of the Basel III Accord call for the possibility to raise external equity. In a first step, we hence extend the model of Chapter 4 by introducing equity as a second source of funding. Moreover, we modify the business cycle to concentrate on the effectiveness of regulatory measures in an economic downturn in which financial stability might be at risk. This model thus serves as the benchmark for the analysis of the margin call and its comparison with the regulatory measures of the Basel III Accord of Chapter 6.

Including two types of external capital, deposits and equity, leaves the driving factor of bank lending unchanged. Bank lending will still be restricted if the funding liquidity of loans becomes too low. This will be the case if the banker has to raise equity to ensure a safe capital structure. In contrast to issuing deposits, external equity enables the banker to renegotiate compensation for applying his skills when granting loans (Hart and Moore, 1994). Therefore the banker cannot pledge against the full value of these loans, so that the funding liquidity of equity is lower than the funding liquidity of deposits. Nevertheless, we will see that the general mechanism works analogously to the one presented in the previous chapter.

In detail, we adjust the business cycle of Chapter 4 as follows. First, we assume that if the economy is in benign conditions, granting loans is risk-free and sufficiently prosperous. In consequence, shareholders are always willing to provide a sufficient amount of funds so that bank lending is never restricted when choosing a safe capital structure. Second, we add an interesting twist to the downturn, which might be more in line with what we observe in reality. In an economic downturn some loans are typically nonperforming. Banks decide to roll over these loans, as writing them off will materialize a factual loss while the rollover might allow for at least some returns in the future. This modification will lead to slightly different lending patterns over the business cycle. If the banker chooses to put the stability of the bank at risk once an economic downturn emerges, we find a strong secular trend in bank lending, which might result in a bank run. Analogously to the previous chapter, this bank run is not caused by an excessive credit boom going bust, but rather by market participants' expectations regarding the evolution of the business cycle. Therefore the empirical observation of credit booms going bust does not have to imply that the latter is caused by the former.

The chapter is organized as follows. Section 5.2 presents the setup of the model. We solve this model by backward induction in section 5.3, i.e. we first identify the banker's optimal behavior in the second period, and take this result as given to determine his optimal strategy over the business cycle. Section 5.4 discusses the robustness of the modifications and identifies implications for bank regulation. Section 5.5 concludes this chapter.

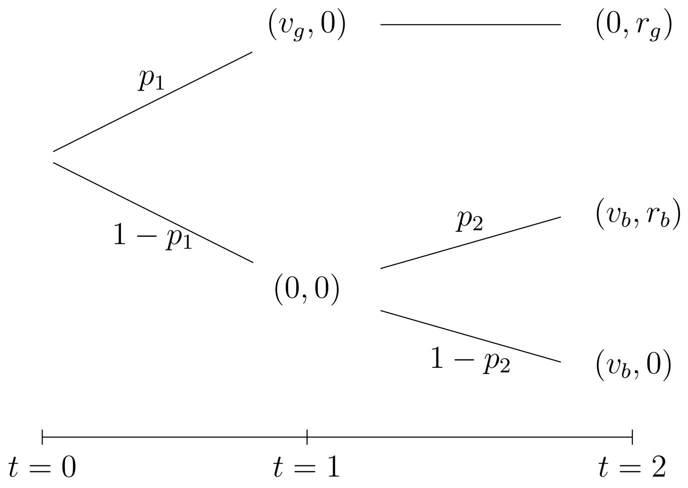

Figure 5.1: Loan earnings of first and second period loans (per unit).
Note: At each node, the first entry refers to loans granted at $t = 0$ and the second entry to loans granted at $t = 1$.

5.2 Setup

5.2.1 Agents and Technologies

As in Chapter 4, we analyze bank lending over the business cycle by considering a representative banker who manages a bank that exists for two periods and three dates, $t = 0, 1, 2$. At the beginning of each period, at date $t = 0$ and $t = 1$, the banker decides on the bank's capital structure and its portfolio. After raising funds from investors, the banker invests the amount a_t in a short-term, risk-free asset that generates a zero net return and grants loans, l_t, which are, again, risky.

Figure 5.1 depicts that loan earnings depend crucially on the state of the economy. As in Chapter 4, at date $t = 1$ the economy is either in an upswing with probability $p_1 \in [0.6, 1)$ or in a downturn. In order to reduce the complexity of the regulatory analysis, we assume that in the upswing, a boom will occur with certainty at the end of the second period. If a downturn occurs at $t = 1$, the economy will either recover from this downturn until $t = 2$, which occurs with probability $p_2 \in [0.6, 1)$, or will run into a recession.[1]

If the economy is in an upswing at $t = 1$, i.e. in the "good" situation, $s = g$, first period loans again materialize a high return, v_g, whereas second period loans are risk-free and will yield a high return, $r_g > 1$, at $t = 2$ with certainty.[2] Moreover, we modify the situation in the downturn as follows. In this bad situation, $s = b$, some

[1]Restricting attention to $p_1, p_2 \geq 0.6$ reduces complexity without changing our results qualitatively.

[2]Unless otherwise stated, all returns are again per unit.

first period investment projects fail while the remaining projects are delayed so that first period loans are nonperforming at that time. As expectations about the future are less bright, first period loans will earn a low return, $v_b \in (0, v_g)$, at the end of the second period, if they are rolled over by the banker. We neglect a further impact of the business cycle on the return on nonperforming loans in order to separate the effects resulting from a delay in those of risky returns. This latter effect is again captured by the loans granted in the second period. If the economy recovers from the downturn, these loans will yield $r_b \in (0, r_g)$ at the end of the second period while they will default entirely in the case of a recession. Again, all investment projects have a positive net return ex ante due to $p_1 v_g > 1$ and $p_2 r_b > 1$.

In this chapter we will focus on the liquidity risk of first period loans only, as the impact of the liquidity risk of second period loans is identical to the one discussed in Chapter 4. Considering a mean preserving spread, the mean, μ_1, and the corresponding liquidity risk, Δ_1, of first period loans are given by

$$\mu_1 := p_1 v_g + (1 - p_1)\, v_b, \qquad \Delta_1 := v_g - v_b, \tag{5.1}$$

while the mean, $\mu_{2,s}$, of second period loans read

$$\mu_{2,g} := r_g, \qquad \mu_{2,b} := p_2 r_b. \tag{5.2}$$

Changes in the liquidity risk, Δ_1, again allow us to analyze varying magnitudes of the business cycle. If the liquidity risk, Δ_1, increases, the return on delayed loans declines. Accordingly, business cycle fluctuations at $t = 1$ increase. Making use of the definition of Δ_1, we can again rewrite first period loans' returns as follows:

$$v_g = \mu_1 + (1 - p_1)\, \Delta_1, \tag{5.3}$$

$$v_b = \mu_1 - p_1 \Delta_1. \tag{5.4}$$

As both the mean, μ_1, and the liquidity risk, Δ_1, of first period loans are identical to Chapter 4, changes in the bank's lending patterns are therefore caused by the delay of first period loans in the downturn.

Similar to Chapter 4, we assume that the banker is needed to collect the full value of loans, as neither debtholders nor shareholders possess the necessary skills. However, applying these skills generates non-pecuniary costs of granting loans for the banker. These costs follow an increasing and convex function, c, of the loan volume, l_t, with $c(0) = c'(0) = 0$. We again normalize the costs of investing in the risk-free asset to zero.

At $t = 0$ the banker possesses no funds of his own, so that granting loans will again only be feasible if he raises sufficient capital from investors who are unrestricted in funds. All agents are risk neutral and have a discount rate of zero. As investors are patient, they will always wait for their repayment if this is at least as beneficial as an early withdrawal. There is perfect competition among these investors. As they have access to a risk-free storage technology, they only provide funding if their expected net return is positive. Also the banker's behavior remains unchanged as he seeks to maximize his expected profit.

5.2.2 Contracting Friction and Capital Structure

At the beginning of each period, the banker raises fresh funds from investors, who can decide to place their funds either in the form of deposits, d_t, with a face value, δ_t, or in the form of equity, e_t. Assuming that the banker's skills are required to collect the full value of loans, leads to the hold-up problem described in Chapter 4. While issuing demandable deposits mitigates renegotiations regarding the promised repayment, it bears the risk of a bank run even if the banker applies his skills on behalf of investors.

The banker might protect himself against fluctuations in bank earnings by issuing equity. As the value of equity correlates with the value of the bank, shareholders will receive lower payments if the bank is less profitable. Equity thus serve as a buffer in bad times. However, shareholders cannot discipline the banker like depositors. By threatening to withhold his skills, the banker renegotiates and demands a share of the bank's profits (after satisfying depositors' claims) as compensation for his commitment. As a consequence, shareholders only receive a share $1 - \lambda \leq 0.5$ of the bank's current profits, net of its liabilities vis-à-vis depositors (Diamond and Rajan, 2000). Therefore the banker might face a financial constraint when issuing equity. As the banker possesses the bargaining power, both shareholders' and depositors' participation constraint is fulfilled with equality. Hence they both expect to receive a payoff equal to their investment. Accordingly, investors are indifferent between becoming depositors or shareholders.

In the following analysis, we will focus on the interesting cases in which the resulting conflict of interest between investors and the banker at least potentially imposes a restriction on bank lending. We thus restrict attention to a negative funding liquidity of first and second period loans in the downturn at $t = 1$ if they are solely financed by equity, i.e. $(1-\lambda)p_1 v_g < 1$ and $(1-\lambda)p_2 r_b < 1$.[3] This implies that for each loan granted in these states, the banker cannot raise enough equity to refinance this loan. Hence the banker has to co-finance the bank's investments, at least to some extent, by issuing deposits.

The banker is free to choose the bank's capital structure. In contrast to Chapter 4, we will distinguish between four modes of operation, m_t, which might occur given that certain regulatory measures are in place. Again, the banker operates in the "safe" mode, $\mathcal{S}$, if the face value of deposits, δ_t, is relatively small so that each materialized return is sufficiently large to pay off depositors. Accordingly, a bank run will never occur in the safe mode and the expected profits of loans are given by

$$\phi_0^{\mathcal{S}}(l_0) = (\mu_1 - 1)\, l_0 - c(l_0), \qquad \phi_{1,s}^{\mathcal{S}}(l_{1,s}) = (\mu_{2,s} - 1)\, l_{1,s} - c(l_{1,s}). \tag{5.5}$$

Operating in the "risky" mode, $\mathcal{R}$, implies that depositors will only receive the face value if loans materialize a high return. Otherwise, the returns are too low, so that depositors will run on the bank. Therefore the expected return on bank loans declines. As second period loans are risk-free in the upswing, this mode is only feasible at $t = 0$ and in the downturn at $t = 1$. The respective profits of loans in the risky mode are given by[4]

$$\phi_0^{\mathcal{R}}(l_0) = (p_1 v_g - 1)\, l_0 - c(l_0), \qquad \phi_{1,b}^{\mathcal{R}}(l_{1,b}) = (p_2 r_b - 1)\, l_{1,s} - c(l_{1,b}). \tag{5.6}$$

With regulatory measures in place, bank lending might be restricted in both the safe and the risky mode up to the point that the banker might be unable to grant any loans at all. In both cases, the bank is technically safe and is able to satisfy existing claims of depositors. However, in order to distinguish this behavior from the other two modes, we refer to this behavior as the "non-lending" mode, $\mathcal{N}$. As in the previous chapter, the banker will close the bank and thus operate in the "failure" mode, $\mathcal{F}$, if he is unable to satisfy existing claims.

The first best loan volume of first period loans, l_0^{fb}, is again given by $\phi_0^{\mathcal{S}\,\prime}\left(l_0^{\text{fb}}\right) = 0$, while the first best loan volume of second period loans, $l_{1,s}^{\text{fb}}$, is determined by $\phi_{1,s}^{\mathcal{S}\,\prime}\left(l_{1,s}^{\text{fb}}\right) = 0$. As the banker's private costs are non-verifiable, a third party cannot determine whether the bank's loan volume is actually efficient.

[3] This might impose an additional restriction on the liquidity risk of first period loans in the form of $\Delta_1 < \frac{1-(1-\lambda)p_1\mu_1}{(1-\lambda)p_1(1-p_1)}$. Considering that returns in the downturn will never be negative, we thus restrict our attention to liquidity risks lower than $\overline{\Delta}_1 := \min\{\frac{\mu_1}{p_1}, \frac{1-(1-\lambda)p_1\mu_1}{(1-\lambda)p_1(1-p_1)}\}$.

[4] As second period loans yield no return if the economic recovery holds off, it follows that $\phi_{1,b}^{\mathcal{R}}(l_{1,b}) = \phi_{1,b}^{\mathcal{S}}(l_{1,b})$.

5.3 Bank Behavior

As in Chapter 4, this section presents the subgame-perfect equilibrium of the model. By choosing the bank's portfolio and capital structure, the banker again aims to maximize his expected profit. Applying backward induction, we first investigate the banker's optimal behavior in the second period, and then we turn to the first period.

5.3.1 Second Period

At the beginning of the second period, the economy is either in benign conditions or experiencing a downturn. We first determine the banker's behavior at $t = 1$ in the upswing, i.e. in the good state, $s = g$. In this state, first period loans materialize a high return, $v_g > 1$, and the risk-free assets yield a_0. Both returns will be used to pay off the face value, δ_0, to depositors. First period's cash flow per unit of loans granted at $t = 0$ is therefore given by $\omega_{1,g} = \frac{v_g l_0 + a_0 - \delta_0}{l_0} > 0$.

As second period loans are risk-free in the upswing, the banker will operate either in the safe mode or in the failure mode at $t = 1$. In the former case, $m_{1,g} = \mathcal{S}$, his optimization problem reads

$$\max_{l_{1,g}, a_{1,g}, \delta_{1,g} \in \mathbb{R}^+} \pi_{1,g} = \lambda \left[r_g l_{1,g} + a_{1,g} - \delta_{1,g} \right] - c\left(l_{1,g}\right) \tag{5.7}$$

$$\text{s.t.} \quad l_{1,g} + a_{1,g} = \omega_{1,g} l_0 + d_{1,g} + e_{1,g}, \tag{5.8}$$

$$d_{1,g} = \delta_{1,g} \quad \text{with} \quad \delta_{1,g} \leq r_g l_{1,g} + a_{1,g}, \tag{5.9}$$

$$e_{1,g} = (1 - \lambda) \left[r_g l_{1,g} + a_{1,g} - \delta_{1,g} \right] - (1 - \lambda)\omega_{1,g} l_0. \tag{5.10}$$

Equation (5.8) reflects the bank's budget constraint in the good state at $t = 1$. The banker grants second period loans, $l_{1,g}$, and invests $a_{1,g}$ in the risk-free asset. For this purpose, he takes the current cash flow, $\omega_{1,g} l_0$, issues new deposits, $d_{1,g}$, and raises the amount $e_{1,g}$ from shareholders. Operating in the safe mode restricts the face value of deposits to $r_g l_{1,g} + a_{1,g}$. (See equation (5.9).) If the banker increases the face value above this threshold, depositors would run on the bank immediately, so that a bank closure occurs at $t = 1$. According to equation (5.10), shareholders will provide equity in the amount of their expected payoff at $t = 2$ subtracted by the amount they could already extract at $t = 1$. At the end of the second period, they will receive the share $1 - \lambda$ of the bank's profits, i.e. the materialized earnings of the bank's portfolio after depositors are paid off. However, shareholders could force the banker to pay them a share $1 - \lambda$ of the bank's positive cash flow, $\omega_{1,g} l_0$, early, at $t = 1$. In principle, $e_{1,g}$ can therefore become negative. In this case, shareholders will extract the amount $|e_{1,g}|$ from the bank at $t = 1$ by selling their shares to the banker. Buying additional shares will thus only be beneficial for shareholders if expected profits at $t = 2$ are sufficiently large. Finally, equation (5.7) reflects the banker's expected profit, $\pi_{1,g}$, at the beginning of the second period. He will obtain the share λ of the bank's profits at the end of the second period, net of depositors' claims. Moreover, he bears the costs of managing second period loans.

As in Chapter 4, the cash flow that materializes in the upswing is positive due to $v_g > 1$. Moreover, the return on second period loans is certain with $r_g > 1$ so that the funding liquidity of second period loans when operating in the safe mode is also positive. We can thus directly conclude that bank lending will never be restricted in the upswing at $t = 1$.[5] Suppose the banker possesses more funds than needed to invest in second period loans. Then all remaining funds will be invested in the risk-free asset $a_{1,g}$, which yields a zero net return in the safe mode. As the safe mode is always profitable for the banker, we obtain analogously to Lemma 4.1:

Lemma 5.1. *If the economy is in an upswing at date $t = 1$, the banker's optimal decision on the mode of operation, $m_{1,g}$, and bank lending, $l_{1,g}$, will have the following properties:*

$$m^*_{1,g} = \mathcal{S}, \quad l^*_{1,g} = l^{fb}_{1,b} \quad \forall\ l_0. \tag{5.11}$$

Proof. Omitted. □

The downturn differs from the upswing in two respects. First, loans granted in the first period are nonperforming and are rolled over. Therefore the bank's cash flow per unit of loans granted at $t = 0$ in the downturn is negative and given by $\omega_{1,b} = \frac{a_0 - \delta_0}{l_0}$. Second, the future value of the bank is risky, so that the banker will choose between three modes of operation.

Unless the banker operates in the failure mode, $m_{1,b} = \mathcal{F}$, which results in an immediate bank closure, his optimization problem in the bad state at $t = 1$ reads

$$\max_{l_{1,b}, a_{1,b}, \delta_{1,b} \in \mathbb{R}^+} \pi_{1,b} = \lambda E\left[\max\left\{v_b l_0 + r_{b,j} l_{1,b} + a_{1,b} - \delta_{1,b}, 0\right\}\right] - c\left(l_{1,b}\right) \tag{5.12}$$

$$\text{s.t.} \quad l_{1,b} + a_{1,b} = \omega_{1,b} l_0 + d_{1,b} + e_{1,b}, \tag{5.13}$$

$$d_{1,b} = \begin{cases} \delta_{1,b} & \text{if} \quad m_{1,b} = \mathcal{S}: \ \delta_{1,b} \leq v_b l_0 + a_{1,b}, \\ p_2 \delta_{1,b} & \text{if} \quad m_{1,b} = \mathcal{R}: \ \delta_{1,b} \in \left(v_b l_0 + a_{1,b}, v_b l_0 + r_b l_{1,b} + a_{1,b}\right], \end{cases} \tag{5.14}$$

$$e_{1,b} = (1 - \lambda) E\left[\max\left\{v_b l_0 + r_{b,j} l_{1,b} + a_{1,b} - \delta_{1,b}, 0\right\}\right], \tag{5.15}$$

[5]Therefore the non-lending mode will be irrelevant for the benchmark scenario. It may only be optimal for certain regulatory measures in place, as we will show in Chapter 6.

with $j = \{h, l\}$, $r_{b,h} = r_b$ and $r_{b,l} = 0$. Analogously to the upswing, equation (5.13) reflects the bank's budget constraint in the downturn. As the cash flow, $\omega_{1,g} l_0$, is negative, capital in the form of debt, $d_{1,b}$, and equity, $e_{1,b}$, not only has to finance both second period loans, $l_{1,b}$, and the investment in the risk-free asset, $a_{1,b}$, but also has to cover the existing debt overhang. According to (5.14), depositors provide funds depending on the face value, $\delta_{1,b}$. If the banker operates in the safe mode, they will receive this face value with certainty and will not demand a premium. Therefore, they provide funds equal to the face value of deposits. An increase in the face value above $v_b l_0 + a_{1,b}$ implies that the banker operates in the risky mode. Depositors thus expect to receive a payment only if the economy recovers from the downturn. If a recession occurs at $t = 2$, depositors will run on the bank and all values will be destroyed. In consequence, depositors provide funds up to $p_2 \delta_{1,b}$, which implies a premium to compensate their risk taking. Due to the debt overhang, shareholders are unable to extract a rent in the downturn. However, because of limited liability they cannot be forced to place additional capital to cover the debt overhang either. Shareholders are thus willing to provide equity in the amount of their expected payoff. (See equation (5.15).) Finally, the banker's expected profit in the downturn is given by equation (5.12). He receives the share λ of all returns subtracted by the pecuniary and non-pecuniary costs of lending. As limited liability applies to the banker as well, his expected pecuniary profit is nonnegative.

Suppose the banker operates in the safe mode in the downturn. In this case, the expected return on the risk-free asset equals its investment cost so that the banker is again indifferent with respect to this investment. However, the safe mode will only be feasible if the face value of deposits is sufficiently low. see (5.14). Therefore bank lending is restricted to

$$[1 - (1 - \lambda) p_2 r_b] l_{1,b} \leq (v_b + \omega_{1,b}) l_0. \tag{5.16}$$

As we assume that second period loans will default entirely if the economic recovery holds off, operating in the safe mode will only be feasible if the banker finances second period loans entirely by equity. Due to the banker's rent extraction, this results in a negative funding liquidity of second period loans, $(1 - \lambda) p_2 r_b - 1$. The banker has to close the funding gap in the amount of $1 - (1 - \lambda) p_2 r_b$ per unit of second period loans by pledging against delayed first period loans. As the return on these loans is independent of the business cycle, depositors are willing to provide funds up to $v_b l_0$. As first period loans have been financed already in the first period, the funding liquidity of first period loans is $v_b l_0$ and therefore positive. The banker will use this funding to co-finance second period loans and to cover the existing debt overhang, $\omega_{1,b}l_0$. The restriction on bank lending in the downturn thus again depends on the loan volume granted in the first period, as in Chapter 4. However, if the debt overhang is too high or the return on first period loans, v_b, too low, so that the funding liquidity of first period loans is not sufficient to cover the debt overhang, the safe mode will be unavailable.

The banker will operate in the risky mode, $\mathcal{R}$, if he issues deposits with a face value larger than $v_b l_0 + a_{1,b}$. This allows the banker to receive more funds from depositors. However, depositors will only receive this face value if the economy recovers from the downturn. If a recession occurs at $t = 2$, the bank run will destroy all values. According to (5.14), they provide funds up to $p_2\delta_{1,b}$. In consequence, bank lending is restricted to

$$[p_2 r_b - 1]l_{1,b} \geq -p_2 v_b l_0 - \omega_{1,b}l_0 + (1 - p_2)a_{1,b}. \tag{5.17}$$

Independent of the mode of operation, the expected return on second period loans is not affected by the bank run. Therefore issuing more deposits in the risky mode increases the funding liquidity of second period loans again to $p_2 r_b - 1 > 0$. However, it likewise decreases the funding liquidity of delayed first period loans to $p_2 v_b$. The banker has to use both the funding liquidity of first period loans and the excess liquidity of second period loans to cover the existing debt overhang in the downturn. As in Chapter 4, the banker will never invest in the risk-free asset if he operates in the risky mode. As the bank run destroys the value of all bank assets, the expected profit of these assets turns out to be negative. Bank lending might thus again be restricted by a lower bound. If the banker's liquidity is, however, too low to cover the debt overhang, operating in the risky mode will result in a negative expected profit for the banker, so that he will choose a different mode of operation.

Operating in the failure mode, $\mathcal{F}$, implies an early bank closure at $t = 1$. Due to the debt overhang, neither depositors nor shareholders will receive any payment. Similar to Chapter 4, we compare the resulting expected profits of all modes available to obtain:

Lemma 5.2. *If the economy is in a downturn at date $t = 1$, the banker's decision on the mode of operation, $m_{1,b}$, and bank lending, $l_{1,b}$, will have the following properties:*

- *Given $v_b + \omega_{1,b} \geq 0$, then*

$$\begin{aligned} m^*_{1,b} &= \mathcal{S}, \quad l^*_{1,b} = l^{fb}_{1,b} \quad && \text{if } l_0 \geq \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} &= \mathcal{S}, \quad l^*_{1,b} = l^{max}_1 \quad && \text{if } l_0 \in [l^{min}_0, \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} &= \mathcal{R}, \quad l^*_{1,b} = l^{fb}_{1,b} \quad && \text{if } l_0 < l^{min}_0, \end{aligned} \tag{5.18}$$

- *Given* $v_b + \omega_{1,b} < 0$, *then*

$$\begin{aligned} m^*_{1,b} &= \mathcal{R}, \quad l^*_{1,b} = l^{fb}_{1,b} \quad \text{if} \;\; l_0 \leq l^{max}_0, \\ m^*_{1,b} &= \mathcal{F}, \quad l^*_{1,b} = 0 \qquad \text{if} \;\; l_0 > l^{max}_0, \end{aligned} \tag{5.19}$$

with $l^{max}_0 := -\frac{\phi^{\mathcal{R}}_{1,b}\left(l^{fb}_{1,b}\right)}{p_2 v_b + \omega_{1,b}}$ *and* $l^{max}_1 := \frac{v_b + \omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0$ *while* l^{min}_0 *is implicitly defined by*

$$(1 - p_2)v_b l_0 + \phi^{\mathcal{S}}_{1,b}\left(l^{max}_1(l_0)\right) = \phi^{\mathcal{R}}_{1,b}(l^{fb}_1). \tag{5.20}$$

Proof. See appendix. □

As long as the return on delayed loans is sufficient to refinance the debt overhang in the downturn, the banker can choose between all three modes of operation. Operating in the safe mode, $\mathcal{S}$, leads to a financial constraint, as second period loans have a negative funding liquidity. Since the banker has to pledge against the first period's nonperforming loans to co-finance second period loans, this constraint is less tight as the first period loan volume, l_0, increases. Accordingly, operating in the safe mode generates an intertemporal link between bank lending in the first and second periods. If first period loans are sufficiently large, the banker will therefore prefer the unrestricted safe mode over both the risky mode, $\mathcal{R}$, and the failure mode, $\mathcal{F}$. If first period loans are rather low, the banker again compares expected losses resulting from a restriction of granting loans in the safe mode with expected losses resulting from a bank run in the risky mode. As long as first period loans are larger than $l^{\min}_0$, the restriction in the safe mode is comparatively low and the banker prefers the safe mode, $\mathcal{S}$, over the risky mode, $\mathcal{R}$. A loan volume below $l^{\min}_0$ will both tighten the restriction in the safe mode and lower the value that is destroyed in a bank run. Accordingly, the banker prefers the risky mode over the safe mode for smaller amounts of first period loans.

If too many loans default in the downturn, so that the remaining return, v_b, becomes too small, the banker can only choose between the risky mode and the failure mode. As long as both second period loans and the funding liquidity of delayed first period loans are sufficiently large to offset the debt overhang, the banker will always prefer the risky mode, $\mathcal{R}$, over the failure mode, $\mathcal{F}$. However, if first period loans are larger than $l^{\max}_0$, the banker will be unable to satisfy the claims of first period's depositors. In this case, operating in the risky mode would result in a negative expected profit so that the banker prefers to close the bank.

5.3.2 First Period

After deriving the banker's optimal behavior at the beginning of the second period, we are now in a position to determine the banker's optimal decision with respect to the bank's capital structure and portfolio at $t = 0$ and therefore the optimal strategy over the business cycle. We start again by clarifying the banker's optimization problem at the beginning of the first period, before we discuss these optimal strategies.

Unless the banker operates in the failure mode, $\mathcal{F}$, which results in an immediate bank closure at the beginning of the first period, his optimization problem at $t = 0$ reads:

$$\max_{l_0, a_0, \delta_0 \in \mathbb{R}^+} \pi_0 = p_1 \pi_{1,g}(l_{1,g}^*) + (1 - p_1)\, \pi_{1,b}(l_{1,b}^*) - c(l_0) \tag{5.21}$$

$$\text{s.t.} \quad l_0 + a_0 = d_0 + e_0, \tag{5.22}$$

$$d_0 = \begin{cases} \delta_0 & \text{if} \quad m_0 = \mathcal{S}: \; m_{1,b}^* \neq \mathcal{F} \\ p_1 \delta_0 & \text{if} \quad m_0 = \mathcal{R}: \; m_{1,b}^* = \mathcal{F} \end{cases}, \tag{5.23}$$

$$e_0 = (1 - \lambda) \left[p_1 \omega_{1,g} + (1 - p_1) \max\{\omega_{1,b}, 0\} \right] l_0. \tag{5.24}$$

As in Chapter 4, the banker anticipates his optimal behavior in the future when maximizing his expected profit, π_0, at the beginning of the first period. He considers the budget constraint (5.22), which states that the total amount invested in loans, l_0, and in the risk-free asset, a_0, must coincide with the amount obtained from depositors, d_0, and shareholders, e_0, at $t = 0$. Depositors' willingness to provide funds, d_0, crucially depends on the banker's mode of operation in the downturn. If they anticipate receiving the face value of deposits, δ_0, with certainty, which implies that the banker operates in the safe mode, $m_0 = \mathcal{S}$, they will provide deposits in the amount of this face value, i.e. $d_0 = \delta_0$. However, if depositors anticipate that the banker operates in the risky mode, $m_0 = \mathcal{R}$, a bank run will occur in the downturn at $t = 1$. Accordingly, they will demand a premium to compensate their risk taking and will provide funds up to the expected repayment at the end of the first period, i.e. up to $p_1 \delta_0$. Equation (5.24) reflects that shareholders provide equity in the amount of their expected share of the bank's profits. Due to limited liability, they do not face any losses in the downturn in which the first period's portfolio yields a negative cash flow, $\omega_{1,b}$. It follows from the analysis of the second period that shareholders will not participate in the returns of delayed first period loans either, as the banker will raise additional equity in the downturn so that first period stocks are fully wiped out. However, if economic conditions are benign at $t = 1$, shareholders will receive the share $1-\lambda$ of the cash flow $\omega_{1,g}l_0 > 0$. The banker's expected profit, π_0, is given by equation (5.21). With probability p_1, the economy will be in an upswing at $t=1$ and the banker's expected profit is $\pi_{1,g}(l^*_{1,g})$, which is implicitly defined by Lemma 5.1. Otherwise the economy experiences a downturn and the banker's expected profit equals $\pi_{1,b}(l^*_{1,b})$, which is specified based on the findings of Lemma 5.2. Granting loans again imposes private costs, $c(l_0)$, on the banker depending on the volume of first period loans, l_0.

In a first step, we identify the banker's behavior given the subgame-perfect modes at $t=1$. Analogously to Chapter 4, we have to distinguish between three combinations of modes over the business cycle. These modes will only depend on the chosen mode of operation in the downturn, as the banker will always operate in the safe mode once the economic conditions turn out to be good at $t=1$, i.e. $m_{1,g}=\mathcal{S}$.

Suppose the banker always operates in the safe mode independent of the date or state of the economy, so that $m_0=\mathcal{S}$ and $m_{1,b}=\mathcal{S}$, or in short $m=\mathcal{SS}$. As the bank will never default, either after the first or the second period, investing in the risk-free asset does not affect the bank's profit at any date. Accordingly, the banker will only invest in the risk-free asset if he collects too many funds or if the bank's internal capital is too large. Recall that the safe mode will only be feasible in the downturn at $t=1$ if the sum of the bank's cash flow, $\omega_{1,b}l_0$, and the funding liquidity of delayed loans, $v_b l_0$, is positive. This sum is equivalent to the cash flow that materializes in the downturn in Chapter 4, in which the first period loans' earnings can be collected at the end of the first period, see (4.19). We can thus directly conclude that bank lending will again not be restricted in the first period. The banker's investment decision will only have an impact on his ability to grant loans in the downturn. Considering the overall funds available from first period investments, $\omega_{1,b}l_0 + v_b l_0$, bank lending in the downturn will be restricted to

$$l_1^{\max} = \frac{\mu_1 - \lambda p_1 \Delta_1 - 1}{[1-(1-\lambda)p_1][1-(1-\lambda)p_2 r_b]} l_0 =: \psi l_0. \tag{5.25}$$

Operating in the safe mode is feasible as long as the cash flow and the funding liquidity of first period loans is positive, i.e. $\mu_1 - \lambda p_1 \Delta_1 - 1 > 0$. This implies that nonperforming loans are still sufficiently profitable at the end of the second period, after being rolled over, to cover the negative cash flow and the funding gap of second period loans. Again, equation (5.25) reflects the intertemporal link between granting loans in the first period and in the downturn. The banker may loosen the restriction by increasing bank lending in the first period. The more loans are granted in the first period, the larger will be the value of bank assets in the downturn. Accordingly, the banker can pledge more against delayed loans to close the funding gap of second period loans. The factor ψ again shows the overall relative contribution of first period loans' funding liquidity to fill the funding gap of second period loans in the downturn. As long as the liquidity risk is small, an overinvestment is beneficial for the banker. However, the impact of an overinvestment in the first period on the banker's ability to grant loans in the downturn becomes weaker the higher the liquidity risk, Δ_1. In consequence, overinvesting is less beneficial if ψ becomes small. We denote the threshold of first period loans' liquidity risk for which ψ declines to zero by

$$\Delta_1^{\psi} := \frac{\mu_1 - 1}{\lambda p_1}. \tag{5.26}$$

For all liquidity risks above Δ_1^{ψ} operating according to $\mathcal{SS}$ is not feasible.

Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if the economy is in a downturn at $t = 1$ so that $m = \mathcal{SR}$. It follows from Lemma 5.2 that bank lending is not restricted in the downturn when operating in the risky mode. However, if the economy runs into a recession at the end of the second period, the value of nonperforming loans will be destroyed in a bank run. Therefore the funding liquidity of first period loans is only $p_2 v_b l_0$. If these funds are too low to cover the negative cash flow in the downturn, the banker will have to use the excess liquidity of granting second period loans in order to pay off first period depositors. As depositors' claims depend on the first period loan volume, bank lending in the first period is restricted to

$$-\left[p_2(\mu_1 - p_1\Delta_1) - \tfrac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1}\right] l_0 \leq \phi_{1,b}^{\mathcal{R}}\left(l_{1,b}^{\mathrm{fb}}\right). \tag{5.27}$$

While the expected profit of second period loans in the risky mode, given by the RHS of (5.27), reflects the excess liquidity of granting loans according to the first best in the downturn, the LHS captures the potential funding gap resulting from first period's investments. Bank lending will only be restricted, if the funding liquidity of nonperforming loans $p_2(\mu_1 - p_1\Delta_1)l_0$ is too low to cover the negative cash flow $-\tfrac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1} l_0$. This will be the case if the liquidity risk is rather high. Recall from Lemma 5.2 that granting loans above the first best in the downturn yields a negative expected profit for the banker. Accordingly, the banker has to reduce bank lending in the first period in order to operate according to $m = \mathcal{SR}$.

Moreover, the potential bank run at the end of the second period has an additional impact on bank lending in the first period. It will decrease the expected return on first period loans by $(1 - p_1)(1 - p_2)(\mu_1 - p_1\Delta_1)$. In consequence, even if the restriction on bank lending in the first period is not binding, the banker will underinvest in the first period. Explicitly considering nonperforming loans in the downturn, this imposes an additional cutback in bank lending in comparison to the results of Chapter 4. We neglect a potential underinvestment in the downturn when operating in the risky mode by setting the return on second period loans that materializes in a recession to zero. Therefore, bank lending will always follow a secular trend in this setting if the banker operates according to $\mathcal{SR}$.

Finally, suppose the banker increases the face value of deposits in order to increase bank lending in the first period. He therefore operates in the risky mode in the first period, which results in a bank run, i.e. in the failure mode, once the economy is in the downturn at $t = 1$, so that $m = \mathcal{RF}$. Both banker and investors will only receive a profit, if the economic conditions turn out to be good at $t = 1$. Hence the expected return on first period loans declines so that the banker grants loans according to $l_0^{\mathcal{R}} < l_0^{\text{fb}}$. This investment increase in the liquidity risk, Δ_1, as the return on first period loans, which is destroyed in the downturn, decreases. Again, the banker never invests in the risk-free asset due to it negative expected profit.

The banker will never close the bank at the beginning of the first period. As $p_1 v_g > 1$, it is always beneficial for the banker to grant loans in the first period. Comparing the expected profits of all combined modes presented above, we obtain:

Proposition 5.3. *For $\Delta_1 < \overline{\Delta}_1$, the banker's optimal decisions on the mode of operation, m, and bank lending, l_t, at $t = 0$ and $t = 1$ have the following properties:*

$$
\begin{array}{lllll}
\mathcal{A}: & m^* = \mathcal{SS}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if } \Delta_1 \leq \Delta_1^{\mathcal{A}}, \\
\mathcal{B}: & m^* = \mathcal{SS}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \text{if } \Delta_1 \in \left(\Delta_1^{\mathcal{A}}, \Delta_1^{\mathcal{B}}\right], \\
\mathcal{C}: & m^* = \mathcal{SR}, & l_0^* = l_0^{\mathcal{SR}} < l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if } \Delta_1 \in \left(\Delta_1^{\mathcal{B}}, \Delta_1^{\mathcal{C}}\right], \\
\mathcal{D}: & m^* = \mathcal{SR}, & l_0^* = l_0^{max} < l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if } \Delta_1 \in \left(\Delta_1^{\mathcal{C}}, \Delta_1^{\mathcal{D}}\right], \\
\mathcal{E}: & m^* = \mathcal{RF}, & l_0^* = l_0^{\mathcal{R}} < l_0^{fb}, & l_{1,b}^* = 0 & \text{if } \Delta_1 > \Delta_1^{\mathcal{D}},
\end{array}
$$

with all critical values being defined in the appendix.

Proof. See appendix. □

The proposition states that the banker's optimal behavior over the business cycle depends again on the liquidity risk of first period loans, Δ_1. We restrict our attention to liquidity risks below $\overline{\Delta}_1$, which ensures that the return on nonperforming loans remains nonnegative, and which maintains that the funding liquidity of equity financing at least potentially imposes a restriction on bank lending. Depending on the liquidity risk, one of five different strategies will be optimal, as Figure 5.2 illustrates. This figure is designed analogously to Figure 4.2. The upper quadrant depicts first period loans whereas the lower quadrant displays second period loans

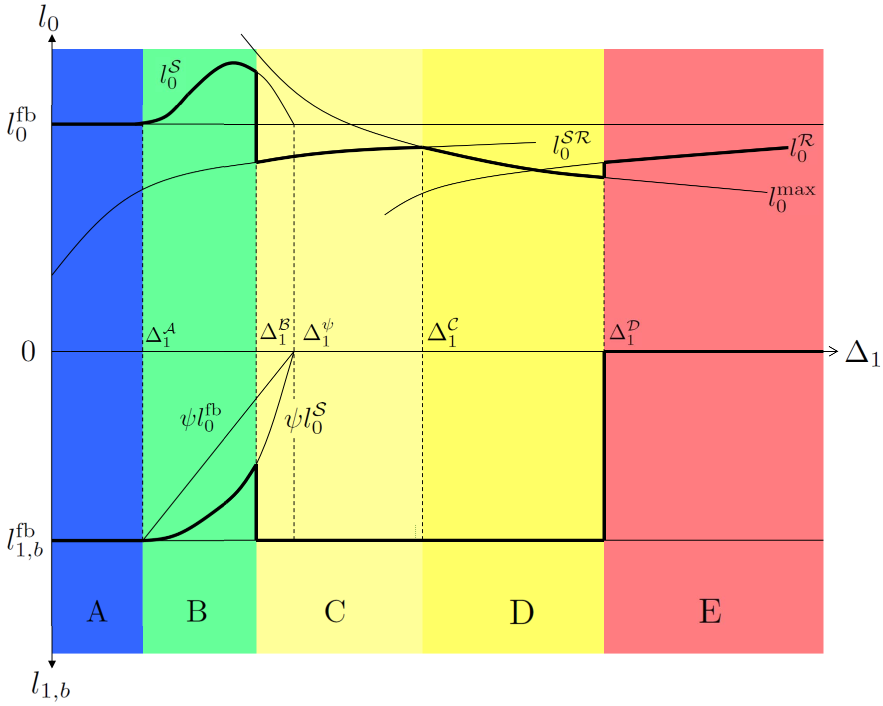

Figure 5.2: Optimal lending and capital structure decision at $t = 0$ and in the bad situation at $t = 1$

in the downturn at $t = 1$. In both quadrants the thick line highlights the optimal loan volume for a given liquidity risk Δ_1. A deviation of the thick line from the first best loan volumes, which are not affected by changes in the liquidity risk, identifies a less efficient bank lending structure. Again, the green area, B, depicts a lending behavior that is inefficient but that maintains a safe capital structure, whereas the yellow areas, C and D, as well as the red area, E, identify different degrees of inefficient bank lending and risk taking. In both yellow areas a bank run will only occur if a recession materializes at the end of the second period. The dark yellow area, D, identifies a stronger inefficiency with respect to bank lending compared with the light yellow area, C, as the restriction on granting loans in the first period becomes binding. The red area, E, illustrates a lending pattern that entails an early bank run, in the downturn at $t = 1$.

As long as no regulatory measures are considered, which might impose additional restrictions on either of these strategies, there exists the same unique ordering of these strategies with respect to the liquidity risk, Δ_1, as obtained in Proposition 4.3. If the liquidity risk, Δ_1, is very low, i.e. $\Delta_1 \leq \Delta_1^{\mathcal{A}}$, the banker operates according to strategy $\mathcal{A}$. He always grants loans according to the first best without imposing a risk on the bank. Therefore, this strategy again depicts the preferred strategy from the welfare perspective.

An increase in the liquidity risk to $\Delta_1 \in (\Delta_1^{\mathcal{A}}, \Delta_1^{\mathcal{B}}]$ implies a restriction on bank lending in the downturn so that strategy $\mathcal{A}$ is no longer feasible. In this range the banker will still operate in the safe mode in both periods so that the bank will never default. However, the restriction on bank lending imposes a negative effect on the real economy. We denote this strategy again by $\mathcal{B}$. The banker will overinvest in the first period by granting loans $l_0^{\mathcal{S}} > l_0^{\text{fb}}$ in order to loosen the potential restriction on bank lending in the second period from ψl_0^{fb} to $\psi l_0^{\mathcal{S}}$. Therefore he balances efficiency losses in the first period with efficiency gains in the downturn. In consequence, bank lending becomes procyclical over the business cycle. Up to a certain threshold, an increase in the liquidity risk will result in an even stronger procyclical effect. The restriction on bank lending in the downturn tightens by an increase in the liquidity risk, Δ_1. In order to loosen the restriction on bank lending, the banker has to grant even more loans in the first period. However, the overinvestment becomes more costly the larger the deviation from the first best loan volume. Balancing expected costs and benefits from overinvesting in the first period, the costs of granting loans above the first best in the first period increase in the liquidity risk. At the same time, expected returns will only increase to a smaller extent in the downturn. Therefore the extent of procyclicality decreases for larger liquidity risks up to the point that the banker again grants loans to the first best, as bank lending is restricted to zero in the downturn.

If first period loans bear a liquidity risk in the range of $(\Delta_1^{\mathcal{B}}, \Delta_1^{\mathcal{P}}]$, operating in the safe mode at all times is either not feasible or yields a rather low expected profit. The banker will therefore operate in the risky mode if economic conditions turn out to be bad at $t = 1$. Accordingly, a bank run will occur if the economy slides into a recession at the end of the second period. Due to the modification with respect to first and second period loans' earnings in the downturn, this bank run will only destroy the value of first period loans. Second period loans always default in a recession, irrespective of the mode of operation. In consequence, operating in the risky mode in the downturn will lead to an underinvestment in the first period, while the banker will grant loans according to the first best in the second period. As long as bank lending is not restricted in the first period, i.e. (5.27) does not hold with strict inequality, the banker will operate according to strategy $\mathcal{C}$ and grant first period loans in the amount of $l_0^{\mathcal{SR}}$. In this interval, the liquidity risk of first period loans is rather large so that the value of delayed loans that is destroyed in the bank run is small. Moreover, the restriction on bank lending is very tight when operating in the safe mode in the downturn. The expected profit of strategy $\mathcal{C}$ is thus larger that of strategy $\mathcal{B}$. However, an increase in the liquidity risk will also reduce the funding liquidity of nonperforming loans in the downturn. Therefore the banker might be unable to refinance the existing debt overhang at that time if he grants loans in the amount of $l_0^{\mathcal{SR}}$. In order to prevent a negative expected profit, he will thus operate according to strategy $\mathcal{D}$ by cutting bank lending even further to $l_0^{\max}$. In contrast to Chapter 4, the lending patterns of strategies $\mathcal{C}$ and $\mathcal{D}$ therefore both follow a secular trend. Again, the bank run that occurs in the recession is not caused by an excessive credit boom.

Finally, if the liquidity risk increases above $\Delta_1^{\mathcal{D}}$, the banker will operate according to strategy $\mathcal{E}$, which imposes the largest risk taking feasible. He operates in the risky mode immediately at $t = 0$ and thus risks an outright failure already in the downturn at $t = 1$. Therefore, he is able to increase bank lending in the first period to $l_0^{\mathcal{R}} > l_0^{\max}$. This strategy is the more valuable for a larger liquidity risk, Δ_1. An increase in the liquidity risk lowers the return on nonperforming loans in the downturn. Accordingly, the value that is destroyed in a bank run at $t = 1$ declines. Simultaneously, the expected return on first period loans when operating in the risky mode increases, so that the expected marginal return on first period loans increases. Moreover, the restriction on bank lending when operating in the safe mode becomes tighter so that the banker prefers strategy $\mathcal{E}$ over strategy $\mathcal{D}$.

5.4 Discussion

5.4.1 Robustness

We modified the model presented in Chapter 4 in order to develop a benchmark for the comparison of different regulatory measures that will be undertaken in Chapter 6. In this section, we will argue that these modifications are not critical for our results.

The margin call presented in Chapter 3 will only be applicable to this model if we allow for raising equity as well. In contrast to debtholders, shareholders participate in the bank's success and receive a share $1 - \lambda$ of the bank's profits. As the banker possesses the bargaining power due to his specific skills, he only has to ensure that both shareholders and debtholders expect to receive a payoff equivalent to the amount of their respective investment. Hence their participation constraint is always satisfied with equality. We find that bank lending does not primarily depend on the type of external capital. As in Chapter 4, the driving factor is the banker's ability to extract rents at all and therefore the funding liquidity of both first and second period loans. Due to the possibility of raising equity, the funding liquidity is now expressed in more complex terms, but the argument remains unchanged. As long as the funding liquidity and the cash flow are both positive, bank lending is unrestricted. Moreover, the banker might use a positive cash flow to co-finance loans with a negative funding liquidity. In order to focus on the case that banks have to raise deposits to co-finance investments, we assume a negative funding liquidity when operating in the safe mode in the first period and in the downturn at $t = 1$. Considering equity thus leads to the same results with respect to bank lending as obtained in Chapter 4.

The difference with respect to bank lending results from the modification with respect to the timing of first period's loan earnings. If the banker operates in the safe mode, it will be irrelevant whether first period loans materialize a return in the downturn at $t = 1$ or at the end of the second period. As no values are destroyed until $t = 2$, the expected return on delayed loans equals the cash flow of first period loans that materialized in the downturn in Chapter 4. However, operating in the risky mode in the downturn generates a wedge between the funding liquidity of nonperforming loans and the cash flow that was feasible in the previous chapter. As the bank run in a recession will destroy the value of first period loans, the funding liquidity of delayed loans declines. Accordingly, the expected return on first period loans decreases and an underinvestment occurs. Such an asymmetry over the business cycle is more realistic, as nonperforming loans can be observed to a larger extent in times of distress (Burger *et al.*, 2009).

Moreover, we neglect the liquidity risk of second period loans in order to reduce the complexity of the analysis. Changes in $\Delta_{2,b}$ will have the same impact as presented in Chapter 4. As second period loans will default entirely once the economy is in a recession at the end of the second period, we henceforth simply consider the largest $\Delta_{2,b}$ feasible in Chapter 4.

As argued in Section 4.4.1, strictly larger returns in an upswing than in a downturn are not crucial for our results. In this chapter, we reduce complexity even further by abstracting from liquidity risks in the upswing altogether. Although this adjustment will not affect the impact of the different regulatory measures discussed in Chapter 6, we might end up in rather complex scenarios otherwise.

5.4.2 Implications for Financial Stability and Bank Regulation

As the modifications of this model alter the lending patterns over the business cycle only to a small extent, we can draw the same conclusions with respect to its implications for financial stability and bank regulation. If the liquidity risks are small, bank lending over the business cycle will become procyclical. Although the banker overinvests in good times in order to foster bank lending in bad times, financial stability is never at risk. If the liquidity risks are more pronounced, the inefficiency of this lending pattern will increase and the banker will prefer to choose a fragile capital structure. This enables him to increase bank lending. Financial stability will only be at risk if economic conditions turn out to be very poor at the end of the second period. In this case, bank lending is always characterized by a secular trend due to the changes with respect to the timing of loan earnings. If the economy runs into a recession so that a bank run emerges, this pattern will resemble a credit bust. However, as the banker will underinvest in good times, this credit supply is never excessive. If the liquidity risk increases even further, the banker will increase the risk of financial stability in order to increase bank lending. If business cycle fluctuations are already quite large in the downturn, as the expected return on nonperforming loans, v_b, is rather low, the banker will prefer to gamble in the first period. He will still underinvest in the first period but financial instability might occur at the end of the first period.

Including external equity financing, our model is suitable to analyze the impact of different regulatory proposals on the trade-off between financial stability and efficient bank lending. Referring to the bank of this model as a representative bank and the liquidity risks as systemic risks, the probability of a bank run again reflects the risk of a common shock.

As in the previous chapter, the results are constrained efficient so that regulatory intervention will never achieve a Pareto improvement. However, we will argue in Chapter 6 that the regulator has a strong incentive to increase financial stability at the cost of less efficient bank lending. We will thus compare the margin call with three main instruments of the Basel III Accord to identify which measure is able to achieve financial stability at the lowest cost with respect to a cutback in lending.

5.5 Conclusion

In this chapter, we have modified the model of Chapter 4 in order to provide the benchmark for the comparison of the margin call with main measures of the Basel III Accord. We have extended the framework by considering shareholders as a second type of investors, as both the margin call and the Basel III Accord demand the possibility of raising equity. As the bargaining power remains with the banker, this modification has no impact on the bank's lending decisions. Depending on the liquidity risk in the economy, similar lending patterns will occur to those observed in Chapter 4. Bank lending will be either procyclical, will follow a secular trend or will be suppressed in the first period. These lending patterns coincide with different degrees of financial instability, which are more pronounced the higher the liquidity risk.

Moreover, we have reduced the complexity of the model presented in Chapter 4 in two aspects. First, we considered constant liquidity risks of second period loans. While the liquidity risk in the downturn has been set to ensure that second period loans will not materialize a return in a recession, we neglected the liquidity risk in the upswing altogether. Second, we slightly modified the intertemporal link between first and second period lending, by including nonperforming first period loans in the downturn, which have to be rolled over in order to yield returns in the future. Both adjustments allow one to focus on the impact of regulation on the main linkage between first period lending and the banker's optimal behavior in the downturn, which we will do in the following chapter.

Chapter 6

Comparison of Regulatory Measures

After adjusting the benchmark model of Chapter 4 in the previous chapter, we are now in a position to analyze the impact of different regulatory measures on the trade-off between financial stability and bank lending. Explicitly considering banks instead of LFIs, we compare the margin call presented in Chapter 3 with three main instruments of the Basel III Accord. These are risk-weighted capital requirements, countercyclical capital buffer requirements and the liquidity coverage ratio. In contrast to the findings of Hart and Zingales, we identify that the margin call is no free lunch but faces a similar trade-off to the other regulatory measures. However, all measures differ in the magnitude of this trade-off. Our results support the argument that risk-weighted capital requirements may induce procyclical bank lending. Countercyclical capital buffer requirements are able to reduce this tendency but might result in a disintermediation, if the regulator misjudges the liquidity risk in the economy. The liquidity coverage ratio will impose a similar effect to the margin call if the ratio is high.

6.1 Introduction

The previous two chapters have illustrated that bankers will put the stability of banks at risk if liquidity risks in the economy are high. If these risks materialize so that a financial crisis emerges, this may have a tremendous effect on economic output, unemployment and therefore on overall welfare. Yan *et al.* (2012) give an overview of the literature on the costs of financial crises. While temporary losses might reach 20 percent of pre-crisis GDP, permanent losses may be in the range of 40-300%. The main problem, however, is that financial institutions do not internalize their systemwide impact (see e.g. Rochet and Tirole, 1996; Perotti and Suarez, 2009a; Acharya, 2009). Accordingly, regulation aims to incentivize banks to reduce risk taking to ensure financial stability.

However, regulation is no free lunch. It might impose diverse costs on the economy as well. Therefore, regulation has to consider both costs and benefits when deciding on the optimal regulatory measure. The literature identifies several trade-offs resulting from regulatory measures, e.g. a trade-off between financial stability and bank lending (see e.g. Dietrich and Hauck, 2012), between financial stability and competition (Allen and Gale, 2004) or between financial stability and price stability (Borio, 2006). We focus on the first type of trade-off and thus on costs in terms of less efficient bank lending. Recall from Chapter 4 and 5 that efficient bank lending will only be feasible if the bank is able to issue a sufficient level of deposits or if the bank possesses internal funds. Imposing a restriction on deposits may therefore lead to a restriction on bank lending. As we do not consider an explicit welfare measure, we cannot evaluate the social benefits of any regulation. Taking the advantages of regulatory intervention as given, we identify which regulatory measure imposes the lowest costs in terms of a cutback in bank lending.

In detail, we compare the margin call with three main measures of the Basel III Accord: risk-weighted capital requirements, countercyclical capital buffer requirements and the liquidity coverage ratio. The margin call can be understood as a counterproposal to these recently implemented regulatory measures, which emerged in the aftermath of the world financial crisis. The main difference is that all measures of the Basel III Accord are based on balance sheet information and therefore data from the past, while the margin call focuses on market participants' expectations regarding the institution's future development. Moreover, the Basel Accord is only applicable to banks.

In a first step, we specify our preliminary result of Proposition 3.3 by explicitly considering the impact of the funding liquidity on bank lending over the business cycle, given that the margin call is in place. If the margin call is triggered each time the CDS price becomes positive, operating in the risky mode will never be seen as an optimal strategy. In line with the findings of Hart and Zingales (2011) financial stability will thus prevail for all liquidity risks. However, the banker will only grant loans as long as the funding liquidity when operating in the safe mode is sufficiently large. As this will not be the case for larger liquidity risks, the banker has to operate in the non-lending mode. In this mode, the bank is factually safe but intermediation is fully disrupted. Financial stability can thus only be achieved at the cost of a severe credit crunch.

Afterwards, we analyze the impact of a constant risk-weighted capital ratio in Section 6.3. As in the Basel II Accord, these capital requirements demand that the value of equity has to exceed a certain share of risky assets. The value of equity is determined as the residual value of the bank's balance sheet. For a given asset portfolio, the regulatory capital ratio restricts the banker's ability to issue deposits. Suppose that the regulator implements a capital ratio that will only impose a binding restriction on deposits, and therefore on bank lending, if the banker chooses a risky capital structure. In this case, the decline in the bank's profit when putting the stability of the bank at risk will lower his incentive to operate in this risky mode. In consequence, financial stability might increase, which is in line with the findings of e.g. Yilmaz (2009). However, our results also support the argument presented in Section 2.3 that a risk-sensitive capital ratio might fuel procyclical lending. Without any regulation in place, we identified procyclical lending, which was accompanied by a safe capital structure so that financial stability was never at risk. Implementing a risk-weighted capital ratio may, however, induce a second type of procyclical lending that is linked to a threat to financial stability. Again, an overinvestment in normal times is not causal for the materialization of liquidity risks, as we still abstract from any feedback effects of bank lending on the real economy. Concentrating on this direction of causality might therefore add new insights into the effectiveness of different regulatory measures.

Our framework is not suitable to distinguish between the impact of the risk-weighted capital ratio and the leverage ratio, which is also part of the Basel III Accord. As we only consider two types of assets, a risk-free asset and risky loans, the leverage ratio would simply be a multiple of the capital ratio. In order to differentiate the effects of a leverage ratio and a risk-weighted capital ratio we would thus have to incorporate the possibility of more than two assets, which is beyond the scope of this chapter.

In order to reduce procyclical lending, the risk-weighted capital ratio will be extended by the possibility of a countercyclical capital buffer in Section 6.4. Demanding larger capital ratios in prosperous times forces banks to build up buffers that can be drawn down in bad times. Therefore these buffers aim to dampen credit growth in good times while fostering it in bad times. Section 6.4 shows that if countercyclical capital buffers are not too large, they might reduce procyclical lending, which is accompanied by a risky capital structure. Depending on the extent of this buffer, financial stability may however decline, as a mitigation in procyclicality leads to an increase in the bank's profits. Accordingly, putting the stability of the bank at risk might become more attractive again. Moreover, strongly countercyclical capital buffers might result in a disintermediation, i.e. they might cut back lending and increase financial instability. If capital requirements are too large in prosperous times and liquidity risks are rather low, the banker might be unable to raise a sufficient amount of equity to fulfill the requirements. Consequently the banker will be unable to grant any loans at all. However, this implies that the banker has no assets to pledge against in an economic downturn in order to fulfill the funding gap of equity financing. The banker will have to increase the face value of deposits, and thus operate in the risky mode, to grant any loans at all.

Section 6.5 analyzes another newly implemented regulatory measure of the Basel III Accord.[1] In order to increase banks' capacity to absorb shocks, banks have to cover a certain share of net cash outflows by high quality liquid assets. Therefore the liquidity coverage ratio aims to allow regulators additional time to find appropriate tools to manage a financial crisis. The advantage of the measure is that it will not impose a restriction on bank lending as long as the banker chooses a safe capital structure. The banker will always be able to fulfill the liquidity coverage ratio by a simple balance sheet extension. He issues more deposits that are invested in the risk-free asset until the ratio is sufficiently large. Operating in the risky mode yields a negative expected profit from the risk-free asset so that the liquidity coverage ratio will impose a binding restriction on bank lending. Analogously to the risk-weighted capital requirements, this might induce procyclical lending and decrease the banker's willingness to put the stability of the bank at risk.

Note that our framework is not eligible to analyze the impact of contingent convertible bonds (CoCos), which are also considered in the new regulatory framework. As described in Section 2.5, these bonds will convert into equity if a predefined scenario emerges. Consequently, CoCos constitute complete contracts. As our model economy considers incomplete contracts between banker and shareholders as well as depositors, we cannot analyze this measure.

We will compare all regulatory proposals in Section 6.6 to show that there is no one-size-fits-all regulatory solution. Different measures seem suitable to achieve financial stability at the lowest cutback in bank lending, depending on the liquidity risk in the economy. Therefore our results contribute to the debate on whether the Basel Accords are suitable for both industrialized economies and emerging economies (see e.g. Powell, 2002; Stephanou and Mendoza, 2005). While the first

[1] We cannot consider the net stable funding ratio as this instrument aims to affect banks' long-term investments.

two Basel Accords where primarily developed for industrialized countries, many emerging economies adopted these regulatory measures as well. In contrast, the current Basel Committee for Banking Supervision setting up the Basel III Accord also comprises emerging economies. Whether these measures are suitable for all member states remains in dispute. For instance, Acharya (2012) argues that India should keep its dynamic sector risk-weighted adjustment approach and its asset-level leverage restrictions instead of adopting the new Basel Accord.

This chapter proceeds as follows. Based on the modified framework developed in Chapter 5, we apply backward induction when determining the impact of each regulatory measure. Accordingly, we will always start to identify the banker's optimal behavior in the second period with respect to bank lending and risk taking. Taking these results as given, we exhibit the optimal strategy over the business cycle, depending on the liquidity risk in the economy. After comparing the results in Section 6.6, we conclude this chapter with Section 6.7.

6.2 Margin Call

In a first step, we analyze the impact of the regulatory margin call by Hart and Zingales (2011). In line with the analysis presented in Chapter 3, we will consider a margin call that is triggered each time the CDS price becomes positive.

In analogy to Hart and Zingales, we assume that any market participant inside or outside the bank may enter into a CDS contract on the bank. As we consider symmetric information, all market participants possess the same information regarding the potential states of the economy and the respective returns on bank loans. Hence the CDS is fairly priced. If the banker chooses a safe capital structure, he will always be able to pay off depositors, independent of the state of the economy. As the bank thus never defaults, the demand of CDS, and thus the CDS price, is zero. If the banker operates in the risky mode, the bank's probability of default will be positive. Market participants will buy CDS to protect themselves against potential losses. This increased demand in CDS results in a positive CDS price and will thus trigger the margin call.

Similarly to the analysis of Hart and Zingales, we identify that a threshold of zero basis points results in financial stability for all liquidity risks. However, in contrast to their findings we find that for certain liquidity risks this will only be feasible at the cost of a credit crunch.

6.2.1 Bank Behavior in the Second Period

Analyzing the impact of a margin call, we first determine the banker's optimal behavior in both states of the economy at $t = 1$ and then we identify the optimal behavior over the business cycle.

Suppose the economy is in an upswing at $t = 1$. With the economy in this state, the banker is always able to operate in the unrestricted safe mode without any regulatory measures in place, as Lemma 5.1 shows. All market participants are able to observe this behavior. Hence there is no need to buy CDS contracts and the margin call will never be triggered. As with Lemma 5.1 we can thus conclude:

Lemma 6.1. *If the economy is in an upswing at date $t = 1$ and the regulatory margin call is in place, the banker's optimal decision on the mode of operation, $m_{1,g}$, and bank lending, $l_{1,g}$, will have the following properties:*

$$m^*_{1,g} = \mathcal{S}, \quad l^*_{1,g} = l^{fb}_{1,b} \quad \forall\ l_0. \tag{6.1}$$

Proof. Omitted. □

Suppose the economy is in a downturn at $t = 1$. As market participants are able to identify the bank's capital structure, the margin call will not be triggered as long as the banker operates in the safe mode. If he operates in the risky mode and is therefore unable to pay off depositors in the case of a recession at $t = 2$, market participants will buy CDS contracts. The resulting increase in the CDS price above zero will trigger the margin call.

When operating in the risky mode, the banker may either raise additional equity or sell risky assets to prevent the takeover. Shareholders provide funds as long as their expected net return is nonnegative. As shareholders' participation constraint is, however, already fulfilled with equality, the banker is unable to raise additional equity. In order to achieve a decline in the CDS price to zero basis points, the banker would have to sell risky loans. If the return on these sales covers potential losses in a recession, the CDS price will decline to zero. However, we have argued above that the banker is needed to collect the full value of loans. Due to this relationship lending, selling loans yields returns too low to cover potential losses. As a result, a fire sale is not able to prevent the takeover.

Operating in the risky mode will thus always lead to a takeover by the regulator. As described in Chapter 3, this implies a haircut for both the banker and shareholders. Analogously to the fire sale, this results in a negative expected profit for the banker, as he has to bear private costs of granting loans without receiving any compensation for his effort.

Both in the failure mode and in the non-lending mode, the banker is unable to grant second period loans. While the bank is closed in the former case, the bank survives in the latter case as the banker is able to pay off first period depositors. As the bank is not at risk in the non-lending mode, the margin call will never be triggered. Comparing the banker's expected profit of the different modes feasible in the downturn thus yields:

Lemma 6.2. *If the economy is in a downturn at date $t = 1$ and the regulatory margin call is in place, the banker's decision on the mode of operation, $m_{1,b}$, and bank lending, $l_{1,b}$, will have the following properties:*

- *Given $v_b + \omega_{1,b} \geq 0$, then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{fb}_{1,b} & \text{if } l_0 \geq \frac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{max}_1 & \text{if } l_0 \in (0, \frac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} = \mathcal{N}, & l^*_{1,b} = 0 & \text{if } l_0 = 0, \end{array} \tag{6.2}$$

- *Given $v_b + \omega_{1,b} < 0$, then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{N}, & l^*_{1,b} = 0 & \text{if } l_0 = 0, \\ m^*_{1,b} = \mathcal{F}, & l^*_{1,b} = 0 & \text{if } l_0 > 0. \end{array} \tag{6.3}$$

Proof. See appendix. □

Operating in the risky mode, $\mathcal{R}$, always results in a takeover and leads to a negative expected profit. Hence the banker never prefers the risky mode over the safe mode, $\mathcal{S}$. He will thus grant loans with a safe capital structure as long as the safe mode is available, i.e. as long as the return on nonperforming loans, v_b, covers the negative cash flow, $\omega_{1,b}$, that has materialized in the downturn. If the return on first period loans is however too low so that the safe mode is not feasible, the banker prefers both the failure mode, $\mathcal{F}$, and the non-lending mode, $\mathcal{N}$, over the risky mode, $\mathcal{R}$, as both have a nonnegative expected profit. As the funding liquidity of first period loans is too low to pay off first period depositors, a bank run will occur if the banker has granted first period loans. He will only be able to operate in the non-lending mode if depositors hold no existing claims against the bank, i.e. if no loans have been granted in the first period.

6.2.2 Bank Behavior in the First Period

The banker faces the same alternatives when deciding on the bank's portfolio and capital structure in the first period. As long as he operates in the safe mode or in the non-lending mode at $t = 0$, the CDS price will be equal to zero. In both cases market participants have no need to protect themselves against a potential default. However, the margin call will be triggered if the banker operates in the risky mode. In this case, he increases the face value of deposits to an extent that implies a bank run in the downturn at $t = 1$. As with the risky mode in the second period, the bank will be taken over by the regulator. Shareholders are unwilling to provide additional funds and the banker cannot raise funds by selling risky assets. Accordingly, the risky mode yields a negative expected profit for the banker. We thus obtain:

Proposition 6.3. *If the regulatory margin call is in place and $\Delta_1 < \overline{\Delta}_1$, the banker's optimal decisions on the mode of operation, m, and bank lending, l_t, at $t = 0$ and $t = 1$ will have the following properties:*

$$\begin{array}{lllll}
\mathcal{A}: & m^* = \mathcal{SS}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \;\; \Delta_1 \leq \Delta_1^{\mathcal{A}}, \\
\mathcal{B}: & m^* = \mathcal{SS}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \text{if} \;\; \Delta_1 \in \left(\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}\right], \\
\mathcal{X}: & m^* = \mathcal{NN}, & l_0^* = 0 < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \text{if} \;\; \Delta_1 > \Delta_1^{\psi},
\end{array}$$

with all critical values being defined in the appendix.

Proof. See appendix. □

The proposition shows that the banker will never operate in the risky mode at any time if the margin call is in place. Due to negative expected profits resulting from the takeover, the banker thus never prefers strategies $\mathcal{C}$, $\mathcal{D}$ or $\mathcal{E}$, independent of the liquidity risk in the economy. As the safe mode remains unchanged, the banker prefers the unrestricted safe mode as long as strategy $\mathcal{A}$ is feasible, i.e. as long as the liquidity risk Δ_1 is lower than $\Delta_1^{\mathcal{A}}$. Again, this constitutes the preferred strategy from a welfare perspective as financial stability is achieved without a cutback in lending. The banker prefers strategy $\mathcal{B}$ and thus the restricted safe mode for all liquidity risks up to Δ_1^{ψ}. For all liquidity risks larger than Δ_1^{ψ}, the restriction on bank lending in the downturn is so tight that the banker is unable to grant any loans at that time. In consequence, the banker will operate according to strategy $\mathcal{X}$ by granting loans neither in the first period nor in the downturn. He thus prevents a negative expected profit resulting from private costs of granting loans that are not compensated by a participation in the return on these loans.

With respect to achieving financial stability, our results thus support the findings of Hart and Zingales presented in Chapter 3. Analyzing the banker's investment decision in both periods, we are able to highlight the impact of the funding liquidity in more detail. Hence Proposition 6.3 constitutes a specification to our preliminary result obtained in Proposition 3.3. Depending on the liquidity risks in the economy

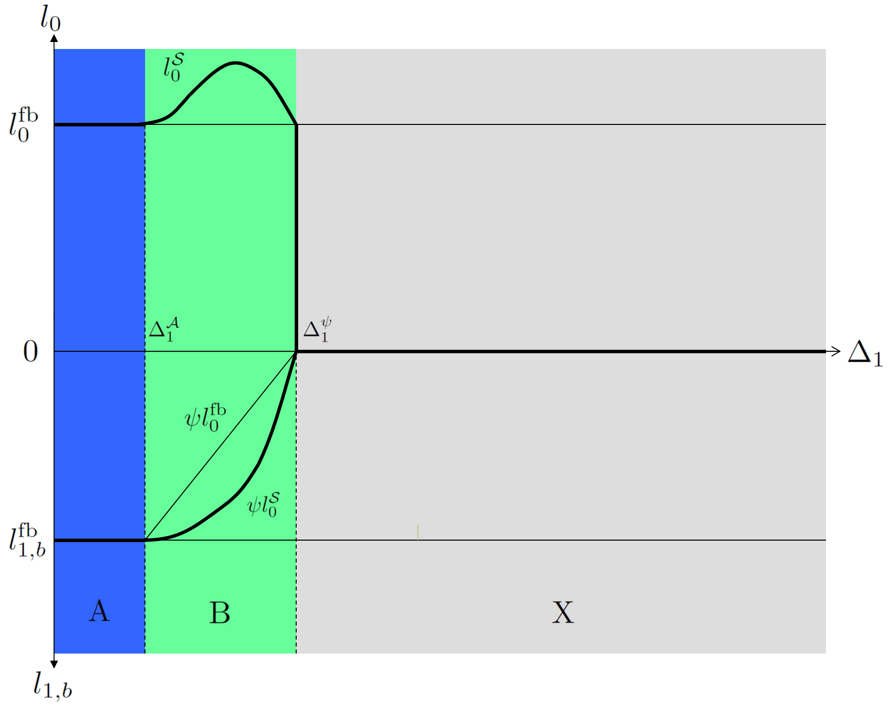

Figure 6.1: Optimal lending and capital structure decision at $t = 0$ and in the bad situation at $t = 1$ with a regulatory margin call in place

and thus on the funding liquidity of first and second period loans, the margin call might not be the free lunch argued by Hart and Zingales. If the liquidity risk is too large, we observe the same trade-off between financial stability and efficient bank lending that prevails for all other regulatory measures, which we will discuss below.

The actual proposal of the margin call considers a threshold of 100 basis points. In our setting, this would imply that the banker was able to operate in the risky mode as long as the probability of a bank run either in the downturn or the recession remains below one percent.[2] We thus have to distinguish between three cases. As long as both $1-p_1$ and $1-p_2 \leq 0.01$, the margin call is never triggered and the banker operates as described in Proposition 5.3. The margin call will thus be ineffective. If both $1 - p_1$ and $1 - p_2 > 0.01$, operating in the risky mode will lead to a takeover both in the first period and in the downturn at $t = 1$. Hence the results obtained in Proposition 6.3 persist. If the threshold is too large to trigger the margin call when the banker operates in the risky mode either in the first period or in the downturn, i.e. if either $1 - p_1$ or $1 - p_2 \leq 0.01$, then the margin call will only increase financial stability for certain liquidity risks.

[2]The relation between the CDS price and the bank's probability of default is described in more detail in Chapter 7.

6.3 Capital Requirements

In this section we analyze the impact of risk-weighted capital requirements, which are one of the main measures of the Basel Accords. In our model economy, the bank can only invest in a risk-free asset and in risky loans. Putting a risk-weight of zero on the risk-free asset, capital requirements focus solely on the volume of risky loans. In detail, the value of equity has to cover at least the share κ of all risky loans. Note that the value of equity is not necessarily identical to the amount of funds shareholders are willing to provide at any date t, as we will indicate below.

As long as the regulator possesses the same information regarding the bank's assets and the other exogenous variables, she can set capital requirements without imposing unnecessary restrictions on bank lending. This implies that the capital ratio should lead to no further restrictions on bank lending if the bank is already stable, i.e. if the banker operates in the safe mode. Accordingly, the capital ratio has to be sufficiently low so that neither the safe mode in the first period nor the safe mode in the downturn at $t = 1$ will be affected. However, the capital ratio also has to be sufficiently high to make the risky mode less attractive to the banker. This will be the case, if capital requirements are so high that bank lending will be restricted when putting the stability of the bank at risk. Technically, all three conditions are satisfied, if $\kappa \in (1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}, \min\{1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}, 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}\})$.[3] Both upper limits ensure that bank lending will never be additionally restricted when operating in the safe mode, while the lower limit implicates that the risky mode will always be affected.

Implementing risk-weighted capital requirements increases financial stability for certain liquidity risks. Their restriction on the face value of deposits results in a restriction on bank lending in the risky mode. In consequence, the banker's expected profit from operating in the risky mode declines and the safe mode might become more beneficial. However, we find that procyclical lending becomes more likely. As the banker will also face a restriction on bank lending in the downturn when operating in the risky mode, he will increase bank lending in the first period in order to loosen the potential restriction in the future. Hence procyclical lending will also occur for larger liquidity risks and is no longer restricted to a safe capital structure.

[3]Considering a risk-sensitive capital ratio $\kappa(p_1, p_2)$, which depends on the respective probability of default in each period, would be more consistent with the Basel Accord but does not change our results qualitatively. In order to reduce complexity, we thus analyze a fixed capital ratio within predetermined boundaries that depend on the probability of success.

Assets		Liabilities	
loans	$l_{1,g}$	value of equity	$\varepsilon_{1,g}$
risk-free assets	$a_{1,g}$	face value of deposits	$\delta_{1,g}$

Figure 6.2: Bank balance sheet in the good state at $t = 1$

6.3.1 Bank Behavior in the Second Period

Suppose economic conditions are benign so that the bank is in an upswing at $t = 1$. At this stage, the banker's decisions with respect to the bank's portfolio and capital structure lead to the bank's balance sheet presented in Figure 6.2. The value of equity $\varepsilon_{1,g}$ is determined by the bank's assets, $l_{1,g} + a_{1,g}$, subtracted by the face value of deposits, $\delta_{1,g}$. According to the capital requirements, this value of equity has to be equivalent to at least κ of risky loans. However, in the good state second period loans are risk-free as they will yield a high return, r_g, at the end of the second period with certainty. Hence capital requirements will always be fulfilled if the economy is in an upswing at $t = 1$. We thus obtain analogously:

Lemma 6.4. *If the economy is in an upswing at date $t = 1$ and a capital ratio $\kappa \in (1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}, \min\{1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}, 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}\})$ is in place, the banker's optimal decision on the mode of operation, $m_{1,g}$, and bank lending, $l_{1,g}$, will have the following properties:*

$$m^*_{1,g} = \mathcal{S}, \quad l^*_{1,g} = l^{fb}_{1,b} \quad \forall\ l_0. \tag{6.4}$$

Proof. Omitted. □

The intuition of this result also follows Lemma 5.1. If the economy is in an upswing, the banker can always operate in the safe mode, $\mathcal{S}$, independent of the liquidity risks of the economy. As second period loans are not risky, capital requirements impose no restriction on bank lending for any mode. Consequently, the funding liquidity of second period loans when operating in the safe mode remains unchanged and bank lending will never be restricted. The banker thus prefers the safe mode of operation over the failure mode, $\mathcal{F}$, and the non-lending mode, $\mathcal{N}$, and grants loans according to the first best. The risky mode, $\mathcal{R}$, is not available in this situation.

If the economy is in the downturn at $t = 1$, first period loans are nonperforming and will be rolled over until the end of the second period. Accordingly, the bank's balance sheet changes as illustrated in Figure 6.3. The value of equity, $\varepsilon_{1,b}$, is then

Assets		Liabilities	
loans	l_0	value of equity	$\varepsilon_{1,b}$
loans	$l_{1,b}$		
risk-free assets	$a_{1,b}$	face value of deposits	$\delta_{1,b}$

Figure 6.3: Bank balance sheet in the bad state at $t = 1$

determined by the bank's assets, $l_0 + l_{1,b} + a_{1,b}$, subtracted by the face value of deposits, $\delta_{1,b}$. As both first and second period loans are risky in the downturn, capital requirements demand that the value of equity, $\varepsilon_{1,b}$, has to cover at least the share κ of all risky loans, i.e.

$$l_0 + l_{1,b} + a_{1,b} - \delta_{1,b} \geq \kappa(l_0 + l_{1,b}). \tag{6.5}$$

Therefore the face value of deposits is restricted to

$$\delta_{1,b} \leq (1 - \kappa)(l_0 + l_{1,b}) + a_{1,b}. \tag{6.6}$$

We determined the banker's optimization problem in the downturn already in Subsection 5.3.1. We obtain the optimal bank behavior analogously by additionally taking into account that deposits might be restricted according to equation (6.6). Whether this restriction affects bank lending depends on the size of κ and the mode of operation.

Suppose the banker operates in the safe mode, $\mathcal{S}$, so that in the absence of any regulation the face value of deposits is restricted to $v_b l_0 + a_{1,b}$, see equation (5.14). The restriction resulting from capital requirements will become binding if $(1 - \kappa)(l_0 + l_{1,b}) + a_{1,b} < v_b l_0 + a_{1,b}$. This will be the case if either v_b is relatively large as Δ_1 is low or if second period loans, $l_{1,b}$, are relatively low. However, as long as capital requirements are restricted to $\kappa < 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}$, the funding liquidity of second period loans will turn out to be less negative than in the benchmark scenario. Moreover, we will demonstrate below that the funding liquidity of first period loans will always remain positive if capital requirements are restricted to $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$. The banker will thus face no additional restriction on bank lending in the safe mode if capital requirements are in place. In consequence, his optimal behavior in the safe mode remains identical to that obtained in Chapter 5.

Suppose the banker operates in the risky mode, $\mathcal{R}$, in the downturn so that in the absence of any regulation the face value of deposits is restricted to $v_b l_0 + r_b l_{1,b} +$

$a_{1,b}$. (See equation (5.14).) The restriction resulting from capital requirements will become binding if $(1-\kappa)(l_0+l_{1,b})+a_{1,b} < v_b l_0 + r_b l_{1,b} + a_{1,b}$. This will be the case if the capital ratio, κ, is sufficiently large. In contrast to Chapter 5, it follows from the optimization problem that bank lending will thus be restricted according to

$$[1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)]\, l_{1,b} \leq [(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}]\, l_0. \qquad (6.7)$$

Due to the restriction on issuing deposits, the banker has to co-finance the share, κ, of second period loans by raising equity. If $\kappa > 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}$, this will result in a negative funding liquidity of second period loans, i.e. $(1-\lambda)p_2 r_b + \lambda p_2(1-\kappa) - 1 < 0$. Moreover, κ will reduce the funding liquidity of nonperforming loans. As long as the funding liquidity, $(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa)$, remains larger than the negative cash flow, $\omega_{1,b}$, per unit of loans the banker can close the funding gap of second period loans. Analogously to the safe mode, bank lending will be restricted when operating in the risky mode if both the capital ratio, κ, and the liquidity risk, Δ_1, are sufficiently large. An increase in the liquidity risk reduces the return, v_b, on nonperforming loans that will materialize at $t=2$ and therefore first period loans' funding liquidity.

Suppose the banker operates in the failure mode, $\mathcal{F}$, by closing the bank in the downturn at $t=1$. This behavior is obviously not affected by any regulation, so that the banker's optimal behavior remains unchanged.

Suppose that the restriction on bank lending is so tight that granting loans is unfeasible, either in the safe mode or in the risky mode. As long as the banker is able to pay off first period depositors by pledging against nonperforming loans, the bank will survive by granting no loans at all. In contrast to the failure mode, the bank will remain in place until the end of the second period when operating in the non-lending mode, $\mathcal{N}$, and the return on nonperforming loans can still be collected.

Comparing the expected profit of all modes available in the downturn at $t=1$, we obtain:

Lemma 6.5. *If the economy is in a downturn at date $t=1$ and a capital ratio $\kappa \in (1-\frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}, \min\{1-\frac{1-(1-\lambda)p_2 r_b}{\lambda}, 1-\frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}\})$ is in place, the banker's decision on the mode of operation, $m_{1,b}$, and bank lending, $l_{1,b}$, will have the following properties:*

- *Given* $v_b + \omega_{1,b} \geq 0$, *then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{fb}_{1,b} & \text{if } l_0 \geq \frac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{max}_1 & \text{if } l_0 \in [l^{min}_{0,\kappa}, \frac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} = \mathcal{R}, & l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}\} & \text{if } l_0 \in (0, l^{min}_{0,\kappa}), \\ m^*_{1,b} = \mathcal{N}, & l^*_{1,b} = 0 & \text{if } l_0 = 0, \end{array} \tag{6.8}$$

- *Given* $v_b + \omega_{1,b} < 0$, *then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{N}, & l^*_{1,b} = 0 & \text{if } l_0 = 0, \\ m^*_{1,b} = \mathcal{R}, & l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}\} & \text{if } l_0 \in (0, l^{max}_{0,\kappa}], \\ m^*_{1,b} = \mathcal{F}, & l^*_{1,b} = 0 & \text{if } l_0 > l^{max}_{0,\kappa}, \end{array} \tag{6.9}$$

with $l^{max}_{0,\kappa} := -\frac{\phi^{\mathcal{R}}_{1,b}\left(\min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}\}\right)}{p_2 v_b + \omega_{1,b}}$ *and* $l^{max}_{1,\kappa} := \frac{(1-\lambda)p_2 v_b + \lambda p_2 (1-\kappa) + \omega_{1,b}}{1-(1-\lambda)p_2 r_b - \lambda p_2 (1-\kappa)} l_0$ *while* $l^{min}_{0,\kappa}$ *is implicitly defined by*

$$(1 - p_2) v_b l_0 + \phi^{\mathcal{S}}_{1,b} \left(l^{max}_1 (l_0)\right) = \phi^{\mathcal{R}}_{1,b}(\min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}(l_0)\}). \tag{6.10}$$

Proof. See appendix. □

In the downturn, the banker can choose between all four modes of operation at $t = 1$, as long as the return on nonperforming loans, v_b, covers the debt overhang, $\omega_{1,b}$. Given that capital requirements are not too large, bank lending in the safe mode, $\mathcal{S}$, faces no additional restriction in the downturn. As long as first period loans are sufficiently large, the banker can pledge enough against these delayed loans to co-finance second period loans and bank lending will not be restricted. Bank lending in the safe mode will be restricted by $l^{\max}_1$ if the funding liquidity of first period loans declines, i.e. if the banker has granted too few loans in the first period. In contrast to the safe mode, capital requirements will affect bank lending in the risky mode, $\mathcal{R}$. Restricting the face value of deposits results in a restriction on bank lending. As with the safe mode, the banker is unable to finance second period loans by solely issuing deposits. His ability to grant loans thus analogously depends on the first period loan volume. If bank lending is restricted to $l^{\max}_{1,\kappa}$, the banker's expected profit in the second period decreases. In comparison to the unchanged restricted safe mode, the risky mode becomes less attractive. Accordingly, if the restriction on bank lending in the risky mode becomes binding, the banker will prefer the safe mode over the risky mode for a lower first period loan volume, i.e. for $l^{\min}_{0,\kappa} < l^{\min}_0$. If the banker has granted no loans at all in the first period, both the safe and the

Assets		Liabilities	
loans	l_0	value of equity	ε_0
risk-free assets	a_0	face value of deposits	δ_0

Figure 6.4: Bank balance sheet at $t = 0$

risky mode are technically feasible. However, in both modes the banker is unable to grant any loans in the downturn so that he will operate in the non-lending mode, $\mathcal{N}$.

If $v_b + \omega_{1,b} < 0$, the funding liquidity of first period loans is too low to cover the negative cash flow and the safe mode is not feasible. If the banker has issued no loans in the first mode, he will again operate in the non-lending mode, $\mathcal{N}$. For all other loan volumes, the banker prefers to operate in the risky mode, $\mathcal{R}$, as long as this coincides with a nonnegative expected profit. The risky mode is, however, only feasible, if the banker can cover the debt overhang by pledging enough against second period loans. This will only be the case, if the funding liquidity of second period loans remains positive despite the capital requirements. If the capital ratio, κ, is so large that the funding liquidity of second period loans becomes negative, the risky mode will likewise not be feasible as $l_{1,\kappa}^{\max} < 0$. If $l_{1,\kappa}^{\max} > 0$, the banker's expected profit will remain positive if the debt overhang is not too large, i.e. if first period loans are lower than $l_{0,\kappa}^{\max}$. If the banker has granted more loans in the first period, the funding liquidity of second period loans will be too low to pay off first period depositors. Hence the banker has to close the bank at $t = 1$ and operates in the failure mode, $\mathcal{F}$. Depending on whether the restriction on bank lending is binding in the risky mode, the banker prefers the failure mode for a lower loan volume $l_{0,\kappa}^{\max} \leq l_0^{\max}$.

6.3.2 Bank Behavior in the First Period

After determining changes in the banker's investment decision and risk taking behavior in the second period, we are now in a position to determine his optimal behavior at the beginning of the first period, at $t = 0$. As in the preceding section, we first analyze the impact of the capital ratio, κ, on potential restrictions on bank lending, and then discuss changes in the optimal behavior.

The banker's decisions in the first period with respect to the bank's portfolio and capital structure are illustrated in the bank's balance sheet in Figure 6.4. The value of equity, ε_0, is determined by the bank's assets, $l_0 + a_0$, subtracted by the face value of deposits, δ_0. As in the second period, capital requirements demand that the value of equity, ε_0, has to cover at least the share κ of first period loans

$$l_0 + a_0 - \delta_0 \geq \kappa l_0. \tag{6.11}$$

Therefore the face value of deposits is restricted to

$$\delta_0 \leq (1 - \kappa) l_0 + a_0. \tag{6.12}$$

Whether the additional restriction on deposits (6.12) imposes a restriction on bank lending in the first period again depends on κ and the mode of operation. Without any regulation in place, the capital ratio that the banker voluntarily chooses in both the safe and the risky modes depends on the liquidity risk in the economy. A larger liquidity risk, Δ_1, increases the positive cash flow, $\omega_{1,g}$, of first period loans that materializes in an upswing at $t = 1$. Therefore it follows from equation (5.24) that shareholders are willing to provide more capital for a given level of deposits. Again, an increase in equity funds leads to a larger value of equity, given by the LHS of (6.11). In consequence, the capital ratio increases in the liquidity risk, Δ_1, for both the safe and the risky mode. As the banker issues more deposits in the risky mode, the capital ratio of this mode at $t = 0$ is always lower than the capital ratio of the safe mode. We can thus already conclude that the banker will always be able to fulfill a given capital ratio, κ, if the liquidity risk is sufficiently large.

Suppose the banker operates in the safe mode, $\mathcal{S}$, at $t = 0$. We determined the banker's optimization problem in the first period in Subsection 5.3.2. If the restriction on the face value of deposits resulting from capital requirements becomes binding, bank lending will thus be restricted by

$$-\omega_{1,b} l_0 \leq (1 - \kappa) l_0. \tag{6.13}$$

As this restriction does not depend on the loan volume granted in the first period, either bank lending is not restricted at all or operating in the safe mode is not feasible as bank lending is entirely restricted. As long as the cash flow, $\omega_{1,b}$, per unit of first period loans that materializes in the downturn is positive, the banker has financed first period loans solely by equity. In consequence, the banker's capital ratio is equivalent to one, so that a regulatory capital ratio is negligible. If first period loans are partially financed by issuing deposits, $\omega_{1,b}$ will become negative. As long as the share of equity financing that the banker chooses voluntarily is larger than the regulatory capital ratio, κ, (6.13) will always hold. Otherwise, operating in the safe mode will not be feasible. As the regulator has no incentive to prevent the safe mode, we will henceforth assume that $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$ so that bank lending will not be restricted in the safe mode.

Suppose the banker operates in the risky mode, $\mathcal{R}$, at $t = 0$. In this case, capital requirements will always impose a restriction on the face value of deposits as $(1-\kappa)l_0 + a_0 < v_g l_0 + a_0$. Therefore bank lending in the risky mode is restricted to

$$[1-(1-\lambda)p_1 v_g - \lambda p_1(1-\kappa)]l_0 \leq 0. \tag{6.14}$$

The banker will only be able to grant loans in the first period, if the funding liquidity of first period loans remains positive. As capital requirements limit the amount of deposits, the funding liquidity of first period loans in the risky mode is given by $(1-\lambda)p_1 v_g + \lambda p_1(1-\kappa) - 1$. In consequence, the banker's ability to operate in the risky mode at $t = 0$ depends on the capital ratio, κ, and the liquidity risk, Δ_1, that determines the return on first period loans in an upswing at $t = 1$. The funding liquidity will only be positive, if κ is not too large. This ensures that the banker can issue a sufficient deposit volume to co-finance the investment. As the return on first period loans in the upswing, v_g, increases in Δ_1, it follows for a given capital ratio, κ, that the risky mode at $t = 0$ is feasible for all liquidity risks that ensure a positive funding liquidity of first period loans, i.e. for all

$$\Delta_1 \geq \frac{1-\lambda p_1 - (1-\lambda)p_1\mu_1 + \lambda p_1 \kappa}{(1-\lambda)p_1(1-p_1)} =: \Delta^{\mathcal{E}}_{1,\kappa}. \tag{6.15}$$

Accordingly, bank lending is not restricted and the banker's optimal behavior in the risky mode at $t = 0$ remains unchanged. For all $\Delta_1 < \Delta^{\mathcal{E}}_{1,\kappa}$, the risky mode is, however, not feasible.

Suppose the banker operates in the non-lending mode, $\mathcal{N}$, at $t = 0$. By definition this implies that he grants no loans in the first period. In contrast to the failure mode, this option might be beneficial as it allows the banker to grant loans in the second period if the economy is in an upswing at $t = 1$.

Comparing the expected profits for each combination of modes feasible, we obtain:

Proposition 6.6. *If a capital ratio* $\kappa \in (1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}, \min\{1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}, 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}\})$ *is in place and* $\Delta_1 < \overline{\Delta}_1$*, the banker's optimal decisions on the mode of operation,* m*, and bank lending,* l_t*, at* $t = 0$ *and* $t = 1$ *will have the following*

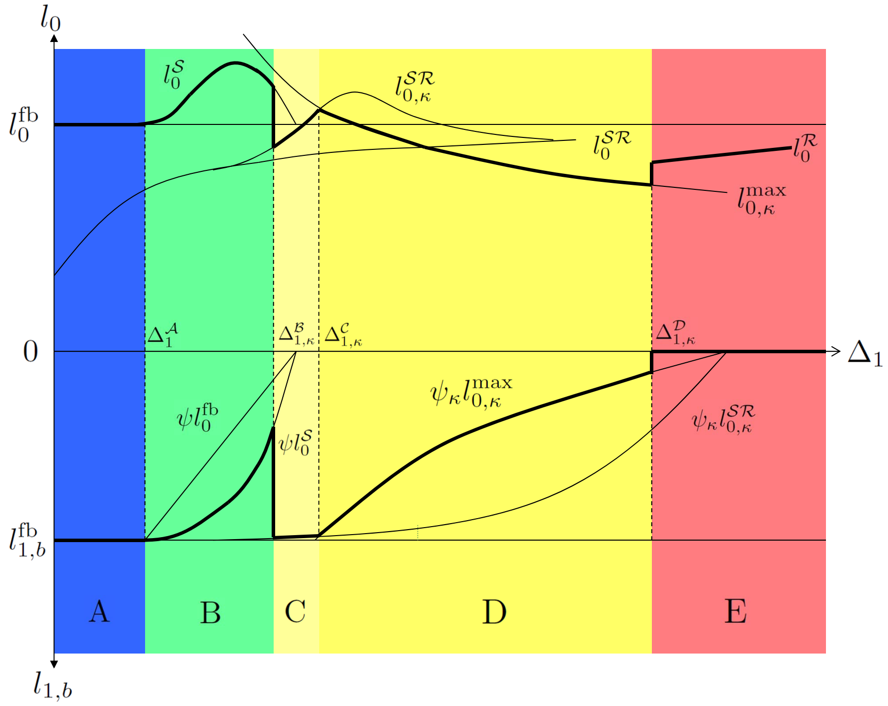

Figure 6.5: Optimal lending and capital structure decision at $t = 0$ and in the bad situation at $t = 1$ with a regulatory capital ratio, κ, in place

properties:

$$
\begin{array}{llllll}
\mathcal{A}: & m^* = \mathcal{SS}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \textit{if} & \Delta_1 \leq \Delta_1^{\mathcal{A}}, \\
\mathcal{B}: & m^* = \mathcal{SS}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \textit{if} & \Delta_1 \in \left(\Delta_1^{\mathcal{A}}, \Delta_{1,\kappa}^{\mathcal{B}}\right], \\
\mathcal{C}: & m^* = \mathcal{SR}, & l_0^* = l_{0,\kappa}^{\mathcal{SR}}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\kappa}^{max}\} & \textit{if} & \Delta_1 \in \left(\Delta_{1,\kappa}^{\mathcal{B}}, \Delta_{1,\kappa}^{\mathcal{C}}\right], \\
\mathcal{D}: & m^* = \mathcal{SR}, & l_0^* = l_{0,\kappa}^{max}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\kappa}^{max}\} & \textit{if} & \Delta_1 \in \left(\Delta_{1,\kappa}^{\mathcal{C}}, \min\{\Delta_{1,\kappa}^{\mathcal{D}}, \Delta_{1,\kappa}^{\psi}\}\right], \\
\mathcal{X}: & m^* = \mathcal{NN}, & l_0^* = 0 < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \textit{if} & \Delta_1 \in \left(\Delta_{1,\kappa}^{\psi}, \Delta_{1,\kappa}^{\mathcal{E}}\right], \\
\mathcal{E}: & m^* = \mathcal{RF}, & l_0^* = l_0^{\mathcal{R}} < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \textit{if} & \Delta_1 > \max\{\Delta_{1,\kappa}^{\mathcal{D}}, \Delta_{1,\kappa}^{\mathcal{E}}\},
\end{array}
$$

with all critical values being defined in the appendix.

Proof. See appendix. □

Imposing capital requirements that never affect bank lending in the safe mode increases financial stability for certain liquidity risks in the economy. Figure 6.5 illustrates Proposition 6.6 for the case that the interval $(\Delta_{1,\kappa}^{\psi}, \Delta_{1,\kappa}^{\mathcal{E}}]$ is empty so that strategy $\mathcal{X}$ is never optimal. As both strategies $\mathcal{A}$ and $\mathcal{B}$ remain unchanged, the banker prefers to operate in the unrestricted safe mode as long as strategy $\mathcal{A}$ is feasible, i.e. for all $\Delta_1 \leq \Delta_1^{\mathcal{A}}$. From a welfare perspective, strategy $\mathcal{A}$ is again the preferred strategy. In contrast to the benchmark obtained in Proposition 5.3, it is striking that bank lending will not only be procyclical in strategy $\mathcal{B}$, when the banker always operates in the safe mode, but also in strategy $\mathcal{C}$, which implies the risky mode in the downturn at $t = 1$ and the unrestricted safe mode in the first period. Recall from Lemma 6.5 that capital requirements might result in a restriction on bank lending in the downturn if the banker operates in the risky mode. Similarly to strategy $\mathcal{B}$, he seeks to ease this restriction on bank lending in the downturn by choosing the optimal loan volume in the first period accordingly. Hence he grants more loans than without regulation in the first period, $l_{0,\kappa}^{\mathcal{SR}} \geq l_0^{\mathcal{SR}}$, in order to reduce potential losses in the downturn.

Deviating from the optimal loan volumes of the benchmark scenario both in the first period and in the downturn leads to a reduction of the banker's expected profit from strategy $\mathcal{C}$. Strategy $\mathcal{B}$ might thus remain more beneficial even for larger liquidity risks. In consequence, if $\Delta_1^{\mathcal{B}} \neq \Delta_1^{\psi}$ and if bank lending is already restricted in the downturn when operating in the risky mode for $\Delta_1^{\mathcal{B}}$, the regulation will entail that the banker switches to the riskier strategy $\mathcal{C}$ at a larger threshold $\Delta_{1,\kappa}^{\mathcal{B}} > \Delta_1^{\mathcal{B}}$. Financial stability will thus increase for all liquidity risks $\Delta_1 \in (\Delta_1^{\mathcal{B}}, \Delta_{1,\kappa}^{\mathcal{B}}]$. If either $\Delta_1^{\mathcal{B}} = \Delta_1^{\psi}$ or if bank lending is not restricted in the risky mode for $\Delta_1^{\mathcal{B}}$, capital requirements will, however, have no impact on financial stability for these liquidity risks.

The impact on financial stability is ambiguous for larger liquidity risks. Strategy $\mathcal{D}$ implies that the banker operates in the risky mode in the downturn, but is restricted in bank lending when operating in the safe mode in the first period. As capital requirements impose an additional restriction on bank lending in the downturn, the restriction on first period loans becomes tighter, i.e. $l_{0,\kappa}^{\max} < l_0^{\max}$. Capital requirements thus result in a decline of the expected profit from strategy $\mathcal{D}$. Accordingly, this strategy becomes less beneficial and the banker might prefer strategy $\mathcal{E}$ for lower liquidity risks. As strategy $\mathcal{E}$ corresponds to a bank run in the downturn at $t = 1$, this would imply a decrease in financial stability. However, due to capital requirements, strategy $\mathcal{E}$ is only feasible for liquidity risks larger than $\Delta_1^{\mathcal{E}}$. If $\Delta_1^{\mathcal{E}} > \Delta_1^{\mathcal{D}}$, the banker will thus have to remain with strategy $\mathcal{D}$ as long as this strategy is feasible, or will prefer strategy $\mathcal{X}$. In the latter case, the banker will grant no loans in the first period and in the downturn so that the bank actually remains stable. If the banker chooses strategy $\mathcal{X}$, this will constitute an increase in financial stability. Moreover, financial stability will increase if the banker prefers strategy $\mathcal{D}$ also for all liquidity risks in the interval of $(\Delta_1^{\mathcal{D}}, \Delta_1^{\mathcal{E}}]$.

In both cases, an increase in financial stability comes at the cost of less efficient bank lending. Moreover, our results support the argument presented in Chapter 2 that risk-weighted capital requirements might amplify procyclical lending.

As the risk-weighted capital ratio yields similar effects to the leverage ratio for this model economy, we neglect this measure in our analysis. Defining the leverage ratio as equity over total exposure, the Basel III Accord suggests a ratio of 3% (BCBS, 2014). In comparison to the risk-weighted capital ratio, the denominator includes all assets and neglects any risk weights. As we only consider two types of assets, a risk-free asset and risky loans, we can set the risk weighting of loans as equal to one. In the absence of a liquidity coverage ratio, the banker has no incentive to invest in the risk-free asset, except maybe in an economic upswing. Accordingly, the leverage ratio in our model is identical to the capital ratio. If the risk weighting on loans was not equal to one, the leverage ratio would simply be a multiple of the capital ratio. In order to differentiate the effects of a leverage ratio and a risk-weighted capital ratio we would thus have to incorporate the possibility of more than two assets.

6.4 Countercyclical Capital Buffer Requirements

In response to the world financial crisis, regulators decided to counteract the procyclicality of risk-weighted capital requirements by augmenting the new Basel III Accord with a countercyclical capital buffer. The aim of larger capital requirements in good times is to tighten banks' lending opportunities and therefore to impede excessive credit growth. Moreover, raising capital might be difficult in bad times. Lower requirements in these times enable banks to use their capital buffers to cover potential losses. Therefore bank lending is supposed to decrease to a lower extent.[4] Switzerland is the only country that has implemented this regulatory measure prematurely. Since September 2013, a countercyclical capital buffer of 1% applies to all mortgage loans taken out in Switzerland. Swiss regulators thus aim to counteract an erroneous trend in their national mortgage market (SNB, 2013a).

Analogously to Section 6.3, we define the bank's capital ratio, κ, as the value of equity over all risky loans. Imposing a countercyclical capital buffer, the banker faces higher capital requirements in normal times, $\kappa_g > \kappa$, and lower capital requirements in bad times, $\kappa_b < \kappa$. As the economic conditions in the first period are relatively

[4] The wording countercyclical capital buffer might be confusing. While this buffer is supposed to have countercyclical effects on bank lending, the buffer itself is cyclical.

prosperous, we assume that the regulatory capital ratio, κ_g, applies for both the upswing at $t = 1$ and for the first period.

The impact of this regulatory measure depends on the magnitude of the countercyclicality, i.e. the difference between the capital ratios in good and bad times. As long as κ_g is low enough, capital requirements will only affect bank lending in the risky mode. In comparison to the capital ratio, κ, of Section 6.3, weakly countercyclical capital buffer requirements have mixed effects with respect to financial stability. A higher capital ratio in the first period implies that the banker is unable to operate in the risky mode, even for larger liquidity risks. As a result, financial stability may increase for these risks. However, a lower capital ratio in the downturn at $t = 1$ loosens the restriction on bank lending when choosing a risky capital structure. Accordingly, a countercyclical capital buffer will dampen the procyclical effect on bank lending that we have identified for risk-weighted capital requirements. This is in line with the findings of Angelini and Gerali and Drehmann and Gambacorta (2012). A lower capital ratio might therefore decrease financial stability for lower liquidity risks, as the expected profit of a risky capital structure in the downturn increases.

In this section we will, however, focus on a more interesting case. Suppose the regulator possesses imperfect information regarding the probabilities of the states and the liquidity risks in the economy.[5] Based on this information, she implements a strongly countercyclical capital buffer, which will not only impose a restriction on bank lending when choosing a risky capital structure, but also when the bank is already safe.[6]

We find that such a strongly countercyclical capital buffer entails undesirable effects for bank lending. If the countercyclicality becomes too strong, the regulation may restrict bank lending by increasing financial instability. For lower liquidity risks, a severe credit crunch will occur in the first period although financial stability is not at risk. Moreover, the banker has to operate in the risky mode in the downturn, as he cannot pledge against first period's investments.

6.4.1 Bank Behavior in the Second Period

We start to analyze the impact of a strongly countercyclical capital buffer in the second period. If the economy is in benign conditions, the bank will face a larger

[5] We provide a more detailed analysis based on information asymmetry in Chapter 7.

[6] As this is a more realistic scenario, it is important to identify economic conditions with the help of adequate proxies. For a discussion regarding reasonable indicators, see e.g. Kashyap *et al.* (2008), Goodhart (2008), Brunnermeier *et al.* (2009) and Repullo and Suarez (2013).

capital ratio, $\kappa_g > \kappa$. In order to reduce complexity, the capital ratio in bad times declines to $\kappa_b = 0$.

Suppose the economy is in an upswing at $t = 1$ so that second period loans will yield a sufficiently large return, r_g, at the end of the second period with certainty. In this situation even larger capital requirements impose no effect. As second period loans are risk-free, the capital ratio can always be fulfilled. Similarly to Lemma 6.4, we can thus conclude:

Lemma 6.7. *If the economy is in an upswing at date $t = 1$ and a countercyclical capital ratio, $\kappa_g > \kappa$, is in place, the banker's optimal decision on the mode of operation, $m_{1,g}$, and bank lending, $l_{1,g}$, will have the following properties:*

$$m^*_{1,g} = \mathcal{S}, \quad l^*_{1,g} = l^{fb}_{1,b} \quad \forall\ l_0. \tag{6.16}$$

Proof. Omitted. □

Suppose the economy is in a downturn at $t = 1$ and the capital ratio is set to zero. The situation in the downturn is thus the same situation as in Chapter 5, in which no regulation is in place. Consequently, we can directly conclude:

Lemma 6.8. *If the economy is in a downturn at date $t = 1$ and a countercyclical capital ratio, $\kappa_b = 0$, is in place, the banker's decision on the mode of operation, $m_{1,b}$, and bank lending, $l_{1,b}$, will have the following properties:*

- *Given $v_b + \omega_{1,b} \geq 0$, then*

$$\begin{aligned} &m^*_{1,b} = \mathcal{S}, \quad l^*_{1,b} = l^{fb}_{1,b} && \text{if } l_0 \geq \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ &m^*_{1,b} = \mathcal{S}, \quad l^*_{1,b} = l^{max}_1 && \text{if } l_0 \in [l^{min}_0, \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ &m^*_{1,b} = \mathcal{R}, \quad l^*_{1,b} = l^{fb}_{1,b} && \text{if } l_0 < l^{min}_0, \end{aligned} \tag{6.17}$$

- *Given $v_b + \omega_{1,b} < 0$, then*

$$\begin{aligned} &m^*_{1,b} = \mathcal{R}, \quad l^*_{1,b} = l^{fb}_{1,b} && \text{if } l_0 \leq l^{max}_0, \\ &m^*_{1,b} = \mathcal{F}, \quad l^*_{1,b} = 0 && \text{if } l_0 > l^{max}_0. \end{aligned} \tag{6.18}$$

Proof. Omitted. □

As argued in Lemma 5.2, the safe mode, $\mathcal{S}$, is feasible as long as the return on nonperforming loans, v_b, is sufficiently large to cover the negative cash flow, $\omega_{1,b}$, that has materialized in the downturn. Moreover, the banker needs funds to close the funding gap of second period loans. In consequence, bank lending in the second period depends on the investment decision made in the first period. If the loan volume granted in the first period is lower than $l_0^{\min}$, the restriction on bank lending will be so tight that the banker will prefer to put the stability of the bank at risk. Operating in the risky mode, $\mathcal{R}$, allows him to issue more deposits, so that the funding liquidity of second period loans becomes positive. He can thus increase bank lending and, therewith, his expected profit.

If the safe mode is not available because the return on first period loans is too low to pay off first period depositors, the banker will have to choose between the risky mode, $\mathcal{R}$, and the failure mode, $\mathcal{F}$. As long as the first period loans are not too large, the second period loans are sufficiently profitable to cover the first period loans' losses. As bank lending is not restricted in the risky mode, the banker is thus able to grant loans according to the first best. If, however, too many loans have been granted in the first period, operating in the risky mode yields a negative expected profit. In consequence, the banker prefers to close the bank at $t = 1$ for all $l_0 > l_0^{\max}$.

6.4.2 Bank Behavior in the First Period

As economic conditions in the first period are sufficiently prosperous, a regulatory capital ratio of $\kappa_g > \kappa$ applies at $t = 0$. Considering a strongly countercyclical capital buffer, this ratio is so large than it may not only affect bank lending in the risky mode but also in the safe mode. It follows from Section 6.3 that a capital ratio of κ_g restricts the face value of deposits to

$$\delta_0 \leq (1 - \kappa_g)l_0 + a_0, \tag{6.19}$$

independent of the mode of operation. We have argued that the bank's capital ratio without any regulation in place increases in the liquidity risk, Δ_1. The larger the liquidity risk with respect to first period loans, the larger is the return on these loans that will materialize in the upswing at $t = 1$. As first period loans are nonperforming in the downturn, shareholders will only receive a payoff in good times. Accordingly, they are willing to provide more funds when they expect a higher payoff in the upswing and the capital ratio increases. This argument applies for both the safe and the risky mode. As the banker will issue more deposits in the latter mode, the capital ratio of the safe mode will always exceed the capital ratio of the risky mode. Hence the capital ratio will only affect bank lending in the safe mode, if the liquidity risk, Δ_1, is low.

Suppose the banker operates according to $\mathcal{SS}$ or $\mathcal{SR}$ so that the capital structure in the first period is safe. If restriction (6.19) becomes binding, we have shown in Section 6.3 that this implies a restriction on bank lending in the first period in the form of

$$-\omega_{1,b} l_0 \leq (1-\kappa_g) l_0. \tag{6.20}$$

Again it holds that the cash flow, $\omega_{1,b} l_0$, which will materialize in the downturn at $t = 1$, will be negative if first period loans are also financed by deposits. For lower liquidity risks debt financing is less crucial as the return on nonperforming loans in the downturn is still rather high. Moreover, shareholders expect a rather low payoff in an upswing. Accordingly, they provide less funds. Imposing a strongly countercyclical capital buffer in the first period $\kappa_g > 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$ thus demands an increase in equity financing, which the banker is unable to fulfill. In consequence, the safe mode will be unfeasible, if the liquidity risk, Δ_1, is lower than

$$\Delta_{1,\kappa_g}^{\mathcal{Y}} := \frac{1-(1-\lambda)p_1\mu_1 - [1-(1-\lambda)p_1](1-\kappa_g)]}{(1-\lambda)p_1(1-p_1)}. \tag{6.21}$$

For all $\Delta_1 > \Delta_{1,\kappa_g}^{\mathcal{Y}}$, first period loans materialize a sufficiently large return in the upswing. This allows the banker to raise enough funds from shareholders to fulfill the capital ratio, κ_g. As (6.20) holds, bank lending will not be restricted.

Suppose the banker operates according to $\mathcal{RF}$ by choosing a risky capital structure at $t = 0$. As the bank's capital ratio in the risky mode is always lower than in the safe mode, the capital ratio, κ_g, will likewise impose a restriction on the risky mode. Based on the elaboration in Section 6.3 we can likewise conclude that operating in the risky mode is only feasible for all liquidity risks

$$\Delta_1 \geq \frac{1-\lambda p_1 - (1-\lambda)p_1\mu_1 + \lambda p_1 \kappa_g}{(1-\lambda)p_1(1-p_1)} =: \Delta_{1,\kappa_g}^{\mathcal{E}}. \tag{6.22}$$

For all $\Delta_1 < \Delta_{1,\kappa_g}^{\mathcal{E}}$ the banker is again unable to operate in the risky mode, $\mathcal{R}$, in the first period. As the banker raises less equity in the risky mode than in the safe mode, independent of the liquidity risk, it follows directly that $\Delta_{1,\kappa_g}^{\mathcal{E}} > \Delta_{1,\kappa_g}^{\mathcal{Y}}$.

Suppose the banker operates according to $\mathcal{NR}$ by granting no loans in the first period. Any regulatory capital ratio in the first period can then be fulfilled, so that this mode is always feasible. In contrast to the previous cases of the non-lending mode in the first period, a capital ratio of zero allows the banker to still operate in the risky mode in the downturn. Although he cannot pledge against bank assets of the first period, the funding liquidity of second period loans is sufficiently large. Hence he grants loans according to the first best.

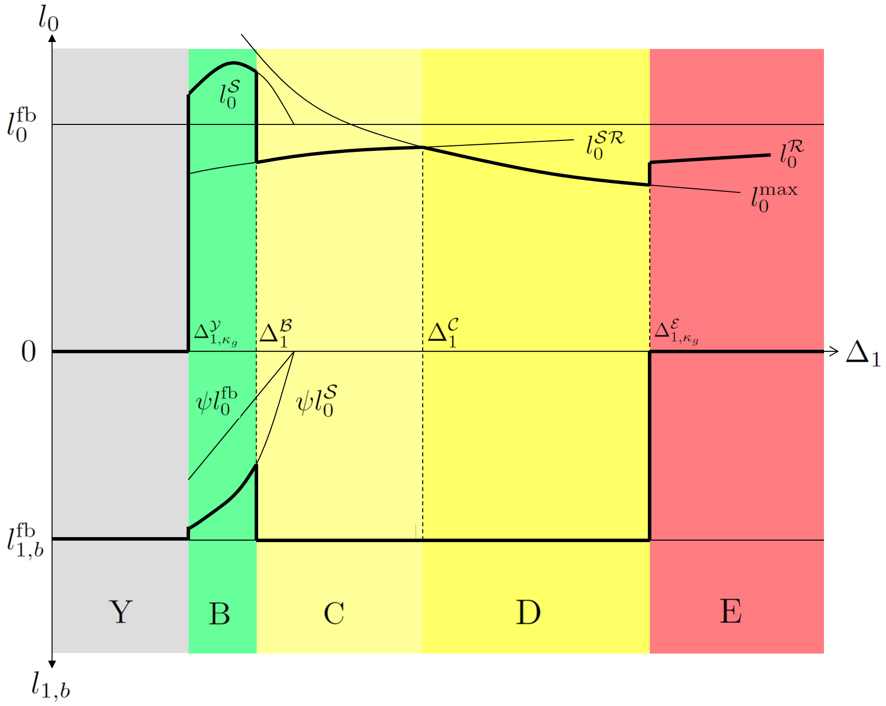

Figure 6.6: Optimal lending and capital structure decision at $t = 0$ and in the bad situation at $t = 1$ with a strongly countercyclical regulatory capital ratio in place

Comparing the expected profits for each combination of modes feasible, we obtain:

Proposition 6.9. *If a countercyclical capital ratio with $\kappa_b = 0 < \kappa$ in the downturn at $t = 1$ and $\kappa_g > \kappa$ otherwise is in place and $\Delta_1 < \overline{\Delta}_1$, the banker's optimal decisions on the mode of operation, m, and bank lending, l_t, at $t = 0$ and $t = 1$ will have the following properties:*

$$\begin{array}{lllll}
\mathcal{Y}: & m^* = \mathcal{NR}, & l_0^* = 0 < l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \;\; \Delta_1 \leq \Delta_{1,\kappa_g}^{\mathcal{Y}}, \\
\mathcal{A}: & m^* = \mathcal{SS}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \;\; \Delta_1 \in \left(\Delta_{1,\kappa_g}^{\mathcal{Y}}, \Delta_1^{\mathcal{A}}\right], \\
\mathcal{B}: & m^* = \mathcal{SS}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} & \text{if} \;\; \Delta_1 \in \left(\max\{\Delta_{1,\kappa_g}^{\mathcal{Y}}, \Delta_1^{\mathcal{A}}\}, \Delta_1^{\mathcal{B}}\right], \\
\mathcal{C}: & m^* = \mathcal{SR}, & l_0^* = l_0^{\mathcal{SR}} < l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \;\; \Delta_1 \in \left(\max\{\Delta_{1,\kappa_g}^{\mathcal{Y}}, \Delta_1^{\mathcal{B}}\}, \Delta_1^{\mathcal{C}}\right], \\
\mathcal{D}: & m^* = \mathcal{SR}, & l_0^* = l_0^{max}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \;\; \Delta_1 \in \left(\max\{\Delta_{1,\kappa_g}^{\mathcal{Y}}, \Delta_1^{\mathcal{C}}\}, \max\{\Delta_1^{\mathcal{D}}, \Delta_{1,\kappa_g}^{\mathcal{E}}\}\right], \\
\mathcal{E}: & m^* = \mathcal{RF}, & l_0^* = l_0^{\mathcal{R}} < l_0^{fb}, & l_{1,b}^* = 0 & \text{if} \;\; \Delta_1 > \max\{\Delta_1^{\mathcal{D}}, \Delta_{1,\kappa_g}^{\mathcal{E}}\},
\end{array}$$

with all critical values being defined in the appendix.

Proof. See appendix. □

Implementing a strongly countercyclical capital buffer has two effects. Financial stability might increase for larger liquidity risks. However, for small liquidity risks, Proposition 6.9 identifies a distintermediation, which is also illustrated in Figure 6.6.

For small liquidity risks, Δ_1, a strongly countercyclical capital buffer will result in a total disruption of bank lending in the first period. If the banker is unable to fulfill the large capital ratio, κ_g, when operating in the safe mode, he will be also unable to operate in the risky mode. Accordingly, the banker cannot grant any loans at all but has to wait until the end of the first period. If the economic conditions turn out to be good, he will again operate in the unrestricted safe mode. However, if a downturn emerges, the banker will possesse no assets to pledge against while the funding liquidity of a safe capital structure will be negative. In consequence, the safe mode is unavailable in the downturn. The banker can only operate in the risky mode and grants loans according to the first best. We denote this strategy by $\mathcal{Y}$.

Recall from Chapter 5 that the banker prefers a safe capital structure over the business cycle for smaller liquidity risks. Depending on whether bank lending is restricted in the downturn, the banker will thus either choose strategy $\mathcal{A}$ or $\mathcal{B}$. If the implementation of a strongly countercyclical capital buffer cuts back lending while increasing the threat to the stability of the bank, disintermediation prevails. The larger the capital ratio in good times, and therefore also the threshold of liquidity risk $\Delta_{1,\kappa_g}^{\mathcal{Y}}$, the stronger this effect is.

For all liquidity risks above $\Delta_{1,\kappa_g}^{\mathcal{Y}}$ operating in the safe mode is feasible in the first period without any additional restriction on bank lending. Considering no capital ratio in the downturn thus implies that strategy $\mathcal{A}$, $\mathcal{B}$, $\mathcal{C}$ and $\mathcal{D}$ are identical to the strategies presented in Chapter 5. Accordingly, the thresholds of liquidity risks for which the banker switches from one strategy to another remains unchanged. The banker will thus put the stability of the bank at risk for all liquidity risks above $\Delta_1^{\mathcal{B}}$. For all liquidity risks above $\Delta_1^{\mathcal{C}}$ the banker has to cut back bank lending in the first period to $l_0^{\max}$ in order to maintain a nonnegative expected profit over the business cycle.

If the regulatory capital ratio in the first period is sufficiently high, countercyclical capital buffer requirements will increase financial stability for larger liquidity risks. In this case, operating in the risky mode is not feasible and the banker can only choose strategy $\mathcal{E}$ for liquidity risks larger than $\Delta_{1,\kappa_g}^{\mathcal{E}}$. While strategy $\mathcal{E}$ results in a bank run early, in the downturn at $t = 1$, strategy $\mathcal{D}$ will impose a threat to the stability of the bank only if the economy runs into a recession at $t = 2$. Accordingly, financial stability will increase if the banker chooses strategy $\mathcal{D}$ also for larger liquidity risks $\Delta_1 \in (\Delta_1^{\mathcal{D}}, \Delta_{1,\kappa_g}^{\mathcal{E}}]$.

Identifying the disintermediation of regulatory intervention for lower liquidity risks, our results support the argument of Caprio (2010) that banks might be unable to take sufficiently large risks to compensate their shareholders if the regulatory capital ratio is too large. In this case, the banker cannot credibly commit himself to pay shareholders a payoff above their expected profit. In consequence, he is unable to raise enough equity to fulfill the capital requirement. As long as the liquidity risks of first period loans are exogenous, the banker is unable to increase the risks of bank assets, which would allow him to raise more funds from shareholders.

6.5 Liquidity Coverage Ratio

The Basel III Accord furthermore includes a liquidity coverage ratio to ensure that a certain share of banks' liabilities is covered by liquid assets. The aim of this liquidity ratio is to enable banks to survive a predefined stress scenario for a certain time. This provides extra time for regulators to consider further policy measures. In detail, the liquidity coverage ratio in the Basel III Accord is defined as stock of high quality liquid assets over net cash outflows over a 30-day time period (BCBS, 2010).

We transfer this measure into our setting as follows. Denoting the regulatory liquidity coverage ratio by η, we define this ratio as $\eta := \frac{a_t}{\delta_t}$. Therefore the liquidity coverage ratio captures the share of risk-free assets in the face value of deposits. If this ratio is equal to or larger than one, the bank in our model economy will never default. The return on risk-free assets is always sufficiently large to pay off all depositors. However, such a large liquidity coverage ratio is not needed to ensure financial stability. Nonperforming loans will always materialize a nonnegative return, even if the economy runs into a recession at $t = 2$. A liquidity coverage ratio below one is thus sufficient for our model economy.

The Basel III Accords demands a ratio larger than one. However, this ratio is based on the assumption that not all depositors will withdraw their funds within 30 days, e.g. due to a prevailing deposit insurance or confirmations by the government that deposits are safe. Therefore the Basel III Accord considers only a fraction of the face value of deposits when determining the liquidity coverage ratio. As our definition thus yields a lower liquidity coverage ratio, focusing on the range of $\eta \in (0, 1)$ is sufficient to analyze the impact of this regulatory measure.

In order to identify the effect of the liquidity coverage ratio, we abstract from any additional capital requirements in this section. Combining both measures is, however, not too complex. Similarly to capital requirements, the liquidity coverage ratio will impose a restriction on the face value of deposits. Hence the bank will satisfy all regulatory measures at the same time, if the measure with the strongest restriction on deposits is fulfilled.

The liquidity coverage ratio has a similar impact to the risk-weighted capital requirements. Restricting bank lending when the banker operates in the risky mode generates two effects. The banker will compensate a potential restriction in the downturn by increasing bank lending ex ante. Hence bank lending might also become procyclical for a risky capital structure. However, the deviation of the original lending pattern reduces the banker's expected profit when operating in the risky mode. As this mode becomes less beneficial, the banker will prefer a safe capital also for a larger interval of liquidity risks and financial stability will increase.

6.5.1 Bank Behavior in the Second Period

We begin our analysis of the impact of a liquidity coverage ratio $\eta \in (0, 1)$ by determining the banker's optimal behavior in the second period. In order to identify the direct impact of this regulatory measure, we neglect any additional capital requirements.

Suppose the economy is in an upswing at $t = 1$, as first period loans materialize a high return, v_g. In this situation second period loans will yield a positive net return at the end of the second period with certainty. If the banker operates in the safe mode, investing in the risk-free asset, $a_{1,g}$, will thus yield a zero net return. In order to fulfill the regulatory liquidity coverage ratio, the banker simply issues more deposits, which are invested in this risk-free asset. This balance sheet extension has no impact on the banker's ability to grant loans but increases the share of investments in the risk-free asset. Similarly to both capital requirements, the banker therefore has no need to change his optimal behavior in the upswing and we obtain:

Lemma 6.10. *If the economy is in an upswing at date $t = 1$ and a liquidity coverage ratio, η, is in place, the banker's optimal decision on the mode of operation, $m_{1,g}$, and bank lending, $l_{1,g}$, will have the following properties:*

$$m^*_{1,g} = \mathcal{S}, \quad l^*_{1,g} = l^{fb}_{1,b} \quad \forall\ l_0. \tag{6.23}$$

Proof. Omitted. □

Suppose the economy is in a downturn at $t = 1$, so that the materialized cash flow of first period's investments turns out to be negative. In this situation the banker has to use some funds to pay off first period depositors. Hence these funds are not available to invest in the risk-free asset.

If the banker operates in the safe mode, this will constitute no problem. As with the safe mode in the upswing, the expected profit of the risk-free asset is non-negative. The banker will thus again extend the balance sheet by issuing more deposits, which are invested in the risk-free asset. Consequently, any liquidity coverage ratio will be fulfilled without resulting in an additional restriction on bank lending.

However, the liquidity coverage ratio will impose a restriction on bank lending if the banker operates in the risky mode. Recall from Chapter 5 that the risky mode will result in a bank run if the economy runs into a recession at $t = 2$. This implies that all values are destroyed, even the value of risk-free assets. Accordingly, the expected profit of the risk-free asset when operating in the risky mode becomes negative, i.e. $p_2 - 1 < 0$. In the absence of any regulatory measure, the banker will thus invest no funds in the risk-free asset. However, this behavior leads to a liquidity coverage ratio of zero. Therefore any regulatory liquidity coverage ratio demands that a share of funds has to be invested in the risk-free asset. The liquidity coverage ratio hence restricts the face value of deposits to

$$\delta_{1,b} \leq \frac{a_{1,b}}{\eta}. \tag{6.24}$$

This restriction will become binding if it is tighter than $v_b l_0 + r_b l_{1,b} + a_{1,b}$. Suppose the restriction on the face value of deposits, (6.24), is binding. Then bank lending in the risky mode is restricted to

$$[1 - (1-\lambda)p_2 r_b]\, l_{1,b} \leq [(1-\lambda)p_2 v_b + \omega_{1,b}]\, l_0 + \left[\frac{1-\eta}{\eta} - (1-p_2)\right] a_{1,b}. \tag{6.25}$$

As the face value of deposits is restricted by the investment in the risk-free asset, the funding liquidity of second period loans when operating in the risky mode becomes negative. In order to close the funding gap $(1-\lambda)p_2 r_b - 1$, the banker has to pledge against nonperforming loans and the risk-free asset. The funding liquidity of delayed first period loans when operating in the risky mode $(1-\lambda)p_2 v_b$ will be lower than in the safe mode if the banker can only raise equity but no deposits against these loans. Accordingly, the restriction on bank lending in the risky mode will only be less tight than in the safe mode if an investment in the risk-free asset results in an easing of this restriction. Such an effect will only be feasible if the liquidity coverage ratio is not too large. For all $\eta < \frac{\lambda p_2}{1-(1-\lambda)p_2}$ the funding liquidity of the risk-free asset remains positive, although the expected profit of this asset, $1 - p_2$, is negative. The lower the liquidity coverage ratio, the less tight is the restriction on the face value of deposits (6.24). The banker can thus use the additional deposits in the amount of $\frac{1-\eta}{\eta}a_{1,b}$ to close the funding gap of second period loans. For all $\eta \geq \frac{\lambda p_2}{1-(1-\lambda)p_2}$, the restriction on deposits is too tight. In this case, the banker would have to use equity to invest in the risk-free asset in order to fulfill the regulatory liquidity coverage ratio. As these funds are then not available to finance second period loans, bank lending will be restricted even further. In consequence, the banker would prefer not to invest in the risk-free asset. This would restrict the face value of deposits to zero, which implies that the banker chooses a safe, instead of a risky capital structure.

Obviously, the liquidity coverage ratio will impose no effect on the banker in the failure mode and in the non-lending mode. In both cases, the banker grants no loans in the downturn. Issuing deposits is only necessary in the non-lending mode to pay off first period depositors. As η is lower than one, the banker can again issue additional deposits, which are invested in the risk-free asset to ensure that the liquidity coverage ratio is fulfilled. As in the safe mode, this will only result in a balance sheet extension.

Comparing the expected profit of all modes available in the downturn at $t = 1$, we obtain:

Lemma 6.11. *If the economy is in a downturn at date $t = 1$ and a liquidity coverage ratio $\eta < \frac{\lambda p_2}{1-(1-\lambda)p_2}$ is in place, the banker's decision on the mode of operation, $m_{1,b}$, and bank lending, $l_{1,b}$, will have the following properties:*

- *Given $v_b + \omega_{1,b} \geq 0$, then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{fb}_{1,b} & \text{if } l_0 \geq \frac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} = \mathcal{S}, & l^*_{1,b} = l^{max}_1 & \text{if } l_0 \in [l^{min}_{0,\eta}, \frac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} = \mathcal{R}, & l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\eta}\} & \text{if } l_0 \leq l^{min}_{0,\eta}, \end{array} \tag{6.26}$$

- *Given $v_b + \omega_{1,b} < 0$, then*

$$\begin{array}{lll} m^*_{1,b} = \mathcal{R}, & l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\eta}\} & \text{if } l_0 \leq l^{max}_{0,\eta}, \\ m^*_{1,b} = \mathcal{F}, & l^*_{1,b} = 0 & \text{if } l_0 > l^{max}_{0,\eta}, \end{array} \tag{6.27}$$

with $l^{max}_{0,\eta} := -\frac{\phi^{\mathcal{R}}_{1,b}\left(\min\{l^{fb}_{1,b}, l^{max}_{1,\eta}\}\right)-(1-p_2)a_{1,b}}{p_2 v_b+\omega_{1,b}}$ and $l^{max}_{1,\eta} := \frac{(1-\lambda)p_2 v_b+\omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0 + \frac{\frac{1-\eta}{\eta}-(1-p_2)}{1-(1-\lambda)p_2 r_b} a_{1,b}$ while $l^{min}_{0,\eta}$ is implicitly defined by

$$(1-p_2)(v_b l_0 + a_{1,b}) + \phi^{\mathcal{S}}_{1,b}\left(l^{max}_1(l_0)\right) = \phi^{\mathcal{R}}_{1,b}(\min\{l^{fb}_{1,b}, l^{max}_{1,\eta}(l_0)\}). \tag{6.28}$$

Proof. See appendix. □

As long as the liquidity coverage ratio is not too large, it will result in a restriction on bank lending in the risky mode, $\mathcal{R}$, but will not prevent this mode entirely. Accordingly, this lemma has a similar pattern to both the risk-weighted capital requirements and the countercyclical capital buffer requirements. If the return on nonperforming loans is sufficiently large that $v_b + \omega_{1,b} > 0$, the banker may use these funds to pay off first period depositors and will thus never close the bank in the downturn. As the liquidity coverage ratio imposes a restriction on bank lending in the risky mode, it follows that both the restriction in the safe mode, $\mathcal{S}$, and in the risky mode, $\mathcal{R}$, become less tight as the volume of first period loans increases. In comparison to the benchmark scenario, the restriction on bank lending in the risky mode will lead to a decline in the banker's expected profit. Therefore the banker might prefer the safe mode, $\mathcal{S}$, even for a lower loan volume, $l_{0,\eta}^{\min} < l_0^{\min}$. Note, however, that despite the restriction on bank lending, the risky mode will be feasible for all l_0. As the liquidity coverage ratio is not too large, the banker is always able to loosen the restriction on bank lending by investing in the risk-free asset. Therefore he is always able to grant some loans in the downturn so that the non-lending mode is never optimal.

If the return on first period loans is too low, i.e. $v_b + \omega_{1,b} < 0$, the safe mode is unavailable. The banker will thus prefer the risky mode, $\mathcal{R}$, over the failure mode, $\mathcal{F}$, as long as the risky mode generates a nonnegative expected profit. The expected profit in the risky mode declines as first period loan volume increases. If first period loans exceed $l_{0,\eta}^{\max}$, the return on second period loans is too low to compensate losses resulting from the investment in first period loans. In consequence, the banker will close the bank in the downturn for all $l_0 > l_{0,\eta}^{\max}$. If the restriction on bank lending in the downturn when operating in the risky mode is binding, this threshold will be even lower than in the benchmark case, i.e. $l_{0,\eta}^{\max} \leq l_0^{\max}$.

Suppose the liquidity coverage ratio is so large that the risky mode is not feasible at all, i.e. $\eta \geq \frac{\lambda p_2}{1-(1-\lambda)p_2}$. The banker will then prefer the safe mode for all $l_0 > 0$. For $l_0 = 0$ he will operate in the non-lending mode, $\mathcal{N}$. If the safe mode is not available, the banker has to close the bank in the downturn for all $l_0 > 0$. If he has granted no loans in the first period, the banker will again operate in the non-lending mode.

6.5.2 Bank Behavior in the First Period

Taking into account the banker's decision on bank lending and risk taking in the second period, we are now able to identify the banker's behavior in the first period. As long as the liquidity coverage ratio is not too large, all modes are feasible in the first period.

Suppose the banker operates according to $\mathcal{SS}$ or $\mathcal{SR}$, so that the capital structure in the first period is safe. Bank lending in the safe mode is again independent of the investment in risk-free assets. Accordingly, the banker issues additional deposits at the beginning of the first period and extends the bank's balance sheet to fulfill the liquidity coverage ratio. The liquidity coverage ratio will thus not affect bank lending if the capital structure of the bank remains safe.

This will change, if the banker operates according to $\mathcal{RF}$ by choosing a risky capital structure in the first period. With a liquidity coverage ratio in place, the face value of deposits is then restricted to

$$\delta_0 \leq \frac{a_0}{\eta}. \tag{6.29}$$

This imposes a trade-off with respect to the investment in the risk-free asset. As the bank will be closed in the downturn at $t = 1$, the expected profit of the risk-free asset a_0 will reduce to $p_1 - 1 < 0$. In the absence of any regulatory measure, investing in the risk-free asset is thus not profitable. However, if the banker forbears from investing in the risk-free asset, this will curtail bank lending entirely. Considering the restriction on the face value of deposits (6.29), bank lending in the first period when operating in the risky mode is restricted to

$$[1 - (1 - \lambda)p_1(\mu_1 - p_1\Delta_1)]l_0 \leq \left[\frac{1-\eta}{\eta}\lambda p_1 - (1 - p_1)\right] a_0. \tag{6.30}$$

Suppose the banker issues no deposits, as $a_0 = 0$, so that first period loans are solely financed by equity. Such a behavior results in a negative funding liquidity of first period loans as $(1 - \lambda)p_1(\mu_1 - p_1\Delta_1) < 1$, see the LHS of (6.30). Granting first period loans will therefore only be feasible, if the banker issues deposits to close the funding gap, $1 - (1 - \lambda)p_1(\mu_1 - p_1\Delta_1)$. However, issuing deposits demands that the share η has to be invested in the risk-free asset, a_0. The banker will issue deposits if this eases the restriction on bank lending in the first period. This will only be the case, if the liquidity coverage ratio is not too large. An $\eta < \frac{\lambda p_1}{1-(1-\lambda)p_1}$ ensures that the advantage of loosening the restriction on bank lending in the first period, by investing a share of deposits in the risk-free asset, $\frac{1-\eta}{\eta}\lambda p_1$, exceeds the expected loss

$1 - p_1$ of this investment. Accordingly, the banker can ease the restriction on bank lending by issuing more deposits, which are partially invested in the risk-free asset. The remaining deposits are used to close the funding gap of first period loans.

Suppose the banker operates in the non-lending mode by granting no loans at $t = 0$. While this will yield a zero net return at the end of the first period with certainty, it allows the bank to survive the first period and maybe to invest in the second period.

Comparing the expected profits of all combined modes, we obtain:

Proposition 6.12. *If a liquidity coverage ratio* $\eta < \min\{\frac{\lambda p_1}{1-(1-\lambda)p_1}, \frac{\lambda p_2}{1-(1-\lambda)p_2}\}$ *is in place and* $\Delta_1 < \overline{\Delta}_1$*, the banker's optimal decisions on the mode of operation,* m*, and bank lending,* l_t*, at* $t = 0$ *and* $t = 1$ *will have the following properties:*

$$\begin{array}{llllll}
\mathcal{A}: & m^* = \mathcal{SS}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} & \Delta_1 \leq \Delta_1^{\mathcal{A}}, \\
\mathcal{B}: & m^* = \mathcal{SS}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \text{if} & \Delta_1 \in \left(\Delta_1^{\mathcal{A}}, \Delta_{1,\eta}^{\mathcal{B}}\right], \\
\mathcal{C}: & m^* = \mathcal{SR}, & l_0^* = l_{0,\eta}^{\mathcal{SR}}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\eta}^{max}\} & \text{if} & \Delta_1 \in \left(\Delta_{1,\eta}^{\mathcal{B}}, \Delta_{1,\eta}^{\mathcal{C}}\right], \\
\mathcal{D}: & m^* = \mathcal{SR}, & l_0^* = l_{0,\eta_{\mathcal{SR}}}^{max}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\eta}^{max}\} & \text{if} & \Delta_1 \in \left(\Delta_{1,\eta}^{\mathcal{C}}, \Delta_{1,\eta}^{\mathcal{D}}\right], \\
\mathcal{E}: & m^* = \mathcal{RF}, & l_0^* = \min\{l_0^{\mathcal{R}}, l_{0,\eta_{\mathcal{RF}}}^{max}\} < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \text{if} & \Delta_1 > \Delta_{1,\eta}^{\mathcal{D}},
\end{array}$$

with all critical values being defined in the appendix.

Proof. See appendix. □

As the liquidity coverage ratio never affects bank lending in the safe mode but always restricts bank lending in the risky mode, the proposition and its graphical illustration in Figure 6.7 show that financial stability may increase for certain liquidity risks. The banker again prefers strategy $\mathcal{A}$ as long as the restriction on bank lending in the downturn is not binding, i.e. for all $\Delta_1 \leq \Delta_1^{\mathcal{A}}$. As financial stability is never at risk when the banker chooses strategy $\mathcal{A}$, this constitutes the preferred strategy from a welfare perspective.

Similarly to the fixed capital requirements discussed in Section 6.3, a binding restriction on bank lending in the downturn at $t = 1$ when operating in the risky mode will induce procyclical lending for strategy $\mathcal{C}$. As the banker deviates from the optimal bank lending, both in the first period and in the downturn, the expected profit from strategy $\mathcal{C}$ declines. If bank lending in the risky mode is already restricted for $\Delta_1^{\mathcal{B}}$, the banker will prefer strategy $\mathcal{B}$ over strategy $\mathcal{C}$ even for larger liquidity risks. In this case financial stability will increase for all $\Delta_1 \in (\Delta_1^{\mathcal{B}}, \Delta_{1,\eta}^{\mathcal{B}}]$ compared with the benchmark scenario of Proposition 5.3. If, however, the restriction on bank lending in the risky mode becomes binding only for liquidity risks larger than $\Delta_1^{\mathcal{B}}$, or if the banker already prefers strategy $\mathcal{B}$ over strategy $\mathcal{C}$ for all liquidity risks for which strategy $\mathcal{B}$ is feasible, i.e. $\Delta_1^{\mathcal{B}} = \Delta_1^{\psi}$, the liquidity coverage ratio will not improve financial stability for these lower liquidity risks.

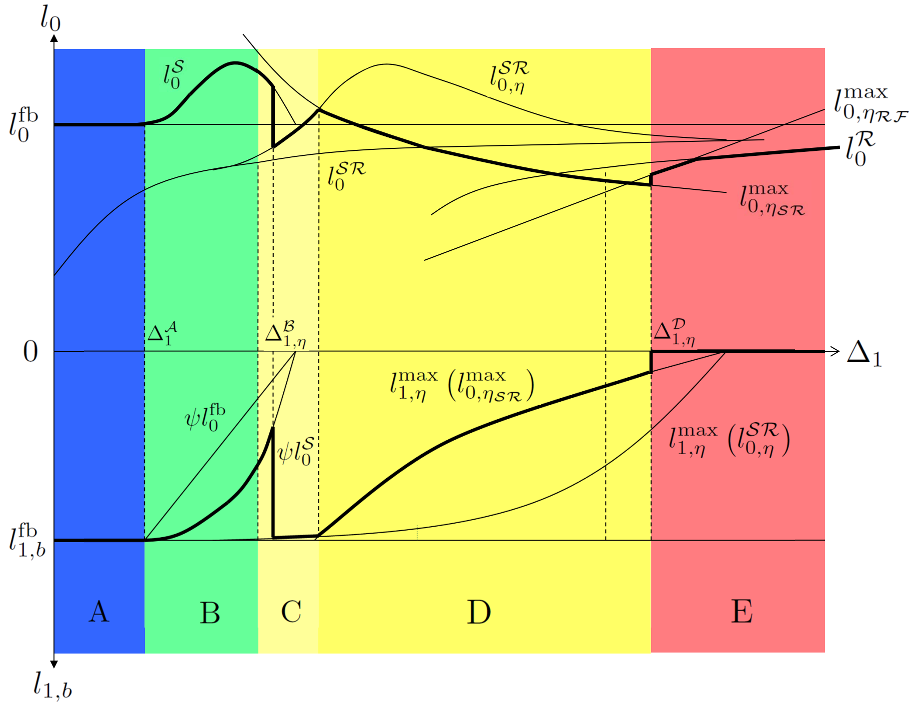

Figure 6.7: Optimal lending and capital structure decision at $t = 0$ and in the bad situation at $t = 1$ with a liquidity coverage ratio, η, in place

The impact on financial stability is ambiguous for larger liquidity risks, as the liquidity coverage ratio restricts bank lending in the risky mode both in first period and in the downturn at $t = 1$. Suppose the banker operates according to strategy $\mathcal{D}$, which implies a risky capital structure in the downturn. If the restriction on bank lending becomes binding in the downturn at $t = 1$, bank lending will also decline in the first period. In order to ensure that the expected profit from strategy $\mathcal{D}$ remains nonnegative, bank lending in the first period is restricted to $l_{0,\eta\mathcal{SR}}^{max} \leq l_0^{max}$. Accordingly, the expected profit from strategy $\mathcal{D}$ declines compared with the benchmark scenario. Suppose the banker operates according to strategy $\mathcal{E}$, which implies a risky capital structure already in the first period. This will lead to a bank run if the economic conditions turn out to be poor at $t = 1$. If the restriction of bank lending resulting from the liquidity coverage ratio is binding in the first period, the expected profit of strategy $\mathcal{E}$ will likewise be lower than in the benchmark case. Accordingly, financial stability increases or decreases depending on the relative changes of the expected profits of both strategies. Bank lending in the first period will not be restricted for strategy $\mathcal{E}$ if the liquidity risks are sufficiently large. In this case, shareholders provide more funds, so that the funding gap of first period loans is relatively low. Financial stability will therefore decline if the threshold, $\Delta_1^{\mathcal{C}}$, of the benchmark scenario is quite large. In this case, the liquidity coverage ratio will impose a larger loss on strategy $\mathcal{D}$ than on strategy $\mathcal{E}$ so that the banker will prefer strategy $\mathcal{E}$ for lower liquidity risks $\Delta_{1,\eta}^{\mathcal{C}} < \Delta_1^{\mathcal{C}}$.

Suppose the liquidity coverage ratio is larger than both $\frac{\lambda p_1}{1-(1-\lambda)p_1}$ and $\frac{\lambda p_2}{1-(1-\lambda)p_2}$. In this case operating in the risky mode is not available, either in the first period or in the downturn at $t = 1$. Accordingly, the banker will operate according to strategy $\mathcal{A}$ and strategy $\mathcal{B}$ as long as these strategies are feasible. For all $\Delta_1 > \Delta_1^{\psi}$ the safe mode is no longer feasible in the downturn and the banker will have to operate according to strategy $\mathcal{X}$. He will thus always choose the non-lending mode except for the upswing at $t = 1$. Accordingly, the result is identical to the effect of the margin call. Financial stability is achieved for all liquidity risks, but at the cost of a severe credit crunch for all $\Delta_1 > \Delta_1^{\psi}$. This is in line with the findings of De Nicolò *et al.* (2014) who argue that liquidity requirements may hamper banks' maturity transformation to a point where bank lending becomes safe but highly inefficient.

The Basel III Accord considers the implementation of a liquidity coverage ratio in combination with the capital requirements presented above. As all regulatory measures impose a restriction on the face value of deposits, the combination of these measures is not too complex. Pivotal is always the tightest restriction on the face value of deposits. As long as this restriction is fulfilled, all other regulatory measures are achieved as well. We would thus obtain a combination of the different propositions when analyzing all regulatory measures simultaneously.

We find that the liquidity coverage ratio might likewise increase financial stability at the cost of less efficient bank lending. As operating in the risky mode in the downturn might be accompanied by a binding restriction on bank lending, procyclical lending might again occur, not only for a safe capital structure but also when the banker puts the stability of the bank at risk. In order to reduce this procyclical effect, Perotti and Suarez (2011) suggest implementing liquidity requirements that are larger in good times and lower in bad times. In our model larger liquidity requirements in good times will only result in an artificial demand for risk-free assets. Lowering liquidity requirements in an economic downturn will reduce procyclical lending but will likewise increase financial instability for certain liquidity risks.

6.6 Discussion

After determining the impact of the four regulatory measures on the trade-off between financial stability and efficient bank lending, we are now in a position to compare these measures. Although all measures are able to increase financial stability for certain liquidity risks, they impose varying effects on bank lending. Note that our results are constrained efficient. Accordingly, regulatory intervention never constitutes a Pareto improvement but will always result in dead weight losses. Assuming that social costs of financial crises are severe, a regulator is incentivized to achieve financial stability, but at the lowest cost with respect to cutting back bank lending.

Without any regulation in place, the banker prefers financial stability over the business cycle as long as choosing a safe capital structure yields the highest expected profit, i.e. for all $\Delta_1 \leq \Delta_1^{\mathcal{B}}$. Suppose the banker prefers the safe capital structure, and thus strategy $\mathcal{A}$ or $\mathcal{B}$, as long as the safe mode is available, i.e. up to $\Delta_1^{\mathcal{B}} = \Delta_1^{\psi}$. In this case, no regulatory measure is able to increase financial stability for liquidity risks above $\Delta_1^{\mathcal{B}}$. Regulation might thus only add up if the banker prefers financial stability only for $\Delta_1^{\mathcal{B}} < \Delta_1^{\psi}$.

All regulatory measures impose a restriction on bank lending in the downturn when operating in the risky mode, except for the strongly countercyclical capital buffer requirements. If this restriction becomes binding, the expected profit of the risky capital structure declines and imposing a threat to financial stability becomes less attractive. Accordingly, the expected profit from strategy $\mathcal{C}$ will decrease for $\Delta_1^{\mathcal{B}}$ if the restriction on bank lending is binding for this liquidity risk. In this case, choosing a safe capital structure, and thus strategy $\mathcal{B}$, yields a higher expected profit. Consequently, financial stability will increase for some liquidity risks above $\Delta_1^{\mathcal{B}}$.

For larger liquidity risks, the regulator aims to increase financial stability by incentivizing the banker to maintain a safe capital structure at least in the first period. While strategy $\mathcal{D}$ will impose a threat to financial stability only if the economy runs into a recession at $t = 2$, financial instability will occur in the downturn if the banker chooses strategy $\mathcal{E}$. As both strategies incorporate the risky mode at some point, the implementation of any regulatory measure will reduce the expected profit for both strategies. Therefore financial stability might not necessarily increase for larger liquidity risks. While the effect is unambiguous for strongly countercyclical capital buffer requirements and the margin call, it depends on the specification of risk-weighted capital requirements and the liquidity coverage ratio.

All regulatory measures analyzed in this chapter differ in their restriction on the face value of deposits, and therefore in their restriction on bank lending. Given that the regulator possesses the same information as all other market participants, she is able to observe the factual liquidity risk in the economy, the critical values that mark a shift in the banker's optimal strategies and the potential restrictions of bank lending for each regulatory measure. Hence she will prefer the regulatory measure that is able to achieve financial stability for the respective liquidity risk at the lowest cutback in bank lending. However, in reality we observe two obstacles.

First, implementing new regulatory measures typically takes time and is associated with transition costs.[7] Accordingly, switching from one measure to another based on the currently prevailing liquidity risk in the economy does not constitute an optimal solution. In consequence, the regulator has to choose the regulatory measure that achieves financial stability for the liquidity risks that she considers most likely to occur in the future. If she aims to achieve financial stability at all times, or most of the time, both the margin call and a sufficiently large liquidity coverage ratio seem to be advisable. Both regulatory measures will prevent risky capital structures at all times. However, such a strong regulatory intervention may be accompanied by a severe credit crunch for large liquidity risks, as bank lending will be totally disrupted.

Second, the regulator may possess less information regarding business cycle fluctuations than other market participants. We highlighted the problem resulting from asymmetric information for the countercyclical capital buffer requirements in Subsection 6.4. Although we have not explicitly analyzed the impact of asymmetric information for the other regulatory measures, similar effects may emerge. Analogously to the countercyclical capital buffer requirements, an overly large risk-weighted capital ratio may result in the same disintermediation for small liquidity risks as the strongyl countercyclical capital ratio. Likewise, the regulator may implement a liquidity coverage ratio significantly larger than one, which will not only prevent the risky mode but also the safe mode. In this case, the banker has to use some equity funds to fulfill the liquidity coverage ratio. This will impose an additional restriction on bank lending although the bank is not at risk, so that a severe credit crunch may emerge. Finally, the effectiveness of the margin call might also be affected by asymmetric information. We will therefore consider this scenario is more detail in Chapter 7.

To sum up, regulatory intervention is no free lunch: it comes at the cost of less efficient bank lending. Due to different restrictions on bank lending, we cannot identify a one-size-fits-all strategy. The regulator has to decide on the appropriate measure depending on the liquidity risks that are most likely to emerge in any given economy. Given that emerging economies might face larger liquidity risks on

[7] Angelini and Gerali argue that early announcements of regulatory changes, as performed with the Basel III Accord, help to reduce transition costs by allowing financial institutions to adjust their capital ratios at a slower pace.

average, we can thus conclude that they might prefer different regulatory measures to industrialized economies.

6.7 Conclusion

In this chapter we have identified the impact of four regulatory measures on the trade-off between financial stability and efficient bank lending. We compared the margin call proposed by Hart and Zingales (2011) with three main aspects of the Basel III Accord: the risk-weighted capital ratio, the countercyclical capital buffer and the liquidity coverage ratio.

We find that all measures are able to increase financial stability for certain liquidity risks in the economy. However, they differ with respect to their impact on bank lending. In the benchmark scenario, procyclical lending was always accompanied by a safe capital structure. As the implementation of regulatory measures may impose a restriction on bank lending in the downturn, even when the banker chooses a risky capital structure, a similar procyclical lending pattern might arise. In contrast to the original effect, this procyclicality imposes a threat to financial stability. The bank will default if the economy runs into a recession. In the case of symmetric information, the regulator is able to choose the regulatory measure that is accompanied by the lowest reduction in bank lending for a particular liquidity risk in the economy. Observing that regulatory measures take time to fully implement, the regulator might prefer a measure that achieves financial stability for those liquidity risks that are most likely to occur. If the volatility of this liquidity risk is rather high, our analysis suggests choosing either the margin call or a sufficiently large liquidity coverage ratio. However, both approaches will entirely disrupt bank lending if the liquidity risk is actually high. Accordingly, there is no one-size-fits-all strategy; rather, the optimal regulatory measure depends on the economic conditions.

Considering asymmetric information in the case of countercyclical capital buffer requirements, we have shown that regulatory intervention might cause a disintermediation. If regulatory measures impose an additional restriction on bank lending even when financial stability can be achieved without these measures, regulation is off its target. In this case, the intervention will cut back lending while increasing financial instability.

As asymmetric information is, however, more likely to occur in reality than symmetric information, we will consider this aspect for the margin call in the next chapter. In contrast to our analysis of the countercyclical capital buffer requirements, we will assume that not only the regulator but all market participants possess less information regarding the value of bank assets than the banker.

Chapter 7

Margin Call with Asymmetric Information

Regulatory intervention may be a shot in the dark if potential threats to financial stability cannot be observed by market participants. In this chapter we analyze the impact of bankers' private information regarding the value of banks' assets on the effectiveness of the margin call. As investors are only able to form expectations about banks' assets, they either overestimate or underestimate their expected payoff. Depending on the extent of information asymmetry, this may either lead to a reallocation of banks' profits or a change in banks' investment costs. In the latter case, investors are unable to infer banks' risk taking. As a result, bank lending might turn out to be excessive or curtailed. In the presence of such private information, imposing a regulatory measure like the margin call might turn out to be ineffective or might even result in a disintermediation.

7.1 Introduction

In the previous chapter we considered the impact of different regulatory measures in an economy with symmetric information. Although bankers, investors and the regulator had to form expectations about business cycle fluctuations, they all possessed the same information regarding expected loan returns. We concluded that all regulatory proposals discussed in Chapter 6 are able to increase financial stability for certain liquidity risks, but impose different restrictions on bank lending. Opposing the findings of Hart and Zingales (2011) presented in Chapter 3, we confirmed that the margin call, like all other regulatory measures, cuts back lending for certain liquidity risks. As a matter of fact, symmetric information is, however, rather unlikely. Asymmetric information may disturb the effectiveness of financial regulation if investors or regulators are unable to detect potential threats to financial stability.

This chapter sets out to evaluate the effectiveness of the margin call given that bankers possess private information regarding banks' assets. In the run up to a crisis, bankers typically identify potential risks earlier than their investors. Accordingly, investors are overestimating the expected return on banks' assets and may provide too much funding compared with the fundamentally justified value of their investment. Such a situation might result in unwanted effects. Two prominent examples of the world financial crisis may illustrate this point. The multinational investment banking firm Goldman Sachs was recently accused of selling collateralized debt obligations to investors, while using their private information to bet short against them at the same time. This behavior led to a record fine of 550 billion U.S. dollars in 2010. In a similar vein, the global financial derivative broker MF Global seems to have violated SEC (Securities and Exchange Commission) and CFTC (Commodity Futures Trading Commission) reporting standards and misused client account funds. Both cases demonstrate how financial intermediaries may misuse their private information to attract liquidity, which might lead to excess investment. More generally, Jordà *et al.* (2011) analyze bank lending over an extended period of time. They provide empirical evidence that many pre-crisis times have been characterized by credit booms. On the other hand, financial intermediaries might also face difficulties in receiving sufficient liquidity to foster bank lending. For instance, this was observed in the aftermath of the world financial crisis (IMF, 2010, pp. 24-28). We will argue that both patterns can be explained by investors having informational disadvantage regarding potential threats to financial stability.

In order to understand both bankers' and investors' behavior in the presence of asymmetric information, an intertemporal analysis is not essential. We thus abstract from the dynamic setup of the previous chapters and focus on an economic downturn in which financial stability might be at risk. Building on the previous two chapters, we assume for this situation that a debt overhang occurs, as bank loans financed in the previous period are nonperforming, i.e. they are not paid off in the downturn. Knowing that these loans will yield at least some returns in the future, the banker decides to roll over all nonperforming loans. Prior to the downturn, all market participants had the same information regarding the expected return on these loans. By monitoring bank assets the banker, however, gained private information. He is thus able to identify the return on nonperforming loans that will materialize in the future. As neither investors nor the regulator possess this information, they have to make their decisions based on the ex ante expected return on nonperforming loans. Accordingly they either overestimate or underestimate the value of bank assets.

Depending on the extent of the information asymmetry, investors' misjudgment of bank assets might affect the banker's investment decision in a downturn. As the banker possesses no funds on his own, he has to raise funds to cover the debt overhang and to finance new investment projects. In the case of investors overestimating bank assets, investors may provide too much funding. Analogously, the banker might receive too little funding if investors underestimate the return on nonperforming loans, and thus the value of bank assets.

As long as investors are still able to identify a bank's risk taking, they observe whether the banker is able to pay off the face value of deposits at the end of the period. In this case, the information asymmetry will not affect the bank's investment costs and will only result in a redistribution of profits between shareholders and the banker. All investors provide funds equivalent to their expected payoff. As depositors are able to identify their expected payoff, the lack of information is irrelevant for their investment decision. However, if shareholders overestimate the expected return on bank assets, they will provide too much funding. When the return on nonperforming loans materializes, they will thus receive too low a payoff compared with their investment costs. In this case, the banker benefits from investors' misperception. However, he will suffer if investors underestimate the value of bank assets. In this case, shareholders provide fewer funds compared with their payoff after nonperforming loans materialize a comparatively high return.

The banker's investment decision is affected when investors are unable to identify the riskiness of the bank's capital structure. In this case, they not only misjudge the return on nonperforming loans, but also the probability with which the bank will be able to pay off its investors. In consequence, depositors provide either too little or too much funding as well. If investors underestimate the bank's risk taking, they expect a larger return not only on nonperforming loans but also on loans granted in the downturn. Both shareholders and depositors will therefore provide more funds than required, which lowers the banker's marginal costs of granting loans. The banker increases the loan volume, so that bank lending becomes excessive. Likewise, an overestimation of the bank's risk taking results in investors not providing enough funds. As marginal costs of granting loans increase, bank lending is hampered. In contrast to our findings in the previous chapters, the overinvestment resulting from investors' lack of information regarding the value of bank assets is accompanied by a risky, rather than a safe capital structure.

Being aware of these lending patterns, investors could conclude that they have underestimated banks' risk taking each time they observe excessive lending. In consequence, they would reduce funds, which would lead to a decline in bank lending. However, we have witnessed in the world financial crisis that investors were unable to assess the value of banks' assets or the amount of banks' risk taking. For instance, MF Global was able to raise funds as investors were unable to detect its risk taking in European sovereign bonds. We thus rule out the possibility of investors drawing precise conclusions on the return on nonperforming loans. In this analysis we assume that investors are unable to identify whether loans granted in the downturn correspond to an efficient investment or to an over- or underinvestment.

When investors are unable to identify the bank's risk taking, the effectiveness of the margin call might be hampered. This will especially be crucial if investors underestimate the riskiness of the bank's capital structures. In this case, they understate the bank's probability of default and buy fewer CDS contracts to insure themselves against potential losses. Hence the CDS price might be too low to trigger the margin call. The banker may benefit from this situation in two ways. Besides keeping his job, which enables him to receive a share of the bank's profits, the banker might generate an additional return by buying CDS contracts at a reduced price. However, we assume that investors are observing his activities in the CDS market and will thus draw the correct conclusion. They will increase their demand, which drives up the price of CDS. As a takeover is never beneficial for the banker, he thus has no incentive to reveal his private information.

In order to shed light on the interesting case that the CDS price might be too low to trigger the margin call, we consider a positive threshold of the CDS price which allows for a positive probability of default. In contrast to the analysis in the previous chapters, we thus include the original proposal by Hart and Zingales (2011) that the margin call should be triggered each time the CDS price exceeds 100 basis points. We find that investors' lack of information regarding the value of banks' assets may increase the probability of default compared with the outcome under symmetric information. If investors underestimate banks' risk taking, the margin call might not be triggered, so that financial instability will persist. Moreover, the implementation of this margin call might result in a disintermediation as it might cut back lending without increasing financial stability. This will be the case if bankers aim to disguise their risk taking.

The chapter is organized as follows. Section 7.2 presents the setup of the model. This model is solved by determining the pooling equilibrium resulting from the principal-agent problem in Section 7.3, given that the condition of delayed loans is either good or bad. Afterwards we analyze the impact of the margin call for each condition of delayed loans feasible in Section 7.4. Section 7.5 discusses the robustness of this model and draws implications for bank regulation. Section 7.6 concludes this chapter.

7.2 Setup

7.2.1 Agents and Technologies

We now focus on a banker who manages a bank in a downturn. The bank lives for one more period and two dates, $t = 1, 2$. In this downturn at $t = 1$, loans granted in the past turn out to be nonperforming as they do not pay off at the agreed time. However, the banker can decide to roll over these loans to earn at least some returns at the end of the period, i.e. at $t = 2$. At the beginning of the period two scenarios are feasible, depending on the return on nonperforming loans, which are depicted in Figure 7.1. With probability q, the condition of nonperforming loans is good, $k = b_g$, and they will materialize a high return, v_{b_g}, at the end of the period.[1] Otherwise, their condition is bad, $k = b_b$, and their return will only add up to $v_{b_b} \in (0, v_{b_g})$. Having accompanied these loans in the past, the banker observes the condition of nonperforming loans while investors only possess information about the ex ante probabilities and returns of both scenarios. They will only be able to discover the condition at $t = 2$ when all investments materialize their respective returns.

In the downturn, the banker also decides on the bank's capital structure and its portfolio. Due to nonperforming loans, the downturn is characterized by a debt overhang so that the banker has to raise funds in the form of deposits or equity to satisfy investors' claims resulting from the past. With the remaining funds he invests the amount $a_{1,k}$ in a risk-free asset which yields a zero net return and grants $l_{1,k}$ as loans. The return on these loans is risky.

At $t = 2$, the economy may either recover from the downturn, which occurs with probability $p_2 \in [0.6, 1)$, or run into a deeper recession.[2] In contrast to the asymmetric information with respect to the return on nonperforming loans, all agents possess the same information regarding the expected return on new loans. Independent of the condition, k, of nonperforming loans, loans granted at $t = 1$ will yield a return r_b in the recovery and will default entirely if the economy runs into a recession. The

[1] Unless otherwise indicated, all returns are per unit.

[2] As in the proceeding chapters, this restriction on the probability of a recovery reduces complexity without changing the results qualitatively.

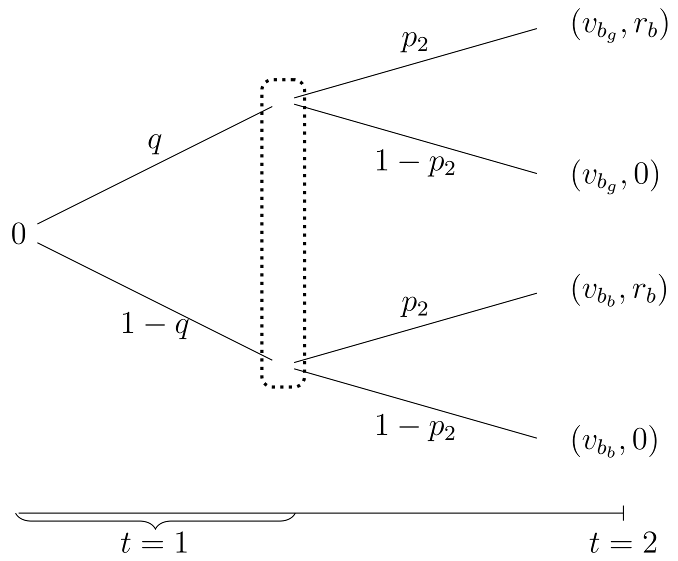

Figure 7.1: Loan earnings in the downturn (per unit).
Note: At the end nodes, the first entry refers to loans granted in the past and the second entry to loans granted at $t = 1$.

expected return on loans granted in the downturn is thus given by

$$\mu_{2,b} := p_2 r_b, \tag{7.1}$$

with $\mu_{2,b} \in [1, \frac{1}{q}]$. As long as the mean of loan returns, $\mu_{2,b}$, is larger than one, the positive net return ensures that granting loans is generally worthwhile at the beginning of the period.[3]

Observing the bank's investment decisions in the downturn sends no signal regarding the condition, k, of nonperforming loans, as market participants are unable to identify the banker's non-pecuniary costs of granting loans. These costs accrue as the banker has to apply his skills to collect the return on the bank's portfolio. While the cost of granting loans follows an increasing and convex function, c, of the loan volume, $l_{1,k}$, with $c(0) = c'(0) = 0$, we normalize the costs of investing in the risk-free asset to zero. In contrast to the analysis of the previous chapters, these costs are unobservable for both investors and the regulator. Accordingly, they are unable to draw any conclusions from bank lending at $t = 1$ regarding the condition of nonperforming loans. In particular, they are not able to identify whether the loan volume corresponds to an overinvestment or underinvestment.

In this chapter we focus on the liquidity risk resulting from the banker's private information regarding the condition of nonperforming loans. Analogously to

[3]Restricting this mean to $\frac{1}{q}$ reduces the complexity of the analysis without changing the results quantitatively.

the proceeding chapters, we consider variations of this liquidity risk given a mean preserving spread. Therefore, we define the mean of nonperforming loans in the downturn by

$$v_b := qv_{b_g} + (1-q)v_{b_b}, \tag{7.2}$$

and the liquidity risk resulting from the information asymmetry regarding the condition of nonperforming loans by

$$\Delta_\nu := v_{b_g} - v_{b_b}. \tag{7.3}$$

Both the mean, v_b, and the liquidity risk, Δ_ν, are public information to all market participants. Changes in Δ_ν allow us to analyze varying magnitudes of the liquidity risk, which will affect the banker's ability to raise funds. We will see below that the impact of this asymmetric information will depend on whether the condition is good or bad. Based on the definition of Δ_ν, we can rewrite the return on nonperforming loans that materializes at the end of the period according to

$$v_{b_g} = v_b + (1-q)\,\Delta_\nu, \tag{7.4}$$

$$v_{b_b} = v_b - q\Delta_\nu. \tag{7.5}$$

As the banker possesses no funds of his own, he has to raise capital from investors, who are unrestricted in funds, to both cover the existing debt overhang and to grant loans. There is perfect competition among investors. Having access to a risk-free storage technology, they will only provide funds if their expected net return is nonnegative. The banker seeks to maximize his expected profit net of his private lending costs. All agents are risk neutral and have a discount rate of zero.

7.2.2 Contracting Friction and Capital Structure

Depending on the condition of nonperforming loans, the banker raises funds at the beginning of the period, i.e. at $t = 1$, from investors who will choose to place their funds either as deposits $d_{1,k}$ with a face value $\delta_{1,k}$ or as equity $e_{1,k}$. The difference between the face value $\delta_{1,k}$ and the amount provided by depositors reflects the premium on deposits. As the banker's skills are needed to collect the full value of loans, the investment suffers from the same incomplete contract problem which forms the basis of the previous chapters. Due to his knowledge in granting loans, the banker might threaten to refuse to use his skills. Therefore, he might renegotiate investors' payments after the investment is made (Hart and Moore, 1994).

By issuing demandable deposits, the banker commits himself to use his skills on behalf of investors. Depositors would run on the bank, resulting in the destruction of all values, each time the banker tried to renegotiate their payments. The disadvantage of deposits is, however, that due to investments in risky loans a bank run may even occur if the banker applies his skills.

Raising equity enables the banker to protect himself against these bankruptcy risks. As shareholders' payoff depends on the value of the bank, their payoff will decline if the bank is less profitable. Therefore, equity serves as a buffer in bad times. However, the disadvantage of equity arises from the banker's opportunity to renegotiate shareholders' payoff. By threatening to withhold his skills, the banker demands a share, $\lambda \in [0.5, 1]$, of the bank's profits net of depositors' claims. Therefore the banker cannot pledge against the full value of loans when raising equity. In consequence, bank lending might be restricted (Diamond and Rajan, 2000). As the bargaining power regarding investors' compensation lies with the banker, both shareholders and depositors will receive a payoff equivalent to their participation constraint. In consequence, both shareholders and depositors expect to receive a payoff which covers their investment costs, so that investors are indifferent between these two types of investment.

Henceforth, we again focus on the situation in which the resulting conflict of interest between banker and investors might impose a binding restriction on bank lending. This is the case when the funding liquidity of new loans that are solely financed by equity is negative, i.e. if $(1 - \lambda)p_2 r_b < 1$. As shareholders provide too little funding to cover the investment costs of granting loans, the banker has to co-finance these loans, either by issuing deposits or by pledging against the return on nonperforming loans.

As the banker decides on the bank's capital structure, we have to distinguish between three modes of operation, $m_{1,k}$, in the downturn given a certain condition, k, of first period loans. The banker will operate in the safe mode, $\mathcal{S}$, if the face value of deposits, $\delta_{1,k}$, is so small that depositors will always be paid off at the end of the period, irrespective of the state of the economy. In this case, they will never run on the bank. If the face value of deposits is too large to pay off depositors in the recession at $t = 2$, the banker will operate in the risky mode, $\mathcal{R}$. Depositors will receive this face value only if the economy recovers from the downturn, but they will run on the bank in times of a recession. If the banker is unable or unwilling to raise sufficient funds to cover the existing debt overhang in the downturn, he will have to close the bank at $t = 1$ and will thus operate in the failure mode, $\mathcal{F}$.

As neither depositors nor shareholders are able to observe the condition of first period loans, they can only form expectations regarding the mode of operation. As long as the face value of deposits implies the same mode of operation for both the good condition, $k = b_g$, and the bad condition, $k = b_b$, investors are aware of the mode of operation. Therefore, information asymmetry only persists with respect to the condition of nonperforming loans. This is the case for $m = \frac{\mathcal{S}}{\mathcal{S}}, \frac{\mathcal{R}}{\mathcal{R}}$ or $\frac{\mathcal{F}}{\mathcal{F}}$ with the upper item identifying the mode of operation in the good condition, $k = b_g$, and the lower item depicting the mode of operation in the bad condition, $k = b_b$. However, if the face value of deposits implies different modes for the two feasible conditions, investors will face an additional lack of information regarding the mode of operation. As the return on delayed loans is larger in the good condition, $k = b_g$, investors might thus expect three further combinations which are $m = \frac{\mathcal{S}}{\mathcal{R}}, \frac{\mathcal{S}}{\mathcal{F}}$ and $\frac{\mathcal{R}}{\mathcal{F}}$.

As loans granted at $t = 1$ do not materialize a return in the recession, independent of the mode of operation, the expected profits of these loans are identical for the safe and risky mode and read[4]

$$\phi_{1,k}^{\mathcal{S}}\left(l_{1,k}\right) = \phi_{1,k}^{\mathcal{R}}\left(l_{1,k}\right) = \left(\mu_{2,b} - 1\right) l_{1,k} - c\left(l_{1,k}\right). \tag{7.6}$$

The first best loan volume in the downturn is thus again given by $\phi_{1,k}^{\mathcal{S}\,\prime}\left(l_{1,k}^{\text{fb}}\right) = 0$. As the banker's private costs are unobservable, neither investors nor the regulator can identify whether the loan volume granted in the downturn is efficient. Hence drawing any conclusions from the bank's investment on the condition of nonperforming loans is unfeasible.

7.3 Bank Behavior

In this section, we present the pooling equilibrium for each condition of nonperforming loans feasible. The banker observes the return on these loans that will materialize at the end of the period. However, he has to take into account investors' lack of information when deciding on the bank's portfolio and capital structure to maximize his expected profit. In the downturn, the bank's cash flow, $\omega_{1,b} l_0$, is negative. In consequence, the banker has to use some fresh funds to cover the debt overhang.

[4] As the focus of this chapter lies on the information asymmetry regarding the returns on nonperforming loans, we reduce complexity of loans granted in the downturn. For the impact of different returns on these loans when operating in the safe or risky mode, we refer to Chapter 4.

Unless the banker operates in the failure mode, $\mathcal{F}$, which leads to a bank closure in the downturn, his optimization problem at $t = 1$, given that he observes the condition, k, of first period loans while investors form expectations regarding this condition, is given by

$$\max_{l_{1,k}, a_{1,k}, \delta_{1,k} \in \mathbb{R}^+} \pi_{1,k} = \lambda E \left[\max \left\{ v_k l_0 + r_b l_{1,k} + a_{1,k} - \delta_{1,k}, 0 \right\} |k \right] - c(l_{1,k}) \tag{7.7}$$

$$\text{s.t.} \quad l_{1,k} + a_{1,k} = \omega_{1,b} l_0 + d_{1,k} + e_{1,k}, \tag{7.8}$$

$$d_{1,k} = \begin{cases} \delta_{1,k} & \text{if} \quad m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}} \\ \left[q + (1-q) p_2 \right] \delta_{1,k} & \text{if} \quad m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}} \\ q \delta_{1,k} & \text{if} \quad m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{F}} \\ p_2 \delta_{1,k} & \text{if} \quad m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}} \\ q p_2 \delta_{1,k} & \text{if} \quad m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{F}} \end{cases}, \tag{7.9}$$

$$e_{1,k} = (1 - \lambda) E \left[\max \left\{ v_k l_0 + r_b l_{1,k} + a_{1,k} - \delta_{1,k}, 0 \right\} \right]. \tag{7.10}$$

Equation (7.8) reflects the bank's budget constraint at $t = 1$. Depending on the condition, k, the banker grants loans, $l_{1,k}$, and invests $a_{1,k}$ in the risk-free asset. In order to finance these investments and to cover the existing debt overhang, $\omega_{1,b} l_0$, the banker raises funds to the amount of $d_{1,k}$ from depositors and $e_{1,k}$ from shareholders. Investors' willingness to provide funds crucially depends on their expectations regarding the mode of operation, m. As long as the face value of deposits is low, depositors will always receive this face value at the end of the period, independent of the condition of nonperforming loans.[5] In this case the banker operates according to $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$ so that a bank run will never occur at $t = 2$. It follows from the first line of equation (7.9) that depositors are thus willing to provide funds equal to the face value, $\delta_{1,k}$, i.e. they do not demand a premium for their investment. If the face value lies in the interval, which implies that the banker will operate in the risky mode independent of the condition, k, depositors will only receive this face value if the economy recovers from the downturn, i.e. only with probability p_2. If a recession emerges, the bank's returns will be too low to compensate all depositors, so they will run on the bank. Accordingly, they will only provide funds up to $p_2 \delta_{1,k}$ if they expect the mode $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$, as reflected by the fourth line of equation (7.9). In both cases, depositors' lack of information thus has no impact on their willingness to provide funds.

[5] We will specify the respective intervals of the face value of deposits in the following subsections when we discuss each mode's expected feasibility in more detail.

However, the face value of deposits might lie in an interval which results in different modes for the two conditions feasible. In these cases, depositors will also provide funds equivalent to their expected payoff at $t = 2$. Suppose, the face value indicates that the banker will repay depositors with certainty if the condition of nonperforming loans is good, $k = b_g$, which happens with probability q, but only during a recovery if the condition is bad, $k = b_b$, so that $m = \frac{\mathcal{S}}{\mathcal{R}}$. Depositors thus expect to receive the face value of deposits with probability $q + (1 - q)p_2$ and provide funds accordingly. (See second line of equation (7.9).) If the face value of deposits suggests that the banker operates in the failure mode when the condition is bad, depositors will only expect to receive a payment with probability q, i.e. if the condition of nonperforming loans turns out to be good. Depending on the mode of operation for $k = b_g$, they will either provide funds in the amount of $q\delta_{1,k}$ or $qp_2\delta_{1,k}$.[6]

As shareholders form the same expectations as depositors regarding the mode of operation, they provide equity equivalent to their expected payoff, as equation (7.10) reflects. Depending on the condition, k, and the state of the economy at $t = 2$, they receive the share $1 - \lambda$ of the bank's returns, net of depositors' claims, as long as this profit is nonnegative. In contrast to depositors, shareholders are always affected by the information asymmetry regarding the return on nonperforming loans, as this return determines the bank's profits. Finally, equation (7.7) exhibits the banker's expected profit, $\pi_{1,k}$, at the end of the period. He will obtain the share λ of the bank's returns after depositors have been paid off, and he has to bear non-pecuniary costs of granting loans. However, his expectations regarding the bank's profits differ from those of investors. As he is able to observe the return on nonperforming loans, he considers the conditional expectation given that a certain condition, k, has materialized in the downturn.

In the following subsection we will first analyze the banker's behavior in the downturn if the condition of nonperforming loans is bad. Afterwards we identify his behavior given that the good condition materializes.

7.3.1 Bad Condition

If the condition of nonperforming loans is bad, $k = b_b$, six expected modes are feasible. In the following section we discuss each of them in more detail before we obtain the banker's optimal behavior depending on the extent of the liquidity risk, Δ_ν.

[6]We will see below that restricting the mean, $\mu_{2,b}$ to $\frac{1}{q}$, ensures that the banker will never operate in these two latter expected modes of operation. Offsetting this assumption increases complexity of our analysis without generating sufficient additional information.

Safe Mode

Suppose the banker operates in the safe mode, $\mathcal{S}$, which restricts the face value of deposits to $\delta_{1,b_b} \leq v_{b_b} l_0 + a_{1,b_b}$. In this case, the bank's returns at $t = 2$ are always sufficiently large to pay off depositors, so that a bank run will never occur. Moreover, the banker knows that investors expect the mode $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$, as expected returns are even higher when the condition of nonperforming loans is good. It follows from (7.10) that shareholders provide equity in the amount of

$$e_{1,b_b} = (1-\lambda)\left[\left(qv_{b_g} + (1-q)v_{b_b}\right) l_0 + p_2 r_b l_{1,b_b} + a_{1,b_b} - \delta_{1,b_b}\right]. \tag{7.11}$$

Shareholders' lack of information regarding the return on nonperforming loans results in an overestimation of the return on nonperforming loans. If shareholders knew that the condition was bad, they would only provide funds equivalent to $(1-\lambda)v_{b_b}$ per nonperforming loan. However, as they expect a larger return on these loans, v_{b_g}, with probability q, they provide too much funding. Meanwhile, equation (7.9) indicates that depositors provide funds equal to the face value of deposits. As the repayment of this face value is certain, depositors provide no additional funds to the banker. When operating according to $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$, the banker thus receives too much funding, in the amount of

$$(1-\lambda)q\left(v_{b_g} - v_{b_b}\right) l_0 = (1-\lambda)q\Delta_\nu l_0. \tag{7.12}$$

As investors are only unable to observe the return on nonperforming loans but face no information asymmetry regarding the bank's risk taking, these additional funds are independent of the loan volume granted in the downturn. At $t = 2$, investors will observe the return on nonperforming loans. However, shareholders possess no bargaining power to increase their payment. In consequence, equity financing is more beneficial to the banker than debt financing. The banker will thus choose a lower leverage, as this allows him to extract more rents.

Moreover, the additional funds might affect the banker's investment decision at $t = 1$. Investors' informational disadvantage increases the funding liquidity of nonperforming loans so that the banker might be able to grant more loans in the downturn. If he operates in the safe mode, it follows from the optimization problem that bank lending will be restricted according to

$$[1-(1-\lambda)p_2 r_b]\, l_{1,b_b} \leq v_{b_b} l_0 + (1-\lambda)q\Delta_\nu l_0 + \omega_{1,b} l_0. \tag{7.13}$$

Loans granted at $t = 1$ will default entirely if the recession occurs at $t = 2$. Accordingly the banker will only operate in the safe mode if these loans are solely financed by equity. However, equity financing leads to a negative funding liquidity, as $(1-\lambda)p_2 r_b < 1$. The banker has to close this funding gap, $1-(1-\lambda)p_2 r_b$ per unit of loans, by pledging against nonperforming loans. Due to investors' lack of information with respect to the return on nonperforming loans, the funding liquidity of these loans is given by the return $v_{b_b} l_0$ that will materialize at $t = 2$ and the additional funds provided by shareholders, $(1-\lambda)q\Delta_\nu l_0$. The banker will use these funds to co-finance new loans and to cover the existing debt overhang, $\omega_{1,b} l_0$. Accordingly, the restriction on bank lending in the downturn depends on the loan volume, l_0, granted in the past and the liquidity risk, Δ_ν. Operating in the safe mode will thus only be feasible, if the funding liquidity of nonperforming loans is large enough to cover the debt overhang. This is the case, if either the return v_{b_b} or the misperception of the condition is sufficiently large. The higher the liquidity risk, Δ_ν, and the higher investors' misjudgment of the condition, the stronger is the impact of asymmetric information on the funding liquidity. The latter is reflected by the probability that the condition of nonperforming loans is good, q.

Although sharesholders provide too much funding, the banker will never grant loans above the first best when operating according to $m = \frac{\mathcal{S}}{\mathcal{S}}$. If the funding liquidity of nonperforming loans is sufficiently large, so that bank lending is not restricted, the banker will either reduce the deposit volume or place the excess liquidity in the risk-free asset.

Recall from the dynamic analysis of the previous chapters that the banker might also be incentivized to loosen the restriction on granting loans in the downturn by increasing bank lending prior to the downturn. As this intertemporal link has the same impact as discussed in the previous chapters, we neglect this dynamic in this chapter and analyze only the optimal behavior in the downturn.

Risky Mode

Suppose the banker increases the face value of deposits to $\delta_{1,b_b} \in (v_{b_b} l_0 + a_{1,b_b}, v_{b_b} l_0 + r_b l_{1,b_b} + a_{1,b_b}]$ so that he operates in the risky mode, $\mathcal{R}$. Whether investors are able to conclude that the banker operates in the risky mode depends on the face value of deposits. As long as the face value is lower than $v_{b_g} l_0 + a_{1,b_b}$, the banker will operate in the safe mode if the condition is good. Therefore investors expect the mode $m = \frac{\mathcal{S}}{\mathcal{R}}$. However, a face value above $v_{b_g} l_0 + a_{1,b_b}$ indicates that the banker will never be able to pay off depositors in a recession. The banker thus operates in the risky mode independent of the condition of nonperforming loans, so that the expected mode is $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$.

Suppose the face value indicates that the banker will always operate in the risky mode, i.e. $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$. This will be the case, if the liquidity risk Δ_ν is rather low.[7] It follows from (7.10) that shareholders provide equity in the amount of

$$e_{1,b_b} = (1-\lambda)p_2\left[\left(qv_{b_g} + (1-q)v_{b_b}\right)l_0 + r_b l_{1,b_b} + a_{1,b_b} - \delta_{1,b_b}\right]. \tag{7.14}$$

Similarly to $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$, due to the lack of information regarding the return on nonperforming loans, shareholders provide too much funding. As investors are still certain about the mode of operation, depositors expect to receive a payment only if the economy recovers from the downturn. Therefore they provide funds equivalent to their expected payoff without providing additional funds to the banker, as the fourth line of equation (7.9) reflects. The banker receives too many funds in the amount of

$$(1-\lambda)p_2 q\Delta_\nu l_0, \tag{7.15}$$

when operating according to $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$, which is again independent of the loan volume, l_{1,b_b}, granted in the downturn. Again, the banker prefers to raise equity as this allows him to extract more rents.

As long as the face value of deposits implies that the banker operates in the risky mode, the additional funds impose no effect on the banker's investment decision in the downturn but will only change the relation of equity financing to debt financing. Due to the potential bank run in the case of a recession, the expected profit of the risk-free asset remains negative, so that an investment in this asset will never be optimal. As the risky mode allows the banker to increase the face value of deposits, it follows from the optimization problem that bank lending is restricted according to

$$[p_2 r_b - 1]\, l_{1,b_b} \geq -p_2 v_{b_b} l_0 - (1-\lambda)qp_2\Delta_\nu l_0 - \omega_{1,b} l_0 + (1-p_2)a_{1,b_b}. \tag{7.16}$$

An increase in the face value of deposits imposes two effects. It results in a positive funding liquidity of loans granted in the downturn, $p_2 r_b > 1$, and in a lower funding liquidity of nonperforming loans, $p_2 v_{b_b} + (1-\lambda)qp_2\Delta_\nu$, as a share of these loans will default in a bank run. The banker will use the excess liquidity of new loans and the

[7] Technically, a low liquidity risk, $\Delta_\nu = v_{b_g} - v_{b_b}$, implies that the threshold, $v_{b_g} l_0 + a_{1,b_b}$, which determines investors' expected mode, is close to the lower bound of the interval $v_{b_b} l_0 + a_{1,b_b}$. Moreover, it is more likely that this threshold lies in the interval of the risky mode. If the banker is able to increase the face value of deposits above the threshold by granting loans, l_{1,b_b}, in the downturn, investors will thus infer from this face value that the banker operates in the risky mode.

funding liquidity of nonperforming loans to cover the existing debt overhang, $\omega_{1,b}l_0$. Although investing in the risk-free asset is not profitable, the excess liquidity will never result in an overinvestment, as shareholders' provision of additional funds is not sufficient to cover the debt overhang entirely. The banker always has to raise deposits to some extent to finance new loans. If the overall liquidity is too low to cover the debt overhang, the restriction on bank lending becomes binding, see equation (7.16). In this case, operating in the risky mode will result in a negative expected profit, so that the banker prefers to close the bank in the downturn. This, however, implies that the banker switches to the failure mode and is thus a contradiction to operating in the risky mode.

Suppose the liquidity risk is quite high. In this case, the face value indicates that the banker would operate in the safe mode in the good condition, i.e. $m = \begin{smallmatrix}\mathcal{S}\\ \mathcal{R}\end{smallmatrix}$. Therefore investors not only face a lack of information regarding the condition of nonperforming loans, but this informational disadvantage also results in a misperception of the mode of operation. It follows from equation (7.10) that in this case shareholders provide equity in the amount of

$$\begin{aligned} e_{1,b_b} = &(1-\lambda)\left[p_2 v_{b_b} l_0 + q\left(v_{b_g} - p_2 v_{b_b}\right) l_0\right] \\ &+ (1-\lambda)\left[p_2 r_b l_{1,b_b} + (p_2 + q(1-p_2))(a_{1,b_b} - \delta_{1,b_b})\right], \end{aligned} \tag{7.17}$$

which implies additional funds in the amount of $(1-\lambda)q[\left(v_{b_g} - p_2 v_{b_b}\right) l_0 + (1-p_2)(a_{1,b_b} - \delta_{1,b_b})]$ to the banker.

Moreover, due to investors misperception regarding the mode of operation, depositors provide too much funding compared with their expected payoff. It follows from equation (7.9), that they provide additional funds in the amount of $q(1-p_2)\delta_{1,k}$. In total, the banker thus receives additional funds in the amount of

$$(1-\lambda)q\left(v_{b_g} - p_2 v_{b_b}\right) l_0 + (1-\lambda)q(1-p_2)a_{1,b_b} + \lambda q(1-p_2)\delta_{1,b_b}, \tag{7.18}$$

when operating according to $m = \begin{smallmatrix}\mathcal{S}\\ \mathcal{R}\end{smallmatrix}$. Due to the information asymmetry regarding the bank's risk taking, these additional funds also depend on the investment in the risk-free asset and the face value of deposits. Therefore, investors' lack of information will not only affect the funding liquidity of nonperforming loans, but might also impose an effect on the investment costs of loans granted at $t = 1$. As the expected profit of the risk-free asset remains negative although investors' additional funds lowering the investment costs, the banker will never place any excess liquidity in this asset. However, as the banker receives additional funds from both depositors and shareholders, these funds also lower the banker's investment costs of new loans.

If the banker granted loans according to the first best, marginal investment costs would be lower than marginal revenues. In consequence, the banker would increase bank lending until marginal costs and revenues of granting loans in the downturn were balanced. As long as bank lending is not restricted, the information asymmetry with respect to the bank's risk taking will thus result in an overinvestment if the banker operates according to $m = \frac{\mathcal{S}}{\mathcal{R}}$.

If the liquidity risk, Δ_ν, is relatively small, it follows from the optimization problem that bank lending will be restricted according to

$$\begin{aligned}[1-(1-\lambda)p_2 r_b]\, l_{1,b_b} \leq\ & \omega_{1,b} l_0 + p_2 v_{b_b} l_0 - (1-q)(1-p_2) a_{1,b_b} \\ & + \lambda q (1-p_2) v_{b_g} l_0 + (1-\lambda) q (v_{b_g} - p_2 v_{b_b}) l_0 + \lambda p_2 \Delta_\nu l_0. \end{aligned} \tag{7.19}$$

In this case, the face value of deposits is quite low, so that the banker has to finance new loans with equity. This results in a funding gap of $1-(1-\lambda)p_2 r_b$ per unit of loans granted in the downturn. The banker closes this funding gap and covers the existing debt overhang, $\omega_{1,b} l_0$, by using the funding liquidity of nonperforming loans. Besides the expected return on nonperforming loans, $p_2 v_{b_b} l_0$, this funding liquidity comprises the additional funds provided by both depositors and shareholders, $\lambda q(1-p_2) v_{b_g} l_0$ and $(1-\lambda) q (v_{b_g} - p_2 v_{b_b}) l_0$ respectively. However, as the banker increases the face value of deposits above the return that materializes in the recession given that the condition is bad, he will have to repay a larger share if the economy recovers from the downturn. While this increase in the face value of deposits results in a reduction in his expected return in the recovery, it increases the funding liquidity by $\lambda p_2 \Delta_\nu l_0$. However, if the liquidity risk, Δ_ν, is sufficiently large, the face value of deposits is so large that bank lending will never be restricted as long as the banker is willing to operate according to $m = \frac{\mathcal{S}}{\mathcal{R}}$.

Failure Mode

Suppose the banker operates in the failure mode, $\mathcal{F}$, by closing the bank at $t = 1$. Depending on the potential mode of operation in the good condition of first period loans, the banker might be able to raise funds from investors in order to cover the debt overhang. This redistribution of wealth from new investors to old depositors leaves the banker's expected profit unchanged. We can thus already conclude that the banker is indifferent between all three expected modes, $m = \frac{\mathcal{S}}{\mathcal{F}}$, $\frac{\mathcal{R}}{\mathcal{F}}$ and $\frac{\mathcal{F}}{\mathcal{F}}$, when operating in the failure mode.

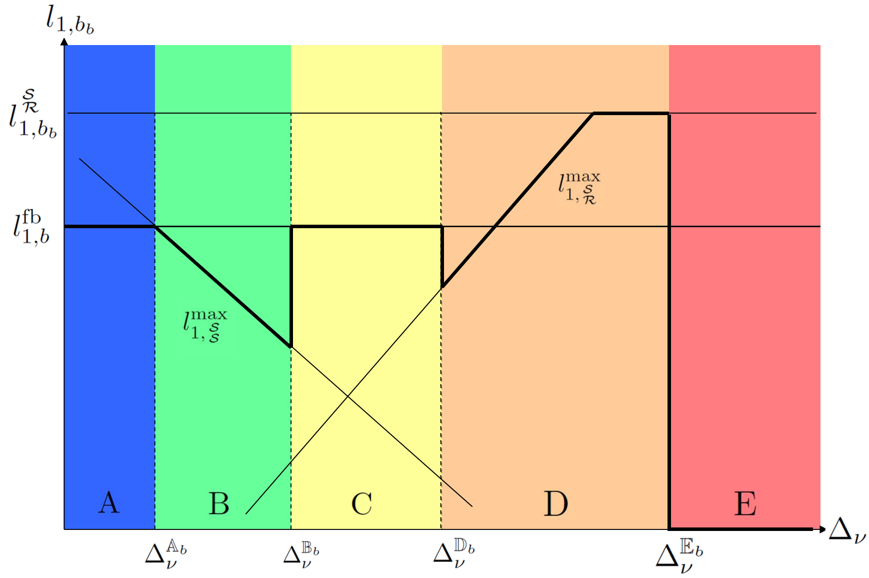

Figure 7.2: Optimal bank lending and capital structure given the bad condition, $k = b_b$, of nonperforming loans

Equilibrium

Comparing the banker's expected profits of all modes feasible when the condition of first period loans is bad, we obtain:

Proposition 7.1. *If the economy is in a downturn at date $t = 1$ with the condition of nonperforming loans being bad, i.e. $k = b_b$, and $\Delta_\nu \leq \frac{v_b}{q}$, the banker's decision on the mode of operation, m, and bank lending, l_{1,b_b}, will have the following properties:*

$$
\begin{array}{llll}
\mathbb{A}_b: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l_{1,b_b}^* = l_{1,b}^{fb} & \text{if} \quad \Delta_\nu < \min\{\Delta_\nu^{\mathbb{A}_b}, \Delta_\nu^{\mathbb{C}_b}\}, \\
\mathbb{B}_b: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l_{1,b_b}^* = l_{1,\frac{\mathcal{S}}{\mathcal{S}}}^{max} & \text{if} \quad \Delta_\nu \in [\Delta_\nu^{\mathbb{A}_b}, \min\{\Delta_\nu^{\mathbb{B}_b}, \Delta_\nu^{\mathbb{C}_b}\}), \\
\mathbb{C}_b: & m^* = \frac{\mathcal{R}}{\mathcal{R}}, & l_{1,b_b}^* = l_{1,b}^{fb} & \text{if} \quad \Delta_\nu \in \left[\Delta_\nu^{\mathbb{B}_b}, \Delta_\nu^{\mathbb{D}_b}\right), \\
\mathbb{D}_b: & m^* = \frac{\mathcal{S}}{\mathcal{R}}, & l_{1,b_b}^* = \min\{l_{1,b_b}^{\frac{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{max}\} & \text{if} \quad \Delta_\nu \in \left[\max\{\Delta_\nu^{\mathbb{C}_b}, \Delta_\nu^{\mathbb{D}_b}\}, \Delta_\nu^{\mathbb{E}_b}\right], \\
\mathbb{E}_b: & m^* = \frac{m_{1,b_g}}{\mathcal{F}}, & l_{1,b_b}^* = 0 & \text{if} \quad \Delta_\nu > \Delta_\nu^{\mathbb{E}_b},
\end{array}
$$

with all critical values being defined in the appendix.

Proof. See appendix. □

The proposition indicates that the banker's optimal behavior crucially depends on the liquidity risk, Δ_ν. We restrict this liquidity risk to $\frac{v_b}{q}$ to ensure that the return on nonperforming loans remains positive. Depending on the spread between the return on nonperforming loans in the good condition and in the bad condition, five strategies have to be distinguished. These five strategies are depicted in Figure 7.2. The thick black line illustrates optimal bank lending in the downturn, given that the condition of nonperforming loans is bad. A deviation of the thick black line from the first best loan volume, l^{fb}_{1,b_b}, marks a less efficient lending structure. In analogy to the previous chapters, the blue and green areas depict the interval of liquidity risks in which the bank is never at risk. While the blue area, A, indicates that bank lending is not restricted, the green area, B, identifies inefficient bank lending. In the yellow area, C, bank lending is efficient but the stability of the bank is at risk, as depositors will run on the bank if a recession occurs at the end of the period. Finally, the orange and red areas capture different degrees of risks to the stability of the bank and inefficient lending. Similarly to the yellow area, the orange area, D, illustrates a scenario in which the bank will only default in the case of a recession, while the red area, E, implies that a bank run will occur in the downturn. It is striking that inefficiencies can result from both underinvestments and overinvestments.

There exists a unique ordering with respect to the banker's risk taking behavior. If the liquidity risk of nonperforming loans, Δ_ν, is very low, i.e. $\Delta_\nu < \min\{\Delta_\nu^{\mathbb{A}_b}, \Delta_\nu^{\mathbb{C}_b}\}$, the banker operates according to strategy $\mathbb{A}_b$. While he operates in the safe mode, investors also expect this mode, independent of the condition of nonperforming loans. As the funding liquidity of these loans is sufficiently large, the banker is able to grant new loans according to the first best. Therefore, this strategy denotes the preferred strategy from a welfare perspective.

If the liquidity risk increases to $\Delta_\nu \in [\Delta_\nu^{\mathbb{A}_b}, \min\{\Delta_\nu^{\mathbb{B}_b}, \Delta_\nu^{\mathbb{C}_b}\})$, the additional funds provided by investors increase. However, the return on nonperforming loans decreases to a larger extent so that the overall funding liquidity decreases. In consequence, bank lending is restricted but the bank is still not at risk. We denote this strategy by $\mathbb{B}_b$.

As the restriction on bank lending is stronger the larger the liquidity risk, Δ_ν, the banker's expected profit from strategy $\mathbb{B}_b$ declines. For larger liquidity risks the banker thus prefers to put the bank's stability at risk by issuing more deposits. This allows him to increase bank lending and therefore his expected profit but lowers the expected return on nonperforming loans. If a recession occurs at $t = 2$, expected returns will be too low to cover depositors' claims, so that they will run on the bank. Depending on the expectations of investors, they will either anticipate this behavior with certainty or will face an additional lack of information with respect to the riskiness of the bank's capital structure. If the interval $\left[\Delta_\nu^{\mathbb{B}_b}, \Delta_\nu^{\mathbb{D}_b}\right)$ is non-empty, investors will be aware of the risky mode. This will be the case, if the banker does not prefer to disguise his risk taking by choosing strategy $\mathbb{D}_b$ over strategy $\mathbb{A}_b$, which corresponds to the unrestricted safe mode. Then, the banker operates according to strategy $\mathbb{C}_b$, i.e. he is able to raise sufficient funds, so that bank lending is not restricted. If, however, the liquidity risk, Δ_ν, is in the range of $\left[\max\{\Delta_\nu^{\mathbb{C}_b}, \Delta_\nu^{\mathbb{D}_b}\}, \Delta_\nu^{\mathbb{E}_b}\right]$, the face value of deposits implies that the bank's capital structure would be safe if the condition of nonperforming loans was good. As a result, both depositors and shareholders provide too much funding for the banker. As these additional funds lower the investment costs of loans granted at $t = 1$, the banker's expected profit increases. In consequence, the banker will prefer to disguise his risk taking, i.e. he will operate according to strategy $\mathbb{D}_b$, even if this implies a restriction in bank lending.

Finally, if the liquidity risk becomes too large, so that $\Delta_\nu > \Delta_\nu^{\mathbb{E}_b}$, operating in the risky mode will result in a negative expected profit for the banker, even if he conceals the risky capital structure. Accordingly, he prefers strategy $\mathbb{E}_b$ and closes the bank at $t = 1$. As argued above, this strategy is independent of investors' expectations regarding the optimal behavior given that the condition of first period loans was good.

7.3.2 Good Condition

If the condition of nonperforming loans is good, we will also have to distinguish between six expected modes. As in the previous subsection, we will comment on each expected mode to derive the banker's optimal behavior depending on the liquidity risk, Δ_ν.

Safe Mode

Suppose the banker operates in the safe mode, $\mathcal{S}$, which implies that the face value of deposits is restricted to $\delta_{1,b_g} \leq v_{b_g} l_0 + a_{1,b_g}$. In this case, investors have to distinguish between three expected modes of operation. As long as the face value of deposits is below $v_{b_b} l_0 + a_{1,b_g}$, the banker would also operate in the safe mode if the condition were bad, so that investors expect the mode $m = {\mathcal{S} \atop \mathcal{S}}$. If the face value of deposits is larger, investors' expectations depends on whether the face value is larger or smaller than the bank's return in the recovery, given that the condition of nonperforming loans was bad, $v_{b_b}l_0 + p_2r_bl_{1,b_g} + a_{1,b_g}$. As long as the face value is lower than $v_{b_b}l_0 + p_2r_bl_{1,b_g} + a_{1,b_g}$, the banker would operate in the risky mode if the condition were bad. Such a face value corresponds to the expected mode $m = \frac{\mathcal{S}}{\mathcal{R}}$. A face value above $v_{b_b}l_0 + p_2r_bl_{1,b_g} + a_{1,b_g}$ indicates the failure mode in the bad condition so that investors expect the mode $m = \frac{\mathcal{S}}{\mathcal{F}}$.

Suppose the face value indicates that the banker would always operate in the safe mode, i.e. $m = \frac{\mathcal{S}}{\mathcal{S}}$, as $\delta_{1,b_g} \leq v_{b_b}l_0 + a_{1,b_g}$. It follows from equation (7.10) that in this case shareholders provide equity in the amount of

$$e_{1,b_g} = (1-\lambda)\left[\left(qv_{b_g} + (1-q)v_{b_b}\right)l_0 + p_2r_bl_{1,b_g} + a_{1,b_g} - \delta_{1,b_g}\right]. \tag{7.20}$$

In contrast to the bad condition, shareholders' lack of information regarding the return on nonperforming loans results in a burden for the banker. As investors expect a lower return v_{b_b} with probability $1-q$, although the return is v_{b_g}, shareholders provide too little funding compared with the case in which they knew the return on nonperforming loans. As with the bad condition, the repayment of the face value of deposits is certain, so that depositors provide funds in an amount equilvant to this face value, as equation (7.9) indicates. Consequently, the banker only receives too little funding from shareholders. This reduction of funds amounts to

$$(1-\lambda)(1-q)\Delta_\nu l_0, \tag{7.21}$$

which depends on the volume of nonperforming loans and the liquidity risk resulting from asymmetric information with respect to the return on these loans. Raising equity thus becomes more expensive for the banker than issuing deposits, so that the banker prefers debt financing over equity financing. However, an increase in the leverage ratio reduces the banker's ability to extract rents per unit of loans. As investors' expectations are the same as in the bad condition, bank lending is again restricted by

$$[1-(1-\lambda)p_2r_b]\,l_{1,b_g} \leq v_{b_g}l_0 + \omega_{1,b}l_0 - (1-\lambda)(1-q)\Delta_\nu l_0. \tag{7.22}$$

This restriction is identical to the one presented in equation (7.13). As long as the banker seeks to operate in the safe mode, loans granted in the downturn have to be financed by equity, which results in the negative funding liquidity, $(1-\lambda)p_2r_b - 1 < 0$. Closing the funding gap of $1-(1-\lambda)p_2r_b$ per unit of loans is thus only feasible by pledging against nonperforming loans. As investors are unable to observe the condition of nonperforming loans, this funding liquidity is identical for both conditions. However, the RHS of equation (7.22) captures the funding liquidity of nonperforming loans as the return on these loans, $v_{b_g} l_0$, lowered by the reduction of funds, $(1-\lambda)(1-q)\Delta_\nu l_0$, due to investors' lack of information. Again, the banker will only be able to operate according to $m = \begin{smallmatrix}\mathcal{S}\\\mathcal{S}\end{smallmatrix}$ if this funding liquidity will cover the existing debt overhang, $\omega_{1,b} l_0$. If investors' informational disadvantage is, however, too high, as either the liquidity risk, Δ_ν, or their misjudgment of the condition is too large, this mode will not be feasible for the banker. In contrast to the case that the condition of nonperforming loans is bad, $k = b_b$, investors' misjudgment is now captured by the probability that the condition of nonperforming loans is bad, $1 - q$.

Suppose the face value indicates that the banker would operate in the risky mode if the condition of first period loans were bad, i.e. $m = \begin{smallmatrix}\mathcal{S}\\\mathcal{R}\end{smallmatrix}$. In this case, it follows from equation (7.10) that shareholders provide equity in the amount of

$$\begin{aligned} e_{1,b_g} &= (1-\lambda)\left[v_{b_g} l_0 - (1-q)\left(v_{b_g} - p_2 v_{b_b}\right) l_0\right] \\ &\quad + (1-\lambda)\left[p_2 r_b l_{1,b_g} + [1-(1-q)(1-p_2)]\left(a_{1,b_g} - \delta_{1,b_g}\right)\right]. \end{aligned} \tag{7.23}$$

Again, the good condition differs from the bad condition as shareholders provide too little funding instead of too much funding for the banker. However, they provide the same amount for both conditions, i.e. equation (7.23) is identical to equation (7.17). Compared with the situation in which investors only face asymmetric information with respect to the return on nonperforming loans, the lack of information regarding the mode of operation leads to an additional reduction in funds. The burden resulting from raising equity sums up to $(1-\lambda)(1-q)[\left(v_{b_g} - p_2 v_{b_b}\right) l_0 + (1-p_2)\left(a_{1,b_g} - \delta_{1,b_g}\right)]$. Analogously, investors' inability to infer the bank's risk taking also results in a burden for the banker when issuing deposits. In this case, it follows from equation (7.9) that depositors provide too little funding in the amount of $(1-q)(1-p_2)\delta_{1,b_g}$, so that the overall reduction of funds amounts to

$$(1-\lambda)(1-q)\left[\left(v_{b_g} - p_2 v_{b_b}\right) l_0 + (1-p_2) a_{1,b_g}\right] + \lambda(1-q)(1-p_2)\delta_{1,b_g}. \tag{7.24}$$

As both shareholders and depositors provide less funding compared with the payoff they will receive at the end of the period, the bank's investment cost of granting loans in the downturn increases. In consequence, the banker will never grant loans according to the first best, as this would correspond to marginal costs exceeding marginal revenues. In contrast to the underinvestment which occurs in the presence of symmetric information, this underinvestment resembles the credit rationing of Stiglitz and Weiss (1981). Moreover, it follows from equation (7.24) that the reduction in providing funds increases the investment cost of the risk-free asset as well. As the expected profit becomes negative, the banker will only invest in loans, although the bank is safe.

Operating according to $m = \frac{\mathcal{S}}{\mathcal{R}}$ will impose the same restriction on bank lending as given in equation (7.19) if the liquidity risk, Δ_ν, is small

$$\begin{aligned}\left[1-(1-\lambda)p_2 r_b\right] l_{1,b_b} \leq \omega_{1,b} l_0 + v_{b_g} l_0 - (1-q)(1-p_2) a_{1,b_g} \\ - (1-q)[1-\lambda p_2] v_{b_g} l_0 + (1-\lambda)(1-q) p_2 v_{b_b} l_0.\end{aligned} \tag{7.25}$$

In this case, the banker has to co-finance the funding gap of new loans, $1-(1-\lambda)p_2 r_b$, and the debt overhang, $\omega_{1,b} l_0$, by pledging against nonperforming loans. However, the funding liquidity of nonperforming loans is now captured by the return on these loans, $v_{b_g} l_0$, lowered by the reduction of funds resulting from investors' lack of information given by the remaining three terms of the RHS of equation (7.25). If the liquidity risk, Δ_ν, is sufficiently large, the funding liquidity of loans granted at $t=1$ is always positive, so that bank lending will not be restricted. The banker thus operates according to $m = \frac{\mathcal{S}}{\mathcal{R}}$ as long as this yields him a nonnegative expected profit.

Suppose the face value indicates that the banker would operate in the failure mode if the condition of nonperforming loans was bad, i.e. $m = \frac{\mathcal{S}}{\mathcal{F}}$. Recall that investors are unable to determine the banker's private costs for granting loans. Hence, they cannot draw any conclusion from a positive loan volume to the return on nonperforming loans. It follows from equation (7.10) that due to investors' lack of information regarding the mode of operation, shareholders only provide equity in the amount of

$$e_{1,b_g} = (1-\lambda) q \left[v_{b_g} l_0 + p_2 r_b l_{1,b_g} + a_{1,b_g} - \delta_{1,b_g} \right], \tag{7.26}$$

while depositors will provide funds equivalent to $q\delta_{1,b_g}$. Therefore, the overall reduction in funds is larger than the reduction given that $m = \frac{\mathcal{S}}{\mathcal{R}}$. In consequence, marginal costs of granting loans increase even further and are equal to $\frac{1}{q}$. It follows from the restriction of $\mu_{2,b}$ that $r_b \in [\frac{1}{p_2}, \frac{1}{qp_2})$. Accordingly, asymmetric information with respect to the bank's risk taking results in a negative expected profit of loans granted in the downturn, i.e. $p_2 r_b - \frac{1}{q} < 0$. Moreover, the expected profit of the risk-free asset is also negative, so that the banker abstains from making any investments at $t=1$. However, the banker might raise funds to cover the existing debt overhang by pledging against nonperforming loans. As these loans will materialize a return at the end of the period with certainty, the banker would yield a low profit. Such a behavior will only be feasible if the liquidity risk, Δ_ν, is sufficiently large so that the return on nonperforming loans is high enough, but still low enough to ensure that operating in the safe mode is feasible.

Risky Mode

The banker will operate in the risky mode, $\mathcal{R}$, if he increases the face value of deposits to $\delta_{1,b_g} \in (v_{b_g} l_0 + a_{1,b_g}, v_{b_g} l_0 + r_b l_{1,b_g} + a_{1,b_g}]$. In this case, investors have to distinguish between two expected modes of operation. As long as the face value of deposits is below $v_{b_b} l_0 + r_b l_{1,b_g} + a_{1,b_g}$, investors are able to infer the mode of operation, as the banker would also operate in the risky mode if the condition were bad, i.e. $m = {}^{\mathcal{R}}_{\mathcal{R}}$. A face value above $v_{b_b} l_0 + r_b l_{1,b_g} + a_{1,b_g}$ would, however, imply that the banker would operate in the failure mode if the condition of nonperforming loans was bad. Thus the expected mode is $m = {}^{\mathcal{R}}_{\mathcal{F}}$.

Suppose the face value indicates that the banker would always operate in the risky mode, independent of the condition of nonperforming loans, i.e. $m = {}^{\mathcal{R}}_{\mathcal{R}}$. It follows from equation (7.10) that shareholders will provide equity in the amount of

$$e_{1,b_g} = (1-\lambda)p_2 \left[\left(q v_{b_g} + (1-q) v_{b_b} \right) l_0 + r_b l_{1,b_g} + a_{1,b_g} - \delta_{1,b_g} \right]. \qquad (7.27)$$

As with the expected safe mode $m = {}^{\mathcal{S}}_{\mathcal{S}}$, depositors possess full information on their repayments. As they will only be paid off if the economy recovers from the downturn, they provide funds equivalent to $p_2 \delta_{1,b_g}$. Hence, only equity financing results in too little funding for the banker. This reduction in funding amounts to

$$(1-\lambda)(1-q)p_2 \Delta_\nu l_0. \qquad (7.28)$$

As the face value of deposits allows investors to conclude the mode of operation, debt financing is again less costly than equity financing. The banker thus increases the bank's leverage, which, however, corresponds to a lower rent extraction per unit of loans. The investment cost of granting loans in the downturn remains unchanged. As the banker issues a sufficiently large deposit volume, bank lending is thus never restricted when operating according to $m = {}^{\mathcal{R}}_{\mathcal{R}}$. Recall from condition (7.16) that the expected profit becomes negative when the restriction on bank lending becomes binding.

Suppose the face value indicates that the banker would operate in the failure mode if the condition of nonperforming loans was bad, i.e. $m = {}^{\mathcal{R}}_{\mathcal{F}}$. It follows from equation (7.10) that in this case shareholders will only provide equity in the amount of

$$e_{1,b_g} = (1-\lambda)qp_2 \left[v_{b_g} l_0 + r_b l_{1,b_g} + a_{1,b_g} - \delta_{1,b_g} \right], \qquad (7.29)$$

while depositors will provide funds equivalent to $qp_2\delta_{1,b_g}$. Therefore the mode uncertainty will again lead to an increase in marginal costs of granting loans above expected marginal revenues. As the expected profit of the risk-free asset is always negative when operating in the risky mode, the banker will hence neither invest in risky loans nor in the risk-free asset. Moreover, as the reduction in funding is larger than for $m = \frac{\mathcal{S}}{\mathcal{F}}$, the banker will never pledge against nonperforming loans in order to cover the existing debt overhang.

Failure Mode

Suppose the banker operates in the failure mode, $\mathcal{F}$, by closing the bank at $t = 1$. As this is observable by all market participants, they know that the mode $m = \frac{\mathcal{F}}{\mathcal{F}}$ has been chosen and will provide no funds at all.

Equilibrium

Comparing the banker's expected profits for all modes feasible when the condition of nonperforming loans is good, we obtain:

Proposition 7.2. *If the economy is in a downturn at date $t = 1$ with the condition of nonperforming loans being good, i.e. $k = b_g$, and $\Delta_\nu \leq \frac{v_b}{q}$, the banker's decision on the mode of operation, m, and bank lending, l_{1,b_g}, will have the following properties:*

$$
\begin{array}{lllll}
\mathbb{A}_g: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l^*_{1,b_g} = l^{fb}_{1,b} & \textit{if} & \Delta_\nu \leq \Delta_\nu^{\mathbb{A}_g}, \\
\mathbb{B}_g: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l^*_{1,b_g} = l^{max}_{1,\frac{\mathcal{S}}{\mathcal{S}}} & \textit{if} & \Delta_\nu \in (\Delta_\nu^{\mathbb{A}_g}, \min\{\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{C}_g}\}], \\
\mathbb{C}_g: & m^* = \frac{\mathcal{S}}{\mathcal{R}}, & l^*_{1,b_g} = \min\{l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}, l^{max}_{1,\frac{\mathcal{S}}{\mathcal{R}}}\} & \textit{if} & \Delta_\nu^{\mathbb{B}_g} < \Delta_\nu^{\mathbb{C}_g} \textit{ and } \Delta_\nu \in \left(\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{D}_g}\right], \\
\mathbb{D}_g: & m^* = \frac{\mathcal{R}}{\mathcal{R}}, & l^*_{1,b_g} = l^{fb}_{1,b} & \textit{if} & \Delta_\nu \in \left(\max\{\min\{\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{C}_g}\}, \Delta_\nu^{\mathbb{D}_g}\}, \Delta_\nu^{\mathbb{F}_g}\right], \\
\mathbb{E}_g: & m^* = \frac{\mathcal{F}}{\mathcal{F}}, & l^*_{1,b_g} = 0 & \textit{if} & \Delta_\nu > \Delta_\nu^{\mathbb{F}_g},
\end{array}
$$

with all critical values being defined in the appendix.

Proof. See appendix. □

Analogously to Proposition 7.1, the banker's optimal behavior will crucially depend on the liquidity risk, Δ_ν, if the condition of first period loans is good. Proposition 7.2 indicates that we have to distinguish between five strategies. Figure 7.3 illustrates the equilibrium for the case that $\Delta_\nu^{\mathbb{B}_g} > \Delta_\nu^{\mathbb{C}_g}$. The blue area, A, illustrates efficient bank lending which is accompanied by a safe capital structure. In the green area, B, the bank is still not at risk, but bank lending is not efficient. Different degrees of threat to the stability of the bank are again exhibited in the yellow and

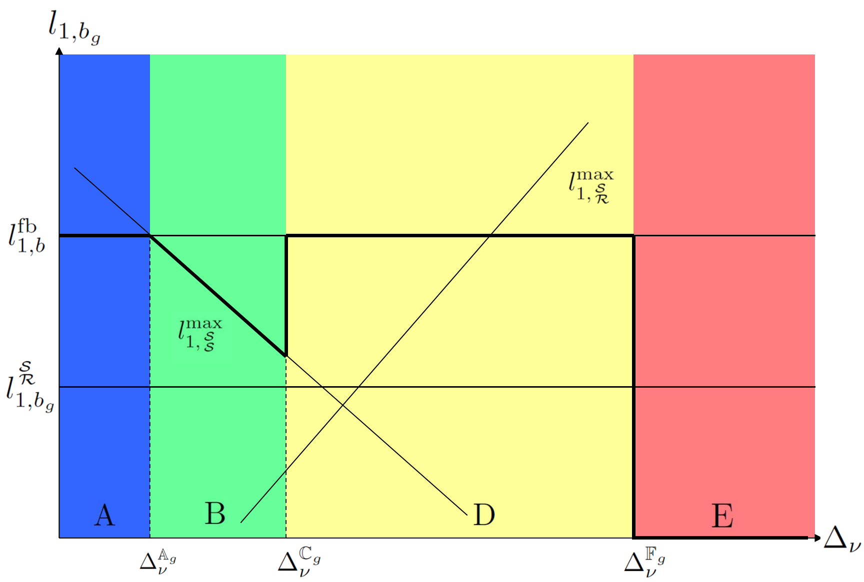

Figure 7.3: Optimal bank lending and capital structure given the good condition, $k = b_g$, of nonperforming loans

red areas. The yellow area, D, corresponds to an efficient bank lending with a bank run occurring only if a recession materializes at the end of the period, while the bank will close already at $t = 1$ in the red area, E.

Again, there exists a unique ordering with respect to these strategies and thus the banker's risk taking, which is similar to the strategies given that the condition of nonperforming loans is bad, presented in Proposition 7.1. If the liquidity risk is very low, so that $\Delta_\nu \leq \Delta_\nu^{\mathbb{A}_g}$, the banker operates according to strategy $\mathbb{A}_g$. In this case, investors are able to identify the safe mode of operation and the funding liquidity of nonperforming loans is sufficiently large that the restriction on bank lending is not binding. Granting loans according to the first best without putting the stability of the bank at risk thus corresponds to the preferred strategy in terms of welfare.

If the liquidity risk increases to $\Delta_\nu \in (\Delta_\nu^{\mathbb{A}_g}, \min\{\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{C}_g}\})$, the funding liquidity of nonperforming loans decreases as investors provide too little funding. Therefore, the restriction on bank lending becomes binding and the banker's expected profit declines as well. We denote this strategy by $\mathbb{B}_g$.

It might be beneficial for the banker to keep investors in the dark about his mode of operation. If investors expect the risky mode for the bad condition, but the banker operates in the safe mode as the return on nonperforming loans is large, he operates according to strategy $\mathbb{C}_g$. This strategy leads to an increase in the funding liquidity of nonperforming loans. Hence, the banker might be able to increase bank lending even though investors' lack of information regarding the bank's risk taking results in higher investment costs of granting new loans. An increase in bank lending will be feasible if the funding liquidity of new loans financed with equity is sufficiently large, e.g. if r_b is high. If the return on nonperforming loans is also large, the banker will only need a small deposit volume to close the funding gap. In this case the additional investment costs are low. If $\Delta_\nu^{\mathbb{B}_g} < \Delta_\nu^{\mathbb{C}_g}$, i.e. if the anticipated risky mode leads to lower expected profits than the concealed risky mode, strategy $\mathbb{C}_g$ is optimal for all liquidity risks in the interval $(\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{D}_g}]$.

For larger liquidity risks, $\Delta_\nu \in (\max\{\min\{\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{C}_g}\}, \Delta_\nu^{\mathbb{D}_g}\}, \Delta_\nu^{\mathbb{F}_g}]$, the expected profit of the different safe modes is too low, either due to the restriction on bank lending or due to the increase in investment costs. Therefore, the banker prefers to put the stability of the bank at risk, which allows him to grant loans according to the first best. We denote this strategy by $\mathbb{D}_g$. However, the banker's expected profit from this strategy decreases as the liquidity risk, Δ_ν, increases, as this leads to a further reduction of funds provided to the banker.

The burden on bank lending resulting from the reduction in funds is too large for all $\Delta_\nu > \Delta_\nu^{\mathbb{F}_g}$. In this case, choosing strategy $\mathbb{D}_g$ yields a negative expected profit for the banker. In consequence, he prefers to close the bank at $t = 1$ and thus operates according to strategy $\mathbb{E}_g$.

To sum up, if the banker possesses private information regarding the value of bank assets, a reallocation of bank profits between the banker and investors will occur. While the banker benefits when investors overestimate bank assets, the informational asymmetry imposes a burden on him in case investors underestimate the value of bank assets. Investment costs of bank lending will only be affected if investors' lack of information regarding the value of bank assets results in a misperception of the bank's risk taking. We find that the banker may grant loans excessively if investors underestimate the riskiness of the bank, as this leads to lower investment costs of granting loans. Likewise, bank lending may be additionally restricted, if investors overestimate the probability of a bank run.

7.4 Margin Call

In contrast to the analysis of Chapters 3 and 6, we now apply the margin call corresponding to the original proposal. Hart and Zingales (2011) suggest that the margin call will be triggered if the price on the bank's CDS contracts exceeds 100 basis points. We will first determine the CDS price based on the information available to all market participants, before we analyze the impact of the margin call on the banker's behavior for the different conditions of nonperforming loans.

7.4.1 Credit Default Swap Price

Investors buy CDS contracts to insure themselves against potential losses in case of a default. Note that we build on the analysis of Hart and Zingales by abstracting from an in-depth analysis of the CDS market. Such an analysis would imply, first, that we explicitly consider risk-averse investors in order to provide a rationale for the CDS market to exist. However, risk-averse investors would demand a risk-premium for providing funds to the bank. This would increase the complexity of our analysis without changing the results qualitatively. Second, we would also have to consider the counterparty of these insurance contracts. In order to keep our analysis simple, we implicitly assume that this counterparty possesses the same information as investors and the regulator.

In this section, we examine a CDS market in which all market participants have symmetric information regarding the trading behavior of the banker. Thus we exclude the possibility that the banker might disguise his risk taking and use his private information additionally to benefit from buying CDS cheaply. As the CDS price, $\mathcal{P}$, is fairly priced due to arbitrage, investors pay a fee proportional to the expected value that will be destroyed in a default. As the CDS price is typically measured in basis points, investors aiming to hedge one percent per unit of investment are thus willing to pay a CDS price of 100 basis points. The share that investors aim to hedge depends on the probability of default and the recovery rate of the underlying asset, i.e. the amount that is still available to investors after the default has materialized. The CDS price thus reads

$$\mathcal{P} = \alpha(1-\rho) \cdot 10,000, \tag{7.30}$$

with α reflecting the probability of default and ρ exhibiting the recovery rate of the bank's assets. Multiplying by 10,000 yields the CDS price in basis points. In our model, a bank run destroys all values of the bank's portfolio. Accordingly we will henceforth set $\rho = 0$, so that the CDS price equals the probability of default in basis points.

Abstracting from any additional frictions in the CDS market, the CDS price reflects the true probability of default as long as market participants are able to infer the banker's mode of operation. As the bank will never default if the banker operates in the safe mode, the CDS price will be equal to zero, i.e. $\mathcal{P}^{\mathcal{S}}_{\mathcal{S}} = 0$. Operating in the risky mode will lead to a bank run if a recession occurs. The CDS price is thus given by $\mathcal{P}^{\mathcal{R}}_{\mathcal{R}} = (1 - p_2) \cdot 10,000$.

However, the indicator function of the CDS price will malfunction if the banker operates according to $m = {}^{\mathcal{S}}_{\mathcal{R}}$. In this case, investors again form expectations about the probability of default based on the probability of the respective condition of nonperforming loans. With probability q they expect the bank to be safe while with probability $1 - q$ they expect that the bank will default if a recession occurs at $t = 2$. Hence, the CDS price will be equivalent to $\mathcal{P}^{\mathcal{S}}_{\mathcal{R}} = (1-q)(1-p_2) \cdot 10,000$. Two types of errors might occur. Suppose the condition of nonperforming loans is good, as their return is equal to v_{b_g}. In this case the bank is safe so that the CDS price indicates an overly high probability of default (Type II error). If the margin call is triggered, this will only impose costs for the regulator. She will have to perform a stress test which enables her to identify the bank's probability of default. As the regulator observes the safe capital structure, she is forced to provide additional equity herself. However, if the condition of nonperforming loans is bad so that their return is lower, v_{b_b}, the banker will operate in the risky mode and the CDS price will reflect an overly low probability of default (Type I error). The latter case imposes a threat on financial stability, as the margin call's threshold might be too low to identify banks' risk taking.

In order to focus on the interesting case, in which the CDS price does not always reflect the bank's risky capital structure, we assume that investors' expected probability of default in the case of $m = {}^{\mathcal{S}}_{\mathcal{R}}$ is too low to trigger the margin call. Considering a threshold of 100 basis points implies that the margin call is supposed to be triggered each time the probability of default exceeds one percent. If $(1 - q)(1 - p_2) < 0.01$, investors' misperception results in an overly low CDS price. This is the case if investors regard it as rather unlikely that nonperforming loans will materialize a low return, v_{b_b}, at the end of the period, and if the probability of a recession, $1 - p_2$, is low. In order to ensure that the CDS price is generally applicable as an indicator of the bank's probability of default, the probability of a recession exceeds one percent, i.e. $(1 - p_2) > 0.01$. Therefore the margin call will be triggered each time market participants are able to correctly identify the risky mode.

7.4.2 Bank Behavior

We will start to comment on the banker's behavior given that the margin call is in place when the return on nonperforming loans is v_{b_b}. Afterwards, we present the impact of the margin call where the condition of these loans is good, so that the return v_{b_g} will materialize at $t = 2$.

Bad Condition

Suppose the banker knows that the return on nonperforming loans is low, i.e. $k = b_b$. As long as market participants are able to identify that the banker operates in the safe mode, the stability of the bank is not at risk and the margin call will never be triggered. If investors infer that the banker has choosen a risky capital structure, they will buy CDS contracts to protect themselves against potential losses resulting from a bank run. Thus, the CDS price will exceed 100 basis points and the margin call will be triggered. As the banker will, however, be unable to raise additional equity, the regulator will have to perform a stress test that will confirm the bank's probability of default. Therefore, she will take over and replace the banker. Shareholders will be wiped out. As the banker will not participate in the bank's profits while bearing private costs of granting loans, operating in the risky mode will thus never be beneficial if investors are able to comprehend the bank's risk taking from the face value of deposits. However, operating in the risky mode may be optimal if market participants underestimate the bank's risk taking. In this case, investors will buy less CDS contracts, so that the price remains below the threshold of the margin call. As argued above, the banker will not buy CDS contracts to benefit from his private information, as this would reveal the condition of nonperforming loans to all market participants. The margin call would be triggered and the banker would be replaced. As he would not participate in the bank's profits, although bearing the private costs of granting loans, the banker never discloses his private information regarding his risk taking. In consequence, operating in the risky mode is feasible, as long as the risky capital structure is not detected by investors. Comparing all strategies feasible under the margin call, we thus obtain:

Proposition 7.3. *If the margin call is in place and the economy is in a downturn at date* $t = 1$ *with the condition of nonperforming loans being bad, i.e.* $k = b_b$*, and* $\Delta_\nu \leq \frac{v_b}{q}$*, the banker's decision on the mode of operation,* m*, and bank lending,* l_{1,b_b}*,*

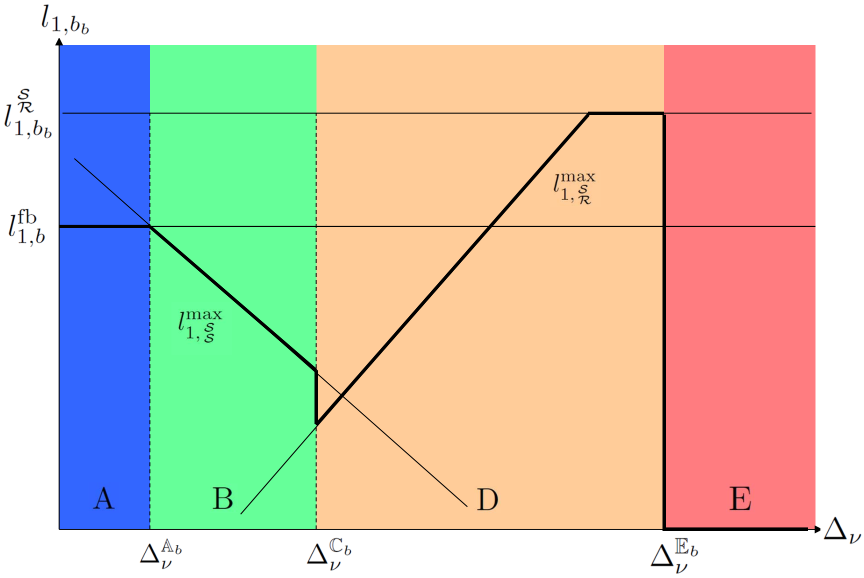

Figure 7.4: Optimal bank lending and capital structure given the bad condition, $k = b_b$, of nonperforming loans with a regulatory margin call in place

will have the following properties:

$$
\begin{array}{llll}
\mathbb{A}_b: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l_{1,b_b}^* = l_{1,b}^{fb} & \text{if} \quad \Delta_\nu < \min\{\Delta_\nu^{\mathbb{A}_b}, \Delta_\nu^{\mathbb{C}_b}\}, \\
\mathbb{B}_b: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l_{1,b_b}^* = l_{1,\frac{\mathcal{S}}{\mathcal{S}}}^{max} & \text{if} \quad \Delta_\nu \in [\Delta_\nu^{\mathbb{A}_b}, \Delta_\nu^{\mathbb{C}_b}), \\
\mathbb{D}_b: & m^* = \frac{\mathcal{S}}{\mathcal{R}}, & l_{1,b_b}^* = \min\{l_{1,b_b}^{\frac{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{max}\} & \text{if} \quad \Delta_\nu \in \left[\Delta_\nu^{\mathbb{C}_b}, \Delta_\nu^{\mathbb{E}_b}\right], \\
\mathbb{E}_b: & m^* = \frac{\mathcal{F}}{\mathcal{F}}, & l_{1,b_b}^* = 0 & \text{if} \quad \Delta_\nu > \Delta_\nu^{\mathbb{E}_b}.
\end{array}
$$

Proof. Omitted. □

The proposition indicates that implementing the margin call might increase the stability of the bank for certain liquidity risks. Comparing these results with Proposition 7.1 shows that operating in the risky mode and granting loans according to the first best is not feasible as investors are able to identify the bank's risk taking. If strategy $\mathbb{C}_b$ is optimal in the absence of any regulation, i.e. if the interval, $\left[\Delta_\nu^{\mathbb{B}_b}, \Delta_\nu^{\mathbb{D}_b}\right)$, is non-empty, imposing the margin call will increase the stability of the bank for some liquidity risks. As operating in the disguised risky mode imposes a tight restriction on bank lending for lower liquidity risks, the banker prefers to operate in the less restricted safe mode for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{C}_b}$. In comparison to Proposition 7.1, the stability of the bank increases in the interval $\left[\Delta_\nu^{\mathbb{B}_b}, \Delta_\nu^{\mathbb{C}_b}\right)$, see Figure 7.4.

At the same time, the margin call might induce unwanted effects. If the banker operates according to strategy $\mathbb{D}_b$, he imposes the same threat on the stability of the bank as choosing strategy $\mathbb{C}_b$. However, if the undetected risky mode, strategy $\mathbb{D}_b$, results in a restriction on bank lending, whereas the identified risky mode, strategy $\mathbb{C}_b$, allows the banker to grant loans according to the first best, the margin call will result in a disintermediation in the interval $\left[\Delta_\nu^{\mathbb{C}_b}, \Delta_\nu^{\mathbb{D}_b}\right)$. For these liquidity risks, bank lending is reduced although the probability of a bank run does not decrease. Note that for $\Delta_\nu = \Delta_\nu^{\mathbb{C}_b}$, choosing strategy $\mathbb{D}_b$ implies an even lower loan volume than choosing strategy $\mathbb{B}_b$. As the banker is able to disguise his risk taking when choosing strategy $\mathbb{D}_b$, his investment costs decrease. Consequently, granting less loans in the undetected risky mode is more profitable than granting more loans in the safe mode.

Good Condition

Suppose the banker knows that nonperforming loans materialize a high return v_{b_g}, i.e. $k = b_g$. Analogously to the case of a low return, the margin call will never be triggered if market participants expect the safe mode with certainty. In contrast, if they are able infer from the face value of deposits that the banker operates in the risky mode, the margin call will again always be triggered. As the banker's profit becomes negative, the identified risky mode is again never optimal. If the banker operates in the safe mode while investors expect the risky mode for the bad condition of nonperforming loans, the CDS price will not reflect the true probability of default. In this case, the CDS price will be positive but will remain below the threshold. The banker could be incentivized to trigger the margin call by buying CDS contracts. As all market participants are able to observe his trading, the CDS price would increase and the margin call would be triggered. The stress test would confirm the bank's safe capital structure and the regulator would have to provide additional equity, which would increase the banker's ability to extract rents. However, we neglect this possibility by assuming that the banker faces large stigma costs when the regulator becomes a shareholder of the bank. Comparing all strategies feasible under the margin call, we thus obtain:

Proposition 7.4. *If the margin call is in place and the economy is in a downturn at date $t = 1$ with the condition of nonperforming loans being good, i.e. $k = b_g$, and $\Delta_\nu \leq \frac{v_b}{q}$, the banker's decision on the mode of operation, m, and bank lending, l_{1,b_g},*

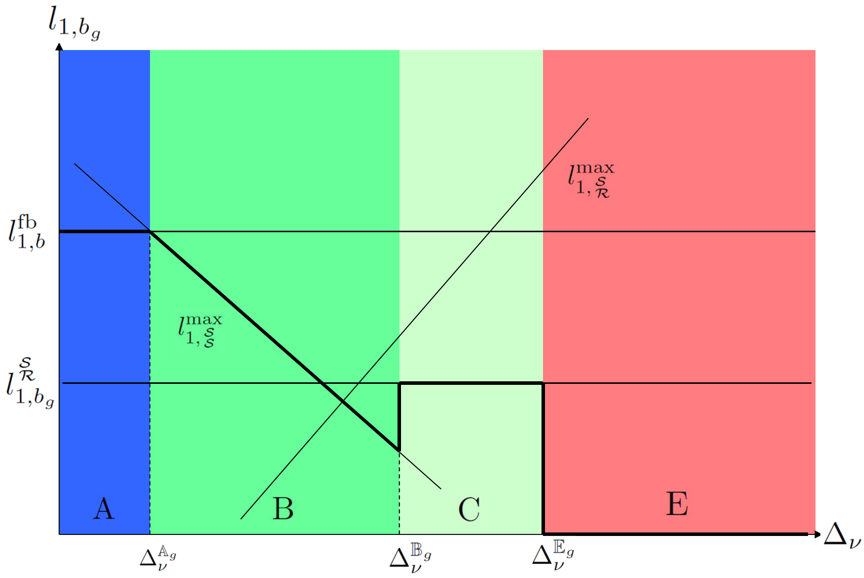

Figure 7.5: Optimal bank lending and capital structure given the good condition, $k = b_g$, of nonperforming loans with a regulatory margin call in place

will have the following properties:

$$
\begin{array}{llll}
\mathbb{A}_g: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l_{1,b_g}^* = l_{1,b}^{fb} & \text{if} \;\; \Delta_\nu \leq \Delta_\nu^{\mathbb{A}_g}, \\
\mathbb{B}_g: & m^* = \frac{\mathcal{S}}{\mathcal{S}}, & l_{1,b_g}^* = l_{1,\frac{\mathcal{S}}{\mathcal{S}}}^{max} & \text{if} \;\; \Delta_\nu \in (\Delta_\nu^{\mathbb{A}_g}, \Delta_\nu^{\mathbb{B}_g}], \\
\mathbb{C}_g: & m^* = \frac{\mathcal{S}}{\mathcal{R}}, & l_{1,b_g}^* = \min\{l_{1,b_g}^{\frac{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{max}\} & \text{if} \;\; \Delta_\nu \in \left(\Delta_\nu^{\mathbb{B}_g}, \Delta_\nu^{\mathbb{E}_g}\right], \\
\mathbb{E}_g: & m^* = \frac{\mathcal{F}}{\mathcal{F}}, & l_{1,b_g}^* = 0 & \text{if} \;\; \Delta_\nu > \Delta_\nu^{\mathbb{E}_g},
\end{array}
$$

with $\Delta_\nu^{\mathbb{E}_g} : \pi_{1,b_g}^{\frac{\mathcal{S}}{\mathcal{R}}}\left(l_{1,b_g}^{\frac{\mathcal{S}}{\mathcal{R}}}\right) = 0.$

Proof. Omitted. □

Given that the condition of nonperforming loans is good, the margin call will increase the stability of the bank for certain liquidity risks. With the margin call in place, it will never be optimal to operate in the risky mode if investors are able to infer the bank's risk taking from the face value of deposits. Hence the banker never chooses strategy $\mathbb{D}_g$, see Figure 7.5. A comparison with Proposition 7.2 indicates that the extent of an increase in the stability of the bank depends on whether strategy $\mathbb{C}_g$ is optimal without a regulation in place. If it is already optimal to disguise the safe mode in the absence of any regulation, the bank's probability of default will only decrease for liquidity risks in the interval $(\Delta_\nu^{\mathbb{D}_g}, \Delta_\nu^{\mathbb{F}_g}]$. If, however, strategy $\mathbb{D}_g$ is always more beneficial than strategy $\mathbb{C}_g$, the stability of the bank increases for all liquidity risks for which the banker preferred to operate in the risky mode, $\substack{\mathcal{R} \\ \mathcal{R}}$, i.e. for all $\Delta_\nu \in (\Delta_\nu^{\mathbb{C}_g}, \Delta_\nu^{\mathbb{F}_g}]$.

In the absence of the margin call, the banker will only operate according to strategy $\mathbb{C}_g$ if this strategy yields a nonnegative expected profit. Recall from Proposition 7.2 that the banker's expected profit from strategy $\mathbb{C}_g$ becomes negative for lower liquidity risks than the expected profit from strategy $\mathbb{D}_g$. Therefore, Proposition 7.4 further exhibits that the risk of a bank run will increase for larger liquidity risks if the condition of nonperforming loans is good. For all liquidity risks in the interval of $(\Delta_\nu^{\mathbb{F}_g}, \Delta_\nu^{\mathbb{E}_g}]$, the margin call leads to a bank run at $t = 1$. Without the regulation in place, the banker would operate according to strategy $\mathbb{D}_g$ so that the bank would only experience a run if the economy ran into a recession at $t = 2$. Moreover, as the banker would grant loans according to the first best when choosing strategy $\mathbb{D}_g$, the margin call not only increases the riskiness of the bank but additionally cuts back lending.

7.5 Discussion

7.5.1 Robustness

In this section, we consider the impact of potential solutions to the principal-agent problem resulting from the banker's informational advantage with respect to the value of bank assets. Moreover, we assess potential changes in the banker's behavior, given that he again optimizes bank lending in a dynamic setting.

A Pareto improvement of the problems resulting from asymmetric information was feasible, if investors could write a contract that would incentivize the banker to reveal the value of bank assets (Stiglitz, 1975). If investors were able to gather the banker's non-pecuniary costs, they would conclude that the return on nonperforming loans was low each time they observed an overinvestment. Consequently, they would provide less funding. However, in reality such a solution might be not applicable, as investors possess too little information on bankers' private, non-pecuniary costs of granting loans. Hence, they are unable to identify whether the loan volume granted in an economic downturn corresponds to an over- or underinvestment.

Following the idea of Spence (1973), it might be likewise beneficial for the banker to signal that the value of bank assets is larger than investors expect. In this analysis, we assume that the banker possesses no funds on his own so that he cannot signal the good condition of nonperforming loans by co-financing new loans. Enriching our setting by this option would be one alternative to increasing the funding provided by investors. The banker would thus be able to increase bank lending. Nevertheless, the argument described above will persist to a smaller extent as long as a certain lack of information remains in place.

If investors were unable to observe the banker's trading activities in the CDS market, the principal-agent problem would become more pronounced. While the banker will never buy CDS contracts if he chooses a safe capital structure, he will additionally benefit from investors' misperception when putting the stability of the bank at risk. Investors will not copy the banker's trading behavior, so that the CDS price remains unaffected. Consequently the banker is unable to force the regulator to become a shareholder of the bank. However, if the banker knows that the probability of default is larger than expected by all other market participants, he can realize a profit by buying CDS contracts at a de facto overly low price. As a result, disguising his risk taking becomes more beneficial than in the case considered in our analysis.

Extending our framework to a dynamic model, as in the previous chapters, will change our results only slightly. At the beginning of the first period, both investors and the banker will have the same expectations regarding the return on nonperforming loans in the downturn. Therefore, the banker will decide on bank lending over the business cycle based on expectations about his optimal behavior in the downturn. Analogously to the argument presented in Chapter 4, he will thus balance expected costs and benefits over time, taking into account the impact of nonperforming loans on his ability to grant loans in the downturn. Hence he might increase bank lending above the first best in good times in order to loosen the restriction on bank lending in the downturn. Note that this overinvestment in the first period corresponds to a safe capital structure, so that financial stability is never at risk. Therefore, the overinvestment resulting from an intertemporal optimization contrasts to the overinvestment identified in this chapter, which arises from investors providing excess liquidity as they are unable to infer the bank's risky capital structure from the face value of deposits.

7.5.2 Implications for Financial Stability and Bank Regulation

Our analysis indicates that the margin call can be considered an appropriate regulatory measure for certain liquidity risks if both investors' informational disadvantage regarding the value of bank assets and the threshold which triggers the margin call are low. However, if investors' lack a lot of information, this threshold might be insufficient, even if threats to financial instability are high, i.e. as the probability of a recession is high. Therefore, it seems advisable to focus on how to achieve better information regarding the risks of bank assets. Market participants are incentivized to obtain this information, as they aim to maximize their investment profits. However, as long as banks are able to hide important information, financial instability might not be detected. A regulator could foster the gathering of information by providing appropriate disclosure rules. If this information was available to investors, informational asymmetry regarding the value of banks' assets could be reduced.

We have identified that the margin call might impose unwanted effects for larger liquidity risks. As long as investors are able to infer banks' risk taking, the margin call will always be triggered. The banker may thus either disguise the bank's risky capital structure, which corresponds to inefficient bank lending, or close the bank in the downturn. In the latter case, the margin call would lead to an immediate bank run and thus a severe credit crunch. Considering the impact of the margin call in a dynamic framework, this effect will be mitigated, as the analysis of Chapter 6 showed. If the banker already anticipates the bank run in the downturn at the beginning of the first period, he will prefer to grant no loans at all when the margin call is in place. Therefore these larger liquidity risks will still result in a severe credit crunch, but will be accompanied by a safe capital structure.

Whether 100 basis points is the appropriate threshold is debatable. On the one hand, CDS prices for both Lehman Brothers and AIG exceeded this threshold several months before Lehman Brothers' bankruptcy in September 2008. This is illustrated in Figure 7.6. Consequently, an early intervention either by the financial institutions or by the regulator might have been feasible. On the other side, a threshold of 100 basis points might lead to overly large amounts of margin calls for more stable institutions. Although JPMorgan Chase is considered to be one of the stable large financial institutions during the world financial crisis, their CDS price exceeded 100 basis points quite frequently in the aftermath of the crisis. Similarly, UBS benefitted from successfully implemented asset purchases as described in Chapter 2.4.2. Despite this intervention, the CDS price stayed above 100 basis points until the end of 2013.

7.6 Conclusion

In this chapter, we have identified that bankers' private information about the value of banks' assets might hamper the effectiveness of the margin call. In contrast to the previous chapters, we abstract from a dynamic setup and focus on the bank

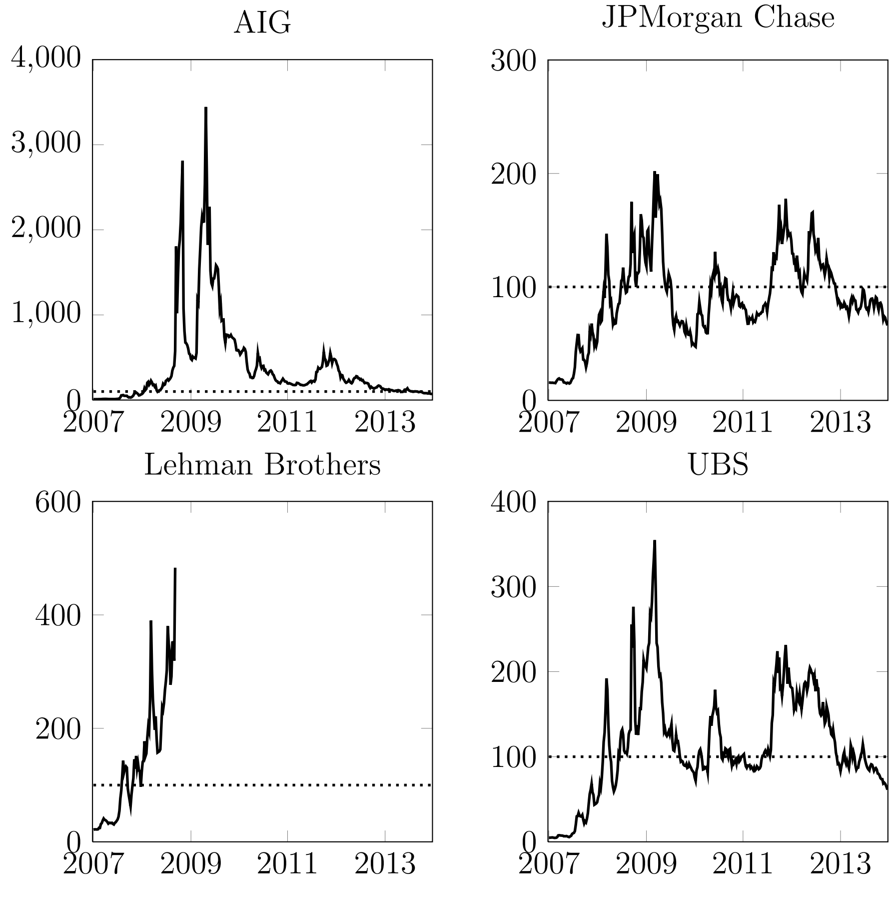

Figure 7.6: Senior five-year CDS prices, 2007-2013
Source: Bloomberg

lending decision in the downturn, during which financial stability might be at risk. Due to monitoring their assets, bankers are able to better assess the return on nonperforming loans in the case of a rollover. Investors, however, have to form expectations on these returns. If investors only face a lack of information about the value of nonperforming loans, this will affect the funding liquidity of these loans in the downturn. Investors provide either too little or too much funding, which results in a reallocation of the bank's profits. However, if investors are additionally unable to understand the riskiness of banks' capital structures from the face value of deposits, their informational disadvantage will affect the investment cost of granting new loans. As a result, the banker might be either confronted with a tighter restriction on bank lending or able to grant loans excessively.

Applying the original design of the margin call proposed by Hart and Zingales (2011) to this setting, we are able to identify that an inappropriate threshold might impose unwanted effects on the banking sector. If the threshold is too large, the banker might be incentivized to leave investors in the dark about the riskiness of the bank's capital structure. Given that investors' lack of information is sufficiently large, he can therewith avoid a takeover by the regulator. In addition, this behavior provides him with excess liquidity, which lowers his investment costs of granting loans. In this case, the margin call is not eligible to increase financial stability, but leads to an excessive credit boom which will bust if a recession materializes. However, if market participants informational disadvantage about the value of banks' assets is not too large and if the threshold of the margin call is sufficiently low, following such a simple policy rule does seem advisable.

Chapter 8

Conclusion and Outlook

Due to globalization and the resulting increased financial integration in recent decades, the complexity of the financial system has become more pronounced. Financial institutions have become more connected with each other, and these linkages are not always obvious to market participants. As a result, detecting systemic risk in time became more difficult for both investors and regulatory agencies. A prominent example of the world financial crisis is the Fed's misperception of the impact of Lehman Brothers' bankruptcy on the financial system. Furthermore, AIG's systemic importance for the CDS market was also not identified until 2008.

In the aftermath of the world financial crisis, several suggestions have been made by policy makers, professionals and scholars alike on how to reduce threats to the stability of the financial system. Regulatory frameworks have become more comprehensive in order to capture the increased complexity of the financial system. The BCBS adjusted the Basel Accord by adding several fine-tuning instruments to increase banks' ability to absorb shocks. The Dodd-Frank Act is even more comprehensive and covers more than 2,300 pages. However, are intricate regulatory measures really needed to reduce systemic risk? The answer of this thesis is: not necessarily.

In this thesis we set out to evaluate the effectiveness of the regulatory margin call by Hart and Zingales (2011). This regulatory measure constitutes a counterproposal to the Basel III Accord, as it is based on market information about prospective developments instead of information about past performance. The margin call is outstanding in two respects. It is both a simple rule and the first proposal that explicitly considers interdependencies between crisis prevention and crisis management measures in a theoretical analysis.

In detail, the margin call suggests the prevention of a financial crises by capital requirements which are based on the price of CDS contracts written on the financial institutions. Hart and Zingales propose that if the CDS price exceeds a threshold of 100 basis points for 30 days, financial institutions have to raise additional equity to build a buffer to absorb potential losses. If this buffer lowers the probability of default, the CDS price will decline. If financial institutions are either unable or unwilling to provide this additional equity buffer, the margin call explicitly determines how regulatory intervention, in the form of crisis management, has to take place. First, the regulator has to perform a stress test. If this stress test confirms potential risks to the stability of the institution and the financial system, she will wipe out shareholders and will replace the manager with a receiver.

Hart and Zingales claim that their proposal is a free lunch. They find that the margin call increases financial stability without imposing any costs in terms of less efficient investments. More precisely, Hart and Zingales argue that their margin call will never hamper any investment project if the net present value of this project is positive. As this statement contradicts the literature on regulation, we challenge their results and take a closer look at the margin call. Finding an arithmetic error in their analysis, we arrive at a different conclusion with respect to financial institutions' investment opportunities. Based on this result, we derive the three research questions of this thesis.

Focusing on banks as one special type of financial institution, we first identify the relevant determinants of bank lending besides the net present value of bank loans. In a dynamic framework, we show that banks' investment decisions over the business cycle are driven by their cash flow, which depends on the success of investments undertaken in the past and the banker's ability to pledge against prospective returns, i.e. their funding liquidity. Both factors are affected by the liquidity risks in the economy. These liquidity risks can be understood as macroeconomic common shocks to the financial sector. Based on the empirical observation of a co-movement between bank lending and the business cycle, the bulk of literature argues that bank lending affects the business cycle. Neglecting these feedback effects, we shed light on the reversed causality, i.e. the impact of business cycle fluctuations on bank lending, which has not received that much attention yet. Depending on the liquidity risk in the economy, we determine different lending patterns. While bankers prefer a safe capital structure if the liquidity risks are small they might be incentivized to put the stability of the financial system at risk by choosing risky capital structures. We identify procyclical lending, a secular trend in granting loans or a curtailing of loans.

Second, we compare the margin call with the main instruments of the Basel III Accord, with respect to the trade-off between financial stability and efficient bank lending. The instruments under investigation are risk-weighted capital requirements, countercyclical capital buffer requirements and the liquidity coverage ratio. We find that there is no one-size-fits-all regulatory measure. While all regulatory measures are able to increase financial stability for certain liquidity risks, they differ with respect to their impact on bank lending. Opposing to the findings in Hart and Zingales (2011), we show that the margin call might result in a severe credit crunch for large liquidity risks. Similar effects may occur when implementing a rather high liquidity coverage ratio. Moreover, our findings support the argument that risk-weighted capital requirements may foster procyclical lending. In contrast to the procyclical lending pattern identified in the benchmark scenario, this lending pattern imposes a threat to financial stability in an economic downturn in which banks are restricted in granting loans. A countercyclical capital buffer may countervail the procyclical effect and thereby reduce the inefficiency with respect to bank lending. However, this comes at the cost of increased risk taking.

For a given liquidity risk in the economy, the regulator might choose the measure that ensures financial stability at the lowest cost. This will, however, only be feasible if the regulator possesses the same information as all other market participants. Moreover, liquidity risks might change over time. In this case, the regulator can only switch from one regulatory measure to another if this switching is not associated with any adjustment costs. Similarly to the rather high liquidity coverage ratio, the margin call ensures financial stability for a comparably broad range of liquidity risks, but might come at the cost of a severe credit crunch if liquidity risks are high. Both measures might thus serve as an appropriate measure to absorb macroeconomic shocks, if the regulator is unable to adjust the regulatory framework frequently. With respect to the trade-off between financial stability and efficient bank lending, we can thus conclude that the costs of the margin call are, to some extent, in line with the costs of other regulatory measures.

Third, we focus on a potential limitation of the margin call. The effectiveness of the CDS price to indicate the probability of default might be hampered in the presence of asymmetric information. Based on the observation that bankers typically possess private information regarding the value of their assets, we analyze the impact of asymmetric information on financial stability and bank lending. If both investors and the regulator face an informational disadvantage with respect to the value of bank assets, they may overestimate or underestimate banks' risk taking. Investors will provide either too little or too much funding in comparison with the fundamentally justified value of their investment. Accordingly, investors' lack of information alters banks' investment costs. Banks may thus either face an additional restriction on bank lending or may grant loans excessively.

With respect to financial stability, asymmetric information might induce both a type I and type II error. If the CDS price indicates an overly high probability of default although the stability of the bank is not at risk, the banker has to bear additional costs. He has to raise additional equity to prevent the stress test or the stress test confirms the stability of the bank so that the regulator becomes a shareholder of the bank. Assuming that governmental injections are associated with stigma costs for the banker, both alternatives constitute costs for the banker. However, the CDS price might also indicate an overly low probability of default. In this case, the effectiveness of the margin call is hampered, as it is not triggered although the stability of the bank and the financial system is at risk. We find that for both types of errors, the margin call might result in a disintermediation. For certain liquidity risks, the margin call will not increase financial stability but will result in an inefficient bank lending. Having identified a similar effect for a strongly countercyclical capital buffer, we argue that the limitations of the margin call are again comparable to other regulatory measures.

We can conclude from the different analyses of the margin call that this regulatory measure exhibits several advantages compared with the instruments of the Basel III Accord. While the latter is only applicable to banks, the margin call allows the extension of regulation to all financial institutions on which CDS contracts are written, such as the insurance corporation AIG. Second, the CDS price contains all kinds of information. Most importantly, this information also comprises expectations about future developments, which might not yet be reflected in banks' balance sheets. The effectiveness of Basel III depends on whether regulators have drawn the right conclusions from the world financial crisis and focus on the relevant key figures to increase financial stability. In contrast, the margin call does not have to identify single indicators and their potential interdependencies, but considers financial institutions' overall risk. As a result, this regulatory measure might be suitable to capture potential threats to financial stability which have not been identified by regulators yet. Finally, the CDS price is easily observable by all market participants. Investors might thus be able to demand a premium when they observe threats to the stability of the financial institution. The institutions might thus be incentivized to reduce their risk taking. Although the margin call is not the free lunch that Hart and Zingales claim, its limitations are comparable with the limitations of other regulatory measures. The margin call might therefore be equally able to reduce banks' risk taking. Accordingly, we can conclude that increased complexity in regulation may not be needed in order to ensure financial stability.

However, this analysis can only be understood as a first step to evaluate the effectiveness of the margin call. Several questions need to be answered, which are beyond the scope of this thesis. Up to now, we have only focused on the impact of the margin call on bank loan supply. In order to identify the adjustment processes in the credit market, and therefore the potential impact on economic growth, a more in-depth analysis is needed, which also includes credit demand. If credit demand is, to some extent, elastic, a cutback in credit supply results in higher interest rates in the credit market, and hence, in a (further) decline of credit to the private sector. A decline in investments may thus result in a slow-down in economic growth. An analysis of such a general equilibrium would shed more light on the social costs resulting from inefficient bank lending.

The CDS market's ability to detect financial institutions' probability of default is essential for the effectiveness of the margin call. Therefore an analysis of which determinants ensure the functioning of this market needs to be carried out. The analysis of the impact of asymmetric information indicates that observing financial institutions' trading activities will be beneficial. Trading these derivatives in an exchange may thus be one factor to consider.

A further crucial aspect is how to reduce the probability of fire sales. Instead of raising additional equity, banks might sell parts of their risky assets to reduce the probability of default. We have argued that fire sales are rather unlikely in the presence of relationship lending. However, if selling risky assets is the only alternative to prevent a takeover, these fire sales might constitute a major threat to the stability of the financial system.

Even if the margin call is beneficial from a welfare perspective, there might be some legal problems in implementing Hart and Zingales' proposal. Although the Dodd-Frank Act provides the legal basis for imposing such a regulatory margin call, this might not be feasible in Europe. For instance, in Germany, wiping out shareholders is incompatible with the federal constitution.

The analytical framework of the margin call may also serve as a starting point to analyze the interdependencies between crisis prevention and crisis management in more detail. Anticipating the regulator's intervention if the bank turns out to be in distress reduces banks' risk taking ex ante. In consequence, financial stability increases. The margin call could thus be compared with other commitments of regulatory intervention during financial crises. Moreover, the interdependency also exists the other way around. For instance, implementing government guarantees as a crisis management measure might increase banks' risk taking after the crisis.

Therefore, a certain crisis prevention measure might be needed to reduce these incentives. In order to analyze this linkage, a different framework is needed, however.

To sum up, the margin call constitutes a simple rule which might be as suitable for increasing financial stability as the measures of the Basel III Accord. Accordingly, this result may incentivize both regulatory agencies and scholars to think about how to improve regulation without further increasing regulatory complexity.

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Appendix

Proof of Lemma 4.1

This proof proceeds in three steps. First, we determine the reduced forms for all modes feasible in the upswing at $t = 1$. Second, we derive the optimal loan volume for each mode. Finally, we compare the expected profit of these modes to show that, independent of the loan volume, l_0, granted in the first period, the expected profit of the safe mode is always larger than the others.

Determination of Reduced Forms

1. Suppose the banker operates in the safe mode. In this case, the face value of deposits is restricted to $\delta_{1,g} \leq r_{g,l} l_{1,g} + a_{1,g}$. Inserting this restriction on deposits as well as the amount provided by depositors (4.9) into the budget constraint (4.8), and making use of (4.5) when applying the budget constraint to the expected profit (4.7), yields

$$\max_{l_{1,g}, a_{1,g} \in \mathbb{R}^+} \pi_{1,g}^{\mathcal{S}} = \omega_{1,g} l_0 + \phi_{1,g}^{\mathcal{S}} \left(l_{1,g} \right) \tag{A.1}$$

$$\text{s.t.} \quad l_{1,g} \geq -\frac{\omega_{1,g}}{r_{g,l} - 1} l_0. \tag{A.2}$$

2. Suppose the banker operates in the risky mode. In this case, the face value of deposits is restricted to $\delta_{1,g} \in (r_{g,l} l_{1,g} + a_{1,g}, r_{g,h} l_{1,g} + a_{1,g}]$. Inserting this restriction on deposits as well as the amount provided by depositors (4.9) into

the budget constraint (4.8), and making use of (4.6) when applying the budget constraint to the expected profit (4.7), yields

$$\max_{l_{1,g},a_{1,g}\in\mathbb{R}^+} \pi_{1,g}^{\mathcal{R}} = \omega_{1,g} l_0 + \phi_{1,g}^{\mathcal{R}}(l_{1,g}) - (1-p_{2,g})a_{1,g}. \tag{A.3}$$

$$\text{s.t.} \quad l_{1,g} \geq -\frac{\omega_{1,g} l_0 + (1-p_2)a_{1,g}}{p_{2,g} r_{g,h} - 1}. \tag{A.4}$$

3. Technically, the bank will not fail if the banker decides to close the bank. In this case, he simply pays off depositors and this expected profit reads

$$\max_{l_{1,g},a_{1,g}\in\mathbb{R}^+} \pi_{1,g}^{\mathcal{F}} = \omega_{1,g} l_0. \tag{A.5}$$

Note that $\omega_{1,g} > 0$, as $p_1 v_g > 1$ and therefore $v_g > 1$. Accordingly, the return on first period loans is sufficiently large to pay off all deposits.

Determination of Optimal Loan Volumes at $t = 1$

In the next step, we determine the optimal loan volume for all modes feasible.

1. Suppose the banker operates in the safe mode. It thus follows directly from (A.1) that $\frac{\partial \pi_{1,g}^{\mathcal{S}}}{\partial l_{1,g}} = \phi_{1,g}^{\mathcal{S}\prime}(l_{1,g})$, which decreases in $l_{1,g}$ and is equal to zero for $l_{1,g} = l_{1,g}^{\text{fb}}$. Moreover, it follows, due to $p_{2,b} r_{b,h} > 1$ and $r_{g,l} > r_{b,h}$, that the RHS of (A.2) is negative so that bank lending is never restricted in the safe mode. As $\frac{\partial^2 \pi_{1,g}^{\mathcal{S}}}{\partial l_{1,g}^2} = -c''(l_{1,g}) < 0$, the optimal loan volume is $l_{1,g}^* = l_{1,g}^{\text{fb}}$.[1]

2. Suppose the banker operates in the risky mode. It thus follows directly from (A.3) that $\frac{\partial \pi_{1,g}^{\mathcal{R}}}{\partial l_{1,g}} = \phi_{1,g}^{\mathcal{R}\prime}(l_{1,g})$, which decreases in $l_{1,g}$ and is equal to zero for $l_{1,g} = l_{1,g}^{\mathcal{R}}$. As the RHS of(A.4) is negative so that bank lending is not restricted, the optimal loan volume is $l_{1,g}^* = l_{1,g}^{\mathcal{R}} < l_{1,g}^{\text{fb}}$.

[1] In the following proofs, we will neglect the second derivative, as the convex cost function always ensures that the obtained loan volumes constitute an optimum.

3. Suppose the banker closes the bank in the downturn. By definition, the optimal loan volume is thus $l_{1,g}^{*} = 0$.

Comparison

Due to $\phi_{1,g}^{\mathcal{S}}(l_{1,g}) > \phi_{1,g}^{\mathcal{R}}(l_{1,g})$ and $l_{1,g}^{\text{fb}} > l_{1,g}^{\mathcal{R}}$, it follows directly that $\pi_{1,g}^{\mathcal{S}*} > \pi_{1,g}^{\mathcal{R}*} > \pi_{1,g}^{\mathcal{F}*} = \omega_{1,g} l_0$. Accordingly, the banker always prefers the safe mode, $\mathcal{S}$, over the risky mode, $\mathcal{R}$, and the failure mode, $\mathcal{F}$, independent of the loan volume granted in the first period.

Proof of Lemma 4.2

This proof proceeds in three steps. First, we determine the reduced forms for all modes feasible in the upswing at $t = 1$. Second, we derive the optimal loan volume for each mode. Finally, we compare the expected profits of the different modes to identify the banker's optimal behavior depending on the loan volume, l_0, granted in the first period.

Determination of Reduced Forms

1. Suppose the banker operates in the safe mode. In this case, the face value of deposits is restricted to $\delta_{1,b} \leq r_{b,l} l_{1,b} + a_{1,b}$. Inserting this restriction on deposits as well as the amount provided by depositors (4.9) into the budget constraint (4.8), and making use of (4.5) when applying the budget constraint to the expected profit (4.7), yields

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi^{\mathcal{S}}_{1,b} = \omega_{1,b} l_0 + \phi^{\mathcal{S}}_{1,b}\left(l_{1,b}\right) \tag{A.6}$$

$$\text{s.t.} \quad l_{1,b} \geq \frac{\omega_{1,b}}{1 - r_{b,l}} l_0 =: l_1^{\max}. \tag{A.7}$$

2. Suppose the banker operates in the risky mode. In this case, the face value of deposits is restricted to $\delta_{1,b} \in (r_{b,l} l_{1,b} + a_{1,b}, r_{b,h} l_{1,b} + a_{1,b}]$. Inserting this restriction on deposits as well as the amount provided by depositors (4.9) into the budget constraint (4.8), and making use of (4.6) when applying the budget constraint to the expected profit (4.7), yields

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi^{\mathcal{R}}_{1,b} = \omega_{1,b} l_0 + \phi^{\mathcal{R}}_{1,b}\left(l_{1,b}\right) - (1 - p_{2,b}) a_{1,b}. \tag{A.8}$$

$$\text{s.t.} \quad l_{1,b} \geq -\frac{\omega_{1,b} l_0 + (1 - p_2) a_{1,b}}{p_{2,b} r_{b,h} - 1} =: l_1^{\min}. \tag{A.9}$$

3. Suppose the banker operates in the failure mode. Due to limited liability, his expected profit thus yields

$$\pi_{1,b}^{\mathcal{F}} = \max\{\omega_{1,b} l_0, 0\}. \tag{A.10}$$

Determination of Optimal Loan Volumes at $t = 1$

In the next step, we determine the optimal loan volume for all modes feasible.

1. Suppose the banker operates in the safe mode. It thus follows directly from (A.6) that $\frac{\partial \pi_{1,b}^{\mathcal{S}}}{\partial l_{1,b}} = \phi_{1,b}^{\mathcal{S}\prime}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l_{1,b}^{\text{fb}}$. Considering the restriction on bank lending (A.7), the optimal loan volume is thus $l_{1,b}^{*} = \min\{l_{1,b}^{\text{fb}}, l_1^{\max}\}$.

2. Suppose the banker operates in the risky mode. It thus follows directly from (A.8) that $\frac{\partial \pi_{1,b}^{\mathcal{R}}}{\partial l_{1,b}} = \phi_{1,b}^{\mathcal{R}\prime}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l_{1,b}^{\mathcal{R}}$. Suppose the restriction on bank lending (A.9) was binding. As granting loans according to $l_1^{\min}$ will always result in a nonpositive expected profit, the banker will never operate in the risky mode if the restriction becomes binding. Accordingly, the optimal loan volume is $l_{1,b}^{*} = l_{1,b}^{\mathcal{R}} < l_{1,b}^{\text{fb}}$.

3. Suppose the banker closes the bank in the downturn. By definition, the optimal loan volume is thus $l_{1,b}^{*} = 0$.

Critical Values of l_0

1. If $\omega_{1,b} > 0$, it follows, due to $l_1^{\max} > 0$ and $l_1^{\min} < 0$, that $\pi_{1,b}^{\mathcal{S}*} > \omega_{1,b} l_0$ and $\pi_{1,b}^{\mathcal{R}*} > \omega_{1,b} l_0$ so that the failure mode is never optimal. Comparing $\pi_{1,b}^{\mathcal{S}*}$ and $\pi_{1,b}^{\mathcal{R}*}$ yields $\pi_{1,b}^{\mathcal{S}*} \geq \pi_{1,b}^{\mathcal{R}*}$ if

$$\phi_{1,b}^{\mathcal{S}}\left(\min\left\{l_{1,b}^{\text{fb}}, l_1^{\max}\right\}\right) \geq \phi_{1,b}^{\mathcal{R}}\left(l_{1,b}^{\mathcal{R}}\right). \tag{A.11}$$

As $l_1^{\max}$ increases in l_0, the banker prefers the safe mode, $\mathcal{S}$, over the risky mode, $\mathcal{R}$, for all $l_0 \geq l_0^{\min}$. For all $l_0 < l_0^{\min}$ the banker prefers the risky mode, $\mathcal{R}$, over the safe mode, $\mathcal{S}$, as $\pi_{1,b}^{\mathcal{R}*} > \pi_{1,b}^{\mathcal{S}*} > \pi_{1,b}^{\mathcal{F}*}$.

2. If $\omega_{1,b} < 0$, it follows due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing $\pi_{1,b}^{\mathcal{R}*}$ and $\pi_{1,b}^{\mathcal{F}*}$ yields, due to $\pi_{1,b}^{\mathcal{R}*}(l_1^{\min}) < 0$, that $\pi_{1,b}^{\mathcal{R}*} \geq \pi_{1,b}^{\mathcal{F}*}$ if

$$-\frac{\phi_{1,b}^{\mathcal{R}}\left(l_{1,b}^{\mathcal{R}}\right)}{\omega_{1,b}} > l_0. \tag{A.12}$$

This condition holds for all $l_0 \leq l_0^{\max}$. Accordingly, the banker will prefer the risky mode, $\mathcal{R}$, over the failure mode, $\mathcal{F}$, for all $l_0 \leq l_0^{\max}$. For all $l_0 > l_0^{\max}$ he will prefer the failure mode, $\mathcal{F}$, over the risky mode, $\mathcal{R}$, as $\pi_{1,b}^{\mathcal{F}*} > \pi_{1,b}^{\mathcal{R}*}$.

Proof of Proposition 4.3

This proof proceeds in three steps. First, we determine the reduced forms for all combinations of modes feasible. Second, we derive the banker's optimal loan volume for each strategy feasible. Finally we compare the expected profits of the different strategies, to identify the banker's optimal behavior, depending on the liquidity risk, Δ_1.

Determination of Reduced Forms

Lemma 4.1 shows that the banker will always operate in the safe mode if the economy is in an upswing at $t = 1$. Accordingly, we only have to consider all combinations feasible based on the modes available in the first period and in the downturn at $t = 1$.

1. Suppose the banker will operate in the safe mode independent of the date or state of the economy, so that $m_0 = \mathcal{S}$ and $m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. In conjunction with Lemma 4.1 and 4.2, inserting the funds provided by depositors (4.18) into the budget constraint (4.17), and making use of the definition of $\phi_t^{m_t}$ and $r_{b,l}$ when applying the budget constraint to the expected profit, yields

$$\max_{l_0,a_0\in\mathbb{R}^+} \pi_0^{\mathcal{SS}}(l_0) = \phi_0^{\mathcal{S}}(l_0) + p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}^{\mathcal{S}}(\max\{l_{1,b}^{\text{fb}}, l_1^{\max}\}) \quad \text{(A.13)}$$

$$\text{with} \quad l_1^{\max} = \frac{\mu_1 - p_1\Delta_1 - 1}{1 - \mu_{2,b} + p_{2,b}\Delta_{2,b}} l_0 =: \psi l_0. \quad \text{(A.14)}$$

2. Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if the economy is in a downturn at $t = 1$, so that $m = \mathcal{SR}$. In conjunction with Lemma 4.1 and 4.2, considering the funds provided by depositors (4.18) into the budget constraint (4.17), and making

use of the definition of $\phi_t^{m_t}$ and $r_{b,h}$ when applying the budget constraint to the expected profit, yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{SR}}(l_0) = \phi_0^{\mathcal{S}}(l_0) + p_1 \phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}^{\mathcal{R}}(l_1^{\mathcal{R}}) \tag{A.15}$$

$$\text{s. t.} \quad l_0 \leq \frac{\phi_{1,b}^{\mathcal{R}}\left(l_1^{\mathcal{R}}\right)}{1-\mu_1+p_1\Delta_1} =: l_0^{\max}. \tag{A.16}$$

3. Suppose the banker operates in the risky mode already in the first period, which results in a bank run in the downturn at $t=1$, so that $m=\mathcal{RF}$. In conjunction with Lemma 4.1 and 4.2, inserting the funds provided by depositors (4.18) into the budget constraint (4.17), and making use of the definition of $\phi_t^{m_t}$ and $r_{b,h}$ when applying the budget constraint to the expected profit, yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{RF}}(l_0) = \phi_0^{\mathcal{R}}(l_0) - (1-p_1)a_0 + p_1 \phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) \tag{A.17}$$

$$\text{s. t.} \quad l_0 > l_0^{\max}. \tag{A.18}$$

Determination of Optimal Loan Volumes at $t=0$

1. Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank lending when operating according to $m=\mathcal{SS}$. It follows from (A.13) that $\frac{\partial \pi_0^{\mathcal{SS}}}{\partial l_0} = \phi_0^{\mathcal{S}\prime}(l_0)$, which decreases in l_0 and is equal to zero for $l_0 = l_0^{\text{fb}}$. Hence the optimal loan volume is $l_0^* = l_0^{\text{fb}}$.

   In order to determine the equilibrium, we have to determine how changes in the liquidity risks Δ_1 and $\Delta_{2,s}$ affect the optimal loan volumes. Due to the mean preserving spread we can conclude that $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$, $\frac{\partial l_{1,g}^{\text{fb}}}{\partial \Delta_{2,g}} = 0$ and $\frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_{2,b}} = 0$.

2. Suppose the banker operates according to strategy $\mathcal{B}$, i.e. he always operates in the safe mode but faces a restriction in the bad situation at $t=1$, i.e. (A.14)

becomes binding. It follows from (A.13) that

$$\frac{\partial \pi_0^{\mathcal{SS}}}{\partial l_0} = \phi_0^{\mathcal{S}\prime}(l_0) + (1-p_1)\phi_{1,b}^{\mathcal{S}\prime}(l_1^{\max})\frac{\partial l_1^{\max}}{\partial l_0}. \tag{A.19}$$

Note that the first term decreases in l_0 as $\frac{\partial c}{\partial l_0}$ increases in l_0. The second term decreases in l_0 as $\frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}$ increases in $l_1^{\max}$, which increases in l_0. This latter effect is positive as long as the safe mode is available, i.e. for all $\frac{\partial l_1^{\max}}{\partial l_0} = \psi > 0$. While the first term is equal to zero for $l_0 = l_0^{\text{fb}}$, the second term is equal to zero for $l_0 = \frac{l_{1,b}^{\text{fb}}}{\psi}$, as this implies $l_1^{\max} = l_{1,b}^{\text{fb}}$. Note that the safe mode is only restricted in the downturn for $l_0^{\text{fb}} < \frac{l_{1,b}^{\text{fb}}}{\psi}$. Consequently, there exists a $l_0^{\mathcal{S}}$ with $l_0^{\mathcal{S}} \in \left[l_0^{\text{fb}}, \frac{l_{1,b}^{\text{fb}}}{\psi}\right]$ for which (A.19) is equal to zero so that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$.

In order to determine how changes of the liquidity risks Δ_1 and $\Delta_{2,b}$ affect the optimal loan volume $l_0^{\mathcal{S}}$, i.e. $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_1}$ and $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_{2,b}}$, respectively, we define the function, $F^{\mathcal{B}}$, as the first order condition of $\pi_0^{\mathcal{SS}}(l_0)$ with respect to l_0:

$$F^{\mathcal{B}} := \left[\mu_1 - 1 - \frac{\partial c}{\partial l_0^{\mathcal{S}}}\right] + (1-p_1)\left[\mu_{2,b} - 1 - \frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}\right]\psi = 0. \tag{A.20}$$

Applying the implicit function theorem yields $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_1} = -\frac{\frac{\partial F^{\mathcal{B}}}{\partial \Delta_1}}{\frac{\partial F^{\mathcal{B}}}{\partial l_0^{\mathcal{S}}}}$ and $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_{2,b}} = -\frac{\frac{\partial F^{\mathcal{B}}}{\partial \Delta_{2,b}}}{\frac{\partial F^{\mathcal{B}}}{\partial l_0^{\mathcal{S}}}}$, respectively. It follows that $\frac{\partial F^{\mathcal{B}}}{\partial \Delta_1} = (1-p_1)\phi_{1,b}^{\mathcal{S}\prime}(l_1^{\max})\frac{\partial \psi}{\partial \Delta_1} - (1-p_1)\psi\frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}\frac{\partial l_1^{\max}}{\partial \Delta_1}$, $\frac{\partial F^{\mathcal{B}}}{\partial \Delta_{2,b}} = (1-p_1)\phi_{1,b}^{\mathcal{S}\prime}(l_1^{\max})\frac{\partial \psi}{\partial \Delta_{2,b}} - (1-p_1)\psi\frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}\frac{\partial l_1^{\max}}{\partial \Delta_{2,b}}$ and $\frac{\partial F^{\mathcal{B}}}{\partial l_0^{\mathcal{S}}} = -\frac{\partial^2 c(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}\,2}} - (1-p_1)\frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}\frac{\partial l_1^{\max}}{\partial l_0^{\mathcal{S}}}\psi < 0$. If the liquidity risks are small, both $\frac{\partial F^{\mathcal{B}}}{\partial \Delta_1}$ and $\frac{\partial F^{\mathcal{B}}}{\partial \Delta_{2,b}}$ will be positive. For small liquidity risks the first term is negative due to $\frac{\partial \psi}{\partial \Delta_1} < 0$ and $\frac{\partial \psi}{\partial \Delta_{2,b}} < 0$ but close to zero as $l_1^{\max}$ is close to $l_{1,b}^{\text{fb}}$, while the second term is positive due to $\frac{\partial l_1^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial l_1^{\max}}{\partial \Delta_{2,b}} < 0$, respectively, and sufficiently large as ψ is large for small liquidity risks. If the liquidity risks are, however, high, then both $\frac{\partial F^{\mathcal{B}}}{\partial \Delta_1}$ and $\frac{\partial F^{\mathcal{B}}}{\partial \Delta_{2,b}}$ will be negative. For larger liquidity risks, ψ is smaller so that the positive effect of the second term decreases. Simultaneously, the negative effect of the first term increases as the difference between $l_1^{\max}$ and $l_{1,b}^{\mathrm{fb}}$ increases. We can thus conclude that $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_1}$ and $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_{2,b}}$ are positive for smaller liquidity risks and negative for larger liquidity risks.

3. Suppose the banker operates according to strategy $\mathcal{C}$, i.e. he opts for the safe mode in the first period, which is not restricted, but for the risky mode in the bad situation at $t = 1$. If follows from (A.15) that $\frac{\partial \pi_0^{\mathcal{SR}}}{\partial l_0} = \phi_0^{\mathcal{S}\prime}(l_0)$, which decreases in l_0 and is equal to zero for $l_0 = l_0^{\mathrm{fb}}$. Hence the optimal loan volume is $l_0^* = l_0^{\mathrm{fb}}$ with $\frac{\partial l_0^{\mathrm{fb}}}{\partial \Delta_1} = 0$. It follows directly from Lemma 4.2 that $\frac{\partial l_{1,b}^{\mathcal{R}}}{\partial \Delta_{2,b}} > 0$.

4. Suppose the banker operates according to strategy $\mathcal{D}$, i.e. he opts for the safe mode in the first period, which is restricted according to (A.16), but for the risky mode in the bad situation at $t = 1$. Hence the optimal loan volume is $l_0^* = l_0^{\max}$. It follows directly from (A.16) that $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$, $\frac{\partial^2 l_0^{\max}}{\partial \Delta_1^2} > 0$ and $\frac{\partial l_0^{\max}}{\partial \Delta_{2,b}} > 0$.[2]

5. Suppose the banker operates according to strategy $\mathcal{E}$, i.e. he opts for the risky mode straight away at $t = 0$ so that the bank will default if the economy is in a downturn at $t = 1$. It follows from (A.17) that $\frac{\partial \pi_0^{\mathcal{RF}}}{\partial l_0} = \phi_0^{\mathcal{R}\prime}(l_0)$, which decreases in l_0 and is equal to zero for $l_0 = l_0^{\mathcal{R}}$. Hence the optimal loan volume is $l_0^* = l_0^{\mathcal{R}}$.

   In order to determine how changes of the liquidity risk, Δ_1, affect the optimal loan volume $l_0^{\mathcal{R}}$, i.e. $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1}$, we define the function, $F^{\mathcal{E}}$, as the first order condition of $\pi_0^{\mathcal{RF}}(l_0)$ with respect to l_0:

$$F^{\mathcal{E}} := p_1 \left(\mu_1 + (1 - p_1)\,\Delta_1\right) - 1 - c'(l_0^{\mathcal{R}}) = 0. \tag{A.21}$$

[2]Note that we need the second derivate to illustrate the results graphically.

Applying the implicit function theorem yields $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} = -\frac{\frac{\partial F^{\mathcal{E}}}{\partial \Delta_1}}{\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}}}$. As $\frac{\partial F^{\mathcal{E}}}{\partial \Delta_1} = (1 - p_1)p_1 > 0$ and $\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}} = -c''(l_0^{\mathcal{R}}) < 0$, we can conclude that $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} > 0$.

Moreover, applying the implicit function theorem yields a unique result for the curvature of $l_0^{\mathcal{R}}$. The curvature is given by

$$\frac{\partial^2 l_0^{\mathcal{R}}}{\partial \Delta_1^2} = -\frac{\frac{\partial^2 F^{\mathcal{E}}}{\partial \Delta_1^2}\left(\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}}\right)^2 - 2\frac{\partial \frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}}}{\partial \Delta_1}\frac{\partial F^{\mathcal{E}}}{\partial \Delta_1}\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}} + \frac{\partial^2 F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}2}}\left(\frac{\partial F^{\mathcal{E}}}{\partial \Delta_1}\right)^2}{\left(\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}}\right)^3} < 0. \tag{A.22}$$

The first term in the numerator is zero due to $\frac{\partial^2 F^{\mathcal{E}}}{\partial \Delta_1^2} = 0$, the second term is negative due to $\frac{\partial \frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}}}{\partial \Delta_1} = -c''(l_0^{\mathcal{R}})\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} < 0$, $\frac{\partial F^{\mathcal{E}}}{\partial \Delta_1} > 0$ and $\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}} < 0$, while the third term is nonpositive due to $\frac{\partial^2 F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}2}} = -c'''(l_0^{\mathcal{R}}) \leq 0$ and $\left(\frac{\partial F^{\mathcal{E}}}{\partial \Delta_1}\right)^2 > 0$, so that the numerator is negative. The denominator is also negative, as $\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{R}}} < 0$. We can thus conclude that $\frac{\partial^2 l_0^{\mathcal{R}}}{\partial \Delta_1^2}$ is negative. The optimal loan volume in the risky mode, $l_0^{\mathcal{R}}$, with respect to the liquidity risk Δ_1 thus depicts a concave curve.[3]

Critical Values of Δ_1

In a next step, we determine the optimal behavior of the banker for a given liquidity risk, Δ_1.

1. We denote $\Delta_1^{\mathcal{A}}$ as the largest risk level for which the banker is still able to operate in the unrestricted safe mode in both periods. Granting loans according to the first best is feasible in the downturn at $t = 1$ as long as $l_0^{\text{fb}} \geq \frac{l_{1,b}^{\text{fb}}}{\psi}$. As the first best loan volumes l_0^{fb} and $l_{1,b}^{\text{fb}}$ are independent of Δ_1 while ψ decreases in Δ_1, there exists a $\Delta_1^{\mathcal{A}}$ so that $\psi l_0^{\text{fb}} = l_{1,b}^{\text{fb}}$, which is given by

$$\Delta_1^{\mathcal{A}} := \frac{\mu_{2,b} - p_{2,b}\Delta_{2,b} - 1}{p_1}\frac{l_{1,b}^{\text{fb}}}{l_0^{\text{fb}}} + \frac{\mu_1 - 1}{p_1},$$

[3] There is no unique result for the curvature of $l_0^{\mathcal{S}}$ for smaller liquidity risks. However, similar calculations show that for larger liquidity risks $l_0^{\mathcal{S}}$ is a concave curve as well.

with $\frac{\partial \Delta_1^{\mathcal{A}}}{\partial \Delta_{2,b}} < 0$. As $\pi_0^{\mathcal{SS}}(l_0^{\text{fb}}) \geq \pi_0^{\mathcal{SS}}(l_0) > \pi_0^{\mathcal{SR}}(l_0) > \pi_0^{\mathcal{RF}}(l_0)$, it is never optimal for the banker to switch to another strategy for all $\Delta_1 \leq \Delta_1^{\mathcal{A}}$.

2. We denote $\Delta_1^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}$ and strategy $\mathcal{C}$. For $\Delta_1 = \Delta_1^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{SS}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{SR}}(l_0) > \pi_0^{\mathcal{RF}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\text{fb}})}{\partial \Delta_1} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$, the expected profit from strategy $\mathcal{B}$ decreases in Δ_1, as (A.13) shows. It follows that $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} \frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_1} + \frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} \frac{\partial l_1^{\max}}{\partial \Delta_1} < 0$, as $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} = 0$, $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} > 0$ and $\frac{\partial l_1^{\max}}{\partial \Delta_1} < 0$. Moreover, it follows from (A.15) that $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\text{fb}})}{\partial \Delta_1} = 0$. Accordingly, there exists a unique $\Delta_1^{\mathcal{B}} > \Delta_1^{\mathcal{A}}$ for which $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) = \pi_0^{\mathcal{SR}}(l_0^{\text{fb}})$ so that for all $\Delta_1 \leq \Delta_1^{\mathcal{B}}$, the banker prefers strategy $\mathcal{B}$ over strategies $\mathcal{C}$, $\mathcal{D}$ and $\mathcal{E}$ as $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) \geq \pi_0^{\mathcal{SR}}(l_0^{\text{fb}}) > \pi_0^{\mathcal{SR}}(l_0^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$, while for all $\Delta_1 > \Delta_1^{\mathcal{B}}$, the banker prefers strategy $\mathcal{C}$ over strategy $\mathcal{B}$ as $\pi_0^{\mathcal{SR}}(l_0^{\text{fb}}) > \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})$. Applying the implicit function theorem on $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) = \pi_0^{\mathcal{SR}}(l_0^{\text{fb}})$ yields $\frac{\partial \Delta_1^{\mathcal{B}}}{\partial \Delta_{2,b}} < 0$.[4]

3. We denote $\Delta_1^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}$ and strategy $\mathcal{D}$, i.e. the highest risk level for which bank lending is not restricted when operating in the safe mode in the first period and in the risky mode in the downturn. It follows from the definitions of $l_0^{\max}$ and v_b that the banker will be indifferent between the two strategies if $l_0^{\text{fb}} = l_0^{\max}$ or if

$$\Delta_1^{\mathcal{C}} = \frac{\phi_{1,b}^{\mathcal{R}}(l_{1,b}^{\mathcal{R}})}{p_1 l_0^{\text{fb}}} + \frac{\mu_1 - 1}{p_1}. \tag{A.23}$$

As $\phi_{1,b}^{\mathcal{R}}(l_{1,b}^{\mathcal{R}}) = [p_{2,b}(\mu_{2,b} + (1 - p_{2,b})\Delta_{2,b}) - 1]l_{1,b}^{\mathcal{R}} - c(l_{1,b}^{\mathcal{R}})$ it follows directly that $\frac{\partial \Delta_1^{\mathcal{C}}}{\partial \Delta_{2,b}} > 0$. Note that as long as $l_0^{\text{fb}} < l_0^{\max}$ it follows that $\pi_0^{\mathcal{SR}}(l_0^{\text{fb}}) >$

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[4]If $F_{\Delta_1^{\mathcal{B}}} := \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) - \pi_0^{\mathcal{SR}}(l_0^{\text{fb}}) = 0$, then $\frac{\partial \Delta_1^{\mathcal{B}}}{\partial \Delta_{2,b}} = -\frac{\frac{\partial F_{\Delta_1^{\mathcal{B}}}}{\partial \Delta_{2,b}}}{\frac{\partial F_{\Delta_1^{\mathcal{B}}}}{\partial \Delta_1}}$. As $\frac{\partial F_{\Delta_1^{\mathcal{B}}}}{\partial \Delta_{2,b}} = \frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} \frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_{2,b}} + \frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} \frac{\partial l_1^{\max}}{\partial \Delta_{2,b}} - \frac{\partial \pi_0^{\mathcal{SR}}(l_{1,b}^{\mathcal{R}})}{\partial l_{1,b}^{\mathcal{R}}} \frac{\partial l_{1,b}^{\mathcal{R}}}{\partial \Delta_{2,b}} < 0$ and $\frac{\partial F_{\Delta_1^{\mathcal{B}}}}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} \frac{\partial l_0^{\mathcal{S}}}{\partial \Delta_1} + \frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} \frac{\partial l_1^{\max}}{\partial \Delta_1} - \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\text{fb}})}{\partial \Delta_1} < 0$ due to $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} = \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\text{fb}})}{\partial l_0^{\text{fb}}} = \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\text{fb}})}{\partial \Delta_1} = 0$, $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} > 0$, $\frac{\partial l_1^{\max}}{\partial \Delta_{2,b}} < 0$, $\frac{\partial l_1^{\max}}{\partial \Delta_1} < 0$, $\frac{\partial \pi_0^{\mathcal{SR}}(l_{1,b}^{\mathcal{R}})}{\partial l_{1,b}^{\mathcal{R}}} > 0$ and $\frac{\partial l_{1,b}^{\mathcal{R}}}{\partial \Delta_{2,b}} > 0$, it follows that $\frac{\partial \Delta_1^{\mathcal{B}}}{\partial \Delta_{2,b}} < 0$.

$\pi_0^{\mathcal{SR}}(l_0^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$, so that the banker prefers strategy $\mathcal{C}$ over strategies $\mathcal{D}$ and $\mathcal{E}$ for all $\Delta_1 \leq \Delta_1^{\mathcal{C}}$. For all $\Delta_1 > \Delta_1^{\mathcal{C}}$ strategy $\mathcal{C}$ is not feasible.

4. We denote $\Delta_1^{\mathcal{D}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}$ and strategy $\mathcal{E}$. It follows from (A.15) that $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} \frac{\partial l_0^{\max}}{\partial \Delta_1}$. Bank lending will only be restricted in the first period, if the materialized cash flow in the downturn is negative, i.e. $\omega_{1,b} l_0 < 0$. As $\omega_{1,b} = v_b - 1$, it follows from the definition of v_b that an increase in Δ_1 leads to a stronger debt overhang. Accordingly, $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial \Delta_1} < 0$ as $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} > 0$ and $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$. Moreover, it follows from (A.17) that $\frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} + p_1(1-p_1) l_0^{\mathcal{R}} > 0$ as $\frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} = 0$. Hence there exists a unique $\Delta_1^{\mathcal{D}} > \Delta_1^{\mathcal{C}} > \Delta_1^{\mathcal{B}} > \Delta_1^{\mathcal{A}}$ for which $\pi_0^{\mathcal{SR}}(l_0^{\max}) = \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$ so that for all $\Delta_1 \leq \Delta_1^{\mathcal{D}}$, the banker prefers strategy $\mathcal{D}$ over strategy $\mathcal{E}$ as $\pi_0^{\mathcal{SR}}(l_0^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$, while for all $\Delta_1 > \Delta_1^{\mathcal{D}}$, the banker prefers strategy $\mathcal{E}$ over strategy $\mathcal{D}$ due to $\pi_0^{\mathcal{SR}}(l_0^{\mathcal{R}}) > \pi_0^{\mathcal{SR}}(l_0^{\max})$. At last, we apply the implicit function theorem on $F_{\Delta_1^{\mathcal{D}}} := \pi_0^{\mathcal{SR}}(l_0^{\max}) - \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}}) = 0$ so that $\frac{\partial \Delta_1^{\mathcal{D}}}{\partial \Delta_{2,b}} = -\frac{\frac{\partial F_{\Delta_1^{\mathcal{D}}}}{\partial \Delta_{2,b}}}{\frac{\partial F_{\Delta_1^{\mathcal{D}}}}{\partial \Delta_1}}$. It follows that $\frac{\partial F_{\Delta_1^{\mathcal{D}}}}{\partial \Delta_{2,b}} = \frac{\partial \pi_0^{\mathcal{SR}}(l_{1,b}^{\mathcal{R}})}{\partial l_{1,b}^{\mathcal{R}}} \frac{\partial l_{1,b}^{\mathcal{R}}}{\partial \Delta_{2,b}} + \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} \frac{\partial l_0^{\max}}{\partial \Delta_{2,b}} - \frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_{2,b}} > 0$ due to $\frac{\partial \pi_0^{\mathcal{SR}}(l_{1,b}^{\mathcal{R}})}{\partial l_{1,b}^{\mathcal{R}}} > 0$, $\frac{\partial l_{1,b}^{\mathcal{R}}}{\partial \Delta_{2,b}} > 0$, $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} > 0$, $\frac{\partial l_0^{\max}}{\partial \Delta_{2,b}} > 0$ and $\frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} = 0$. Furthermore, $\frac{\partial F_{\Delta_1^{\mathcal{D}}}}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} \frac{\partial l_0^{\max}}{\partial \Delta_1} - (\frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} + (1-p_1) p_1 l_0^{\mathcal{R}}) < 0$ due to $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$. We can thus conclude that $\frac{\partial \Delta_1^{\mathcal{D}}}{\partial \Delta_{2,b}} > 0$.

Proof of Lemma 5.2

This proof proceeds in three steps. First, we determine the reduced forms for all modes feasible. Second, we derive the banker's optimal loan volume for each mode. Finally, we compare the expected profits of the different modes to identify the banker's optimal behavior, depending on the loan volume, l_0, granted in the first period.

Determination of Reduced Forms

1. Suppose the banker operates in the safe mode. In this case, the face value of deposits is restricted to $\delta_{1,b} \leq v_b l_0 + a_{1,b}$. Inserting this restriction on deposits as well as the amount provided by depositors (5.14) and shareholders (5.15) into the budget constraint (5.13), and making use of (5.2) and (5.5) when applying the budget constraint to the expected profit (5.12), yields

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi_{1,b}^{\mathcal{S}} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}^{\mathcal{S}}\,(l_{1,b}) \tag{A.24}$$

$$\text{s. t.} \quad [1 - (1-\lambda) p_2 r_b] l_{1,b} \leq (v_b + \omega_{1,b}) l_0. \tag{A.25}$$

2. Suppose the banker operates in the risky mode. In this case, the face value of deposits is restricted to $\delta_{1,b} \leq v_b l_0 + r_b l_{1,b} + a_{1,b}$. Inserting this restriction on deposits as well as the amount provided by depositors (5.14) and shareholders (5.15) into the budget constraint (5.13), and making use of (5.2) and (5.6) when applying the budget constraint to the expected profit (5.12), yields

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi_{1,b}^{\mathcal{R}} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}^{\mathcal{R}}\,(l_{1,b}) - (1-p_2) a_{1,b} \tag{A.26}$$

$$\text{s. t.} \quad [p_2 r_b - 1] l_{1,b} \geq -p_2 v_b l_0 - \omega_{1,b} l_0 + (1-p_2) a_{1,b}. \tag{A.27}$$

3. Suppose the banker operates in the failure mode by closing the bank in the downturn at $t = 1$. Then it follows that

$$\pi^{\mathcal{F}}_{1,b} = \max\{\omega_{1,b} l_0, 0\}. \tag{A.28}$$

Determination of Optimal Loan Volumes at $t = 1$

In the next step, we determine the optimal loan volume for all modes feasible.

1. Suppose the banker operates in the safe mode. It follows from (A.24) that $\frac{\partial \pi^{\mathcal{S}}_{1,b}}{\partial l_{1,b}} = \phi^{\mathcal{S}\prime}_{1,b}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. Considering the restriction on bank lending (A.25), the optimal loan volume is thus $l^*_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}$ with

$$l^{\max}_1 := \frac{v_b + \omega_{1,b}}{1 - (1-\lambda) p_2 r_b} l_0. \tag{A.29}$$

2. Suppose the banker operates in the risky mode. It follows from (A.26) that $\frac{\partial \pi^{\mathcal{R}}_{1,b}}{\partial l_{1,b}} = \phi^{\mathcal{R}\prime}_{1,b}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. The restriction on bank lending becomes binding if

$$l_{1,b} \geq \frac{p_2 v_b l_0 + \omega_{1,b} l_0 - (1-p_2) a_{1,b}}{1 - p_2 r_b} =: l^{\min}_1. \tag{A.30}$$

   Note that for this loan volume the banker's profit turns out to be negative, so that the banker will then not operate according to the risky mode. Hence the optimal loan volume is $l^*_{1,b} = l^{\text{fb}}_{1,b}$.

3. Suppose the banker operates in the failure mode. By definition, the optimal loan volume is thus $l^*_{1,b} = 0$.

Critical Values of l_0

1. If $v_b + \omega_{1,b} > 0$, it follows, due to $l_1^{\max} > 0$ and $l_1^{\min} < 0$, that $\pi_{1,b}^{\mathcal{S}*} > 0$ and $\pi_{1,b}^{\mathcal{R}*} > 0$, so that the failure mode is never optimal. Comparing $\pi_{1,b}^{\mathcal{S}*}$ and $\pi_{1,b}^{\mathcal{R}*}$ yields $\pi_{1,b}^{\mathcal{S}*} \geq \pi_{1,b}^{\mathcal{R}*}$ if

$$(1 - p_2)v_b l_0 + \phi_{1,b}^{\mathcal{S}} \left(\min \left\{l_{1,b}^{\text{fb}}, l_1^{\max}\right\}\right) \geq \phi_{1,b}^{\mathcal{R}} \left(l_{1,b}^{\text{fb}}\right). \tag{A.31}$$

   As $l_1^{\max}$ increases in l_0, this condition holds for all $l_0 \geq l_0^{\min}$. For all $l_0 < l_0^{\min}$ it thus follows that $\pi_{1,b}^{\mathcal{R}*} > \pi_{1,b}^{\mathcal{S}*} > \pi_{1,b}^{\mathcal{F}*}$.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing $\pi_{1,b}^{\mathcal{R}*}$ and $\pi_{1,b}^{\mathcal{F}*}$ yields, due to $\pi_{1,b}^{\mathcal{R}*} \left(l_1^{\min}\right) < 0$, that $\pi_{1,b}^{\mathcal{R}*} \geq \pi_{1,b}^{\mathcal{F}*}$ if

$$-\frac{\phi_{1,b}^{\mathcal{R}} \left(l_{1,b}^{\text{fb}}\right)}{p_2 v_b + \omega_{1,b}} \geq l_0. \tag{A.32}$$

   Hence this condition holds for all $l_0 \leq l_0^{\max}$. For all $l_0 > l_0^{\max}$ it follows that $\pi_{1,b}^{\mathcal{F}*} > \pi_{1,b}^{\mathcal{R}*}$.

Proof of Proposition 5.3

This proof proceeds in three steps. First, we determine the reduced forms for all combinations of modes feasible. Second, we derive the banker's optimal loan volume for each strategy feasible. Finally, we compare the expected profits of the different strategies, to identify the banker's optimal behavior, depending on the liquidity risk, Δ_1. In order to ensure that the return on nonperforming loans remains nonnegative and that the funding liquidity of equity financing at least potentially imposes a restriction on bank lending, the liquidity risk, Δ_1, is restricted to $\overline{\Delta}_1 := \min\left\{\frac{\mu_1}{p_1}, \frac{1-(1-\lambda)p_1\mu_1}{(1-\lambda)p_1(1-p_1)}\right\}$.

Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in an upswing at $t = 1$, we only have to consider all combinations feasible based on the modes available in the first period and in the downturn at $t = 1$.

1. Suppose the banker operates in the safe mode independent of the date or state of the economy, so that $m_0 = \mathcal{S}$ and $m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. In conjunction with Lemma 5.1 and 5.2, inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ and (5.4) when applying the budget constraint to the expected profit (5.21), yields

$$\max_{l_0,a_0\in\mathbb{R}^+} \pi_0^{\mathcal{SS}}(l_0) = \phi_0^{\mathcal{S}}(l_0) + p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}^{\mathcal{S}}(\max\{l_{1,b}^{\text{fb}}, l_1^{\max}(l_0)\}). \tag{A.33}$$

$$\text{with} \quad l_1^{\max} = \frac{\mu_1 - 1 - \lambda p_1\Delta_1}{[1-(1-\lambda)p_1][1-(1-\lambda)p_2 r_b]} l_0 =: \psi l_0. \tag{A.34}$$

2. Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if the economy is in a downturn at $t = 1$, so that $m = \mathcal{SR}$. In conjunction with Lemma 5.1 and 5.2, inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ and (5.4) when applying the budget constraint to the expected profit (5.21), yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{SR}}(l_0) = \phi_0^{\mathcal{S}}(l_0) - (1-p_1)(1-p_2)(\mu_1 - p_1\Delta_1)l_0$$

$$+ p_1 \phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}^{\mathcal{R}}(l_{1,b}^{\text{fb}}) \tag{A.35}$$

$$\text{s.t.} \quad l_0 \leq \frac{\phi_{1,b}^{\mathcal{R}}\left(l_{1,b}^{\text{fb}}\right)}{\frac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1} - p_2(\mu_1 - p_1\Delta_1)} =: l_0^{\max}. \tag{A.36}$$

3. Suppose the banker operates in the risky mode straight away in the first period, which results in a bank run in the downturn at $t = 1$, so that $m = \mathcal{RF}$. In conjunction with Lemma 5.1 and 5.2, inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ when applying the budget constraint to the expected profit (5.21), yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{RF}}(l_0) = \phi_0^{\mathcal{R}}(l_0) - (1-p_1)a_0 + p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) \tag{A.37}$$

$$\text{s.t.} \quad l_0 > l_0^{\max}. \tag{A.38}$$

Determination of Optimal Loan Volumes at $t = 0$

1. Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SS}$. As (A.33) is identical to (A.13) we use the results determined in the proof of Proposition 4.3 that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$ and $\frac{\partial l_{1,g}^{\text{fb}}}{\partial \Delta_1} = \frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_1} = 0$.

2. Suppose the banker operates according to strategy $\mathcal{B}$, i.e. (A.34) becomes binding when operating according to $m = \mathcal{SS}$. As (A.33) is identical to (A.13) except for the definition of $l_1^{\max}$, we can likewise conclude that there exists a $l_0^{\mathcal{S}}$ with $l_0^{\mathcal{S}} \in \left[l_0^{\text{fb}}, \frac{l_{1,b}^{\text{fb}}}{\psi}\right]$ for which $\frac{\partial \pi_0^{\mathcal{SS}}}{\partial l_0}$ is equal to zero so that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$. The argument follows the same steps as presented in the proof of Proposition 4.3. The only difference is that ψ in (A.34) deviates from ψ in (A.14). However, as they both decrease in Δ_1, we can use the results obtained in the proof of Proposition 4.3 to conclude that $l_0^{\mathcal{S}}$ will increase in the liquidity risk if Δ_1 is small but will decrease if Δ_1 is large.

3. Suppose the banker operates according to strategy $\mathcal{C}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SR}$. It follows from (A.35) that

$$\frac{\partial \pi_0^{\mathcal{SR}}}{\partial l_0} = [1-(1-p_1)(1-p_2)]\mu_1 + (1-p_1)(1-p_2)p_1\Delta_1 - 1 - c'(l_0), \quad \text{(A.39)}$$

which decreases in l_0 and is equal to zero for $l_0 = l_0^{\mathcal{SR}}$. Hence the optimal loan volume is $l_0^* = l_0^{\mathcal{SR}}$. In order to determine how changes of the liquidity risk, Δ_1, affect the optimal loan volume, l_0^*, i.e. $\frac{\partial l_0^{\mathcal{SR}}}{\partial \Delta_1}$, we define the function, $F^{\mathcal{C}}$, as the first order condition of $\pi_0^{\mathcal{SR}}(l_0)$ with respect to l_0 for $l_0^{\mathcal{SR}}$:

$$F^{\mathcal{C}} := [1-(1-p_1)(1-p_2)]\mu_1 + (1-p_1)(1-p_2)p_1\Delta_1 - 1 - c'(l_0^{\mathcal{SR}}) = 0. \quad \text{(A.40)}$$

Applying the implicit function theorem yields $\frac{\partial l_0^{\mathcal{SR}}}{\partial \Delta_1} = -\frac{\frac{\partial F^{\mathcal{C}}}{\partial \Delta_1}}{\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}}}$. As $\frac{\partial F^{\mathcal{C}}}{\partial \Delta_1} = (1-p_1)(1-p_2)p_1 > 0$ and $\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}} = -c''(l_0^{\mathcal{SR}}) < 0$, we can conclude that $\frac{\partial l_0^{\mathcal{SR}}}{\partial \Delta_1} > 0$.

Moreover, applying the implicit function theorem yields a unique result for the curvature of $l_0^{\mathcal{SR}}$. The curvature is given by

$$\frac{\partial^2 l_0^{\mathcal{SR}}}{\partial \Delta_1^2} = -\frac{\frac{\partial^2 F^{\mathcal{C}}}{\partial \Delta_1^2}\left(\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}}\right)^2 - 2\frac{\partial \frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}}}{\partial \Delta_1}\frac{\partial F^{\mathcal{C}}}{\partial \Delta_1}\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}} + \frac{\partial^2 F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}2}}\left(\frac{\partial F^{\mathcal{C}}}{\partial \Delta_1}\right)^2}{\left(\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}}\right)^3} < 0. \tag{A.41}$$

The first term in the numerator is zero due to $\frac{\partial^2 F^{\mathcal{C}}}{\partial \Delta_1^2} = 0$, the second term is negative due to $\frac{\partial \frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}}}{\partial \Delta_1} = -c''(l_0^{\mathcal{SR}})\frac{\partial l_0^{\mathcal{SR}}}{\partial \Delta_1} < 0$, $\frac{\partial F^{\mathcal{C}}}{\partial \Delta_1} > 0$ and $\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}} < 0$, while the third term is nonpositive due to $\frac{\partial^2 F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}2}} = -c'''(l_0^{\mathcal{SR}}) \leq 0$ and $\left(\frac{\partial F^{\mathcal{C}}}{\partial \Delta_1}\right)^2 > 0$ so that the numerator is negative. The denominator is also negative, as $\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{SR}}} < 0$. We can thus conclude that $\frac{\partial^2 l_0^{\mathcal{SR}}}{\partial \Delta_1^2}$ is negative. The optimal loan volume in the risky mode, $l_0^{\mathcal{SR}}$, with respect to the liquidity risk, Δ_1, thus depicts a concave curve.

4. Suppose the banker operates according to strategy $\mathcal{D}$, i.e. he faces a restriction on bank lending when operating according to $m = \mathcal{SR}$, as (A.36) becomes binding. Hence the optimal loan volume is $l_0^* = l_0^{\max}$. It follows directly from (A.36) that $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial^2 l_0^{\max}}{\partial \Delta_1^2} > 0$, as $\lambda \in [0.5, 1)$ and $p_1, p_2 \in [0.6, 1)$.[5]

5. Suppose the banker operates according to strategy $\mathcal{E}$, i.e. he operates according to $m = \mathcal{RF}$. As (A.37) is identical to (A.17), we use the results determined in the proof of Proposition 4.3 that the optimal loan volume is $l_0^* = l_0^{\mathcal{R}}$ with $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_0^{\mathcal{R}}}{\partial \Delta_1^2} < 0$.

Critical Values of Δ_1

In a next step, we determine the optimal behavior of the banker for a given liquidity risk, Δ_1.

[5] If both the upswing and the recovery from the downturn were quite unlikely, i.e. p_1 and p_2 were small, $\frac{\partial l_0^{\max}}{\partial \Delta_1}$ would be positive. For these liquidity risks, the restriction on bank lending in the first period is not binding, as the funding liquidity of first period loans is sufficiently large. Hence the banker would never operate in the failure mode, $\mathcal{F}$, in the downturn at $t = 1$.

1. We denote $\Delta_1^{\mathcal{A}}$ as the largest risk level for which the banker is still able to operate in the unrestricted safe mode in both periods. Again, granting loans according to the first best is feasible in the downturn as long as $l_0^{\text{fb}} \geq \frac{l_{1,b}^{\text{fb}}}{\psi}$. As the first best loan volumes l_0^{fb} and $l_{1,b}^{\text{fb}}$ are independent of Δ_1 while ψ decreases in Δ_1, there exists a $\Delta_1^{\mathcal{A}}$ so that $\psi l_0^{\text{fb}} = l_{1,b}^{\text{fb}}$, which is given by

$$\Delta_1^{\mathcal{A}} := \frac{[(1-\lambda)p_2 r_b - 1][1-(1-\lambda)p_1]}{\lambda p_1} \frac{l_{1,b}^{\text{fb}}}{l_0^{\text{fb}}} + \frac{\mu_1 - 1}{\lambda p_1}. \tag{A.42}$$

   As $\pi_0^{\mathcal{SS}}(l_0^{\text{fb}}) \geq \pi_0^{\mathcal{SS}}(l_0) > \pi_0^{\mathcal{SR}}(l_0) > \pi_0^{\mathcal{RF}}(l_0)$, it is never optimal for the banker to switch to another strategy for all $\Delta_1 \leq \Delta_1^{\mathcal{A}}$.

2. We denote $\Delta_1^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}$ and strategy $\mathcal{C}$. For $\Delta_1 = \Delta_1^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{SS}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{SR}}(l_0) > \pi_0^{\mathcal{RF}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\text{fb}})}{\partial \Delta_1} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$, the expected profit from strategy $\mathcal{B}$ decreases in Δ_1, i.e. $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial \Delta_1} < 0$, as (A.33) is identical to (A.13) except for the definition of $l_1^{\max}$. Moreover, it follows from (A.35) that $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}})}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}})}{\partial l_0^{\mathcal{SR}}} \frac{\partial l_0^{\mathcal{SR}}}{\partial \Delta_1} + (1-p_1)(1-p_2)p_1 l_0^{\mathcal{SR}} > 0$, as $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}})}{\partial l_0^{\mathcal{SR}}} = 0$. Accordingly, if there exists a unique $\Delta_1^{\mathcal{B}'} > \Delta_1^{\mathcal{A}}$ for which $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) = \pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}})$, then the banker will prefer strategy $\mathcal{B}$ over strategies $\mathcal{C}$, $\mathcal{D}$ and $\mathcal{E}$ as $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) \geq \pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}}) > \pi_0^{\mathcal{SR}}(l_0^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$ for all $\Delta_1 \leq \Delta_1^{\mathcal{B}'}$, while for all $\Delta_1 > \Delta_1^{\mathcal{B}'}$, the banker prefers strategy $\mathcal{C}$ over strategy $\mathcal{B}$ as $\pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}}) > \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})$. If such a $\Delta_1^{\mathcal{B}'}$ does not exist within $(\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}]$, e.g. as $l_0^{\max}$ becomes binding for a $\Delta_1 \leq \Delta_1^{\psi}$, the banker prefers strategy $\mathcal{B}$ as long as the safe mode is available in the downturn, i.e. for all $\Delta_1 \in (\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}]$ so that

$$\Delta_1^{\mathcal{B}} := \min\{\Delta_1^{\mathcal{B}'}, \Delta_1^{\psi}\}. \tag{A.43}$$

3. We denote $\Delta_1^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}$ and strategy $\mathcal{D}$, i.e. the highest risk level for which bank lending is

not restricted when operating according to $m = \mathcal{SR}$. It follows from the definitions of $l_0^{\max}$ and v_b that the banker is indifferent between the two strategies if $l_0^{\mathcal{SR}} = l_0^{\max}$, or if

$$\Delta_1^{\mathcal{C}} := \frac{\phi_{1,b}^{\mathcal{R}}(l_{1,b}^{\text{fb}})[1-(1-\lambda)p_1]}{p_1[p_2-(1-\lambda)(1-p_1(1-p_2))]l_0^{\mathcal{SR}}} + \frac{\mu_1[p_2+(1-\lambda)p_1(1-p_2)]-1}{p_1[p_2-(1-\lambda)(1-p_1(1-p_2))]}. \tag{A.44}$$

As long as $l_0^{\mathcal{SR}} < l_0^{\max}$ it follows that $\pi_0^{\mathcal{SR}}(l_0^{\mathcal{SR}}) > \pi_0^{\mathcal{SR}}(l_0^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$ so that the banker prefers strategy $\mathcal{C}$ over strategies $\mathcal{D}$ and $\mathcal{E}$ for all $\Delta_1 \leq \Delta_1^{\mathcal{C}}$. For all $\Delta_1 > \Delta_1^{\mathcal{C}}$ strategy $\mathcal{C}$ is not feasible.

4. We denote $\Delta_1^{\mathcal{D}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}$ and strategy $\mathcal{E}$. It follows from (A.35) that $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} \frac{\partial l_0^{\max}}{\partial \Delta_1} + (1-p_1)(1-p_2)p_1 l_0^{\max}$, which is negative for larger liquidity risks due to $\frac{\partial \pi_0^{\mathcal{SR}}(l_0^{\max})}{\partial l_0^{\max}} > 0$ and $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$. Moreover, it follows from (A.37) that $\frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial \Delta_1} = \frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} + p_1(1-p_1)l_0^{\mathcal{R}} > 0$ as $\frac{\partial \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} = 0$. Hence, there exists a unique $\Delta_1^{\mathcal{D}} > \Delta_1^{\mathcal{C}} > \Delta_1^{\mathcal{B}} > \Delta_1^{\mathcal{A}}$ for which $\pi_0^{\mathcal{SR}}(l_0^{\max}) = \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$ so that for all $\Delta_1 \leq \Delta_1^{\mathcal{D}}$, the banker prefers strategy $\mathcal{D}$ over strategy $\mathcal{E}$ as $\pi_0^{\mathcal{SR}}(l_0^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$, while for all $\Delta_1 > \Delta_1^{\mathcal{D}}$, the banker prefers $\mathcal{E}$ over $\mathcal{D}$ due to $\pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}}) > \pi_0^{\mathcal{SR}}(l_0^{\max})$.

Proof of Lemma 6.2

This proof proceeds in the same three steps as the proof of Lemma 5.2.

Determination of Reduced Forms

1. Suppose the banker operates in the safe mode. In this case, the face value of deposits is restricted to $\delta_{1,b} \leq v_b l_0 + a_{1,b}$. As the banker will pay off this face value at $t = 2$ with certainty, the CDS price is equal to zero and the margin call is never triggered. Accordingly, the expected profit is identical to (A.24) with the restriction on bank lending given by (A.25).

2. Suppose the banker operates in the risky mode. In this case, the face value of deposits is restricted to $\delta_{1,b} \leq v_b l_0 + r_b l_{1,b} + a_{1,b}$. As the banker will only pay off this face value only if the economy recovers from the downturn, i.e. with probability p_2, the CDS price will become positive and the margin call is triggered. As the bank possesses no additional values to pledge against, the banker cannot raise more equity from shareholders. Hence this behavior results in a takeover so that the expected profit is given by

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^{\mathcal{R}}_{1,b} = -c\left(l_{1,b}\right). \tag{A.45}$$

3. Suppose the banker operates in the failure mode by closing the bank early, in the downturn at $t = 1$. Then it follows again that

$$\pi^{\mathcal{F}}_{1,b} = 0. \tag{A.46}$$

4. Suppose the banker operates in the non-lending mode by granting no loans at all. This mode is only feasible as long as the funding liquidity of first period

loans covers the negative cash flow that materializes in the downturn. Given that the non-lending mode is feasible, it follows that

$$\max_{a_{1,b}\in\mathbb{R}^+} \pi_{1,b}^{\mathcal{N}}(0) = (v_b + \omega_{1,b})l_0. \tag{A.47}$$

Determination of Optimal Loan Volumes at $t = 1$

1. Suppose the banker operates in the safe mode. We can thus directly conclude from the proof of Lemma 5.2 that the optimal loan volume is thus $l_{1,b}^* = \min\{l_{1,b}^{\text{fb}}, l_1^{\max}\}$.

2. Suppose the banker operates in the risky mode. It follows from (A.45) that $\frac{\partial \pi_{1,b}^{\mathcal{R}}}{\partial l_{1,b}} = -c'(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = 0$. Hence the optimal loan volume is thus $l_{1,b}^* = 0$. This, however, implies that the bank is technically not at risk. We can therefore conclude that the risky mode is not feasible.

3. Suppose the banker operates in the failure mode. By definition, the optimal loan volume is $l_{1,b}^* = 0$.

4. Suppose the banker operates in the non-lending mode. By definition, the optimal loan volume is also $l_{1,b}^* = 0$.

Critical Values of l_0

1. If $v_b + \omega_{1,b} > 0$, it follows, due to $l_1^{\max} > 0$, that $\pi_{1,b}^{\mathcal{S}*} > 0$ so that all other modes are never optimal.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing the failure mode and the non-lending mode yields that the non-lending mode is feasible as long as $l_0 = 0$. In all other cases, the return on first period loans is too low, so that the bank has to be closed.

Proof of Proposition 6.3

This proof proceeds in the same three steps as the proof of Proposition 5.3.

Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in an upswing at $t = 1$, we only have to consider all combinations feasible based on the modes available in the first period and in the downturn at $t = 1$.

1. Suppose the banker will operate in the safe mode independent of the date or state of the economy, so that $m_0 = \mathcal{S}$ and $m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. Then it follows from Lemma 6.1 and 6.2 that the reduced form is identical to (A.33) and (A.34).

2. Suppose the banker operates in the risky mode in the first period, which results in a bank run so that $m = \mathcal{RF}$. This implies that the banker will be unable to pay off depositors if a downturn emerges, i.e. with probability $1 - p_1$. Hence, the CDS price becomes positive and the margin call is triggered. As the bank possesses no additional values to pledge against, the banker cannot raise more equity from shareholders. Hence this behavior results in a takeover so that the reduced form is given by

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{RF}}(l_0) = -c(l_0). \tag{A.48}$$

3. Suppose the banker operates in the non-lending mode both in the first period and in the downturn so that $m = \mathcal{NN}$. By definition, the reduced form is thus given by

$$\max_{a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{NN}}(0) = 0. \tag{A.49}$$

Determination of Optimal Loan Volumes at $t = 0$

1. Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SS}$. We can therefore conclude from the proof of Proposition 5.3 that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$.

2. Suppose the banker operates according to strategy $\mathcal{B}$, i.e. (A.34) becomes binding when operating according to $m = \mathcal{SS}$. Hence we can conclude from the proof of Proposition 5.3 that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$. It holds again that $l_0^{\mathcal{S}}$ will increase in the liquidity risk if Δ_1 is small but will decrease if Δ_1 is large.

3. Suppose the banker operates according to strategy $\mathcal{E}$, i.e. he operates according to $m = \mathcal{RF}$. As this will result in a takeover, the optimal loan volume is $l_0^* = 0$. Again, as this loan volume does not correspond to the risky mode, this implies that strategy $\mathcal{E}$ is not feasible.

4. Suppose the banker operates according to strategy $\mathcal{X}$, i.e. he operates according to $m = \mathcal{NN}$. By definition the optimal loan volume is thus $l_0^* = 0$.

Critical Values of Δ_1

1. We denote $\Delta_1^{\mathcal{A}}$ as the largest risk level for which the banker is still able to operate in the unrestricted safe mode in both periods. Again, granting loans according to the first best is feasible in the downturn at $t = 1$ as long as $l_0^{\text{fb}} \geq \frac{l_{1,b}^{\text{fb}}}{\psi}$, i.e. up to $\Delta_1^{\mathcal{A}}$, which is defined in (A.42).

2. We denote $\Delta_1^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}$ and strategy $\mathcal{X}$, which is the only other alternative feasible. As $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{NN}}(0) = 0$ for all $\Delta_1 < \Delta_1^{\psi}$, it follows that the banker prefers strategy $\mathcal{B}$ over strategy $\mathcal{X}$ for all $\Delta_1 < \Delta_1^{\psi} = \Delta_1^{\mathcal{B}}$. For all $\Delta_1 \geq \Delta_1^{\psi}$, it follows

that neither strategy $\mathcal{A}$ nor strategy $\mathcal{B}$ are feasible, so that the banker prefers strategy $\mathcal{X}$.

Proof of Lemma 6.5

This proof proceeds in the same three steps as the proof of Lemma 5.2.

Determination of Reduced Forms

1. Suppose the banker operates in the safe mode. The regulator aims to impose capital requirements, which will not affect bank lending given that the bank is already stable. Suppose, capital requirements are binding as $(1-\kappa)(l_0 + l_{1,b}) + a_{1,b} \leq v_b l_0 + a_{1,b}$. In this case, inserting the restriction on deposits as well as the amount provided by depositors (5.14) and shareholders (5.15) into the budget constraint (5.13), yields

$$[1-(1-\lambda)p_2 r_b - \lambda(1-\kappa)]l_{1,b} \leq [(1-\lambda)v_b + \lambda(1-\kappa) + \omega_{1,b})]\, l_0. \quad \text{(A.50)}$$

We will show in the proof to Proposition 6.6 that as long as $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$, the funding liquidity of first period loans remains positive. Moreover, restricting the capital ratio to $\kappa < 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}$ results in a positive funding liquidity of second period loans in the downturn, $(1-\lambda)p_2 r_b + \lambda(1-\kappa) - 1 > 0$, and therefore in a negative lower bound for second period loans. The bank is thus able to increase bank lending in the downturn so that $(1-\kappa)(l_0 + l_{1,b}) + a_{1,b} > v_b l_0 + a_{1,b}$. Hence the relevant restriction of the face value of deposits when operating in the safe mode is $\delta_{1,b} \leq v_b l_0 + a_{1,b}$. Inserting this restriction on deposits as well as the amount provided by depositors (5.14) and shareholders (5.15) into the budget constraint (5.13), and making use of (5.2) and (5.5) when applying the budget constraint to the expected profit (5.12) thus yields again

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi_{1,b}^{\mathcal{S}} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}^{\mathcal{S}}\, (l_{1,b}) \tag{A.51}$$

$$\text{s. t.} \quad [1 - (1-\lambda) p_2 r_b] l_{1,b} \leq (v_b + \omega_{1,b}) l_0. \tag{A.52}$$

2. Suppose the banker operates in the risky mode. The regulator aims to impose a binding restriction on bank lending for this mode. Suppose capital requirements are binding as $(1-\kappa)(l_0 + l_{1,b}) + a_{1,b} \leq v_b l_0 + r_b l_{1,b} + a_{1,b}$. Based on (6.7) we identified that the regulation becomes binding for $\kappa > 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}$. In this case, inserting the new restriction on deposits (6.6) as well as the amount provided by depositors (5.14) and shareholders (5.15) into the budget constraint (5.13), and making use of (5.2) and (5.6) when applying the budget constraint to the expected profit (5.12), yields

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi_{1,b}^{\mathcal{R}} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}^{\mathcal{R}}\, (l_{1,b}) - (1-p_2) a_{1,b} \tag{A.53}$$

$$\text{s. t.} \quad [1 - (1-\lambda) p_2 r_b - \lambda p_2 (1-\kappa)]\, l_{1,b} \leq [(1-\lambda) p_2 v_b + \lambda p_2 (1-\kappa) + \omega_{1,b}]\, l_0. \tag{A.54}$$

3. Suppose the banker operates in the failure mode by closing the bank already in the downturn at $t = 1$. Then it follows that

$$\pi_{1,b}^{\mathcal{F}} = 0. \tag{A.55}$$

4. Suppose the banker operates in the non-lending mode by granting no loans at all. This mode is only feasible as long as the funding liquidity of first period loans covers the negative cash flow that materializes in the downturn. Given

that the non-lending mode is feasible, it follows that

$$\max_{a_{1,b}\in\mathbb{R}^+} \pi^{\mathcal{N}}_{1,b}(0) = (v_b + \omega_{1,b})l_0. \tag{A.56}$$

Determination of Optimal Loan Volumes at $t = 1$

In the next step, we determine the optimal loan volume for all modes feasible.

1. Suppose the banker operates in the safe mode. It follows from (A.51) that $\frac{\partial \pi^{\mathcal{S}}_{1,b}}{\partial l_{1,b}} = \phi^{\mathcal{S}\prime}_{1,b}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. Considering the restriction on bank lending (A.52), the optimal loan volume is thus $l^*_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}$ with $l^{\max}_1$ being defined in (A.29).

2. Suppose the banker operates in the risky mode. It follows from (A.53) that $\frac{\partial \pi^{\mathcal{R}}_{1,b}}{\partial l_{1,b}} = \phi^{\mathcal{R}\prime}_{1,b}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. Considering the restriction on bank lending (A.54), the optimal loan volume is thus $l^*_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\}$ with

$$l^{\max}_{1,\kappa} := \frac{[(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}]}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)} l_0. \tag{A.57}$$

3. Suppose the banker operates in the failure mode. The optimal loan volume is thus $l^*_{1,b} = 0$.

4. Suppose the banker operates in the non-lending mode. By definition, the optimal loan volume is also $l^*_{1,b} = 0$.

Critical Values of l_0

1. If $v_b + \omega_{1,b} \geq 0$, it follows, due to $l^{\max}_1 \geq 0$, that $\pi^{\mathcal{S}*}_{1,b} \geq 0$ so that the failure mode is never optimal. Comparing $\pi^{\mathcal{S}*}_{1,b}$ and $\pi^{\mathcal{R}*}_{1,b}$ yields $\pi^{\mathcal{S}*}_{1,b} \geq \pi^{\mathcal{R}*}_{1,b}$ if

$$(1-p_2)v_b l_0 + \phi^{\mathcal{S}}_{1,b}\left(\min\left\{l^{\text{fb}}_{1,b}, l^{\max}_1(l_0)\right\}\right) \geq \phi^{\mathcal{R}}_{1,b}\left(\min\left\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}(l_0)\right\}\right). \tag{A.58}$$

As both $l_1^{\max}$ and $l_{1,\kappa}^{\max}$ increase in l_0, this condition holds for all $l_0 \geq l_{0,\kappa}^{\min}$. For all $l_0 \in (0, l_{0,\kappa}^{\min})$ it thus follows that $\pi_{1,b}^{\mathcal{R}*} > \pi_{1,b}^{\mathcal{S}*} > \pi_{1,b}^{\mathcal{F}*}$. For $l_0 = 0$ neither the safe mode, nor the risky mode are available with a positive loan volume. As the bank technically does not have to default, the banker thus operates in the non-lending mode so that $\pi_{1,b}^{\mathcal{N}*} = 0$.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing $\pi_{1,b}^{\mathcal{R}*}$ and $\pi_{1,b}^{\mathcal{F}*}$ yields, due to $\pi_{1,b}^{\mathcal{R}*}\left(l_1^{\min}\right) < 0$, that $\pi_{1,b}^{\mathcal{R}*} \geq \pi_{1,b}^{\mathcal{F}*}$ if

$$-\frac{\phi_{1,b}^{\mathcal{R}}\left(\min\left\{l_{1,b}^{\mathrm{fb}}, l_{1,\kappa}^{\max}\right\}\right)}{p_2 v_b + \omega_{1,b}} \geq l_0. \tag{A.59}$$

Hence this condition holds for all $l_0 \in (0, l_{0,\kappa}^{\max}]$. For all $l_0 > l_{0,\kappa}^{\max}$ it follows that $\pi_{1,b}^{\mathcal{F}*} > \pi_{1,b}^{\mathcal{R}*}$. Again, $l_0 = 0$ implies that the banker cannot grant any loans when operating in the risky mode. However, no depositors have to be paid off either. Consequently, he will operate in the non-lending mode and $\pi_{1,b}^{\mathcal{N}*} = 0$.

Proof of Proposition 6.6

This proof proceeds in the same three steps as the proof of Proposition 5.3.

Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in an upswing at $t = 1$, we again only have to consider all combinations feasible based on the modes available in the first period and in the downturn at $t = 1$.

1. Suppose the banker will operates in the safe mode independent of the date or state of the economy, so that $m_0 = \mathcal{S}$ and $m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. We stated in the text that capital requirements impose no additional restriction on bank lending in the safe mode. Capital requirements will impose an additional restriction on the face value of the deposits if (6.12) becomes binding. In this case, inserting this restriction on deposits, as well as the amount provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), yields
$$\frac{1-(1-\lambda)p_1 v_g}{1-(1-\lambda)p_1} l_0 \leq (1-\kappa) l_0. \tag{A.60}$$
As $v_g = \mu_1 + (1-p_1)\Delta_1$, this condition will hold for all liquidity risks if $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$. Therefore capital requirements impose no restriction on bank lending and the reduced form, when operating according to $m = \mathcal{SS}$, is identical to (A.33) and (A.34).

2. Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if the economy is in a downturn at $t = 1$, so that $m = \mathcal{SR}$. In conjunction with Lemma 6.4 and 6.5, inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ and (5.4) when applying the budget

constraint to the expected profit (5.21), yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_{0,\kappa}^{\mathcal{SR}}(l_0) = \phi_0^{\mathcal{S}}(l_0) - (1-p_1)(1-p_2)(\mu_1 - p_1\Delta_1)l_0$$

$$+ p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}^{\mathcal{R}}(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}) \quad \text{(A.61)}$$

$$\text{s.t.} \quad l_0 \leq \frac{\phi_{1,b}^{\mathcal{R}}\left(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}\right)}{\frac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1} - p_2(\mu_1 - p_1\Delta_1)} =: l_{0,\kappa}^{\max} \quad \text{(A.62)}$$

with

$$l_{1,\kappa}^{\max} := \psi_\kappa l_0 \quad \text{(A.63)}$$

and

$$\psi_\kappa := \frac{\frac{(1-\lambda)(p_1+p_2[1-(1-\lambda)p_1])\mu_1+(1-\lambda)p_1(1-p_1-p_2[1-(1-\lambda)p_1])\Delta_1-1}{1-(1-\lambda)p_1} + \lambda p_2(1-\kappa)}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)}. \quad \text{(A.64)}$$

3. Suppose the banker operates in the risky mode in the first period, which results in a bank run in the downturn at $t = 1$, so that $m = \mathcal{RF}$. Capital requirements will impose a restriction on the face value of deposits if $(1-\kappa)l_0 + a_0 < v_g l_0 + a_0$, which is always fulfilled. Considering this restriction when inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), yields

$$[1 - (1-\lambda)p_1 v_g - \lambda p_1(1-\kappa)]l_0 \leq 0. \quad \text{(A.65)}$$

In consequence, the risky mode will only be feasible at $t = 0$ if the funding liquidity of first period loans, $(1-\lambda)p_1 v_g + \lambda p_1(1-\kappa) - 1$, is positive. If $\kappa < 1 - \frac{1-(1-\lambda)p_1[\mu_1+(1-p_1)\Delta_1]}{\lambda p_1}$, a sufficient amount of deposits will be issued so that bank lending is feasible and unrestricted. As this threshold depends on the liquidity risk, Δ_1, imposing a regulatory capital ratio, κ, implies that the risky mode at $t = 0$ is feasible for all[6]

$$\Delta_1 \geq \frac{1 - \lambda p_1 - (1-\lambda)p_1\mu_1 + \lambda p_1\kappa}{(1-\lambda)p_1(1-p_1)} =: \Delta_{1,\kappa}^{\mathcal{E}}. \tag{A.66}$$

For all these liquidity risks the reduced form changed only slightly compared with (A.37) and (A.38). In conjunction with Lemma 6.4 and 6.5, inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ when applying the budget constraint to the expected profit (5.21), yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{RF}}(l_0) = \phi_0^{\mathcal{R}}(l_0) - (1-p_1)a_0 + p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) \tag{A.67}$$

$$\text{s.t.} \quad l_0 > l_{0,\kappa}^{\max}. \tag{A.68}$$

4. Suppose the banker operates in the non-lending mode both in the first period and in the downturn, so that $m = \mathcal{NN}$. By definition, the reduced form is thus given by

$$\max_{a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{NN}}(0) = 0. \tag{A.69}$$

Determination of Optimal Loan Volumes at $t = 0$

1. Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SS}$. As the reduced form is identical to (A.33) we can likewise conclude that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$ and $\frac{\partial l_{1,g}^{\text{fb}}}{\partial \Delta_1} = \frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_1} = 0$.

2. Suppose the banker operates according to strategy $\mathcal{B}$, i.e. the restriction on bank lending becomes binding when operating according to $m = \mathcal{SS}$. As the reduced form is identical to (A.33) and (A.34), we can likewise conclude that

[6]Note that due to $\lambda p_1(1-\kappa) > 0$ it follows that $\Delta_{1,\kappa}^{\mathcal{E}} < \overline{\Delta}_1$, so that this combined mode will be feasible for some liquidity risks.

there exists a $l_0^{\mathcal{S}}$ with $l_0^{\mathcal{S}} \in \left[l_0^{\text{fb}}, \frac{l_{1,b}^{\text{fb}}}{\psi}\right]$ for which $\frac{\partial \pi_0^{\mathcal{SS}}}{\partial l_0}$ is equal to zero so that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$. Again it follows that $l_0^{\mathcal{S}}$ will increase in the liquidity risk if Δ_1 is small but will decrease if Δ_1 is large.

3. Suppose the banker operates according to strategy $\mathcal{C}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SR}$. It follows from (A.61) that

$$\begin{aligned} \frac{\partial \pi_0^{\mathcal{SR}}}{\partial l_0} &= \phi_0^{\mathcal{S}\prime}(l_0) - (1-p_1)(1-p_2)(\mu_1 - p_1\Delta_1) \\ &\quad + (1-p_1)\phi_{1,b}^{\mathcal{R}\prime}(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}) \frac{\partial \min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}}{\partial l_0}. \end{aligned} \tag{A.70}$$

Note that the first two terms decrease in l_0. The third term is equal to zero as long as bank lending is not restricted in the downturn. If bank lending is restricted in the downturn, the third term will decrease in l_0 as $\frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}$ increases in $l_{1,\kappa}^{\max}$, which increases in l_0. This latter effect is positive as long as the risky mode is available, i.e. for all $\frac{\partial l_{1,\kappa}^{\max}}{\partial l_0} = \psi_\kappa > 0$. While the first term is equal to zero for $l_0 = l_0^{\mathcal{SR}}$, the second term is equal to zero for $l_0 = \frac{l_{1,b}^{\text{fb}}}{\psi_\kappa}$, as this implies $l_{1,\kappa}^{\max} = l_{1,b}^{\text{fb}}$. Note that the safe mode is only restricted in the downturn for $l_0^{\text{fb}} < \frac{l_{1,b}^{\text{fb}}}{\psi_\kappa}$. Consequently, there exists a $l_{0,\kappa}^{\mathcal{SR}}$ with $l_{0,\kappa}^{\mathcal{SR}} \in \left[l_0^{\mathcal{SR}}, \frac{l_{1,b}^{\text{fb}}}{\psi_\kappa}\right]$ for which (A.70) is equal to zero, so that the optimal loan volume is $l_0^* = l_{0,\kappa}^{\mathcal{SR}}$.

In order to determine how changes of the liquidity risk, Δ_1, affect the optimal loan volume, $l_{0,\kappa}^{\mathcal{SR}}$, i.e. $\frac{\partial l_{0,\kappa}^{\mathcal{SR}}}{\partial \Delta_1}$, we can conclude from (A.40) and (A.41) that $\frac{\partial l_{0,\kappa}^{\mathcal{SR}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_{0,\kappa}^{\mathcal{SR}}}{\partial \Delta_1^2} < 0$ as long as $l_{0,\kappa}^{\mathcal{SR}} = l_0^{\mathcal{SR}}$. If bank lending is restricted in the downturn, we define the function, $F_\kappa^{\mathcal{C}}$, as the first order condition of $\pi_{0,\kappa}^{\mathcal{SR}}(l_0)$ with respect to l_0 for $l_{0,\kappa}^{\mathcal{SR}}$:

$$\begin{aligned} F_\kappa^{\mathcal{C}} &:= [1-(1-p_1)(1-p_2)]\mu_1 + (1-p_1)(1-p_2)p_1\Delta_1 - 1 - \frac{\partial c}{\partial l_{0,\kappa}^{\mathcal{SR}}} \\ &\quad + (1-p_1)\left[\mu_{2,b} - 1 - \frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}\right]\psi = 0. \end{aligned} \tag{A.71}$$

Applying the implicit function theorem yields $\frac{\partial l_{0,\kappa}^{\mathcal{SR}}}{\partial \Delta_1} = -\frac{\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta_1}}{\frac{\partial F_\kappa^{\mathcal{C}}}{\partial l_{0,\kappa}^{\mathcal{SR}}}}$. It follows that $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta_1} = (1-p_1)(1-p_2)p_1 + (1-p_1)\phi_{1,b}^{\mathcal{R}\prime}(l_{1,\kappa}^{\max})\frac{\partial \psi_\kappa}{\partial \Delta_1} - (1-p_1)\psi_\kappa \frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}\frac{\partial l_{1,\kappa}^{\max}}{\partial \Delta_1}$ and $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial l_{0,\kappa}^{\mathcal{SR}}} = -\frac{\partial^2 c(l_{0,\kappa}^{\mathcal{SR}})}{\partial l_{0,\kappa}^{\mathcal{SR}\,2}} - (1-p_1)\frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}\frac{\partial l_{1,\kappa}^{\max}}{\partial l_{0,\kappa}^{\mathcal{SR}}}\psi_\kappa < 0$. If the liquidity risk is small, $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta_1}$ will positive. For small liquidity risks the second term is negative due to $\frac{\partial \psi_\kappa}{\partial \Delta_1} < 0$ but close to zero, as $l_{1,\kappa}^{\max}$ is close to $l_{1,b}^{\text{fb}}$, while the third is positive due to $\frac{\partial l_{1,\kappa}^{\max}}{\partial \Delta_1} < 0$ and sufficiently large, as ψ_κ is large for small liquidity risks. The first term is always positive and constant. If the liquidity risks are large, $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta_1}$ will be negative. For larger liquidity risks ψ_κ is smaller so that the positive effect of the third term decreases while the negative effect of the second term increases as the difference between $l_{1,\kappa}^{\max}$ and $l_{1,b}^{\text{fb}}$ increases. We can thus conclude that $\frac{\partial l_{0,\kappa}^{\mathcal{SR}}}{\partial \Delta_1}$ is positive for smaller liquidity risks and negative for larger liquidity risks.

4. Suppose the banker operates according to strategy $\mathcal{D}$, i.e. he faces a restriction on bank lending when operating according to $m = \mathcal{SR}$, as (A.62) becomes binding. Hence the optimal loan volume is $l_0^* = l_{0,\kappa}^{\max}$. Due to $\frac{\partial l_{1,\kappa}^{\max}}{\partial \Delta_1} < 0$ and the results from the proof of Proposition 5.3 that $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial^2 l_0^{\max}}{\partial \Delta_1^2} > 0$, we can directly conclude that $\frac{\partial l_{0,\kappa}^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial^2 l_{0,\kappa}^{\max}}{\partial \Delta_1^2} > 0$. Strategy $\mathcal{D}$ is feasible as long as $\psi_\kappa \geq 0$. In analogy to Δ_1^ψ, we define the liquidity risk for which $\psi_\kappa = 0$ as $\Delta_{1,\kappa}^\psi$.

5. Suppose the banker operates according to strategy $\mathcal{E}$, i.e. he operates according to $m = \mathcal{RF}$. As long as strategy $\mathcal{E}$ is feasible, i.e. for all $\Delta_1 \geq \Delta_{1,\kappa}^{\mathcal{E}}$, (A.67) is identical to (A.37) so that the optimal loan volume is $l_0^* = l_0^{\mathcal{R}}$ with $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_0^{\mathcal{R}}}{\partial \Delta_1^2} < 0$.

6. Suppose the banker operates according to strategy $\mathcal{X}$, i.e. he operates according to $m = \mathcal{NN}$. By definition this implies that the optimal loan volume is $l_0^* = 0$.

Critical Values of Δ_1

In a next step, we determine the optimal behavior of the banker for a given liquidity risk $\Delta_1 < \overline{\Delta}_1$.

1. We denote $\Delta_1^{\mathcal{A}}$ as the largest risk level for which the banker is still able to operate in the unrestricted safe mode in both periods. As both strategies $\mathcal{A}$ and $\mathcal{B}$ remain unchanged, imposing capital requirements yields the same $\Delta_1^{\mathcal{A}}$ as defined in (A.42).

2. We denote $\Delta_{1,\kappa}^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}$ and strategy $\mathcal{C}$. Recall that for $\Delta_1 = \Delta_1^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{SS}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{SR}}(l_0) > \pi_0^{\mathcal{RF}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\text{fb}})}{\partial \Delta_1} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$, the expected profit from strategy $\mathcal{B}$ decrease in Δ_1, i.e. $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial \Delta_1} < 0$. Moreover, it follows from (A.61) that $\frac{\partial \pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\mathcal{SR}})}{\partial \Delta_1} = \frac{\partial \pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\mathcal{SR}})}{\partial l_{0,\kappa}^{\mathcal{SR}}} \frac{\partial l_{0,\kappa}^{\mathcal{SR}}}{\partial \Delta_1} + (1-p_1)(1-p_2)p_1 l_{0,\kappa}^{\mathcal{SR}} > 0$, as $\frac{\partial \pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\mathcal{SR}})}{\partial l_{0,\kappa}^{\mathcal{SR}}} = 0$. Accordingly, if there exists a unique $\Delta_{1,\kappa}^{\mathcal{B}'} > \Delta_1^{\mathcal{A}}$ for which $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) = \pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\mathcal{SR}})$, then the banker will prefer strategy $\mathcal{B}$ over strategies $\mathcal{C}$, $\mathcal{D}$ and $\mathcal{E}$ as $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) \geq \pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\mathcal{SR}}) > \pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\max}) > \pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}})$ for all $\Delta_1 \leq \Delta_{1,\kappa}^{\mathcal{B}'}$, while for all $\Delta_1 > \Delta_{1,\kappa}^{\mathcal{B}'}$, the banker prefers strategy $\mathcal{C}$ over strategy $\mathcal{B}$ as $\pi_{0,\kappa}^{\mathcal{SR}}(l_{0,\kappa}^{\mathcal{SR}}) > \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})$. If such a $\Delta_{1,\kappa}^{\mathcal{B}'}$ does not exist within $(\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}]$, e.g. as $l_{0,\kappa}^{\max}$ becomes binding for a $\Delta_1 \leq \Delta_1^{\psi}$, the banker prefers strategy $\mathcal{B}$ as long as the safe mode is available in the downturn, i.e. for all $\Delta_1 \in (\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}]$ so that

$$\Delta_{1,\kappa}^{\mathcal{B}} := \min\{\Delta_{1,\kappa}^{\mathcal{B}'}, \Delta_1^{\psi}\}. \tag{A.72}$$

3. We denote $\Delta_{1,\kappa}^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}$ and strategy $\mathcal{D}$, i.e. the highest risk level for which bank lending is not restricted when operating according to $m = \mathcal{SR}$. It follows from the definitions of $l_{0,\kappa}^{\max}$ and v_b that the banker is indifferent between the two strategies

if $l^{\mathcal{SR}}_{0,\kappa} = l^{\max}_{0,\kappa}$ or if

$$\Delta^{\mathcal{C}}_{1,\kappa} := \frac{\phi^{\mathcal{R}}_{1,b}(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\})[1-(1-\lambda)p_1]}{p_1[p_2-(1-\lambda)(1-p_1(1-p_2))]l^{\mathcal{SR}}_{0,\kappa}} + \frac{\mu_1[p_2+(1-\lambda)p_1(1-p_2)]-1}{p_1[p_2-(1-\lambda)(1-p_1(1-p_2))]}. \tag{A.73}$$

As long as $l^{\mathcal{SR}}_{0,\kappa} < l^{\max}_{0,\kappa}$ it follows that $\pi^{\mathcal{SR}}_{0,\kappa}(l^{\mathcal{SR}}_{0,\kappa}) > \pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa}) > \pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0)$ so that the banker prefers strategy $\mathcal{C}$ over strategies $\mathcal{D}$ and $\mathcal{E}$ for all $\Delta_1 \leq \Delta^{\mathcal{C}}_{1,\kappa}$. For all $\Delta_1 > \Delta^{\mathcal{C}}_{1,\kappa}$ strategy $\mathcal{C}$ is not feasible.

4. We denote $\Delta^{\mathcal{D}}_{1,\kappa}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}$ and strategy $\mathcal{E}$. It follows from (A.61) that $\frac{\partial \pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa})}{\partial \Delta_1} = \frac{\partial \pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa})}{\partial l^{\max}_{0,\kappa}} \frac{\partial l^{\max}_{0,\kappa}}{\partial \Delta_1} + (1-p_1)(1-p_2)p_1 l^{\max}_{0,\kappa}$, which is negative for sufficiently large Δ_1 as $\frac{\partial \pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa})}{\partial l^{\max}_{0,\kappa}} > 0$ and $\frac{\partial l^{\max}_{0,\kappa}}{\partial \Delta_1} < 0$. Recall from (A.37) in the proof of Proposition 5.3 that $\frac{\partial \pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0)}{\partial \Delta_1} = \frac{\partial \pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0)}{\partial l^{\mathcal{R}}_0} \frac{\partial l^{\mathcal{R}}_0}{\partial \Delta_1} + p_1(1-p_1)l^{\mathcal{R}}_0 > 0$ as $\frac{\partial \pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0)}{\partial l^{\mathcal{R}}_0} = 0$. Accordingly, if there exists a unique $\Delta^{\mathcal{D}}_{1,\kappa} > \Delta^{\mathcal{C}}_{1,\kappa} > \Delta^{\mathcal{B}}_{1,\kappa} > \Delta^{\mathcal{A}}_1$ for which $\pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa}) = \pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0)$, the banker will prefer strategy $\mathcal{D}$ over strategy $\mathcal{E}$ as $\pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa}) > \pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0)$ for all $\Delta_1 \leq \Delta^{\mathcal{D}}_{1,\kappa}$, while for all $\Delta_1 > \Delta^{\mathcal{D}}_{1,\kappa}$, the banker prefers $\mathcal{E}$ over $\mathcal{D}$ due to $\pi^{\mathcal{RF}}_0(l^{\mathcal{R}}_0) > \pi^{\mathcal{SR}}_{0,\kappa}(l^{\max}_{0,\kappa})$. If such a $\Delta^{\mathcal{D}}_{1,\kappa}$ does not exist within $(\Delta^{\mathcal{C}}_{1,\kappa}, \Delta^{\psi}_{1,\kappa}]$, e.g. as capital requirements are so strict that $\Delta^{\psi}_{1,\kappa} < \Delta^{\mathcal{E}}_{1,\kappa}$, the banker will prefer strategy $\mathcal{D}$ as long as the risky mode is available in the downturn, i.e. for all $\Delta_1 \in (\Delta^{\mathcal{C}}_{1,\kappa}, \Delta^{\psi}_{1,\kappa}]$. In this case, the banker will prefer strategy $\mathcal{X}$ for all $\Delta_1 \in (\Delta^{\psi}_{1,\kappa}, \Delta^{\mathcal{E}}_{1,\kappa})$ and strategy $\mathcal{E}$ as soon as this strategy is feasible, i.e. for all $\Delta_1 > \Delta^{\mathcal{E}}_{1,\kappa}$.

Proof of Proposition 6.9

We proceed again in three steps. First, we determine the reduced forms for all combinations of modes feasible. Second, we derive the banker's optimal loan volume for each strategy feasible. Finally, we compare the expected profits of the different strategies, to identify the banker's optimal behavior depending on the liquidity risk, Δ_1. As this proof is to large extent a combination of the proofs of Propositions 5.3 and 6.6, we shorten this proof accordingly.

Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in an upswing at $t = 1$, we again only have to consider all combinations feasible based on the modes available in the first period and in the downturn at $t = 1$.

1. Suppose the banker will operate in the safe mode independent of the date or state of the economy, so that $m_0 = \mathcal{S}$ and $m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. While $\kappa_b = 0$ implies that capital requirements impose no additional restriction on the face value of deposits in the downturn, $\kappa_g > \kappa$ will result in a restriction on the face value in the first period if (6.12) becomes binding. It follows from (A.60) that the safe mode will be feasible if $\omega_{1,b} \leq 1 - \kappa$. Given that $\omega_{1,b} = \frac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1}$, a countercyclical capital buffer $\kappa_g > 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$ implies that operating in the safe mode in the first period will only be feasible if
$$\Delta_1 \geq \frac{1-(1-\lambda)p_1\mu_1 - [1-(1-\lambda)p_1](1-\kappa_g)]}{(1-\lambda)p_1(1-p_1)} =: \Delta^{\mathcal{Y}}_{1,\kappa_g}. \tag{A.74}$$
As long as this condition is fulfilled, the reduced form when operating according to $m = \mathcal{SS}$ is identical to (A.35) and (A.36).

2. Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if the economy is in a downturn at $t = 1$, so

that $m = \mathcal{SR}$. Operating in the safe mode in the first period will only be feasible if $\Delta_1 \geq \Delta^{\mathcal{Y}}_{1,\kappa_g}$. As the countercyclical capital requirements impose no restriction in the downturn, we can conclude that the reduced form when operating according to $m = \mathcal{SR}$ is identical to (A.35) and (A.36).

3. Suppose the banker operates in the risky mode in the first period, which results in a bank run in the downturn at $t = 1$, so that $m = \mathcal{RF}$. We obtained, in the proof of Proposition 6.6, the result that operating in the risky mode in the first period will be feasible if the liquidity risk, Δ_1, is sufficiently large. Replacing κ with κ_g, operating according to $m = \mathcal{RF}$ is feasible for all $\Delta_1 \geq \Delta^{\mathcal{E}}_{1,\kappa_g}$ with

$$\Delta^{\mathcal{E}}_{1,\kappa_g} := \frac{1 - \lambda p_1 - (1-\lambda)p_1\mu_1 + \lambda p_1 \kappa_g}{(1-\lambda)p_1(1-p_1)}. \tag{A.75}$$

For all these liquidity risks, the reduced form is identical to (A.37) and (A.38), as bank lending is not restricted when the economy is in a downturn at $t = 1$.

Determination of Optimal Loan Volumes at $t = 0$

1. Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SS}$. As long as strategy $\mathcal{A}$ is feasible, the reduced form is identical to (A.33). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$ and $\frac{\partial l_{1,g}^{\text{fb}}}{\partial \Delta_1} = \frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_1} = 0$.

2. Suppose the banker operates according to strategy $\mathcal{B}$, i.e. the restriction on bank lending becomes binding when operating according to $m = \mathcal{SS}$. As long as strategy $\mathcal{B}$ is feasible, the reduced form is identical to (A.33) and (A.34). We can thus likewise conclude that there exists a $l_0^{\mathcal{S}}$ with $l_0^{\mathcal{S}} \in \left[l_0^{\text{fb}}, \frac{l_{1,b}^{\text{fb}}}{\psi}\right]$ for which $\frac{\partial \pi_0^{\mathcal{SS}}}{\partial l_0}$ is equal to zero so that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$. Again it follows that $l_0^{\mathcal{S}}$ will increase in the liquidity risk if Δ_1 is small but will decrease if Δ_1 is large.

3. Suppose the banker operates according to strategy $\mathcal{C}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SR}$. As long as strategy $\mathcal{C}$ is feasible, the reduced form is identical to (A.35) and (A.36). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\mathcal{SR}}$ with $\frac{\partial l_0^{\mathcal{SR}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_0^{\mathcal{SR}}}{\partial \Delta_1^2} < 0$.

4. Suppose the banker operates according to strategy $\mathcal{D}$, i.e. he faces a restriction on bank lending when operating according to $m = \mathcal{SR}$, as (A.62) becomes binding. As long as strategy $\mathcal{D}$ is feasible, the reduced form is identical to (A.35) and (A.36). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\max}$ with $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial^2 l_0^{\max}}{\partial \Delta_1^2} > 0$.

5. Suppose the banker operates according to strategy $\mathcal{E}$, i.e. he operates according to $m = \mathcal{RF}$. As long as strategy $\mathcal{E}$ is feasible, the reduced form is identical to (A.37). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\mathcal{R}}$ with $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_0^{\mathcal{R}}}{\partial \Delta_1^2} < 0$.

6. Suppose the banker operates according to strategy $\mathcal{Y}$, i.e. he operates according to $m = \mathcal{NR}$. Recall from Lemma 6.8 that the risky mode is always feasible, even if the banker grants no loans at all in the first period. By definition this implies that the optimal loan volume is $l_0^* = 0$.

Critical Values of Δ_1

While $\Delta_1^{\mathcal{A}}$, $\Delta_1^{\mathcal{B}}$, $\Delta_1^{\mathcal{C}}$ and $\Delta_1^{\mathcal{D}}$ are defined in the proof of Proposition 5.3, it follows from the fact that $\Delta_{1,\kappa_g}^{\mathcal{Y}} < \Delta_{1,\kappa_g}^{\mathcal{E}}$ that the banker will have to operate according to strategy $\mathcal{Y}$ for all $\Delta_1 \leq \Delta_{1,\kappa_g}^{\mathcal{Y}}$. Moreover, it follows from the definition of $\Delta_{1,\kappa_g}^{\mathcal{E}}$ that the banker will prefer to operate according to strategy $\mathcal{E}$ if both $\pi_0^{\mathcal{RF}}(l_0^{\mathcal{R}}) > \pi_0^{\mathcal{SR}}(l_0^{\max})$ and $\Delta_1 \geq \Delta_{1,\kappa_g}^{\mathcal{E}}$.

Proof of Lemma 6.11

This proof proceeds in the same three steps as the proof of Lemma 5.2.

Determination of Reduced Forms

1. Suppose the banker operates in the safe mode. The liquidity coverage ratio will result in a restriction on the face value of deposits if

$$\frac{a_{1,b}}{\eta} \leq v_b l_0 + a_{1,b}. \tag{A.76}$$

   Limiting the liquidity coverage ratio to $\eta \in (0,1)$ implies that such a restriction is never binding. It follows from (A.24) that investing in the risk-free asset has no impact on the expected profit in the safe mode. In order to fulfill the liquidity coverage ratio, the banker can thus simply issue more deposits that are invested in the risk-free asset. This increases the LHS of (A.76) to a larger extent than the RHS. Accordingly there exists a critical $a_{1,b}$ for which the liquidity coverage ratio imposes no additional restriction on the face value of deposits. The expected profit is therefore identical to (A.24), with the restriction on bank lending given by (A.25).

2. Suppose the banker operates in the risky mode. In this case the expected profit of the risk-free asset is $p_2 - 1 < 0$, see (A.26). In the absence of any regulatory measure, the banker will thus never invest in the risk-free asset when operating in the risky mode so that $a^*_{1,b} = 0$. Therefore, the liquidity coverage ratio will always impose a restriction on the face value of deposits, i.e. $\delta_{1,b} \leq \frac{a_{1,b}}{\eta}$ becomes binding. Inserting this new restriction on deposits as well as the amount provided by depositors (5.14) and shareholders (5.15) into the budget constraint (5.13), and making use of (5.2) and (5.6) when applying

the budget constraint to the expected profit (5.12), yields

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi_{1,b}^{\mathcal{R}} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}^{\mathcal{R}}(l_{1,b}) - (1-p_2)a_{1,b} \tag{A.77}$$

$$\text{s. t.}\quad [1-(1-\lambda)p_2 r_b]\, l_{1,b} \leq [(1-\lambda)p_2 v_b + \omega_{1,b}]\, l_0 + \left[\frac{1-\eta}{\eta} - (1-p_2)\right] a_{1,b}. \tag{A.78}$$

3. Suppose the banker operates in the failure mode by closing the bank early, in the downturn at $t = 1$. Then it follows again that

$$\pi_{1,b}^{\mathcal{F}} = 0. \tag{A.79}$$

Determination of Optimal Loan Volumes at $t = 1$

In the next step, we determine the optimal loan volume for all modes feasible.

1. Suppose the banker operates in the safe mode. We can thus directly conclude from the proof of Lemma 5.2 that the optimal loan volume is $l_{1,b}^* = \min\{l_{1,b}^{\text{fb}}, l_1^{\max}\}$.

2. Suppose the banker operates in the risky mode. It follows from (A.77) that $\frac{\partial \pi_{1,b}^{\mathcal{R}}}{\partial l_{1,b}} = \phi_{1,b}^{\mathcal{R}\prime}(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l_{1,b}^{\text{fb}}$. Considering the restriction on bank lending (A.78), the optimal loan volume is thus $l_{1,b}^* = \min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}$ with

$$l_{1,\eta}^{\max} := \psi_\eta l_0 + \xi_\eta a_{1,b} \tag{A.80}$$

where

$$\psi_\eta := \frac{(1-\lambda)p_2 v_b + \omega_{1,b}}{1-(1-\lambda)p_2 r_b} \tag{A.81}$$

and

$$\xi_\eta := \frac{\frac{1-\eta}{\eta}\lambda p_2 - (1-p_2)}{1-(1-\lambda)p_2 r_b}. \tag{A.82}$$

Comparing (A.81) with (A.29), it follows that $\psi_\eta < \psi$. The optimal loan volume thus depends on ξ_η. As long as $\xi_\eta < 0$ investing in the risk-free asset $a_{1,b}$ results in a negative expected profit and restricts bank lending even further. Hence the optimal investment in the risk-free asset is $a_{1,b}* = 0$. This implies, however, that the banker cannot issue any new deposits. Therefore the risky mode is technically not feasible.

For all $\xi_\eta > 0$, i.e. for all $\eta < \frac{\lambda p_2}{1-(1-\lambda)p_2}$, investing in the risk-free asset loosens the restriction on bank lending. As this investment still corresponds with a negative expected profit, the optimal investment is determined by its first order condition

$$\frac{\partial \pi_{1,b}^{\mathcal{R}}}{\partial a_{1,b}} = \phi_{1,b}^{\mathcal{R}\prime}\left(l_{1,\eta}^{\max}\right)\frac{\partial l_{1,\eta}^{\max}}{\partial a_{1,b}} - (1-p_2). \tag{A.83}$$

In this case, the risky mode is feasible and the optimal loan volume is $l_{1,b}^{*} = \min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}$.

3. Suppose the banker operates in the failure mode. By definition, the optimal loan volume is $l_{1,b}^{*} = 0$.

Critical Values of l_0

1. If $v_b + \omega_{1,b} \geq 0$, it follows, due to $l_1^{\max} \geq 0$, that $\pi_{1,b}^{\mathcal{S}*} \geq 0$, so that the failure mode is never optimal. Comparing $\pi_{1,b}^{\mathcal{S}*}$ and $\pi_{1,b}^{\mathcal{R}*}$ yields $\pi_{1,b}^{\mathcal{S}*} \geq \pi_{1,b}^{\mathcal{R}*}$ if

$$(1-p_2)(v_b l_0 + a_{1,b}) + \phi_{1,b}^{\mathcal{S}}\left(\min\left\{l_{1,b}^{\text{fb}}, l_1^{\max}\right\}\right) \geq \phi_{1,b}^{\mathcal{R}}\left(\min\left\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\right\}\right). \tag{A.84}$$

As both $l_1^{\max}$ and $l_{1,\eta}^{\max}$ increase in l_0, this condition holds for all $l_0 \geq l_{0,\eta}^{\min}$. For all $l_0 < l_{0,\eta}^{\min}$ it follows that $\pi_{1,b}^{\mathcal{R}*} > \pi_{1,b}^{\mathcal{S}*} > \pi_{1,b}^{\mathcal{F}*}$.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing $\pi_{1,b}^{\mathcal{R}*}$ and $\pi_{1,b}^{\mathcal{F}*}$ yields that $\pi_{1,b}^{\mathcal{R}*} \geq \pi_{1,b}^{\mathcal{F}*}$ if

$$-\frac{\phi_{1,b}^{\mathcal{R}}\left(\min\left\{l_{1,b}^{\mathrm{fb}}, l_{1,\kappa}^{\max}\right\}\right) - (1-p_2)a_{1,b}}{p_2 v_b + \omega_{1,b}} \geq l_0. \tag{A.85}$$

Hence this condition holds for all $l_0 \leq l_{0,\eta}^{\max}$. For all $l_0 > l_{0,\eta}^{\max}$ it follows that $\pi_{1,b}^{\mathcal{F}*} > \pi_{1,b}^{\mathcal{R}*}$.

Proof of Proposition 6.12

This proof proceeds in the same three steps as the proof of Proposition 5.3.

Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in an upswing at $t = 1$, we again only have to consider all combinations feasible based on the modes available in the first period and in the downturn at $t = 1$.

1. Suppose the banker will operate in the safe mode independent of the date or state of the economy, so that $m_0 = \mathcal{S}$ and $m^*_{1,b} = \mathcal{S}$, or in short $m = \mathcal{SS}$. As the expected profit (A.33) is independent of a_0, the banker can fulfill any liquidity coverage ratio by issuing more deposits that are invested in the risk-free asset a_0. This only results in a balance sheet extension. Hence the reduced form when operating according to $m = \mathcal{SS}$ is identical to (A.33) and (A.34).

2. Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if the economy is in the downturn at $t = 1$, so that $m = \mathcal{SR}$. In conjunction with Lemma 6.10 and 6.11, inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ and (5.4) when applying the budget constraint to the expected profit (5.21), yields

$$\begin{aligned}\max_{l_0,a_0\in\mathbb{R}^+} \pi_{0,\eta}^{\mathcal{SR}}(l_0) = {} & \phi_0^{\mathcal{S}}(l_0) - (1-p_1)(1-p_2)(\mu_1 - p_1\Delta_1)l_0 && \text{(A.86)}\\ & + p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) + (1-p_1)\left[\phi_{1,b}^{\mathcal{R}}(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}) - (1-p_2)a_{1,b}\right] \\ \text{s. t.}\quad l_0 \le {} & \frac{\phi_{1,b}^{\mathcal{R}}\left(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}\right) - (1-p_2)a_{1,b}}{\frac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1} - p_2(\mu_1 - p_1\Delta_1)} =: l_{0,\eta_{\mathcal{SR}}}^{\max} && \text{(A.87)}\end{aligned}$$

with

$$l_{1,\eta}^{\max} := \psi_\eta l_0 + \xi_\eta a_{1,b} \tag{A.88}$$

and

$$\psi_\eta := \frac{(1-\lambda)p_2(\mu_1 - p_1\Delta_1) + \frac{1-(1-\lambda)p_1(\mu_1+(1-p_1)\Delta_1)}{1-(1-\lambda)p_1}}{1-(1-\lambda)p_2 r_b}, \tag{A.89}$$

while ξ_η is defined in (A.82).

3. Suppose the banker operates in the risky mode straight away in the first period which results in a bank run, so that $m = \mathcal{RF}$. In this case the expected profit of the risk-free asset is $p_1 - 1 < 0$, see (A.37). In the absence of any regulatory measure, the banker will thus never invest in the risk-free asset when operating in the risky mode so that $a_0^* = 0$. The liquidity coverage ratio will thus always impose a restriction on the face value of deposits, i.e. $\delta_0 \leq \frac{a_0}{\eta}$ becomes binding. In conjunction with Lemma 6.10 and 6.11, considering this restriction on deposits when inserting the funds provided by depositors (5.23) and shareholders (5.24) into the budget constraint (5.22), and making use of the definition of $\phi_t^{m_t}$ when applying the budget constraint to the expected profit (5.21), yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_{0,\eta}^{\mathcal{RF}}(l_0) = \phi_0^{\mathcal{R}}(l_0) - (1-p_1)a_0 + p_1\phi_{1,g}^{\mathcal{S}}(l_{1,g}^{\text{fb}}) \tag{A.90}$$

$$\text{s.t.}\ \ l_0 \leq \frac{\frac{1-\eta}{\eta}\lambda p_1 - (1-p_1)}{1-(1-\lambda)p_1[\mu_1 + (1-p_1)\Delta_1]} a_0 =: l_{0,\eta\mathcal{RF}}^{\max}. \tag{A.91}$$

Determination of Optimal Loan Volumes at $t = 0$

1. Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SS}$. As the reduced form is identical to (A.33) we can likewise conclude that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$ and $\frac{\partial l_{1,g}^{\text{fb}}}{\partial \Delta_1} = \frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_1} = 0$.

2. Suppose the banker operates according to strategy $\mathcal{B}$, i.e. the restriction on bank lending becomes binding when operating according to $m = \mathcal{SS}$. As the reduced form is identical to (A.33) and (A.34), we can likewise conclude that

there exists a $l_0^{\mathcal{S}}$ with $l_0^{\mathcal{S}} \in \left[l_0^{\text{fb}}, \frac{l_{1,b}^{\text{fb}}}{\psi}\right]$ for which $\frac{\partial \pi_0^{\mathcal{SS}}}{\partial l_0}$ is equal to zero so that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$. Again it follows that $l_0^{\mathcal{S}}$ will increase in the liquidity risk if Δ_1 is small but will decrease if Δ_1 is large.

3. Suppose the banker operates according to strategy $\mathcal{C}$, i.e. he faces no restriction on bank lending when operating according to $m = \mathcal{SR}$. It follows from (A.86) that

$$\frac{\partial \pi_0^{\mathcal{SR}}}{\partial l_0} = \phi_0^{\mathcal{S}\prime}(l_0) - (1-p_1)(1-p_2)(\mu_1 - p_1\Delta_1) + (1-p_1)\phi_{1,b}^{\mathcal{R}\prime}(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}) \frac{\partial \min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}}{\partial l_0}. \tag{A.92}$$

Note that the first two terms decrease in l_0. The third term is equal to zero as long as bank lending is not restricted in the downturn. If bank lending is restricted in the downturn, the third term will decrease in l_0 as $\frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}}$ increases in $l_{1,\eta}^{\max}$, which increases in l_0 for $\psi_\eta > 0$. For $\psi_\eta < 0$ the third term increases in l_0 as $\frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}}$ increases in $l_{1,\eta}^{\max}$, which decreases in l_0. While the first term is equal to zero for $l_0 = l_0^{\mathcal{SR}}$, the second term is equal to zero for $l_0 = \frac{l_{1,b}^{\text{fb}} - \xi_\eta a_{1,b}}{\psi_\eta}$, as this implies $l_{1,\eta}^{\max} = l_{1,b}^{\text{fb}}$. Note that the safe mode is only restricted in the downturn for $l_0^{\text{fb}} < \frac{l_{1,b}^{\text{fb}} - \xi_\eta a_{1,b}}{\psi_\eta}$. Consequently, for $\psi_\eta > 0$ there exists a $l_{0,\eta}^{\mathcal{SR}}$ with $l_{0,\eta}^{\mathcal{SR}} \in \left[l_0^{\mathcal{SR}}, \frac{l_{1,b}^{\text{fb}} - \xi_\eta a_{1,b}}{\psi_\eta}\right]$ for which (A.92) is equal to zero. For $\psi_\eta < 0$ there exists a $l_{0,\eta}^{\mathcal{SR}}$ with $l_{0,\eta}^{\mathcal{SR}} < l_0^{\mathcal{SR}}$ for which (A.92) is equal to zero. The optimal loan volume is thus $l_0^* = l_{0,\eta}^{\mathcal{SR}}$.

In order to determine how changes of the liquidity risk, Δ_1, affect the optimal loan volume $l_{0,\eta}^{\mathcal{SR}}$, i.e. $\frac{\partial l_{0,\eta}^{\mathcal{SR}}}{\partial \Delta_1}$, we can conclude from (A.40) and (A.41) that $\frac{\partial l_{0,\eta}^{\mathcal{SR}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_{0,\eta}^{\mathcal{SR}}}{\partial \Delta_1^2} < 0$ as long as $l_{0,\eta}^{\mathcal{SR}} = l_0^{\mathcal{SR}}$. Given that bank lending is restricted in the downturn, we define the function, $F_\eta^{\mathcal{C}}$, as the first order condition of

$\pi_{0,\eta}^{\mathcal{SR}}(l_0)$ with respect to l_0 for $l_{0,\eta}^{\mathcal{SR}}$:

$$F_\eta^{\mathcal{C}} := [1-(1-p_1)(1-p_2)]\mu_1 + (1-p_1)(1-p_2)p_1\Delta_1 - 1 - \frac{\partial c}{\partial l_{0,\eta}^{\mathcal{SR}}} + (1-p_1)\left[\mu_{2,b} - 1 - \frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}}\right]\psi_\eta = 0. \tag{A.93}$$

Applying the implicit function theorem yields $\frac{\partial l_{0,\eta}^{\mathcal{SR}}}{\partial \Delta_1} = -\frac{\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta_1}}{\frac{\partial F_\eta^{\mathcal{C}}}{\partial l_{0,\eta}^{\mathcal{SR}}}}$. It follows that $\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta_1} = (1-p_1)(1-p_2)p_1 + (1-p_1)\phi_{1,b}^{\mathcal{R}\prime}(l_{1,\eta}^{\max})\frac{\partial \psi_\eta}{\partial \Delta_1} - (1-p_1)\psi_\eta \frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}} \frac{\partial l_{1,\eta}^{\max}}{\partial \Delta_1}$ and $\frac{\partial F_\eta^{\mathcal{C}}}{\partial l_{0,\eta}^{\mathcal{SR}}} = -\frac{\partial^2 c(l_{0,\eta}^{\mathcal{SR}})}{\partial {l_{0,\eta}^{\mathcal{SR}}}^2} - (1-p_1)\frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}} \frac{\partial l_{1,\eta}^{\max}}{\partial l_{0,\eta}^{\mathcal{SR}}}\psi_\eta < 0$. If the liquidity risk is small, $\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta_1}$ will be positive. For small liquidity risks the second term is negative due to $\frac{\partial \psi_\eta}{\partial \Delta_1} < 0$ but close to zero as $l_{1,\eta}^{\max}$ is close to $l_{1,b}^{\text{fb}}$, while the third is positive, due to $\frac{\partial l_{1,\eta}^{\max}}{\partial \Delta_1} < 0$, and sufficiently large as ψ_η is large for small liquidity risks. The first term is always positive and constant. If the liquidity risks are large, $\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta_1}$ will be negative. For larger liquidity risks, ψ_η is smaller so that the positive effect of the third term decreases while the negative effect of the second term increases as the difference between $l_{1,\eta}^{\max}$ and $l_{1,b}^{\text{fb}}$ increases. We can thus conclude that $\frac{\partial l_{0,\eta}^{\mathcal{SR}}}{\partial \Delta_1}$ is positive for smaller liquidity risks and negative for larger liquidity risks.

4. Suppose the banker operates according to strategy $\mathcal{D}$, i.e. he faces a restriction on bank lending when operating according to $m = \mathcal{SR}$, as (A.87) becomes binding. Hence the optimal loan volume is $l_0^* = l_{0,\eta}^{\max}$. Due to $\frac{\partial l_{1,\eta}^{\max}}{\partial \Delta_1} < 0$ and the results from the proof of Proposition 5.3 that $\frac{\partial l_0^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial^2 l_0^{\max}}{\partial \Delta_1^2} > 0$, we can directly conclude that $\frac{\partial l_{0,\eta}^{\max}}{\partial \Delta_1} < 0$ and $\frac{\partial^2 l_{0,\eta}^{\max}}{\partial \Delta_1^2} > 0$.

5. Suppose the banker operates according to strategy $\mathcal{E}$, i.e. he operates according to $m = \mathcal{RF}$. It follows from (A.91) that this strategy will only be feasible if $\eta < \frac{\lambda p_1}{1-(1-\lambda)p_1}$. In this case, investing in the risk-free asset loosens the restriction on bank lending. However, this investment corresponds with a negative expected profit, so that the optimal investment is determined by its

first order condition

$$\frac{\partial \pi_{0,\eta}^{\mathcal{RF}}}{\partial a_0} = \phi_0^{\mathcal{R}\prime}\left(l_{0,\eta_{\mathcal{RF}}}^{\max}\right)\frac{\partial l_{0,\eta_{RF}}^{\max}}{\partial a_0} - (1-p_1). \tag{A.94}$$

The optimal loan volume is thus $l_0^* = \min\{l_0^{\mathcal{R}}, l_{0,\eta_{RF}}^{\max}\}$. It follows directly from (A.37) that $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_0^{\mathcal{R}}}{\partial \Delta_1^2} < 0$. Moreover, it follows from (A.91) that $\frac{\partial l_{0,\eta_{RF}}^{\max}}{\partial \Delta_1} > 0$ and $\frac{\partial^2 l_{0,\eta_{RF}}^{\max}}{\partial \Delta_1^2} = 0$.

Critical Values of Δ_1

In a next step, we determine the optimal behavior of the banker for a given liquidity risk $\Delta_1 < \overline{\Delta}_1$.

1. We denote $\Delta_1^{\mathcal{A}}$ as the largest risk level for which the banker is still able to operate in the unrestricted safe mode in both periods. As both strategies $\mathcal{A}$ and $\mathcal{B}$ remain unchanged, imposing capital requirements yields the same $\Delta_1^{\mathcal{A}}$ as defined in (A.42).

2. We denote $\Delta_{1,\eta}^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}$ and strategy $\mathcal{C}$. Recall that for $\Delta_1 = \Delta_1^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{SS}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{SR}}(l_0) > \pi_0^{\mathcal{RF}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\text{fb}})}{\partial \Delta_1} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta_1} = 0$, the expected profit from strategy $\mathcal{B}$ decreases in Δ_1, i.e. $\frac{\partial \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})}{\partial \Delta_1} < 0$. Moreover, it follows from (A.86) that $\frac{\partial \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}})}{\partial \Delta_1} = \frac{\partial \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}})}{\partial l_{0,\eta}^{\mathcal{SR}}}\frac{\partial l_{0,\eta}^{\mathcal{SR}}}{\partial \Delta_1} + (1-p_1)(1-p_2)p_1 l_{0,\eta}^{\mathcal{SR}} > 0$, as $\frac{\partial \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}})}{\partial l_{0,\eta}^{\mathcal{SR}}} = 0$. Accordingly, if there exists a unique $\Delta_{1,\eta}^{\mathcal{B}\prime} > \Delta_1^{\mathcal{A}}$ for which $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) = \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}})$, the banker will prefer strategy $\mathcal{B}$ over strategies $\mathcal{C}$, $\mathcal{D}$ and $\mathcal{E}$ as $\pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}}) \geq \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}}) > \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta_{\mathcal{SR}}}^{\max}) > \pi_{0,\eta}^{\mathcal{RF}}(\min l_0^{\mathcal{R}}, l_{0,\eta_{\mathcal{RF}}}^{\max}\})$ for all $\Delta_1 \leq \Delta_{1,\eta}^{\mathcal{B}\prime}$, while for all $\Delta_1 > \Delta_{1,\eta}^{\mathcal{B}\prime}$, the banker prefers strategy $\mathcal{C}$ over strategy $\mathcal{B}$ as $\pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}}) > \pi_0^{\mathcal{SS}}(l_0^{\mathcal{S}})$. If such a $\Delta_{1,\eta}^{\mathcal{B}\prime}$ does not exist within $(\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}]$, e.g. as $l_{0,\eta_{\mathcal{SR}}}^{\max}$ becomes binding for a $\Delta_1 \leq \Delta_1^{\psi}$, the banker will prefer strategy $\mathcal{B}$ as long as the safe mode is available in the downturn, i.e. for all $\Delta_1 \in (\Delta_1^{\mathcal{A}}, \Delta_1^{\psi}]$

so that

$$\Delta_{1,\eta}^{\mathcal{B}} := \min\{\Delta_{1,\eta}^{\mathcal{B}'}, \Delta_1^{\psi}\}. \tag{A.95}$$

3. We denote $\Delta_{1,\eta}^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}$ and strategy $\mathcal{D}$, i.e. the highest risk level for which bank lending is not restricted when operating according to $m = \mathcal{SR}$. It follows from the definitions of $l_{0,\eta_{\mathcal{SR}}}^{\max}$ and v_b that the banker is indifferent between the two strategies if $l_{0,\eta}^{\mathcal{SR}} = l_{0,\eta_{\mathcal{SR}}}^{\max}$ or if

$$\begin{aligned}\Delta_{1,\eta}^{\mathcal{C}} := & \frac{[\phi_{1,b}^{\mathcal{R}}(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}) - (1-p_2)a_{2,b}][1-(1-\lambda)p_1]}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]l_{0,\eta}^{\mathcal{SR}}} \\ & + \frac{\mu_1[p_2 + (1-\lambda)p_1(1-p_2)] - 1}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]}.\end{aligned} \tag{A.96}$$

As long as $l_{0,\eta}^{\mathcal{SR}} < l_{0,\eta_{\mathcal{SR}}}^{\max}$ it follows that $\pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\mathcal{SR}}) > \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta_{\mathcal{SR}}}^{\max}) > \pi_{0,\eta}^{\mathcal{RF}}(\min l_0^{\mathcal{R}}, l_{0,\eta_{\mathcal{RF}}}^{\max}\})$ so that the banker prefers strategy $\mathcal{C}$ over strategy $\mathcal{D}$ and $\mathcal{E}$ for all $\Delta_1 \leq \Delta_{1,\eta}^{\mathcal{C}}$. For all $\Delta_1 > \Delta_{1,\eta}^{\mathcal{C}}$ strategy $\mathcal{C}$ is not feasible.

4. We denote $\Delta_{1,\eta}^{\mathcal{D}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}$ and strategy $\mathcal{E}$. It follows from (A.86) that $\frac{\partial \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\max})}{\partial \Delta_1} = \frac{\partial \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta}^{\max})}{\partial l_{0,\eta_{\mathcal{SR}}}^{\max}} \frac{\partial l_{0,\eta_{\mathcal{SR}}}^{\max}}{\partial \Delta_1} + (1-p_1)(1-p_2)p_1 l_{0,\eta_{\mathcal{SR}}}^{\max}$, which is negative for sufficiently large Δ_1 as $\frac{\partial \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta_{\mathcal{SR}}}^{\max})}{\partial l_{0,\eta_{\mathcal{SR}}}^{\max}} > 0$ and $\frac{\partial l_{0,\eta_{\mathcal{SR}}}^{\max}}{\partial \Delta_1} < 0$. It follows from (A.90) that $\frac{\partial \pi_{0,\eta}^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial \Delta_1} = \frac{\partial \pi_{0,\eta}^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta_1} + p_1(1-p_1)l_0^{\mathcal{R}} > 0$ as $\frac{\partial \pi_{0,\eta}^{\mathcal{RF}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} = 0$. Moreover, it follows from (A.90) that $\frac{\partial \pi_{0,\eta}^{\mathcal{RF}}(l_{0,\eta_{\mathcal{RF}}}^{\max})}{\partial \Delta_1} = \frac{\partial \pi_{0,\eta}^{\mathcal{RF}}(l_{0,\eta_{\mathcal{RF}}}^{\max})}{\partial l_{0,\eta_{\mathcal{RF}}}^{\max}} \frac{\partial l_{0,\eta_{\mathcal{RF}}}^{\max}}{\partial \Delta_1} + p_1(1-p_1)l_{0,\eta_{\mathcal{RF}}}^{\max} > 0$ as $\frac{\partial \pi_{0,\eta}^{\mathcal{RF}}(l_{0,\eta_{\mathcal{RF}}}^{\max})}{\partial l_{0,\eta_{\mathcal{RF}}}^{\max}} > 0$ and $\frac{\partial l_{0,\eta_{\mathcal{RF}}}^{\max}}{\partial \Delta_1} > 0$. Accordingly, there exists a unique $\Delta_{1,\eta}^{\mathcal{D}} > \Delta_{1,\eta}^{\mathcal{C}} > \Delta_{1,\eta}^{\mathcal{B}} > \Delta_1^{\mathcal{A}}$ for which $\pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta_{\mathcal{SR}}}^{\max}) = \pi_{0,\eta}^{\mathcal{RF}}(\min l_0^{\mathcal{R}}, l_{0,\eta_{\mathcal{RF}}}^{\max}\})$, so that for all $\Delta_1 \leq \Delta_{1,\eta}^{\mathcal{D}}$, the banker prefers strategy $\mathcal{D}$ over strategy $\mathcal{E}$ as $\pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta_{\mathcal{SR}}}^{\max}) > \pi_{0,\eta}^{\mathcal{RF}}(\min l_0^{\mathcal{R}}, l_{0,\eta_{\mathcal{RF}}}^{\max}\})$, while for all $\Delta_1 > \Delta_{1,\eta}^{\mathcal{D}}$, the banker prefers $\mathcal{E}$ over $\mathcal{D}$ due to $\pi_{0,\eta}^{\mathcal{RF}}(\min l_0^{\mathcal{R}}, l_{0,\eta_{\mathcal{RF}}}^{\max}\}) > \pi_{0,\eta}^{\mathcal{SR}}(l_{0,\eta_{\mathcal{SR}}}^{\max})$.

Proof of Proposition 7.1

We prove this proposition in three steps. First, we determine the reduced forms for all expected modes feasible. Second, we derive the banker's optimal loan volume for each strategy feasible. Finally, we compare the expected profits of the different strategies, to identify the banker's optimal behavior depending on the liquidity risk, Δ_ν.

Determination of Reduced Forms

1. Suppose the face value of deposits satisfies $\delta_{1,b_b} \leq v_{b_b} l_0 + a_{1,b_b}$. Then the banker operates in the safe mode, which is expected by investors with certainty, so that $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.11) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint to the expected profit (7.7), yields

$$\max_{l_{1,b_b}, a_{1,b_b} \in \mathbb{R}^+} \pi_{1,b_b}^{\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}} = v_b l_0 - \lambda q \Delta_\nu l_0 + \omega_{1,b} l_0 + \phi_{1,b_b}^{\mathcal{S}} \left(l_{1,b_b}\right) \tag{A.97}$$

$$\text{s.t.} \quad l_{1,b_b} \leq \frac{v_b l_0 - \lambda q \Delta_\nu l_0 + \omega_{1,b} l_0}{1 - (1-\lambda) p_2 r_b} =: l_{1,\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}}^{\max}. \tag{A.98}$$

2. Suppose the face value of deposits satisfies $v_{b_b} l_0 + a_{1,b_b} \leq \delta_{1,b_b} \leq \min\{v_{b_g} l_0 + a_{1,b_b}, v_{b_b} l_0 + r_b l_{1,b_b} + a_{1,b_b}\}$. Then, the banker operates in the risky mode but investors expect the safe mode for the good condition of first period loans, so that $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.17) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint

to the expected profit (7.7), yields

$$\max_{l_{1,b_b},a_{1,b_b}\in\mathbb{R}^+} \pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_b} = v_b l_0 - \left(\lambda + \frac{(1-p_2)(1-q)(1-\lambda)}{q+(1-q)p_2}\right) p_2 \Delta_\nu l_0$$
$$+ \frac{p_2}{q+(1-q)p_2}\omega_{1,b} l_0 - (1-p_2)\frac{2q+(1-q)p_2}{q+(1-q)p_2} a_{1,b_b}$$
$$+ \phi^{\mathcal{R}}_{1,b_b}(l_{1,b_b}) + \frac{(1-p_2)q}{q+(1-q)p_2}\left[1-(1-\lambda)p_2 r_b\right] l_{1,b_b} \qquad \text{(A.99)}$$
$$\text{s. t.} \quad l_{1,b_b} \in \left[l^{\min}_{1,\frac{\mathcal{S}}{\mathcal{R}}}, l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{R}}}\right] \qquad \text{(A.100)}$$

with

$$l^{\min}_{1,\frac{\mathcal{S}}{\mathcal{R}}} := \frac{\left[-(q+(1-q)p_2)v_b + q\left[\lambda-(1-q)(1-p_2)\right]\Delta_\nu - \omega_{1,b}\right] l_0 + x}{p_2 r_b + \lambda q(1-p_2) r_b - 1}, \qquad \text{(A.101)}$$
$$l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{R}}} := \frac{\left[(q+(1-q)p_2)v_b + (1-q)\left(q(1-p_2)+\lambda p_2\right)\Delta_\nu + \omega_{1,b}\right] l_0 - x}{1-(1-\lambda)p_2 r_b} \qquad \text{(A.102)}$$

for $x = (1-q)(1-p_2)a_{1,b_b}$.

3. Suppose the face value of deposits satisfies $\min\{v_{b_g} l_0 + a_{1,b_b}, v_{b_b} l_0 + r_b l_{1,b_b} + a_{1,b_b}\} \leq \delta_{1,b_b} \leq v_{b_b} l_0 + r_b l_{1,b_b} + a_{1,b_b}$. Then the banker operates in the risky mode, which is expected by investors with certainty, so that $m = \frac{\mathcal{R}}{\mathcal{R}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.14) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint to the expected profit (7.7), yields

$$\max_{l_{1,b_b},a_{1,b_b}\in\mathbb{R}^+} \pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_b} = p_2 v_b l_0 - \lambda q p_2 \Delta_\nu l_0 + \omega_{1,b} l_0 + \phi^{\mathcal{R}}_{1,b_b}(l_{1,b_b}) - (1-p_2)a_{1,b_b} \qquad \text{(A.103)}$$
$$\text{s. t.} \quad l_{1,b_b} \geq \frac{-p_2 v_b l_0 + \lambda q p_2 \Delta_\nu l_0 - \omega_{1,b} l_0 + (1-p_2)a_{1,b_b}}{p_2 r_b - 1} =: l^{\min}_{1,\frac{\mathcal{R}}{\mathcal{R}}} . \qquad \text{(A.104)}$$

4. Suppose the banker operates in the failure mode by closing the bank at $t = 1$. Then it follows, independent of investors' expectations regarding the banker's mode of operation for the good condition of first period loans, that[7]

$$\max_{l_{1,b_b}, a_{1,b_b} \in \mathbb{R}^+} \pi_{1,b_b}^{\overset{m_{1,b_g}}{\mathcal{F}}} = -c\left(l_{1,b_b}\right). \tag{A.105}$$

Determination of Optimal Loan Volumes at $t = 1$

In the next step we determine the optimal loan volume for all different strategies feasible, given that the condition of first period loans is bad.

1. Suppose the banker operates according to strategy $\mathbb{A}_b$, i.e. he faces no financial restriction when operating in the safe mode, which is expected by investors with certainty, i.e. $m = \substack{\mathcal{S}\\\mathcal{S}}$. It follows from (A.97) that $\frac{\partial \pi_{1,b_b}^{\substack{\mathcal{S}\\\mathcal{S}}}}{\partial l_{1,b_b}} = \phi_{1,b_b}^{\mathcal{S}\prime}\left(l_{1,b_b}\right)$, which decreases in l_{1,b_b} and is equal to zero for $l_{1,b_b} = l_{1,b}^{\text{fb}}$. Hence the optimal loan volume is $l_{1,b_b}^{*} = l_{1,b}^{\text{fb}}$. Considering a mean preserving spread, we can directly conclude that $\frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_\nu} = 0$.

2. Suppose the banker operates according to strategy $\mathbb{B}_b$, i.e. he operates according to the expected safe mode but faces a restriction in bank lending so that (A.98) becomes binding. As $\frac{\partial \pi_{1,b_b}^{\substack{\mathcal{S}\\\mathcal{S}}}}{\partial l_{1,b_b}} = \phi_{1,b_b}^{\mathcal{S}\prime}\left(l_{1,b_b}\right)$ decreases in l_{1,b_b}, the optimal loan volume is $l_{1,b_b}^{*} = l_{1,\substack{\mathcal{S}\\\mathcal{S}}}^{\max}$. Moreover, it follows directly from (A.98) that $\frac{\partial l_{1,\substack{\mathcal{S}\\\mathcal{S}}}^{\max}}{\partial \Delta_\nu} < 0$ and $\frac{\partial^2 l_{1,\substack{\mathcal{S}\\\mathcal{S}}}^{\max}}{\partial \Delta_\nu^2} = 0$.

3. Suppose the banker operates according to strategy $\mathbb{C}_b$, i.e. he operates according to the expected risky mode $m = \substack{\mathcal{R}\\\mathcal{R}}$. The banker will only choose this mode as long as the expected profit is nonnegative. Therefore, the lower bound on bank lending given in (A.104) will never become binding. It follows from (A.103) that $\frac{\partial \pi_{1,b_b}^{\substack{\mathcal{R}\\\mathcal{R}}}}{\partial l_{1,b_b}} = \phi_{1,b_b}^{\mathcal{R}\prime}\left(l_{1,b_b}\right)$, which decreases in l_{1,b_b} and is equal to zero

[7] The three cases only differ with respect to the restriction on bank lending, which in this case is irrelevant for the banker's optimal behavior.

for $l_{1,b_b} = l_{1,b}^{\text{fb}}$. Hence the optimal loan volume is $l_{1,b_b}^{*} = l_{1,b}^{\text{fb}}$ and we can again conclude that $\frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_\nu} = 0$.

4. Suppose the banker operates according to strategy $\mathbb{D}_b$, i.e. he operates in the risky mode but investors expect the safe mode for the good condition of first period loans, so that $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}$. It follows from (A.99) that $\frac{\partial \pi_{1,b_b}^{\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}}{\partial l_{1,b_b}} = \phi_{1,b_b}^{\mathcal{R}\prime}(l_{1,b_b}) + \frac{(1-p_2)q}{q+(1-q)p_2}[1-(1-\lambda)p_2 r_b]$, which decreases in l_{1,b_b} and is equal to zero for $l_{1,b_b} = l_{1,b_b}^{\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}} > l_{1,b}^{\text{fb}}$. Taking into account the restriction on bank lending given by (A.100), the optimal loan volume is thus $l_{1,b_b}^{*} = \min\{l_{1,b_b}^{\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}, l_{1,\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}^{\max}\}$. Note that if the lower bound becomes binding, the expected profit from strategy $\mathbb{D}_b$ turns out to be negative, so that this loan volume is never optimal. It follows from (A.99), (A.101) and (A.102) that $\frac{\partial l_{1,b_b}^{\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}}{\partial \Delta_\nu} = 0$, $\frac{\partial l_{1,\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}^{\max}}{\partial \Delta_\nu} > 0$, $\frac{\partial l_{1,\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}^{\min}}{\partial \Delta_\nu} > 0$, $\frac{\partial^2 l_{1,\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}^{\max}}{\partial \Delta_\nu^2} = 0$ and $\frac{\partial^2 l_{1,\genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}}^{\min}}{\partial \Delta_\nu^2} = 0$, respectively.

5. Suppose the banker operates according to strategy $\mathbb{E}_b$, i.e. he operates in the failure mode. In this case, it follows directly from (A.105) that the optimal loan volume is $l_{1,b_b}^{*} = 0$. Depending on investors' expectations regarding the banker's mode of operation for the good condition of first period loans, the banker might raise funds to cover the existing debt overhang by pledging against delayed loans. If their funding liquidity is sufficiently large, the banker could invest these funds in the risk-free asset. However, this will result in a bank run at $t = 2$ with certainty. As the expected profit of this scenario is also zero, the banker is indifferent between all potential failure modes.

Critical Values of Δ_ν

In the final step, we determine the optimal behavior of the banker for a given liquidity risk, Δ_ν.

1. We denote $\Delta_\nu^{\mathbb{A}_b}$ as the largest risk level for which the banker is still able to operate in the unrestricted expected safe mode. Granting loans according to

the first best is feasible as long as $l^{\text{fb}}_{1,b} \geq l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}$. As the first best loan volume $l^{\text{fb}}_{1,b}$ is independent of Δ_ν while $l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}$ decreases in Δ_ν, there exists a $\Delta^{\mathbb{A}_b}_\nu$ so that $l^{\text{fb}}_{1,b} = l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}$, which is given by

$$\Delta^{\mathbb{A}_b}_\nu := \frac{(1-\lambda)p_2 r_b - 1}{\lambda q} \frac{l^{\text{fb}}_{1,b}}{l^{\text{fb}}_0} + \frac{v_b + \omega_{1,b}}{\lambda q}.$$

As $\pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\text{fb}}_{1,b}) \geq \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l_{1,b_b}) > \pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l_{1,b_b}) > \pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$, it is never optimal for the banker to switch to strategy $\mathbb{B}_b$, $\mathbb{C}_b$ or $\mathbb{E}_b$ for all $\Delta_\nu \leq \Delta^{\mathbb{A}_b}_\nu$.

2. We denote $\Delta^{\mathbb{B}_b}_\nu$ as the risk level for which the banker is indifferent between strategy $\mathbb{B}_b$ and strategy $\mathbb{C}_b$. For $\Delta_\nu = \Delta^{\mathbb{A}_b}_\nu$ it follows that $\pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\text{fb}}_{1,b}) = \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}) > \pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l_{1,b_b}) > \pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$. While $\frac{\partial \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\text{fb}}_{1,b})}{\partial \Delta_\nu} = -\lambda q l_0 < 0$ because of $\frac{\partial l^{\text{fb}}_{1,b}}{\partial \Delta_\nu} = 0$, the expected profit from strategy $\mathbb{B}_b$ decreases in Δ_ν to a larger extent. It follows from (A.97) that $\frac{\partial \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}\left(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}\right)}{\partial \Delta_\nu} = \frac{\partial \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}\left(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}\right)}{\partial l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}} \frac{\partial l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}}{\partial \Delta_\nu} - \lambda q l_0 < 0$, as $\frac{\partial \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}\left(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}\right)}{\partial l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}} > 0$ and $\frac{\partial l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}}{\partial \Delta_\nu} < 0$. Moreover, it follows from (A.103) that $\frac{\partial \pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}\left(l^{\text{fb}}_{1,b}\right)}{\partial \Delta_\nu} = -\lambda q p_2 l_0 < 0$ so that the expected profit from strategy $\mathbb{C}_b$ decreases to a smaller extent in Δ_ν than the respective expected profit from strategies $\mathbb{A}_b$ and $\mathbb{B}_b$. Accordingly there exists a unique $\Delta^{\mathbb{B}_b}_\nu > \Delta^{\mathbb{A}_b}_\nu$ for which $\pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}) = \pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l^{\text{fb}}_{1,b})$, so that for all $\Delta_\nu \leq \Delta^{\mathbb{B}_b}_\nu$, the banker prefers strategy $\mathbb{B}_b$ over strategies $\mathbb{C}_b$ and $\mathbb{E}_b$ as $\pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}) \geq \pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l^{\text{fb}}_{1,b}) > \pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$ while for all $\Delta_\nu > \Delta^{\mathbb{B}_b}_\nu$, the banker prefers strategy $\mathbb{C}_b$ over strategy $\mathbb{B}_b$ as $\pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l^{\text{fb}}_{1,b}) > \pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}})$.

3. We denote $\Delta^{\mathbb{C}_b}_\nu$ as the risk level for which the banker is indifferent between strategy $\mathbb{D}_b$ and strategies $\mathbb{A}_b$ or $\mathbb{B}_b$. While $\pi^{\overset{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\underset{\mathcal{S}}{\mathcal{S}}}\})$ decreases in Δ_ν, as argued above, $\pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(\min\{l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}, l^{\max}_{1,\underset{\mathcal{R}}{\mathcal{S}}}\})$ increases in Δ_ν for small liq-

uidity risks and decreases for larger liquidity risks. While $\frac{\partial \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}\left(l_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}\right)}{\partial \Delta_\nu} = -\left(\lambda + \frac{(1-p_2)(1-q)(1-\lambda)}{q+(1-q)p_2}\right) p_2 l_0 < 0$ because of $\lambda \in [0.5, 1)$ and $p_2 \in [0.6, 1)$ as well as $\frac{\partial l_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}}{\partial \Delta_\nu} = 0$, it follows from (A.99) that

$$\frac{\partial \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}\left(l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\right)}{\partial \Delta_\nu} = \frac{\partial \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}\left(l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\right)}{\partial l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}} \frac{\partial l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}}{\partial \Delta_\nu} - \left(\lambda + \frac{(1-p_2)(1-q)(1-\lambda)}{q+(1-q)p_2}\right) p_2 l_0,$$

with $\frac{\partial \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}\left(l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\right)}{\partial l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}} > 0$ and $\frac{\partial l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}}{\partial \Delta_\nu} > 0$. Hence the expected profit from strategy $\mathbb{D}_b$ increases in Δ_ν for small liquidity risks. In this case, the restriction on bank lending is so tight that the positive effect of a loosening in the restriction on bank lending compensates the negative impact resulting from a lower funding liquidity of nonperforming loans. For larger liquidity risks, the expected profit will decrease in Δ_ν, especially, if the restriction on bank lending in not binding. Accordingly there exists a unique $\Delta_\nu^{\mathbb{C}_b}$ for which $\pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{S}}}(\min\{l_{1,b}^{\text{fb}}, l_{1,\frac{\mathcal{S}}{\mathcal{S}}}^{\max}\}) = \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}(\min\{l_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\})$, so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{C}_b}$, the banker prefers strategy ($\mathbb{A}_b$ over) $\mathbb{B}_b$ over $\mathbb{D}_b$ and $\mathbb{E}_b$ as $\pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{S}}}(\min\{l_{1,b}^{\text{fb}}, l_{1,\frac{\mathcal{S}}{\mathcal{S}}}^{\max}\}) \geq \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}(\min\{l_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\}) > \pi_{1,b_b}^{\overset{m_{1,b_g}}{\mathcal{F}}}(l_{1,b_b})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{C}_b}$, the banker prefers strategy $\mathbb{D}_b$ over strategies $\mathbb{A}_b$ and $\mathbb{B}_b$ as $\pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}(\min\{l_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\}) > \pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{S}}}(\min\{l_{1,b}^{\text{fb}}, l_{1,\frac{\mathcal{S}}{\mathcal{S}}}^{\max}\})$.

4. We denote $\Delta_\nu^{\mathbb{D}_b}$ as the risk level for which the banker is indifferent between strategy $\mathbb{C}_b$ and strategy $\mathbb{D}_b$. We argued above that $\pi_{1,b_b}^{\overset{\mathcal{R}}{\mathcal{R}}}(l_{1,b}^{\text{fb}})$ decreases Δ_ν while $\pi_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}(\min\{l_{1,b_b}^{\overset{\mathcal{S}}{\mathcal{R}}}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\})$ increases in Δ_ν for small liquidity risks and decreases for larger liquidity risks. However, the decrease in the expected profit from strategy $\mathbb{D}_b$ is always smaller than the one of strategy $\mathbb{C}_b$, as the funding liquidity of first period loans is always larger for strategy $\mathbb{D}_b$ than for strategy $\mathbb{C}_b$. Accordingly there exists a unique $\Delta_\nu^{\mathbb{D}_b}$ for which $\pi_{1,b_b}^{\overset{\mathcal{R}}{\mathcal{R}}}(l_{1,b}^{\text{fb}}) =$

$\pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(\min\{l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}, l^{\max}_{1,\overset{\mathcal{S}}{\mathcal{R}}}\})$ so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{D}_b}$, the banker prefers strategy $\mathbb{C}_b$ over strategies $\mathbb{D}_b$ and $\mathbb{E}_b$ as $\pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l^{\text{fb}}_{1,b}) \geq \pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(\min\{l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}, l^{\max}_{1,\overset{\mathcal{S}}{\mathcal{R}}}\}) > \pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{D}_b}$ the banker prefers strategy $\mathbb{D}_b$ over strategy $\mathbb{C}_b$ as $\pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(\min\{l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}, l^{\max}_{1,\overset{\mathcal{S}}{\mathcal{R}}}\}) > \pi^{\overset{\mathcal{R}}{\mathcal{R}}}_{1,b_b}(l^{\text{fb}}_{1,b})$.

5. We denote $\Delta_\nu^{\mathbb{E}_b}$ as the risk level for which the banker is indifferent between strategy $\mathbb{D}_b$ and strategy $\mathbb{E}_b$. We argued above that $\pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b})$ decreases for larger liquidity risks while $\pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$ is independent of Δ_ν. Accordingly there exists a unique $\Delta_\nu^{\mathbb{E}_b} > \Delta_\nu^{\mathbb{D}_b}$ for which $\pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}) = \pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$, so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{E}_b}$ the banker prefers strategy $\mathbb{D}_b$ over strategy $\mathbb{E}_b$ as $\pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}) \geq \pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{E}_b}$ the banker prefers strategy $\mathbb{E}_b$ over strategy $\mathbb{D}_b$ as $\pi^{\overset{m_{1,b_g}}{\mathcal{F}}}_{1,b_b}(l_{1,b_b}) > \pi^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b}(l^{\overset{\mathcal{S}}{\mathcal{R}}}_{1,b_b})$.

Proof of Proposition 7.2

We prove this proposition in the same three steps as in the proof of Proposition 7.1.

Determination of Reduced Forms

1. Suppose the face value of deposits satisfies $\delta_{1,b_g} \leq v_{b_b} l_0 + a_{1,b_g}$. Then the banker operates in the safe mode, which is expected by investors with certainty, so that $m = {\mathcal{S} \atop \mathcal{S}}$. Inserting the restriction on deposits, as well as the amount provided by depositors (7.9) and shareholders (7.20) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint to the expected profit (7.7), yields

$$\begin{aligned} \max_{l_{1,b_g}, a_{1,b_g} \in \mathbb{R}^+} \pi^{\mathcal{S} \atop \mathcal{S}}_{1,b_g} &= v_b l_0 + \lambda q \Delta_\nu l_0 + \omega_{1,b} l_0 + \phi^{\mathcal{S}}_{1,b_g}\left(l_{1,b_g}\right) \\ \text{s. t.} \quad l_{1,b_g} &\leq l^{\max}_{1,{\mathcal{S} \atop \mathcal{S}}} . \end{aligned} \tag{A.106}$$

   with $l^{\max}_{1,{\mathcal{S} \atop \mathcal{S}}}$ being defined in (A.98).

2. Suppose the face value of deposits satisfies $v_{b_b} l_0 + a_{1,b_g} < \delta_{1,b_g} \leq \min\{v_{b_g} l_0 + a_{1,b_g}, v_{b_b} l_0 + r_b l_{1,b_g} + a_{1,b_g}\}$. Then the banker operates in the safe mode but investors expect the risky mode for the bad condition of first period loans, so that $m = {\mathcal{S} \atop \mathcal{R}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.23) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint

to the expected profit (7.7), yields

$$\max_{l_{1,b_g},a_{1,b_g}\in\mathbb{R}^+} \pi_{1,b_g}^{\frac{\mathcal{S}}{\mathcal{R}}} = v_b l_0 + \left(\lambda - \frac{(1-p_2)(1-\lambda)}{q+(1-q)p_2} q\right)(1-q)\Delta_\nu l_0 \qquad \text{(A.107)}$$
$$+ \frac{1}{q+(1-q)p_2}\omega_{1,b} l_0 - \frac{(1-p_2)(1-q)}{q+(1-q)p_2} a_{1,b_g}$$
$$+ \phi_{1,b_g}^{\mathcal{S}}\left(l_{1,b_g}\right) - \frac{(1-p_2)(1-q)}{q+(1-q)p_2}\left[1-(1-\lambda)p_2 r_b\right] l_{1,b_g}$$
$$\text{s.t.} \quad l_{1,b_g} \in \left[l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\min}, l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}\right]$$

with $l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\min}$ and $l_{1,\frac{\mathcal{S}}{\mathcal{R}}}^{\max}$ being defined in (A.101) and (A.102).

3. Suppose the face value of deposits satisfies $\min\{v_{b_g} l_0 + a_{1,b_g}, v_{b_b} l_0 + r_b l_{1,b_g} + a_{1,b_g}\} < \delta_{1,b_g} \leq v_{b_g} l_0 + a_{1,b_g}$. Then the banker operates in the safe mode but investors expect the failure mode for the bad condition of first period loans, so that $m = \frac{\mathcal{S}}{\mathcal{F}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.26) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint to the expected profit (7.7), yields

$$\max_{l_{1,b_g},a_{1,b_g}\in\mathbb{R}^+} \pi_{1,b_g}^{\frac{\mathcal{S}}{\mathcal{F}}} = v_b l_0 + (1-q)\Delta_\nu l_0 + \frac{1}{q}\omega_{1,b} l_0$$
$$+ \phi_{1,b_g}^{\mathcal{S}}\left(l_{1,b_g}\right) - \frac{1-q}{q} l_{1,b_g} - \frac{1-q}{q} a_{1,b_g} \qquad \text{(A.108)}$$
$$\text{s.t.} \quad l_{1,b_g} \leq \frac{q(v_b + (1-q)\Delta_\nu) l_0 + \omega_{1,b} l_0 - (1-q) a_{1,b_g}}{1 - q(1-\lambda)p_2 r_b} =: l_{1,\frac{\mathcal{S}}{\mathcal{F}}}^{\max} . \qquad \text{(A.109)}$$

4. Suppose the face value of deposits satisfies $\min\{v_{b_g} l_0 + a_{1,b_g}, v_{b_b} l_0 + r_b l_{1,b_g} + a_{1,b_g}\} < \delta_{1,b_b} \leq v_{b_b} l_0 + r_b l_{1,b_g} + a_{1,b_g}$. Then the banker operates in the risky mode, which is expected by investors with certainty, so that $m = \frac{\mathcal{R}}{\mathcal{R}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.27) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint to the expected profit

(7.7), yields

$$\begin{aligned}\max_{l_{1,b_g},a_{1,b_g}\in\mathbb{R}^+}\pi_{1,b_g}^{\substack{\mathcal{R}\\\mathcal{R}}} &= p_2v_bl_0+\lambda p_2(1-q)\Delta_\nu l_0+\omega_{1,b}l_0 \\ &\quad+\phi_{1,b_g}^{\mathcal{R}}\left(l_{1,b_g}\right)-(1-p_2)a_{1,b_g} \\ \text{s.t.}\quad & l_{1,b_g}\geq l^{\min}_{1,\substack{\mathcal{R}\\\mathcal{R}}}\,.\end{aligned} \tag{A.110}$$

with $l^{\min}_{1,\substack{\mathcal{R}\\\mathcal{R}}}$ being defined in (A.104).

5. Suppose the face value of deposits satisfies $\max\{v_{b_g}l_0+a_{1,b_g}, v_{b_b}l_0+r_bl_{1,b_g}+a_{1,b_g}\}<\delta_{1,b_b}\leq v_{b_g}l_0+r_bl_{1,b_g}+a_{1,b_g}$. Then the banker operates in the risky mode but investors expect the failure mode for the bad condition of first period loans, so that $m=\genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{F}}$. Inserting the restriction on deposits as well as the amount provided by depositors (7.9) and shareholders (7.29) into the budget constraint (7.8), and making use of (7.5) and (7.6) when applying the budget constraint to the expected profit (7.7), yields

$$\begin{aligned}\max_{l_{1,b_g},a_{1,b_g}\in\mathbb{R}^+}\pi_{1,b_g}^{\substack{\mathcal{R}\\\mathcal{F}}} &= p_2v_bl_0+(1-q)p_2\Delta_\nu l_0+\frac{1}{q}\omega_{1,b}l_0 \\ &\quad+\phi_{1,b_g}^{\mathcal{R}}\left(l_{1,b_g}\right)-\frac{1-q}{q}l_{1,b_g}-\frac{1-q}{q}a_{1,b_g}\end{aligned} \tag{A.111}$$

$$\text{s.t.}\quad l_{1,b_g}\leq\frac{qp_2(v_b+(1-q)\Delta_\nu)l_0+\omega_{1,b}l_0-(1-qp_2)a_{1,b_g}}{1-qp_2r_b}=:l^{\max}_{1,\substack{\mathcal{R}\\\mathcal{F}}}\,. \tag{A.112}$$

6. Suppose the banker operates in the failure mode by closing the bank at $t=1$. As this is always expected by investors, they provide no funds at all so that $\pi_{1,b_g}^{\substack{\mathcal{F}\\\mathcal{F}}}=0$.

Determination of Optimal Loan Volumes at $t=1$

In the next step we determine the optimal loan volume for all different strategies feasible, given that the condition of first period loans is good.

1. Suppose the banker operates according to strategy $\mathbb{A}_g$, i.e. he faces no financial restriction when operating in the safe mode, which is expected by investors with certainty, i.e. $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{S}}$. It follows from (A.106) that $\frac{\partial \pi_{1,b_g}^{\substack{\mathcal{S}\\\mathcal{S}}}}{\partial l_{1,b_g}} = \phi_{1,b_g}^{\mathcal{S}\prime}\left(l_{1,b_g}\right)$, which decreases in l_{1,b_g} and is equal to zero for $l_{1,b_g} = l_{1,b}^{\text{fb}}$. Hence the optimal loan volume is $l_{1,b_g}^{*} = l_{1,b}^{\text{fb}}$. Due to the mean preserving spread we can directly conclude that $\frac{\partial l_{1,b}^{\text{fb}}}{\partial \Delta_\nu} = 0$.

2. Suppose the banker operates according to strategy $\mathbb{B}_g$, i.e. he operates according to the expected safe mode but faces a restriction in bank lending so that (A.98) becomes binding. As $\frac{\partial \pi_{1,b_g}^{\substack{\mathcal{S}\\\mathcal{S}}}}{\partial l_{1,b_g}} = \phi_{1,b_g}^{\mathcal{S}\prime}\left(l_{1,b_g}\right)$ decreases in l_{1,b_g}, the optimal loan volume is $l_{1,b_g}^{*} = l_{1,\substack{\mathcal{S}\\\mathcal{S}}}^{\max}$. Moreover, it follows directly from (A.98) that $\frac{\partial l_{1,\substack{\mathcal{S}\\\mathcal{S}}}^{\max}}{\partial \Delta_\nu} < 0$ and $\frac{\partial^2 l_{1,\substack{\mathcal{S}\\\mathcal{S}}}^{\max}}{\partial \Delta_\nu^2} = 0$.

3. Suppose the banker operates according to strategy $\mathbb{C}_g$, i.e. he operates in the safe mode but investors expect the risky mode for the bad condition of first period loans, so that $m = \genfrac{}{}{0pt}{}{\mathcal{S}}{\mathcal{R}}$. It follows from (A.107) that $\frac{\partial \pi_{1,b_g}^{\substack{\mathcal{S}\\\mathcal{R}}}}{\partial l_{1,b_g}} = \phi_{1,b_g}^{\mathcal{S}\prime}\left(l_{1,b_g}\right) - \frac{(1-p_2)(1-q)}{q+(1-q)p_2}\left[1-(1-\lambda)p_2 r_b\right]$, which decreases in l_{1,b_g} and is equal to zero for $l_{1,b_g} = l_{1,b_g}^{\substack{\mathcal{S}\\\mathcal{R}}} < l_{1,b}^{\text{fb}}$. Taking into account the restriction on bank lending given by (A.100), the optimal loan volume is thus $l_{1,b_g}^{*} = \min\{l_{1,b_g}^{\substack{\mathcal{S}\\\mathcal{R}}}, l_{1,\substack{\mathcal{S}\\\mathcal{R}}}^{\max}\}$. Note that if the lower bound becomes binding, the expected profit of strategy $\mathbb{C}_g$ turns out to be negative so that this loan volume is never optimal. It follows from (A.107), (A.101) and (A.102) that $\frac{\partial l_{1,b_g}^{\substack{\mathcal{S}\\\mathcal{R}}}}{\partial \Delta_\nu} = 0$, $\frac{\partial l_{1,\substack{\mathcal{S}\\\mathcal{R}}}^{\max}}{\partial \Delta_\nu} > 0$ and $\frac{\partial l_{1,\substack{\mathcal{S}\\\mathcal{R}}}^{\min}}{\partial \Delta_\nu} > 0$, respectively.

4. Suppose the banker operates according to strategy $\mathbb{D}_g$, i.e. he operates according to the expected risky mode $m = \genfrac{}{}{0pt}{}{\mathcal{R}}{\mathcal{R}}$. The banker will only choose this mode as long as the expected profit is nonnegative so that the lower bound on bank lending given in (A.104) never becomes binding. It follows from (A.110) that $\frac{\partial \pi_{1,b_g}^{\substack{\mathcal{R}\\\mathcal{R}}}}{\partial l_{1,b_g}} = \phi_{1,b_g}^{\mathcal{R}\prime}\left(l_{1,b_g}\right)$, which decreases in l_{1,b_g} and is equal to zero for $l_{1,b_g} = l_{1,b}^{\text{fb}}$.

Hence the optimal loan volume is $l^*_{1,b_g} = l^{\text{fb}}_{1,b}$ and we can again conclude that $\frac{\partial l^{\text{fb}}_{1,b}}{\partial \Delta_\nu} = 0$.

5. Suppose the banker operates according to strategy $\mathbb{E}_g$, i.e. he operates according to the expected failure mode $m = \frac{\mathcal{F}}{\mathcal{F}}$. In this case, it follows directly that the optimal loan volume is $l^*_{1,b_g} = 0$. Note that the optimal loan volume will be also $l^*_{1,b_g} = 0$, if the banker operates according to $m = \frac{\mathcal{S}}{\mathcal{F}}$ or $m = \frac{\mathcal{R}}{\mathcal{F}}$ due to $\mu_{2,b} \in [1, \frac{1}{q}]$.

Critical Values of Δ_ν

In the final step, we determine the optimal behavior of the banker for a given liquidity risk, Δ_ν.

1. We denote $\Delta_\nu^{\mathbb{A}_g}$ as the largest risk level for which the banker is still able to operate in the unrestricted expected safe mode. Granting loans according to the first best is feasible as long as $l^{\text{fb}}_{1,b} \geq l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{S}}}$. As first best loan volume $l^{\text{fb}}_{1,b}$ is independent of Δ_ν while $l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{S}}}$ decreases in Δ_ν, there exists a $\Delta_\nu^{\mathbb{A}_g}$ so that $l^{\text{fb}}_{1,b} = l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{S}}}$. As $l^{\text{fb}}_{1,b} = l^{\text{fb}}_{1,b}$, we can thus conclude that

$$\Delta_\nu^{\mathbb{A}_g} = \Delta_\nu^{\mathbb{A}_b}.$$

   As $\pi^{\frac{\mathcal{S}}{\mathcal{S}}}_{1,b_g}(l^{\text{fb}}_{1,b}) \geq \pi^{\frac{\mathcal{S}}{\mathcal{S}}}_{1,b_g}\left(l_{1,b_g}\right) > \pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}\left(l_{1,b_g}\right), \pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}\left(l_{1,b_g}\right) > \pi^{\frac{\mathcal{F}}{\mathcal{F}}}_{1,b_g}\left(l_{1,b_g}\right)$, it is never optimal for the banker to switch to another strategy for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{A}_g}$.

2. We denote $\Delta_\nu^{\mathbb{B}_g}$ as the risk level for which the banker is indifferent between strategy $\mathbb{B}_g$ and strategy $\mathbb{C}_g$. While $\pi^{\frac{\mathcal{S}}{\mathcal{S}}}_{1,b_b}(l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{S}}})$ decreases in Δ_ν for sufficiently large Δ_ν, as argued above, $\pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}(\min\{l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b+}, l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{R}}}\})$ increases in Δ_ν as long as strategy $\mathbb{C}_g$ is feasible. While $\frac{\partial \pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}\left(l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b+}\right)}{\partial \Delta_\nu} = \left[\lambda - \frac{(1-p_2)(1-\lambda)}{q+(1-q)p_2} q\right](1-q)l_0 > 0$ because of $\lambda \in [0.5, 1)$ and $p_2 \in [0.6, 1)$ as well as $\frac{\partial l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b+}}{\partial \Delta_\nu} = 0$, it follows from

(A.107) that

$$\frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}\left(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\right)}{\partial \Delta_\nu} = \left[\lambda - \frac{(1-p_2)(1-\lambda)}{q+(1-q)p_2}q\right](1-q)l_0 + \frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}\left(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\right)}{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}} \frac{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}}{\partial \Delta_\nu} > 0,$$

due to $\frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}\left(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\right)}{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}} > 0$ and $\frac{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}}{\partial \Delta_\nu} > 0$. Accordingly there exists a unique $\Delta_\nu^{\mathbb{B}_g}$ for which $\pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}) = \pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}(\min\{l^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b^+}, l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\})$, so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{B}_g}$, the banker prefers strategy $\mathbb{B}_g$ over strategies $\mathbb{C}_g$ and $\mathbb{E}_g$ as $\pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}) \geq \pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}(\min\{l^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b^+}, l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\}) > \pi^{\substack{\mathcal{F}\\ \mathcal{F}}}_{1,b_g}(l_{1,b_g})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{B}_g}$ the banker prefers strategy $\mathbb{C}_g$ over strategy $\mathbb{B}_g$ as $\pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}(\min\{l^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b^+}, l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\}) > \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}})$.

3. We denote $\Delta_\nu^{\mathbb{C}_g}$ as the risk level for which the banker is indifferent between strategy $\mathbb{B}_g$ and strategy $\mathbb{D}_g$. For $\Delta_\nu = \Delta_\nu^{\mathbb{A}_g}$ it follows that $\pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\text{fb}}_{1,b}) = \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}) > \pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}(l_{1,b_g}), \pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}\left(l_{1,b_g}\right) > \pi^{\substack{\mathcal{F}\\ \mathcal{F}}}_{1,b_g}(l_{1,b_g})$. While $\frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\text{fb}}_{1,b})}{\partial \Delta_\nu} = \lambda q l_0 > 0$ because of $\frac{\partial l^{\text{fb}}_{1,b}}{\partial \Delta_\nu} = 0$, the expected profit from strategy $\mathbb{B}_g$ decreases in Δ_ν for sufficiently large Δ_ν. It follows from (A.106) that $\frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}\left(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}\right)}{\partial \Delta_\nu} = \frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}\left(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}\right)}{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}} \frac{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}}{\partial \Delta_\nu} + \lambda q l_0$ which is negative for large Δ_ν, as $\frac{\partial \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}\left(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}\right)}{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}} > 0$ and $\frac{\partial l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}}{\partial \Delta_\nu} < 0$. Moreover, it follows from (A.110) that $\frac{\partial \pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}\left(l^{\text{fb}}_{1,b}\right)}{\partial \Delta_\nu} = \lambda p_2(1-q)l_0 > 0$ so that the expected profit from strategy $\mathbb{D}_g$ increases in Δ_ν. Accordingly there exists a unique $\Delta_\nu^{\mathbb{C}_g} > \Delta_\nu^{\mathbb{A}_g}$ for which $\pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}) = \pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b})$, so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{C}_g}$, the banker prefers strategy $\mathbb{B}_g$ over strategies $\mathbb{D}_g$ and $\mathbb{E}_g$ as $\pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}}) \geq \pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b}) > \pi^{\substack{\mathcal{F}\\ \mathcal{F}}}_{1,b_g}(l_{1,b_g})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{B}_g}$, the banker prefers strategy $\mathbb{D}_g$ over strategy $\mathbb{B}_g$ as $\pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b}) > \pi^{\substack{\mathcal{S}\\ \mathcal{S}}}_{1,b_g}(l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{S}}})$.

4. We denote $\Delta_\nu^{\mathbb{D}_g}$ as the risk level for which the banker is indifferent between strategy $\mathbb{C}_g$ and strategy $\mathbb{D}_g$. We argued above that both $\pi^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b_g}(\min\{l^{\substack{\mathcal{S}\\ \mathcal{R}}}_{1,b^+}, l^{\max}_{1,\substack{\mathcal{S}\\ \mathcal{R}}}\})$ and $\pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b})$ increase in Δ_ν. However, the increase of $\pi^{\substack{\mathcal{R}\\ \mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b})$ is larger if bank

lending is not restricted for strategy $\mathbb{C}_g$. Moreover, the lower bound $l^{\min}_{1,\frac{\mathcal{S}}{\mathcal{R}}}$ also increases in Δ_ν so that strategy $\mathbb{C}_g$ becomes unfeasible for larger Δ_ν. Accordingly there exists a unique $\Delta_\nu^{\mathbb{D}_g}$ for which $\pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}(\min\{l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b^+}, l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{R}}}\}) = \pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b})$, so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{D}_g}$ the banker prefers strategy $\mathbb{C}_g$ over strategies $\mathbb{D}_g$ and $\mathbb{E}_g$ as $\pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}(\min\{l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}, l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{R}}}\}) \geq \pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b}) > \pi^{\frac{\mathcal{F}}{\mathcal{F}}}_{1,b_g}(l_{1,b_g})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{D}_g}$, the banker prefers strategy $\mathbb{D}_g$ over strategy $\mathbb{C}_g$ as $\pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b}) > \pi^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b_g}(\min\{l^{\frac{\mathcal{S}}{\mathcal{R}}}_{1,b^+}, l^{\max}_{1,\frac{\mathcal{S}}{\mathcal{R}}}\})$.

5. We denote $\Delta_\nu^{\mathbb{F}_g}$ as the risk level for which the banker is indifferent between strategy $\mathbb{D}_g$ and strategy $\mathbb{E}_g$. We argued above that $\pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b})$ increases as long as strategy $\mathbb{D}_g$ is feasible, i.e. as long as the lower bound on bank lending is not binding, while $\pi^{\frac{\mathcal{F}}{\mathcal{F}}}_{1,b_g}(l_{1,b_g})$ is independent of Δ_ν. As the lower bound $l^{\min}_{1,\frac{\mathcal{R}}{\mathcal{R}}}$ increases in Δ_ν, there exists a unique $\Delta_\nu^{\mathbb{F}_g} > \Delta_\nu^{\mathbb{D}_g}$ for which $\pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b}) = \pi^{\frac{\mathcal{F}}{\mathcal{F}}}_{1,b_g}(l_{1,b_g})$, so that for all $\Delta_\nu \leq \Delta_\nu^{\mathbb{F}_g}$ the banker prefers strategy $\mathbb{D}_g$ over strategy $\mathbb{E}_g$ as $\pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b}) \geq \pi^{\frac{\mathcal{F}}{\mathcal{F}}}_{1,b_g}(l_{1,b_g})$, while for all $\Delta_\nu > \Delta_\nu^{\mathbb{F}_g}$, the banker prefers strategy $\mathbb{E}_g$ over strategy $\mathbb{D}_g$ as $\pi^{\frac{\mathcal{F}}{\mathcal{F}}}_{1,b_g}(l_{1,b_g}) > \pi^{\frac{\mathcal{R}}{\mathcal{R}}}_{1,b_g}(l^{\text{fb}}_{1,b})$.