Implications of Bank Regulation for Credit Intermediation and Bank Stability: A Dynamic Perspective

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Abstract

A bank's decision on loan supply and capital structure determines the future availability of internal funds, and hence its future costs of external finance and vulnerability to risks. This paper sets out to understand these intertemporal links and the influence of bank regulation on the dynamics of loan supply and bank stability. Our model builds on two assumptions, credit risk and financial frictions. Together they create a trade-off between bank stability and efficiency of loan supply, both intratemporal and intertemporal. We study this model to analyze the effects of a risk-weighted capital-to-asset ratio, counter-cyclical capital buffer, liquidity coverage ratio as well as a regulatory margin call. When risks are not observable by supervisors, only regulatory margin calls or liquidity coverage ratios achieve bank stability for all risks. However, for banks with large risks, both instruments will stop credit intermediation.

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1 Introduction

A major objective of bank regulation is to promote the stability of banks. Since 2008 several changes to the Basel Accord have been implemented (Basel Committee on Banking Supervision, 2010). New instruments have also been proposed.[1] These changes and proposals have been criticized, all on similar grounds. Tighter regulations would primarily force banks to back their activities with more equity, which is costlier than other forms of finance for banks. This would be detrimental to the cost and availability of bank loans, threatening economic recovery and growth.

This account is incomplete. Banks refinance their loans and other assets with a combination of deposits, external equity and internal funds. Together with external equity, internal funds reduce a bank's vulnerability to fluctuations in earnings. Unlike equity, however, they are the outcome of past decisions and hence pre-determined at a given point in time. In a dynamic world, the decision on loan supply and capital structure not only determines a bank's current funding position and stability. It also predetermines the future availability of internal funds, the future costs of external finance and the bank's vulnerability to future risks. Vice versa, expected future difficulties with respect to funding and stability should be expected feeding into a bank's loan supply and capital structure today.

This paper sets out to understand these links and the influence of bank regulation on the dynamics of loan supply and bank stability. We study a theoretical model of a forward looking bank to analyze the effects of risk-weighted capital-to-asset ratios, counter-cyclical capital buffers, and liquidity coverage ratios. We also include in our analysis the regulatory margin call proposed by Hart and Zingales (2011). While the former three instruments are well established, the regulatory margin call is a new approach to bank regulation. In a nutshell, when the markets' assessment of a bank's probability of default increases, its CDS spread will rise. If it rises above a threshold to be set by the regulator, a margin call is triggered, i.e. shareholders will have to recapitalize their bank. If the CDS spread does not come down within a given period of time, the regulator performs a stress test and, if this

[1] See, e.g., Kashyap et al. (2008), Hart and Zingales (2011), Acharya et al. (2012) as well as Bulow and Klemperer (2014).

test confirms a risk to the bank's stability, takes over the bank, replaces its management and wipes out shareholders. Interestingly, in contrast to the other three instruments embedded in the Basel III Accord, such a regulatory margin call relies not solely on balance sheet information and on supervisors' expectations. It is also market-based as it places emphasis on market participants' expectations regarding a bank's financial prospects.

The bank in our model is managed by a self-interested, penniless banker and lives for two periods. At the beginning of each period, the banker can use internal funds and raise external funds to buy risk-free liquid assets and grant risky loans. Loans granted in the first period may perform very well after one period and yield a high return, in which case the bank will not face any financial difficulties thereafter. If loans do not perform well, their returns will be low and delayed for another period. Loans granted in the second period will then generate either high or low returns by the end of that period.

The bank's sources of funding are limited. Internal funds available at a certain date are given by the financial resources a banker can command by managing assets originated in the previous period. These resources correspond either to these assets' returns or to their funding liquidity, net of any repayment to external financiers at this date.[2] As for external funds, the banker suffers from a commitment problem as he cannot fully pledge future loan earnings to outside investors. This limitation can be justified by frictions in financial contracting. Following Diamond and Rajan (2000, 2001) the banker's skills are needed to collect the full value of loans but he can commit himself to use these skills only on behalf of depositors. While deposits put the incentives right for the banker they create financial fragility. The reason is that a bank run occurs whenever the banker repays less than what he owes to depositors, even when his earnings are actually too low in which case such a bank run is inefficient for it destroys asset values.[3] Unlike deposits, equity allows the banker to share his loan losses with shareholders. The downside of equity is that the banker can hold up shareholders and divert some of the loan earnings as personal rents when loan earnings exceed what he owes to depositors. The more rents the banker can

[2]Funding liquidity is determined by the banker's ability to raise funds externally against future asset returns.

[3]Such bank runs can be very costly for society (Dell'Ariccia et al., 2008).

extract, the less he can pledge to investors and the tighter is thus the financial constraint on loans.[4]

Against this background, the higher the credit risk, the more likely it is that the banker faces a trade-off between stability and efficiency of loan supply. When he wants to keep the bank stable, the banker has to refinance loans mainly with internal funds and equity. Since internal funds are predetermined and equity is costly, safeguarding financial stability may imply a tight funding constraint on bank loans. This constraint can be eased only if the banker refinances loans to a larger extent with deposits, which however makes the bank financially fragile.

With credit risks being negligible, loan supply is always efficient and bank stability is not an issue. Even when earnings turn out to be low and delayed after the first period, the banker can raise fresh funds against loans which are already on the book. These legacy loans are still rather valuable so that they allow not only to roll over the banker's existing debt but also to support funding for new loans.

When loans granted in the first period exhibit higher but still only modest risks, the banker faces a liquidity problem after one period when loans do not perform well. Internal funds at hand will be small. Hence only little remains to co-finance new loans. At the beginning of the first period, the forward-looking banker anticipates the possibility of a future financial constraint. In order to mitigate the expected losses associated with such a constraint, he will grant more loans in the first period than justified by their NPV, for they will boost internal funds disposable in future bad times. Bank loans will thus be volatile, with excessive loan supply in normal times turning into a credit crunch when conditions get worse later.[5] However, it is not the excessive loan supply which causes a

[4]It is not crucial for our arguments why equity is more expensive from an individual bank's perspective. Hart and Zingales (2011) cite tax advantages, government guarantees and agency costs as three possible reasons for why debt in general, and deposits in particular, can be cheaper than equity. Allen et al. (forthcoming) argue that equity can be costly in the presence of bankruptcy costs when deposit and equity markets are segmented. For a critical view on the implications for the social cost of equity see Admati et al. (2013).

[5]As standard, a credit crunch is defined as an inward shift of loan supply due to bank-specific factors.

later credit crunch. It is rather the possibility of modest future funding problems that will cause both.[6]

For larger, considerable credit risks, the banker expects rather strong funding problems should the loans granted in the first period perform poorly. Granting additional loans in the first period would substantially increase the debt burden should conditions be bad at the end of that period. Hence, it is no longer a cost-efficient way to cover a possible funding gap in the second period. Instead, the banker opts for improving the funding liquidity of second-period loans. Hence, when conditions are not good at the beginning of the second period, he adopts a fragile capital structure and raises funds primarily via new deposits. The bank will thus not survive if new loans perform also poorly at the end of the second period. By backward induction, the banker grants less loans in the first period than justified by their NPV, and should they perform poorly after the first period, he gambles for resurrection in the second period.

Finally, for very high credit risks, the bank will be unable to survive the first period if loans perform poorly. Ex ante, expected earnings of loans in the first period will be small. Hence, loan supply will be quite suppressed and fragile.

We study this model to explore the implications of bank regulation for financial stability and bank lending. With a risk-weighted capital-to-asset ratio, the bank will grant even more loans in the first period and less in the second period should the bank find itself in financial difficulties at this date. The reason is that due to regulation, the funding liquidity of loans will be lower, especially in times that are already financially difficult. In response, the bank makes provisions in the first period ensuring that more internal funds will be available should conditions be bad in the second period. This can be achieved by supplying more loans in the first period, which the bank can later use to raise additional funds if need be. That way the bank mitigates a future funding constraint. Loan supply will thus be even more volatile than without regulation. Such response has been coined as the pro-cyclical effect of bank capital regulation.[7] The new insight from our model,

[6]That way, we give an alternative to the financial instability hypothesis (Minsky, 1986, 1994; Kindleberger, 1978) as an explanation for credit booms that later bust (as documented by Schularick and Taylor, 2012, and Jordà et al., 2013).

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

however, is that higher volatility is not only because a credit crunch in bad times will be more pronounced with regulation—loan supply in good times will be also boosted. Interestingly, this effect happens in our model even with risk-weights being constant.[8]

In order to reduce pro-cyclicality in loan supply, counter-cyclical capital buffers have been introduced in Basel III, with tougher requirements in prosperous times and softer regulations in bad times. In our model, only if the counter-cyclicality of capital buffers is not too pronounced while credit risk is considerable, volatility in loan supply can be mitigated. There is a cost, though. Requiring only a low capital-to-asset ratio when times are financially difficult in the second period does not provide good incentives for the banker to ensure the stability of the bank. At the same time, with a higher capital-to asset ratio in the first period, it actually becomes more costly for the bank to build up internal funds. Not only risk taking becomes then even more attractive to the banker. There are further, novel implications too. For example, when counter-cyclicality is sufficiently strong, the cost of refinancing loans in the first period is prohibitive and loans are granted only in the second period. In the first period the banker may hold only risk-free assets. Should conditions get bad later on, the banker can refinance his lending business only with deposits because he does not command any internal funds at all. The interesting insight here is that such brinkmanship by an allegedly sound bank, which initially holds only risk-free assets, may be the result of counter-cyclical capital regulation.

A third major regulatory instrument implemented in Basel III is the liquidity coverage ratio. It requires a bank to cover its net cash outflows to a certain extent by high quality liquid assets. In our model, the liquidity coverage ratio refers to a bank's deposits and its risk-free assets. The advantage of this instrument is that it will not change loan supply as long as the banker chooses a safe capital structure. To meet the regulatory requirement, he can simply issue additional deposits to be invested in the risk-free asset until the required ratio for the bank as a whole is achieved. When the banker decides against bank stability, holding the risk-free asset will generate a loss. Hence, for a fragile capital structure, imposing a liquidity coverage ratio effectively restricts the volume of deposits and for this reason loan supply and profits. Risk-taking becomes less attractive, for LCR will render

[8]Others have attributed the pro-cyclicality of bank capital regulation to variations in risk-weights over the business cycle, see Repullo and Suarez (2013), Ferri et al. (2001) and Mulder and Montfort (2000).

loans less valuable in building-up internal funds in the risky mode. The banker rather prefers to build up internal funds with a safe capital structure even if this implies a tight restriction on loan supply. As a result, a liquidity coverage ratio tends to increase bank stability at the cost of a higher volatility of loan supply.

The final instrument we consider is the regulatory the margin call. Given its supervisory consequences, banker and shareholders share the incentive to eliminate the risk of a bank run at all times. In the context of our model, financial stability will thus prevail for all credit risks for a margin call is triggered when the bank's default probability is positive. The downside of the margin call is that the banker grants loans only as long as their funding liquidity is still sufficiently large. The model therefore produces three insights. First, with low to modest credit risks, the regulatory margin call has no implications at all. Hence, it does better than imposing risk-weighted capital-to-asset ratios, as it does not induce a higher volatility in loan supply. Second, with considerable yet not too large credit risks, a regulatory margin call will increase financial stability but at a cost of a higher volatility in loan supply. Finally, for larger credit risks, the bank is reduced to holding risk-free, liquid assets only and credit intermediation stops.

The analytical backbones for our research are taken from dynamic banking models such as Bucher et al. (2013), which we have augmented for our purpose by including external equity capital. Repullo and Suarez (2013) also take a dynamic approach to investigate the effects of flat capital requirements versus risk-weighted capital-to-asset ratios. Our model differs primarily by focusing on the funding liquidity of legacy assets, especially in times of financial distress. Moreover, their model cannot formally capture regulatory instruments other than capital-to-asset ratios. Another related paper is Dietrich and Hauck (2012), who analyze the impact of different bail-out schemes on bank loan supply and risk-taking. In contrast to ours, their framework features a one-period world, in which banks start with an exogenous debt overhang. Hyun and Rhee (2011) have looked into the willingness of banks to meet capital regulations through shrinking balance sheets rather than recapitalization. In their model, however, deposits and internal funds as well as possibility and extent of a debt overhang are exogenous. Volatility in credit, with credit being sometimes excessive, can also be found in Lorenzoni (2008). In contrast to this paper, ours explicitly considers credit intermediation by banks, but does not account for interdependencies between credit and asset prices. Finally, Blum (2008) compares risk-weighted capital-to-asset ratios with a leverage ratio. The main argument there is that leverage ratios may rectify disincentives for banks misreporting their risks to the supervisor. In our framework, we do not consider such disincentives. Our main reason for not including the leverage ratio, however, is different. As the debate currently stands, the leverage ratio for the revised Basel III framework will serve primarily as a backstop that complements the risk-weighted minimum capital-to-asset ratios. As such the leverage ratio is not supposed to be permanently binding for banks. To assess its role appropriately, one should not only compare different regulatory instruments as we do here. Combinations of different regulations should also be considered, which is beyond the scope of this paper.

In the model, we do not consider an explicit welfare measure. Taking the advantages of regulatory intervention as given, our approach is to identify the conditions under which a regulatory instrument can achieve financial stability and to assess the costs of doing so in terms of loan supply. Note also that our analysis involves a partial equilibrium model turning off general equilibrium considerations. For example, the bank in our model does not interact with other banks or asset markets which could give rise to systemic risk.[9] There are also no feedback effects such as from a financial accelerator. Papers in this area include Gertler and Kiyotaki (2010) and Meh and Moran (2010). These papers, however, do not allow for constraints that are binding in only a subset of the possible states of the world. Moreover, they do not explore the theoretical implications of different regulatory instruments for the dynamics of loan supply and bank stability.

The remainder of the paper is organized as follows. Section 2 presents the setup of the model. The benchmark model is solved in Section 3 assuming no regulation to be in place. Section 4 explores the effects of flat and counter-cyclical capital-to-asset ratios, liquidity coverage ratio and the regulatory margin call. Section 5 concludes.

[9]Using a similar theoretical framework, Dietrich and Hauck (2014) study the conditions under which interbank trades take place among financially constrained banks. See Arnold et al. (2012) for a survey of the role of systemic risk for macro-prudential bank regulation.

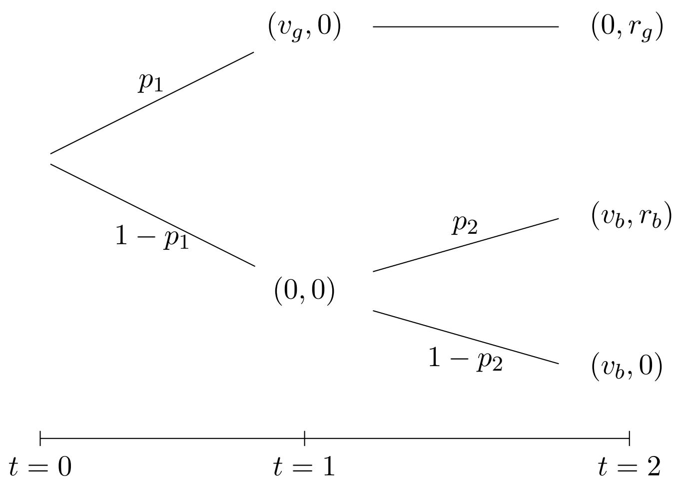

Figure 1: Loan earnings (per unit).
Note: At each node, the first entry refers to loans granted at $t = 0$ and the second entry to loans granted at $t = 1$.

2 Setup

Consider a bank that exists for two periods, or three dates $t \in \{0, 1, 2\}$, respectively. The bank is managed by a profit maximizing banker, who possesses no own funds. At the beginning of each period, at $t = 0$ and $t = 1$, funding can be provided by investors. They are competitively organized, have plenty of funds, and access to a risk-free, zero-return storage technology. Banker and investors are risk-neutral and have no time preference.

At $t = 0$ and $t = 1$, the banker invests the amount $a_t \geq 0$ in a short-term asset and grants $l_t \geq 0$ as loans. While the short-term asset is risk-free and generates a zero net return in each period, loan earnings are risky. They depend on the economic conditions at the beginning of the second period (see Figure 1). At this date $t = 1$, conditions are either good or bad. They are good with probability $p_1 \in [0.6, 1)$.

First-period loans granted at $t = 0$ earn a high return $v_g > 1$ at $t = 1$ under good economic conditions.[10] If, however, conditions are bad, some loans will default while others will delay, resulting in no returns at $t = 1$ and low returns $v_b < 1$ at $t = 2$. Define

[10] Unless otherwise indicated all returns are per unit.

$\Delta := v_g - v_b$, and let $\mu := p_1 v_g + (1 - p_1) v_b$ be the expected return of first-period loans. We assume $\mu > 1$ and rewrite the state-dependent returns as

$$v_g = \mu + (1 - p_1)\,\Delta, \tag{1}$$

$$v_b = \mu - p_1 \Delta. \tag{2}$$

For a given μ, a larger Δ reflects a higher mean preserving spread and thus higher credit risk.[11]

The return of second-period loans granted at $t = 1$ is also assumed to depend on the economic conditions prevailing at this date. If conditions are good, the return will be $r_g > 1$ at $t = 2$. Otherwise, loans will earn either a small return $r_b < r_g$ at that date (with probability $p_2 \in [0.6, 1)$) or nothing at all.[12] We let the expected net returns of second-period loans be positive even in the bad state, i.e. $p_2 r_b > 1$.

The model rests on the notion that there is a contract enforcement problem between the banker and investors. We follow the literature on incomplete contracts in the spirit of Hart and Moore (1994) where bank assets will generate their returns only if the banker employs his specific skills. This gives the banker an incentive to renegotiate or even refuse repayments to investors once he has invested their funds. According to Diamond and Rajan (2000, 2001), demandable deposits eliminate this incentive as any attempt to renegotiate repayments to depositors would trigger an immediate bank run destroying bank assets. The drawback of deposits is that a run occurs when the bank's prospective earnings fall short of depositors' claims. Hence, when loans are risky, deposits imply a risk of destructive runs even if the banker does not misbehave. To prevent such runs, a banker can issue equity shares. The value of equity correlates with the value of the bank and can thus serve as a buffer against fluctuations in loan earnings. The downside of equity is that its value to shareholders is smaller than the value of the bank, which may cause a financial constraint for the banker. This is due to the banker's specific skills and the insufficient disciplining effect of equity, allowing the banker to retain some share of bank profits.

[11] For a given probability p_1, there is a linear relationship between our risk measure Δ and the standard deviations $\Delta\sqrt{p_1(1 - p_1)}$.

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

In our model, we translate these insights into such contract enforcement problems between a banker and investors by making the following assumptions. At the beginning of each period, the banker can raise external funds by issuing deposits and equity. The banker will repay the face value of deposits δ_t at the end of the respective period whenever he is able to do so. Otherwise, depositors will run on the bank. Such run completely destroys all assets of the bank. Only when there is no bank run, the banker pays shareholders a share $1 - \lambda \leq 0.5$ of the bank's cash flow, i.e. loan earnings and returns on the safe asset net of any liabilities vis-à-vis depositors payable at this date. To focus on the interesting cases, in which the resulting conflict of interest between investors and the banker at least potentially imposes a restriction on the banker's behavior, we restrict attention to $(1 - \lambda)p_2 r_b < 1$ and $(1 - \lambda)p_1 v_g < 1$. Hence, for each loan granted either at $t = 0$ or in the bad situation at $t = 1$, the amount the banker can pledge to shareholders falls short of the amount he needs to refinance the loan. Accordingly, in these instances the banker relies on deposits at least to some extent.

For the banker, acquiring and maintaining his specific skills to collect bank asset returns is associated with private and non-verifiable costs. He incurs these costs at the date when the assets are originated. The risk-free asset is rather easy to manage at a cost normalized to zero. The costs associated with loans are an increasing and convex function c of the loan volume l_t with $c(0) = c'(0) = 0$. This assumption is based on the notion that loans, though yielding identical returns, differ in the complexity of their respective underlying projects. Hence, the banker starts to grant loans to those projects which are the easiest to manage and adds the least complex among the remaining projects first to his portfolio.

As everyone is risk neutral, the efficient, first-best loan volume for the first period l_0^{fb} is given by $\mu - 1 = c'(l_0^{fb})$. For loans granted at the beginning of the second period, the first-best loan volume depends on the economic conditions at $t = 1$. If they are good, the first-best loan volume $l_{1,g}^{fb}$ satisfies $r_g - 1 = c'(l_{1,g}^{fb})$. Otherwise, the first-best loan volume $l_{1,b}^{fb}$ is given by $p_2 r_b - 1 = c'(l_{1,b}^{fb})$. Note that since the costs to the banker are non-verifiable, a third party cannot tell whether the lending volume is actually efficient.

3 Benchmark

As the banker is risk neutral and has no time preference, his objective at any date is to maximize the profits he expects to make by the end of the second period, subject to his budget constraints. Profits are given by the loan earnings and asset returns collected at the end of that period, net of payments to investors payable at this date and less the portfolio management costs incurred in each period.

At the beginning of a period, the banker decides on how much funds to raise externally from depositors and from shareholders, which capital structure to implement, and how to invest the available external and internal funds. The banker's decisions determine the mode m in which the bank is operated. Looking at the entire potential lifespan of the bank, three modes of operation can be distinguished. In the "safe" mode $\mathcal{S}$, the banker makes sure that he is always able to repay deposits at the next date, irrespective of the magnitude of bank earnings. In this mode, there is no risk of a bank run, even if bad economic conditions delay first-period loan returns and second-period loans turn out to yield nothing at all. In the "risky" mode $\mathcal{R}$, the banker accepts a run in this worst possible scenario in the second period. In the "failure" mode $\mathcal{F}$, the bank experiences a run already at the end of the first period should economic conditions be bad. Thus, the terms safe, risky and failure refer to the status of the bank at $t = 1$ under bad economic conditions. Under good conditions at this date, a run will never happen because loan returns are neither delayed nor do they fall short of the initial outlay. Each mode $m \in \{\mathcal{S}, \mathcal{R}, \mathcal{F}\}$ involves certain restrictions on the quantity of loans a bank can grant throughout its existence. These restrictions are driven by the bank's internal funds, i.e. the financial resources a banker commands by managing assets and liabilities originated in the past.

Our next step is to spell out the restrictions for each mode. Then, we characterize and explain the behavior of the banker by applying the principle of backward induction. Note that with perfect competition among investors, they provide funds to the bank amounting to what they expect the banker to repay. Hence, raising funds for investments in the risk-free asset will neither increase the banker's profits nor improve his ability to grant loans at any date. We thus disregard the safe asset in this section.

Suppose the banker wishes to operate in the safe mode $\mathcal{S}$ by avoiding a bank run at all times. There will be limited scope for external funding through deposits in this case, particularly when earnings are uncertain. The resulting budget constraints at $t = 1$ are

$$(r_g - 1)\, l_{1,g} + \lambda\,(v_g l_0 - \delta_0) \geq 0, \tag{3}$$

$$[(1-\lambda)\, p_2 r_b - 1]\, l_{1,b} + (v_b l_0 - \delta_0) \geq 0. \tag{4}$$

Constraint (3) refers to good economic conditions at $t = 1$. Loans granted at this date are safe, allowing the banker to borrow against their full prospective return r_g from depositors without risking a run. Accordingly, the funding liquidity of these loans is given by their expected net value $r_g - 1$ to depositors, see the first term in (3). It is positive. The second term in (3) represents the bank's internal funds at $t = 1$ in the good economic state. They are also positive and reflect the banker's ability to retain a share λ of accrued earnings $v_g l_0$ from first-period loans after repaying the face value of deposits δ_0. From (3), we can already conclude that the safe mode $\mathcal{S}$ does not restrict loans at $t = 1$ as long as economic conditions are good.

Constraint (4) applies under bad conditions at $t = 1$. Second-period loans then may fail to yield a return, leaving no scope for deposits. Instead, the banker must seek external funding from shareholders, who receive only a share $1 - \lambda$ of loan earnings. The resulting funding liquidity of second-period loans, captured by the first term in (4), is negative. Hence, these loans are characterized by a funding gap, so that the bank cannot operate safely unless it possesses internal funds at $t = 1$. According to the second term in (4), internal funds will be available if the funding liquidity $v_b l_0$ of delayed first-period loan earnings exceeds the repayment δ_0 to initial depositors at $t = 1$.

At $t = 0$, the budget constraint for the safe mode $\mathcal{S}$ reads

$$l_0 \leq \delta_0 + p_1\,(1-\lambda)\,(v_g l_0 - \delta_0)\,, \tag{5}$$

because initial depositors expect to receive δ_0 in the safe mode, whereas initial shareholders can expect to receive a share $1 - \lambda$ of those earnings in excess of δ_0, that are not delayed at $t = 1$.

Constraint (5) together with (3) and (4) result in the major trade-off associated with the safe mode $\mathcal{S}$, given by

$$l_{1,b} \leq l_1^{\max} \quad \text{with} \quad l_1^{\max} = \psi l_0 = \frac{\frac{\mu-1-\lambda p_1 \Delta}{1-(1-\lambda)p_1}}{1-(1-\lambda)p_2 r_b} l_0. \tag{6}$$

Constraint (6) says that the volume $l_{1,b}$ of second-period loans in the bad state is restricted and that its upper bound is linearly dependent on the volume l_0 of first-period loans. The parameter ψ measures the financial leeway that the banker gains by increasing his loan portfolio by one unit at $t = 0$. It is given by the ratio of the bank's internal funds at $t = 1$ under bad economic conditions (numerator) to the funding gap of loans granted at $t = 1$ (denominator). Internal funds at $t = 1$, and thus ψ, are negatively related to the risk Δ of first-period loans. If Δ is small, delayed returns of first-period loans in the bad state are rather large implying that ψ is positive. Then, first-period loans generate internal funds under bad economic conditions at $t = 1$. These internal funds can serve to close the funding gap of second-period loans. The highest feasible volume $l_1^{\max}$ of second-period loans is higher, the more loans have been granted at $t = 0$. If the risk Δ is too large, ψ is negative at $t = 1$. First-period loans then generate a debt overhang in the bad state at $t = 1$. As a consequence, the safe mode is unavailable and we can define $\Delta^{\psi} := \frac{\mu-1}{\lambda p_1}$ as the largest risk Δ for which the banker can still operate safely.

In the risky mode $\mathcal{R}$, the banker accepts that a bank run occurs at the end of the second period should first-period loan earnings be delayed and second-period loans turn out to yield no return at all. Compared to the safe mode, this alters the budget constraint at $t = 1$ in the bad state to

$$(p_2 r_b - 1)\, l_{1,b} + (p_2 v_b l_0 - \delta_0) \geq 0. \tag{7}$$

This constraint differs from (4) in two respects. First, the risky mode improves the funding liquidity of second-period loans by allowing for deposits instead of equity funding. As a result, the funding liquidity is positive, see the first term in (7). Second, according to the second term in (7), there are less internal funds at $t = 1$. The reason here is that a run may destroy earnings of first-period loans, which lowers their funding liquidity.

The risky mode's budget constraint at $t = 1$ in the good state and at $t = 0$ are identical to (3) and (5), respectively, because a run happens neither during the first period nor in the second period under good conditions. Consequently, we can combine (5) with (3) and (7) to obtain

$$l_{1,b} \geq -\frac{\frac{\mu-1-\lambda p_1\Delta}{1-(1-\lambda)p_1}-(1-p_2)(\mu-p_1\Delta)}{p_2 r_b-1} l_0. \tag{8}$$

Similarly to (6), the denominator in (8) reflects the funding liquidity of second-period loans under bad economic conditions whereas the numerator reflects internal funds at $t = 1$. If the latter are positive, the risky mode does not restrict second-period loans. If, however, internal funds are negative, there is again a trade-off between first and second-period loans. The more loans the banker has granted at date $t = 0$, the higher is the debt overhang at $t = 1$ under bad conditions so that the banker must grant more loans and borrow against them at this date to keep the bank in operation.

In mode $\mathcal{F}$, depositors will run on the bank if they learn that the economic conditions at $t = 1$ will be bad, forcing the bank to immediately cease operation. While the failure of the bank at $t = 1$ in the bad state does not affect its budget constraint at $t = 1$ in the good state, which is still given by (3), the budget constraint at the beginning of the first period changes to

$$l_0 \leq p_1 d_0 + p_1 (1-\lambda)(v_g l_0 - \delta_0), \tag{9}$$

because depositors can expect to get a repayment from the bank in the good state only.

Throughout the bank's existence, the banker compares the relative costs and benefits of the available modes and opts for the mode that maximizes his expected profit. Applying backward induction and indicating optimal values by an asterisk, we obtain

Proposition 1: *The banker's optimal decisions on the mode of operation and bank lending at $t = 0$ and $t = 1$ are characterized by*

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

with all critical values being defined in the appendix.

Proof: See appendix.

The proposition states that depending on the risk Δ of first-period loans, the banker chooses between five strategies. While all strategies lead to a first-best volume $l_{1,g}^{\text{fb}}$ of second-period loans under good economic conditions, they differ with regard to loans granted at $t = 0$ and in the bad state at $t = 1$.

Strategy $\mathcal{A}$ is to operate safely and to lend according to the first-best at all dates and in any state. This strategy maximizes expected profits as it avoids inefficient loan volumes as well as inefficient bank runs. Therefore, the banker implements it whenever he can. Strategy $\mathcal{A}$ is available as long as the risk Δ of first-period loans is rather small. In this case, internal funds generated with first-best lending l_0^{fb} in the first period will fully cover the funding gap associated with first-best lending $l_{1,b}^{\text{fb}}$ in the second period under bad economic conditions.

If the risk level Δ is higher, first-best lending throughout all periods will be infeasible as (6) becomes binding. In response, the banker supplies loans in the first period beyond their first-best level. Doing so generates additional internal funds at $t = 1$ and thus eases the restriction on loan supply at $t = 1$ in the bad state. As a result, loan supply becomes volatile. The optimal loan volume $l_0^{\mathcal{S}}$ balances the marginal cost of the efficiency loss in the first period with the marginal benefit of the efficiency gain in the second period (strategy $\mathcal{B}$).

The higher the risk Δ, the more expensive it is to operate in the safe mode as the creation of internal funds for the bad state at $t = 1$ by means of first-period lending gets more and more difficult. As a consequence, the banker adopts the risky mode at some risk level. In contrast to the safe mode, the risky mode allows for first-best loan supply at $t = 1$ by being associated with a higher funding liquidity of second-period loans. Although there is no need for supplying inefficiently large loan volumes at $t = 0$, the risky mode is by definition costly. A bank run, which occurs in the second period when conditions turn out to be bad twice in a row, destroys valuable loan earnings, making first-period lending less attractive. As a consequence, strategy $\mathcal{C}$ is associated with a loan volume $l_0^{\mathcal{R}}$ at $t = 0$ below the first-best, for it balances marginal costs with lower marginal returns. Since an increase in Δ reduces the amount of earnings lost after a bank run, the expected return of first-period loans as well as $l_0^{\mathcal{R}}$ increases in Δ once the risky mode is adopted.

For even higher risk levels, lending $l_0^{\mathcal{R}}$ in the first period would result in a substantial debt overhang under bad economic conditions at $t = 1$, that exceeds prospective earnings of second-period loans. Anticipating that the bank would respond by defaulting on its debt, depositors are not willing to refinance that much loans at $t = 0$. Accordingly, strategy $\mathcal{D}$ is to signal credibility to depositors by granting a smaller volume of loans $l_0^{\max}$ at $t = 0$, which is associated with a debt overhang equal to the expected net return of second-period loans.

Finally, strategy $\mathcal{E}$ is to opt for an outright failure at $t = 1$ when the bad state materializes at this date. With this strategy, delayed returns on first-period loans can never be collected, which reduces the optimal volume of loans even further to $l_0^{\mathcal{F}} < l_0^{\mathcal{R}}$.

4 Regulatory Instruments

The preceding section has shown that a rational, forward-looking banker may take a chance and risk a bank run if credit risks are large. Bank runs are not only costly to those who are directly involved. They also create negative externalities, e.g. by triggering socially costly instabilities in the financial sector. Therefore, prevention of bank runs is often considered a major objective of bank regulation. Ideally, regulation would achieve this without affecting loan supply. In this section, we derive and compare the implications of four regulatory instruments for bank stability and loan supply. These instruments are risk-weighted capital-to-asset ratios, counter-cyclical capital buffers, liquidity coverage ratios and regulatory margin calls. We assume that these instruments cannot be made contingent on the bank-specific risk Δ but only on the economic state in which a bank finds itself at the beginning of the second period.

4.1 Risk-weighted Capital-to-Asset Ratio

In this section we analyze how banks change their lending behavior and capital structure choice in response to a risk-weighted capital-to-asset ratio, henceforth CAR. To incorporate this instrument in our model economy, we make three assumptions. First, there is a uniform, positive risk weight applied to all loans unless the regulator knows for sure that no loans on a bank's book are risky. In this case loans are treated as a risk-free asset and bear a risk weight of zero. Second, regulatory capital is not restricted to the amount of funds provided by shareholders but may also include the bank's internal funds, as we shall further explain. Third, we restrict attention to CAR that make the risky mode less attractive to bankers without putting safe banks under undue strain. In this regard, we build on two implications from our benchmark scenario. One is that the bank's effective capital-to-asset ratio increases in credit risk. The other implication is that for a given credit risk the bank's effective capital-to-asset ratio is larger in the safe mode than in the risky mode.

It follows that, when economic conditions at $t = 1$ are good, the banker faces good economic conditions for the following period as well. He holds only risk-free loans on the bank's books in the second period, for which a risk weight of zero applies. When economic conditions at $t = 1$ are bad, first-period loans have not generated any income for the bank. The bank will hold legacy loans as well as new loans on its books in the second period. CAR then applies a uniform risk weight to all loans and requires that regulatory capital covers at least a fraction κ of these loans. The value of regulatory capital is given by the book value of bank's assets, $l_0 + l_{1,b} + a_{1,b}$, net of the face value of deposits, $\delta_{1,b}$. Hence, regulatory capital is the larger the more funds are available to finance a bank's assets from any sources other than deposits, which includes external equity as well as internal funds.

When conditions are bad at $t = 1$, CAR implies a constraint on deposits according to

$$\delta_{1,b} \leq (1 - \kappa)(l_0 + l_{1,b}) + a_{1,b}. \tag{10}$$

The regulation makes the risky mode less attractive when it puts an effective upper bound on new deposits for a bank operating in the risky mode. When economic conditions are bad at $t = 1$, a necessary condition for this is $(1 - \kappa)(l_0 + l_{1,b}) + a_{1,b} < v_b l_0 + r_b l_{1,b} + a_{1,b}$. There are two important effects to consider for such a bank. First, a higher CAR will lower the funding liquidity of second-period loans. For a sufficiently tight regulation, i.e. for $\kappa > 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}$, there will be even a funding gap. Second, a higher CAR will reduce the internal funds available to the bank, for the funding liquidity of legacy loans is decreasing in CAR. As long as outstanding deposits are still covered by the funding liquidity, i.e. there are some internal funds, the banker could close any funding gap by granting more loans in the first period. However, as both, a higher loan supply at $t = 0$ and a lower loan supply in the bad state at $t = 1$ will dampen expected profits for the risky mode, a banker has a stronger incentive to operate in the safe mode.

In the first period, the value of capital is again determined by the book value of the bank's assets, $l_0 + a_0$, net of the face value of deposits, δ_0. CAR requires that regulatory capital covers at least a fraction κ of loans, hence imposing once more a constraint on the face value of deposits

$$\delta_0 \leq (1 - \kappa)l_0 + a_0. \tag{11}$$

Similar to above, CAR makes the risky mode less attractive at $t = 0$ when the constraint on deposits is binding for a bank operating in the risky mode already in the first period, i.e. if $(1 - \kappa)l_0 + a_0 < v_g l_0 + a_0$. The banker can grant loans in the first period if their funding liquidity is positive. This is the case when CAR is not too tight and risk is not too small. The latter follows because the return on first-period loans in good economic conditions, which determines what the banker can pay shareholders at most, increases in risk.

Finally, we need to establish the conditions under which CAR does not impose any additional burden on a bank operating in a safe mode. One refers to the funding liquidity of second-period loans when the bank operates in the safe mode. A safe bank will not be affected by the regulation, if the funding liquidity is not impaired by CAR, i.e. if $\kappa < 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}$. Another condition refers to the funding liquidity of first-period loans, i.e. on the advantages of building up internal funds. We know from the benchmark that an unregulated bank, which faces a funding constraint and still wants to operate in the safe mode, will opt for the maximum capital-to-asset ratio that just allows to stay in operation. Hence we restrict attention to $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$, for any higher CAR will result in a negative funding liquidity and render the safe mode impossible.

The implications of CAR for bank stability and loan supply are summarized in the following proposition.

Proposition 2: *Let* $\mathbb{K} := \left[1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}, \min\left\{1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}, 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}\right\}\right]$. *If* $\{\kappa : \kappa \in \mathbb{K}\} \neq \emptyset$, *the banker's optimal response to CAR for all* $\kappa \in \mathbb{K}$ *is characterized by*

$$\begin{array}{lllll}
\mathcal{A}: & m^* = \mathcal{S}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \quad \Delta \leq \Delta^{\mathcal{A}}, \\
\mathcal{B}_{CAR}: & m^* = \mathcal{S}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \text{if} \quad \Delta \in \left(\Delta^{\mathcal{A}}, \Delta_\kappa^{\mathcal{B}}\right], \\
\mathcal{C}_{CAR}: & m^* = \mathcal{R}, & l_0^* = l_{0,\kappa}^{\mathcal{R}} \geq l_0^{\mathcal{R}}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\kappa}^{max}\} & \text{if} \quad \Delta \in \left(\Delta_\kappa^{\mathcal{B}}, \Delta_\kappa^{\mathcal{C}}\right], \\
\mathcal{D}_{CAR}: & m^* = \mathcal{R}, & l_0^* = l_{0,\kappa}^{max}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\kappa}^{max}\} & \text{if} \quad \Delta \in \left(\Delta_\kappa^{\mathcal{C}}, \min\{\Delta_\kappa^{\mathcal{D}}, \Delta_\kappa^{\psi}\}\right], \\
\mathcal{X}_{CAR}: & m^* = \mathcal{S}, & l_0^* = 0 < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \text{if} \quad \Delta \in \left(\Delta_\kappa^{\psi}, \Delta_\kappa^{\mathcal{E}}\right], \\
\mathcal{E}_{CAR}: & m^* = \mathcal{F}, & l_0^* = l_0^{\mathcal{F}} < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \text{if} \quad \Delta > \max\{\Delta_\kappa^{\mathcal{D}}, \Delta_\kappa^{\mathcal{E}}\},
\end{array}$$

with all critical values being defined in the appendix.

Proof: See appendix.

The proposition looks at those regulatory capital-to-asset ratios that make the risky mode less attractive while imposing no additional burdens on banks operating in the safe mode. We gain three important insights. The first refers to a new trade-off between bank stability and volatility in loan supply. As expected profits associated with the risky mode are reduced, bankers facing credit risks larger than $\Delta^{\mathcal{B}}$ but less than some $\Delta_\kappa^{\mathcal{B}}$ will respond to the introduction of CAR by operating their bank in the safe mode at all times. Hence, instead of supplying too few loans in the first period (as they would without CAR), these banks supply more loans at $t = 0$ than justified by their NPV, followed by a credit crunch in $t = 2$ if conditions turn out to be bad (strategy $\mathcal{B}_{\text{CAR}}$). This is because they now do what banks facing lower risks also do: tackle possible future funding problems by boosting internal funds via increased loan supply at $t = 0$ in case it later becomes difficult to raise funds externally.

Second, CAR also amplifies volatility in loan supply without improving bank stability. As argued above, CAR implies a funding constraint in the risky mode. Even if this constraint prevents banks from granting the efficient loan volume under bad conditions at $t = 1$, they may still not switch to the safe mode because switching would lead to an even tighter funding constraint. Instead, some banks will grant additional loans in the first period (strategy $\mathcal{C}_{\text{CAR}}$). This is for two reasons. First, granting more first-period loans helps build up more internal funds for $t = 1$. This is similar to safe banks facing a restriction at $t = 1$. The second reason applies only to regulated risky banks. For them, granting more loans in the first period also increases the book value of total bank assets at $t = 1$, allowing a bank to use more deposits to borrow against newly granted loans at this date under bad conditions. Due to this second effect, granting additional loans at $t = 0$ may even be beneficial if these loans result in a debt overhang at $t = 1$. However, if the debt overhang becomes too pronounced, the bank will observe an upper bound on first-period loans ensuring that it stays in business in the second period ($\mathcal{D}_{\text{CAR}}$). In any case, such banks operate in a risky manner without and with regulation. CAR only increases volatility of their loan supply.

Third, the effects of CAR on bank stability are ambiguous for rather large credit risks. Either CAR induces a bank to implement a fragile capital structure already at the beginning, implying that credit intermediation is stopped by a bank run when conditions become bad at $t = 1$ (strategy $\mathcal{E}_{\text{CAR}}$). Or a bank will grant no loans at all in the first period. Doing so will allow a banker to stay in business and grant loans in the second period should the economy turn out to be in good economic conditions at $t = 1$ (strategy $\mathcal{X}_{\text{CAR}}$). For this bank, the introduction of CAR achieves financial stability but at a very high cost in terms of credit disintermediation.

4.2 Counter-cyclical Capital Buffers

Regulators have suggested to augment the Basel framework with a counter-cyclical capital buffer, henceforth CCB. Tighter capital standards in prosperous times are expected to impede excessive credit growth. Softer requirements in bad times should free up capital to cover additional potential losses, thereby mitigating a possible credit crunch.[13] Accordingly, CCB is primarily meant to reduce volatility in loan supply and not to stabilize banks.

In the context of our model, we assume that the capital-to-asset ratio is zero in financially difficult times, i.e. when economic conditions are bad at $t = 1$. Otherwise, the risk-weighted capital-to-asset ratio κ_g is high and supposed to be binding even for safe banks, for it is their loan supply that is volatile in the absence of other regulations.[14] From the discussion above we know that safe banks will be affected by the regulation already at $t = 0$ if $\kappa_g > 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$, which is what we consider throughout the following analysis.

CCB is best understood when the interactions between a regulatory capital-to-asset ratio, the magnitude of risks, and their mutual effect on the funding liquidity at a certain date are spelled out. With a regulatory capital-to-asset ratio in place at $t = 0$, a lower risk further impedes the ability of a banker to commit himself to the necessary repayments to shareholders in the safe mode. The reason is that with low risk there is only little shareholders can get from every unit of loans. Hence, deposits cannot be replaced with equity to achieve the regulatory requirement without impairing the funding liquidity of loans. CCB effectively increases the costs of building up internal funds as it impedes loan supply in the first period. These costs become prohibitive when first-period loans are too safe, for the funding liquidity of loans is then too small to cover the initial outlay. A similar effect arises in the risky mode, as the expected payoff to shareholders is even lower.

Against this background, CCB has the following effects on bank stability and loan supply.

[13]Such counter-cyclical capital buffer has been introduced by regulators in, e.g., Switzerland in 2013 and Norway in 2015.

[14]If conditions are good at $t = 1$ the capital-to-asset ratio will also be κ_g but, consistent with our argument made before, new loans granted in these circumstances will bear a risk weight of zero.

Proposition 3: *Let* $\kappa_g > 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}$. *The banker's optimal response to CCB is then characterized by*

$$\begin{array}{llllll}
\mathcal{Y}_{CCB}: & m^* = \mathcal{R}, & l_0^* = 0 < l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \textit{if} & \Delta \leq \Delta_{\kappa_g}^{\mathcal{Y}}, \\
\mathcal{A}_{CCB}: & m^* = \mathcal{S}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \textit{if} & \Delta \in (\Delta_{\kappa_g}^{\mathcal{Y}}, \Delta^{\mathcal{A}}], \\
\mathcal{B}_{CCB}: & m^* = \mathcal{S}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} & \textit{if} & \Delta \in (\max\{\Delta_{\kappa_g}^{\mathcal{Y}}, \Delta^{\mathcal{A}}\}, \Delta^{\mathcal{B}}], \\
\mathcal{C}_{CCB}: & m^* = \mathcal{R}, & l_0^* = l_0^{\mathcal{R}} < l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \textit{if} & \Delta \in (\max\{\Delta_{\kappa_g}^{\mathcal{Y}}, \Delta^{\mathcal{B}}\}, \Delta^{\mathcal{C}}], \\
\mathcal{D}_{CCB}: & m^* = \mathcal{R}, & l_0^* = l_0^{max}, & l_{1,b}^* = l_{1,b}^{fb} & \textit{if} & \Delta \in (\max\{\Delta_{\kappa_g}^{\mathcal{Y}}, \Delta^{\mathcal{C}}\}, \max\{\Delta^{\mathcal{D}}, \Delta_{\kappa_g}^{\mathcal{E}}\}], \\
\mathcal{E}_{CCB}: & m^* = \mathcal{F}, & l_0^* = l_0^{\mathcal{F}} < l_0^{fb}, & l_{1,b}^* = 0 & \textit{if} & \Delta > \max\{\Delta^{\mathcal{D}}, \Delta_{\kappa_g}^{\mathcal{E}}\},
\end{array}$$

with all critical values being defined in the appendix.

Proof: See appendix.

The proposition summarizes three important insights from the model. The first is that CCB can prevent volatility in loan supply only by choking off lending in the first period causing a further threat to bank stability in the second period. When risks are small and the capital-to-asset ratio is large relative to risk, the banker will be unable in the first period to grant any loans. This holds true regardless in which mode he would operate the bank, for he cannot credibly commit himself to pay shareholders the required amount. He can merely hold the risk-free asset in the first period. Only if economic conditions turn out to be good after the first period, he will resume lending in the unrestricted safe mode. If conditions are bad after one period, a banker will not be constrained by capital standards anymore. This does not mean, however, that CCB imposes no restriction on the banker when the bank faces financially difficult conditions. Quite the contrary, he will suffer from a potentially even tighter restriction for a reason that would not exist in absence of CCB. This reason relates to a lack of internal funds. With CCB there may simply be no scope for the banker to grant any loans in the first period. Hence, there are no assets against which he can raise fresh funds in financially difficult times. As the funding liquidity of new loans is also too low, the safe mode is unavailable to the banker so that he can operate only in the risky mode (strategy $\mathcal{Y}_{\text{CCB}}$). Note, an increase in the capital-to-asset ratio applied in good times raises the threshold $\Delta_{\kappa_g}^{\mathcal{Y}}$ for credit risks. Hence, more banks will experience this effect.

For all risks above this threshold $\Delta_{\kappa_g}^{\mathcal{Y}}$, the capital-to-asset ratio applied in good times will not be binding for safe banks. They have a higher capital-to-asset ratio anyway, even without the regulation. Therefore, CCB has no effect on them. As it is especially these banks contributing to pro-cyclicality, CCB will not have the intended effect. This is the second insight from our model.

A third insight refers to bank stability again. Recall that without regulation a bank facing high risks will operate in the risky mode already in the first period. With CCB, this strategy may simply be no longer feasible for them. The banker may be forced by CCB to operate in the safe mode in the first period and to build up some internal funds, possibly switching to the risky mode later when economic conditions get bad.

4.3 Liquidity Coverage Ratio

With Basel III, a further innovation has been made to the regulatory framework for banks. Traditionally, capital regulation requires banks to cover risky assets with capital. The new liquidity coverage ratio, henceforth LCR, establishes another link between balance sheet items. It requires banks to cover their expected net cash outflows over some time period by a certain amount of high-quality, liquid assets.

In the context of our model, net cash outflows in each period are given by the total face value of deposits payable at the end of that period. Our risk-free asset is the high-quality, liquid asset the regulation refers to. LCR is then defined by $\eta := \frac{a_t}{\delta_t}$. Note that in our modeling approach we consider the total face value of deposits, for there will be no partial withdrawal of deposits. Hence, in the model LCR can be smaller than one to guarantee bank stability.[15]

Just like CAR, the LCR implies an upper bound on deposits. Unlike CAR, LCR does never affect loans for banks in the safe mode though, no matter how tight the regulation is. The reason is that for them the risk-free asset yields exactly the return required by depositors. Hence, a banker can simply inflate the bank's balance sheet by issuing deposits to be invested in the risk-free asset until the bank meets the requirement. Doing so has no impact on loans so that a banker's decision on building up internal funds is left unchanged.

[15] Basel III is based on the notion that not all depositors will withdraw their funds within that time period. While considering only a fraction of the face value of deposits, the coverage ratio is set to at least one.

Only loan supply by banks in the risky mode is potentially affected by LCR. The regulation puts an upper bound on the face value of deposits. This upper bound is given by

$$\delta_{1,b} \leq \frac{a_{1,b}}{\eta}, \tag{12}$$

if economic conditions are bad at the end of the first period, and

$$\delta_0 \leq \frac{a_0}{\eta}, \tag{13}$$

at the beginning of the first period. When the banker opts for the risky mode at either date, the probability of a bank run and thus of a loss in asset values is strictly positive, for which the expected net return on the risk-free asset is negative. In our benchmark this is exactly the reason why a bank operating in the risky mode would not want to invest in risk-free assets.

The mechanism through which LCR changes incentives for the banker builds on this effect. In principle, without LCR a bank operating in the risky mode would not be restricted in refinancing loans with deposits. In the second period, this holds true for both, new and legacy loans. To comply with LCR, the bank has to hold a certain fraction of total deposits in loss-bearing safe assets. Accordingly, granting loans in the second period is restricted and the benefits of granting loans in the first period for the sake of making provisions for possible future financial difficulties are smaller with LCR. In order to increase internal funds in bad times, the banker thus has to grant more loans than without LCR. That way, LCR is like a tax on a bank which is not operating in the safe mode, reducing the expected profits made in the risky mode. Therefore, LCR makes the risky mode less attractive to the banker.

Two further observations are in order. First, when η is sufficiently large, raising deposits to co-finance the bank's loan portfolio does not pay at all. The losses which accrue from holding so many risk-free assets will more than outweigh the gains associated with improvements in the loans' funding liquidity due to replacing equity shares by deposits. This will be the case either at $t = 0$ or $t = 1$ if $\eta \geq \min\left\{\frac{\lambda p_1}{1-(1-\lambda)p_1}, \frac{\lambda p_2}{1-(1-\lambda)p_2}\right\}$. Second, when economic conditions turn out to be bad at the end of the first period, LCR not only imposes a burden on deposits to refinance new loans but also on deposits raised against nonperforming loans. Accordingly, LCR implies a loss in internal funds if the banker opts for a strategy involving the risky mode at $t = 1$.

This leads us to the following conclusion.

Proposition 4: *Let* $\eta < \min\left\{\frac{\lambda p_1}{1-(1-\lambda)p_1}, \frac{\lambda p_2}{1-(1-\lambda)p_2}\right\}$. *The banker's optimal response to LCR is then characterized by*

$$
\begin{array}{lllll}
\mathcal{A}: & m^* = \mathcal{S}, & l_0^* = l_0^{fb}, & l_{1,b}^* = l_{1,b}^{fb} & \text{if} \quad \Delta \leq \Delta^{\mathcal{A}}, \\
\mathcal{B}_{LCR}: & m^* = \mathcal{S}, & l_0^* = l_0^{\mathcal{S}} > l_0^{fb}, & l_{1,b}^* = \psi l_0^{\mathcal{S}} < l_{1,b}^{fb} & \text{if} \quad \Delta \in \left(\Delta^{\mathcal{A}}, \Delta_\eta^{\mathcal{B}}\right], \\
\mathcal{C}_{LCR}: & m^* = \mathcal{R}, & l_0^* = l_{0,\eta}^{\mathcal{R}} \geq l_0^{\mathcal{R}}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\eta}^{max}\} & \text{if} \quad \Delta \in \left(\Delta_\eta^{\mathcal{B}}, \Delta_\eta^{\mathcal{C}}\right], \\
\mathcal{D}_{LCR}: & m^* = \mathcal{R}, & l_0^* = l_{0,\eta\mathcal{R}}^{max}, & l_{1,b}^* = \min\{l_{1,b}^{fb}, l_{1,\eta}^{max}\} & \text{if} \quad \Delta \in \left(\Delta_\eta^{\mathcal{C}}, \Delta_\eta^{\mathcal{D}}\right], \\
\mathcal{E}_{LCR}: & m^* = \mathcal{F}, & l_0^* = \min\{l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{max}\} < l_0^{fb}, & l_{1,b}^* = 0 < l_{1,b}^{fb} & \text{if} \quad \Delta > \Delta_\eta^{\mathcal{D}},
\end{array}
$$

with all critical values being defined in the appendix.

Proof: See appendix.

LCR does not affect banks exposed to small risks. They will be safe and supply loans according to the first-best (strategy $\mathcal{A}$). Banks with somewhat larger risk exposure will stay safe and their loan supply exhibits volatility, just like in the benchmark case. However, as LCR makes the risky mode less attractive, the risk threshold above which a banker opts for the risky mode will increase. In response to LCR, additional banks — those with $\Delta \in (\Delta^{\mathcal{B}}, \Delta_\eta^{\mathcal{B}}]$ — will thus switch to the safe mode and their loan supply will become volatile.

For a banker who keeps his bank in the risky mode, LCR reduces the expected profits of granting loans in the second period when economic conditions are bad. Due to the restriction on deposits, loan supply may not exceed some upper bound imposed by LCR. In anticipation of this, the banker is incentivized to increase loan supply in the first period to build up more internal funds easing the restriction on granting loans in the second (strategy $\mathcal{C}_{LCR}$). However, such a behavior might be restricted by an upper bound on first-period loans as the funding liquidity of first-period loans has to cover outstanding deposits at $t = 1$ (strategy $\mathcal{D}_{LCR}$). In both cases, the increased volatility results in smaller expected profits for banks.

To conclude, LCR can also increase volatility in loan supply for banks operating in the risky mode. In order to reduce effects like this, Perotti and Suarez (2011) have suggested to implement liquidity requirements that are larger in good times and lower in bad times. The lesson from our model, however, is that 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 volatility in loan supply but will likewise harm bank stability for some ranges of risk levels.

Note that for $\eta > \max\left\{\frac{\lambda p_1}{1-(1-\lambda)p_1}, \frac{\lambda p_2}{1-(1-\lambda)p_2}\right\}$, the risky mode is not available. The banker picks from strategy $\mathcal{A}$ or $\mathcal{B}$ as defined in the benchmark if $\Delta \leq \Delta^{\psi}$. Otherwise he grants loans only once economic conditions at $t = 1$ turned out to be good. The reason is that liquidity requirements can hamper banks to a point where granting loans becomes unprofitable.[16]

4.4 Regulatory Margin Calls

In the last step, we examine the regulatory margin call, henceforth RMC (Hart and Zingales, 2011). RMC stands out from other regulatory instruments. For one, it explicitly combines a measure that aims at preventing financial institutions from getting into financial difficulties with a mechanism of how to manage an institution once it is in distress. Moreover, RMC also constitutes an attempt to reduce the complexity of bank regulation by introducing a simple rule based on market information. As the CDS market is supposedly the leading market with respect to information discovery, the CDS spread on a financial institution is considered to be a reliable indicator for its probability of default.[17]

In the model we operationalize RMC as follows. We assume that a CDS is always fairly priced. When a bank operates in the risky mode, its probability of default is positive, and market participants demand additional CDS contracts. With an increased demand, the CDS spread of this bank is above the threshold of zero basis points. Without any delay, the banker has to raise additional equity to bring down the probability of default. Otherwise the bank will be taken over by the supervisory authority, replacing the bank's management

[16] A similar argument has been made by De Nicolò et al. (forthcoming).

[17] 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.

and wiping out its shareholders.[18] Hence, only for a bank operating in the safe mode the CDS spread does not rise above the threshold.

Unlike the other regulatory instruments discussed above, RMC is the only one that does not depend on the economic conditions a bank faces. When a banker operates in the safe mode, RMC imposes no additional constraint, regardless how economic conditions are. Operating in the risky mode, however, will always trigger the margin call. It is also important to note that RMC does not change the marginal cost or benefits of accumulating internal funds. The main incentive effect of RMC comes from leaving a banker with an expected loss if he opted for the risky mode at any point in time no matter in which economic conditions the bank may actually turn out to be, for he has to bear the costs of granting and managing loans without receiving any compensation for his effort.

Considering these effects for both periods, we obtain

Proposition 5: *The banker's optimal response to RMC is characterized by*

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

with all critical values being defined in the appendix.

Proof: See appendix.

Because of its simple structure, the effects of RMC are quite straight forward. A banker will never operate in the risky mode at any time. As the safe mode is not affected, his preference for the unrestricted safe mode is unchanged for all credit risks Δ below $\Delta^{\mathcal{A}}$ (strategy $\mathcal{A}$). For higher risks up to Δ^{ψ}, loan supply in the safe mode is restricted and feasible (strategy $\mathcal{B}_{RMC}$). Granting any loans in a safe mode is not feasible, however, for risks above Δ^{ψ}. In order to avoid any losses from operating in the risky mode, a banker prefers to grant no loans at all both in the first period and later when economic conditions turn out to be bad. Instead, he holds risk-free assets only and will possibly

[18] Note that any market participant inside or outside the bank may enter into a CDS contract on the bank. We do not need to consider debt explicitly for our analysis, for an underlying is not a requisite for market participants to agree on a CDS contract.

start lending again should conditions turn out to be good at the end of the first period (strategy $\mathcal{X}_{RMC}$).

5 Concluding Discussion

This paper stresses that there is a link between a bank's present and future capital structure choice and loan supply. Capital structure and lending today jointly determine how much funds can be freed up tomorrow. The ability to resort to those internal funds can be pivotal when a bank faces the risk of getting into liquidity problems at some future date, i.e. difficulties in raising fresh funds externally to refinance new loans with positive NPV. In our model such liquidity problems arise because of frictions that make deposits, external equity and internal funds only imperfect substitutes. Equity suffers from an agency problem at the bank management level, but provides a buffer in case of liquidity problems; deposits help overcoming the agency problem, but may impose a threat to the bank's stability; internal funds are neither subject to the agency problem nor do they threaten stability, but they are available only up to a limited amount, for they are the outcome of costly actions taken by the bank management under imperfect information in the past.

The extent of possible future liquidity problems, and hence the dynamic pattern of loan supply and the stability of a bank, hinges on credit risk. In our two-period model the focus is on credit risk associated with loans granted in the first period, gauged by a mean preserving spread in their earnings, which are either high and early or low and delayed. Without regulation, a bank has never difficulties in raising sufficient funds if and only if credit risk is small. To a certain extent, a bank's capital structure is even irrelevant then. The banker has sufficient access to funds, both internally and externally, and is somewhat flexible in substituting deposits for equity in refinancing operations according to the first-best without compromising on stability.

If credit risks are neither small nor too large, loan supply becomes volatile. Initially, it will be excessive compared to the first-best, but only to fall short of the efficient level later on should economic conditions turn out to be bad at the end of the first period. Volatility in loan supply has been the result in other models (e.g. Kiyotaki and Moore, 1997). Our paper differs from those approaches in two ways. First, credit volatility occurs in our model because banks anticipate a future financial constraint. They respond by granting more loans in the present to build up internal resources, which help mitigating financial constraints in the future. Second, credit volatility is not only reflected in a credit crunch when economic conditions are getting difficult, but also in loan supply in normal times being above what is justified by their NPV.

Things are different when risks are more pronounced. In an attempt to gamble for resurrection, a banker refinances the bank's operations only with deposits should economic conditions turn out to be bad at the end of the first period. The reason is that at this date the funding liquidity of first-period loans is too low and outstanding deposits are already large. From an ex-ante perspective, building up internal funds would thus be too costly or even infeasible. Loan supply shows a different pattern in this case. In the first period, the presence of relatively large risks will depress loan supply compared to the first-best. Later on, it will recover irrespective of the state, but the bank's capital structure becomes fragile should the bad state materialize. Hence, the model predicts not only a secular trend in loan supply, but also that the bank collapses eventually should a series of liquidity shocks hit the bank in a row. Our explanations is in contrast to others. Just because a strong credit expansion precedes a bank's failure does not mean that the former actually causes the latter. It is rather the anticipated risk of a potential failure that makes a banker initially cautious in terms of capital structure and loan supply and later on more aggressive once economic conditions worsen. Note that for very large risks, the bank breaks down at the first instance of financial problems, i.e. if economic conditions are bad for the first time.

A major channel through which bank regulation affects the behavior of banks is by changing the costs and benefits of generating internal funds. The four instruments we have considered are often very different in this regard, and their respective comparative advantages depend on the extent of the credit risk. Regulation makes a bank stable only if credit risks are not too large such that granting loans with a safe capital structure is at least feasible. For those risks, CAR, LCR as well as RMC can improve bank stability. All three of them impose a restriction on deposits and thereby on bank loan supply when banks operate in the risky mode. If this restriction becomes binding, banks are more likely to prefer the safe mode. This is because gambling for resurrection once conditions turn bad becomes less attractive relative to building up internal funds prior to financial problems arise.

Yet, how strongly this incentive changes depends on the regulatory instruments. All three of them have in common that some banks, which would be otherwise in the risky mode, will operate in the safe mode where they have an incentive to build up internal funds. Differences exist with respect to banks still operating in the risky mode despite regulation. For them, CAR and a low LCR provide incentives to build up internal funds in the first period as well. The reason is that with these instruments the funding liquidity of second-period loans is too low, even when banks opt for the risky mode if economic conditions are bad. To ease this funding constraint caused by regulation, banks seek to build up internal funds by granting more loans in the first period. RMC and a high LCR do not have such effect on loan supply.

Note that CCB appears to be a rather inadequate instrument. As intended, it does not help improving bank stability. However, to actually reduce volatility in loan supply, CCB has to target banks operating in the safe mode as it is them whose loan supply is volatile. To be effective, capital-to-asset ratios need to be sufficiently tight in economic good times so that issuing deposits in the safe mode is restricted. In this case, however, there is a downside of reducing volatility. For banks exposed to rather small credit risks, the costs of building up internal funds in the first period becomes prohibitive. They stop credit intermediation in the first period, and, due to a lack of internal funds when conditions turn out to be bad after one period, may adopt a fragile capital structure later on.

In conclusion, when banks differ in their credit risks but these risks are not observable by supervisory authorities, bank stability can be achieved and further amplification of credit volatility would be limited to only a small range of credit risks with either RMC or a high LCR. Both instruments would prevent banks from ever putting their stability at risk. However, for larger credit risks, they both come at the cost of a stop in credit intermediation. The other instruments cannot prevent bank runs for a certain range of credit risks.

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Appendix - extended version (considered for online publication only)

A Proof of Proposition 1

This proof proceeds in three steps. Applying backward induction, we start by determining the banker's optimal behavior in the second period. First, we consider the good state at $t = 1$, see section A.1 and Lemma 1. Second, we consider the bad state at $t = 1$, see section A.2 and Lemma 2. Finally, we determine the banker's optimal behavior at $t = 0$, see section A.3.

For each step we proceed as follows. First, we specify the banker's optimization problem. Second, we determine the reduced forms for all modes feasible. Third, 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.

To simplify notation, it is useful to define

$$\phi_0 (l_0) = (\mu - 1) l_0 - c (l_0), \tag{14}$$

$$\phi_{1,g} (l_{1,g}) = (r_g - 1) l_{1,g} - c (l_{1,g}), \tag{15}$$

$$\phi_{1,b} (l_{1,b}) = (p_2 r_b - 1) l_{1,b} - c (l_{1,b}). \tag{16}$$

A.1 Second Period ($t = 1$), Good State

Consider the banker at $t = 1$ in the good state. In analogy to the modes $m \in \{\mathcal{S}, \mathcal{R}, \mathcal{F}\}$ identified in the paper, it is useful to define the modes $m_{1,g} \in \{s, f\}$, which the banker can implement from date $t = 1$ in the bad state onwards. As second-period loans are risk-free under good economic conditions, the banker can operate either in a "safe" mode $m_{1,g} = s$ by avoiding a bank run or in a "failure" mode $m_{1,g} = f$ by immediately closing the bank.

A.1.1 Optimization Problem

Unless the banker chooses $m_{1,g} = f$, his optimization problem reads

$$\max_{l_{1,g}, a_{1,g}, \delta_{1,g} \in \mathbb{R}^+} \pi_{1,g} = \lambda \left[r_g l_{1,g} + a_{1,g} - \delta_{1,g} \right] - c\left(l_{1,g}\right) \tag{17}$$

$$\text{s.t. } \ l_{1,g} + a_{1,g} = \omega_{1,g} l_0 + d_{1,g} + e_{1,g}, \tag{18}$$

$$d_{1,g} = \delta_{1,g} \quad \text{with} \quad \delta_{1,g} \leq r_g l_{1,g} + a_{1,g}, \tag{19}$$

$$e_{1,g} = (1-\lambda) \left[r_g l_{1,g} + a_{1,g} - \delta_{1,g} \right] - (1-\lambda) \omega_{1,g} l_0, \tag{20}$$

with $\omega_{1,g} := v_g - \frac{\delta_0 - a_0}{l_0}$. We will show below that $\omega_{1,g} > 0$, see (56).

Equation (17) reflects the expected profit $\pi_{1,g}$ of the banker. He will obtain a share λ of the bank's profits $r_g l_{1,g} + a_{1,g}$ net of depositors' claims $\delta_{1,g}$, and the costs $c\left(l_{1,g}\right)$ of managing second-period loans. Equation (18) reflects the bank's budget constraint. 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 (19). If the banker increased the face value above this threshold, depositors would run on the bank immediately, so that a bank closure would occur at $t = 1$. Equation (20) reflects the amount provided by shareholders. They provide an amount equal to what they can extract at $t = 2$ subtracted by what they could already extract at $t = 1$. At either date, they can extract a share $1 - \lambda$ of the profit of the bank net of payments to depositors.

A.1.2 Determination of Reduced Forms

A.1.2.1 Safe Mode Suppose the banker operates in the safe mode $m_{1,g} = s$. For this case, inserting (19) and (20) in (18), solving for $\delta_{1,g}$, and inserting the result in (17) and the restriction on $\delta_{1,g}$ in (19) yields

$$\max_{l_{1,g}, a_{1,g} \in \mathbb{R}^+} \pi^s_{1,g} = \lambda \omega_{1,g} l_0 + \phi_{1,g}\left(l_{1,g}\right) \tag{21}$$

$$\text{s.t. } \ (r_g - 1) l_{1,g} \geq -\lambda \omega_{1,g} l_0. \tag{22}$$

A.1.2.2 Failure Mode Suppose the banker operates in the failure mode $m_{1,g} = f$. In this case, he will simply pay off depositors, close the bank and receive a share λ of the current cash flow, so that his expected profit reads

$$\pi_{1,g}^{f} = \lambda\omega_{1,g}l_0. \tag{23}$$

A.1.3 Determination of Optimal Loan Volumes at $t = 1$

A.1.3.1 Safe Mode Suppose the banker operates in the safe mode $m_{1,g} = s$. For this mode, it follows from (21) that $\frac{\partial\pi_{1,g}^{s}}{\partial l_{1,g}} = \phi_{1,g}'\left(l_{1,g}\right)$, which is decreasing in $l_{1,g}$ and equal to zero for $l_{1,g} = l_{1,g}^{\text{fb}}$. Moreover, we have $\frac{\partial\pi_{1,g}^{s}}{\partial a_{1,g}} = 0$ and, since $r_g > 1$ and $\omega_{1,g} > 0$, the LHS of (22) is positive whereas the RHS is negative. Accordingly, $l_{1,g}$ is not restricted. We can conclude that the optimal loan volume $l_{1,g}^{s*}$ and the expected profit $\pi_{1,g}^{s*}$ will have the following properties:

$$l_{1,g}^{s*} = l_{1,g}^{\text{fb}}, \tag{24}$$

$$\pi_{1,g}^{s*} = \lambda\omega_{1,g}l_0 + \phi_{1,g}\left(l_{1,g}^{\text{fb}}\right) \geq 0. \tag{25}$$

A.1.3.2 Failure Mode Suppose the banker operates in the failure mode $m_{1,g} = f$. By definition, the optimal loan volume $l_{1,g}^{f*}$ and the expected profit $\pi_{1,g}^{f*}$ will have the following properties:

$$l_{1,g}^{f*} = 0, \tag{26}$$

$$\pi_{1,g}^{f*} = \lambda\omega_{1,g}l_0 \geq 0. \tag{27}$$

A.1.4 Comparison

Due to $\phi_{1,g}\left(l_{1,g}^{\text{fb}}\right) > 0$, it follows from (25) and (27) that $\pi_{1,g}^{s*} > \pi_{1,g}^{f*}$. Accordingly, the banker always prefers the safe mode $m_{1,g} = s$ over the failure mode $m_{1,g} = f$, irrespective of the loan volume granted in the first period. We can conclude

Lemma 1: *If the economy is in the good state at date $t = 1$, the banker's optimal decision on the mode of operation, $m^*_{1,g}$, bank loan supply, $l^*_{1,g}$, and his expected profit $\pi^*_{1,g}$ will have the following properties:*

$$m^*_{1,g} = s, \quad l^*_{1,g} = l^{fb}_{1,g}, \quad \pi^*_{1,g} = \pi^{s*}_{1,g} \quad \forall\ l_0, \tag{28}$$

where $\pi^{s*}_{1,g}$ is defined by (25).

A.2 Second Period ($t = 1$), Bad State

Consider the banker at $t = 1$ in the bad state. It is useful to define the modes $m_{1,b} = \{s, r, f\}$, which the banker can implement from $t = 1$ in the bad state onwards. As second-period loans are risky in the bad state, the banker can operate either in a "safe" mode $m_{1,b} = s$ by avoiding a bank run irrespective of the final loan earnings, in a "risky" mode $m_{1,b} = r$ by accepting a run in case of zero earnings on second-period loans, or in a "failure" mode $m_{1,b} = f$ by immediately closing the bank.

A.2.1 Optimization Problem

Unless the banker chooses $m_{1,b} = f$, his optimization problem reads

$$\max_{l_{1,b}, a_{1,b}, \delta_{1,b} \in \mathbb{R}^+} \pi_{1,b} = \lambda E \left[\max\left\{v_b l_0 + r_j l_{1,b} + a_{1,b} - \delta_{1,b}, 0\right\}\right] - c\left(l_{1,b}\right) \tag{29}$$

$$\text{s.t.} \ \ l_{1,b} + a_{1,b} = \omega_{1,b} l_0 + d_{1,b} + e_{1,b}, \tag{30}$$

$$d_{1,b} = \begin{cases} \delta_{1,b} & \text{if} \quad m_{1,b} = s: \ \delta_{1,b} \leq v_b l_0 + a_{1,b}, \\ p_2 \delta_{1,b} & \text{if} \quad m_{1,b} = r: \ \delta_{1,b} \in \left(v_b l_0 + a_{1,b}, v_b l_0 + r_b l_{1,b} + a_{1,b}\right], \end{cases} \tag{31}$$

$$e_{1,b} = (1 - \lambda) E \left[\max\left\{v_b l_0 + r_j l_{1,b} + a_{1,b} - \delta_{1,b}, 0\right\}\right], \tag{32}$$

with $j = \{h, l\}$, $r_h = r_b$, $r_l = 0$ and $\omega_{1,b} := -\frac{\delta_0 - a_0}{l_0}$. We will show below that $\omega_{1,b} < 0$, see (57).

Analogously to the good state, equation (29) reflects the banker's expected profit in the bad state. He receives the share λ of all returns less the pecuniary and non-pecuniary costs of granting loans unless there is a bank run, that destroys all assets of the bank. Equation (30) reflects the bank's budget constraint. Note that in the bad state, the cash flow $\omega_{1,b}l_0$ is negative as earnings from first-period loans do not accrue before $t = 2$. According to (31), depositors provide funds depending on the face value $\delta_{1,b}$ of deposits. If the face value is sufficiently low, the banker operates in the safe mode $m_{1,b} = s$ and will repay deposits with certainty, so that depositors provide funds equal to the face value of deposits. If the face value is high, the banker operates in the risky mode $m_{1,b} = r$ and will repay deposits with probability p_2 (with probability $1 - p_2$, there will be a bank run), so that depositors provide funds up to $p_2\delta_{1,b}$. Equation (32) shows that shareholders provide an amount equal to their expected payoff at $t = 2$, as they are unable to extract a rent at the current date $t = 1$ in the bad state due to the negative cash flow at $t = 1$. Because of limited liability they cannot be forced to place additional capital to cover the debt overhang either.

A.2.2 Determination of Reduced Forms

A.2.2.1 Safe Mode Suppose the banker operates in the safe mode $m_{1,b} = s$. For this mode, inserting (31) and (32) in (30), solving for $\delta_{1,b}$, and inserting the result in (29) and the restriction on $\delta_{1,b}$ in (31) yields

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^s_{1,b} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) \tag{33}$$

$$\text{s.t.} \quad [1 - (1-\lambda)p_2 r_b]l_{1,b} \leq (v_b + \omega_{1,b})l_0. \tag{34}$$

A.2.2.2 Risky Mode Suppose the banker operates in the risky mode $m_{1,b} = r$. For this mode, inserting (31) and (32) in (30), solving for $\delta_{1,b}$, and inserting the result in (29) and the restriction on $\delta_{1,b}$ in (31) yields

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^r_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) - (1-p_2)a_{1,b} \tag{35}$$

$$\text{s.t.} \quad [p_2 r_b - 1]l_{1,b} \geq -p_2 v_b l_0 - \omega_{1,b} l_0 + (1-p_2)a_{1,b}. \tag{36}$$

In what follows, we ignore the restriction (36). We discuss below that it is always met when the banker actually chooses $m_{1,b} = r$.

A.2.2.3 Failure Mode Suppose the banker operates in the failure mode $m_{1,b} = f$ by closing the bank in the bad state at $t = 1$. Then it follows that

$$\pi^{f}_{1,b} = 0. \tag{37}$$

A.2.3 Determination of Optimal Loan Volumes at $t = 1$

In the next step, we determine the optimal loan volume for all modes feasible.

A.2.3.1 Safe Mode Suppose the banker operates in the safe mode. It follows from (33) that $\frac{\partial \pi^s_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}\left(l_{1,b}\right)$, which is decreasing in $l_{1,b}$ and equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. Moreover, $\frac{\partial \pi^s_{1,b}}{\partial a_{1,b}} = 0$ and, as $(1-\lambda)\, p_2 r_b < 1$, the LHS of (34) is positive whereas the RHS can be positive or negative. We can conclude that the optimal loan volume $l^{s*}_{1,b}$ and the expected profit $\pi^{s*}_{1,b}$ will have the following properties:

$$l^{s*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}, \tag{38}$$

$$\pi^{s*}_{1,b} = \left(v_b + \omega_{1,b}\right) l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}\right), \tag{39}$$

where $l^{\max}_1$ is defined by

$$l^{\max}_1 := \frac{v_b + \omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0. \tag{40}$$

A.2.3.2 Risky Mode Suppose the banker operates in the risky mode. In this case, it follows from (35) that $\frac{\partial \pi^r_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}\left(l_{1,b}\right)$, which is decreasing in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. Moreover, it follows that $\frac{\partial \pi^r_{1,b}}{\partial a_{1,b}} = -(1-p_2)$. We can conclude that the optimal loan volume $l^{r*}_{1,b}$ and the expected profit $\pi^{r*}_{1,b}$ will have the following properties:

$$l^{r*}_{1,b} = l^{\text{fb}}_{1,b}, \tag{41}$$

$$\pi^{r*}_{1,b} = \left(p_2 v_b + \omega_{1,b}\right) l_0 + \phi_{1,b}\left(l^{\text{fb}}_{1,b}\right). \tag{42}$$

A.2.3.3 Failure Mode Suppose the banker operates in the failure mode. By definition, the optimal loan volume $l_{1,b}^{f*}$ and the expected profit $\pi_{1,b}^{f*}$ will have the following properties:

$$l_{1,b}^{f*} = 0, \tag{43}$$

$$\pi_{1,b}^{f*} = 0. \tag{44}$$

A.2.4 Comparison

1. If $v_b + \omega_{1,b} > 0$, it follows from (39) and (44) that $\pi_{1,b}^{s*} \geq \pi_{1,b}^{f*} = 0$, so that the failure mode is never optimal. Comparing $\pi_{1,b}^{s*}$ as defined in (39) and $\pi_{1,b}^{r*}$ as defined in (42) yields that $\pi_{1,b}^{s*} \geq \pi_{1,b}^{r*}$ if

$$(1 - p_2)v_b l_0 + \phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_1^{\max}\right\}\right) \geq \phi_{1,b}\left(l_{1,b}^{\text{fb}}\right). \tag{45}$$

   As $l_1^{\max}$ increases in l_0, see (40), this condition holds for all $l_0 \geq l_0^{\min}$ as defined below in (51). For all $l_0 < l_0^{\min}$ it thus follows that $\pi_{1,b}^{r*} > \pi_{1,b}^{s*} > \pi_{1,b}^{f*}$.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing $\pi_{1,b}^{r*}$ as defined in (42) and $\pi_{1,b}^{f*}$ as defined in (44) yields that $\pi_{1,b}^{r*} \geq \pi_{1,b}^{f*}$ if

$$(p_2 v_b + \omega_{1,b})\, l_0 \geq -\phi_{1,b}\left(l_{1,b}^{\text{fb}}\right). \tag{46}$$

   As the LHS is decreasing in l_0, this condition holds for all $l_0 \leq l_0^{\max}$ as defined in (49) below. For all $l_0 > l_0^{\max}$ it follows that $\pi_{1,b}^{f*} > \pi_{1,b}^{r*}$.

We obtain

Lemma 2: *If the economy is in the bad state at date $t = 1$, the banker's optimal decision on the mode of operation, $m_{1,b}^*$, bank loan supply, $l_{1,b}^*$, and his expected profit $\pi_{1,b}^*$ will have the following properties:*

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

$$\begin{aligned} m^*_{1,b} &= s, \quad l^*_{1,b} = l^{fb}_{1,b}, \quad \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if } \; l_0 \geq \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} &= s, \quad l^*_{1,b} = l^{max}_1, \quad \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if } \; l_0 \in [l^{min}_0, \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} &= r, \quad l^*_{1,b} = l^{fb}_{1,b}, \quad \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \text{if } \; l_0 < l^{min}_0, \end{aligned} \tag{47}$$

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

$$\begin{aligned} m^*_{1,b} &= r, \quad l^*_{1,b} = l^{fb}_{1,b}, \quad \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \text{if } \; l_0 \leq l^{max}_0, \\ m^*_{1,b} &= f, \quad l^*_{1,b} = 0, \quad \pi^*_{1,b} = \pi^{f*}_{1,b} \quad \text{if } \; l_0 > l^{max}_0, \end{aligned} \tag{48}$$

where $\pi^{s*}_{1,b}$, $\pi^{s*}_{1,b}$ *and* $\pi^{s*}_{1,b}$ *are defined by* (39), (42) *and* (44), *respectively,*

$$l^{max}_0 := -\frac{\phi_{1,b}\left(l^{fb}_{1,b}\right)}{p_2 v_b + \omega_{1,b}}, \tag{49}$$

$$l^{max}_1 := \frac{v_b+\omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0, \tag{50}$$

and where l^{min}_0 *is implicitly defined by*

$$(1-p_2)v_b l_0 + \phi_{1,b}\left(l^{max}_1(l_0)\right) = \phi_{1,b}(l^{fb}_{1,b}). \tag{51}$$

A.3 First period

A.3.1 Optimization Problem

Unless the banker immediately closes the bank at the beginning of the first period, his optimization problem at $t = 0$ reads:

$$\max_{l_0, a_0, \delta_0 \in \mathbb{R}^+} \pi_0 = p_1 \pi_{1,g}(l^*_{1,g}) + (1-p_1)\,\pi_{1,b}(l^*_{1,b}) - c(l_0) \tag{52}$$

$$\text{s.t. } \; l_0 + a_0 = d_0 + e_0, \tag{53}$$

$$d_0 = \begin{cases} \delta_0 & \text{if } \; m_0 = s: \; m^*_{1,b} \neq f \\ p_1 \delta_0 & \text{if } \; m_0 = r: \; m^*_{1,b} = f \end{cases}, \tag{54}$$

$$e_0 = (1-\lambda) p_1 \omega_{1,g} l_0. \tag{55}$$

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 (53), 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 at $t = 1$ in the bad state. If they anticipate receiving the face value of deposits, δ_0, with certainty, which implies that the banker operates in the safe mode, $m_0 = s$, 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, $m_0 = r$, a bank run will occur in the bad state at $t = 1$. As the run happens with probability $1 - p_1$, depositors will provide only funds up to $p_1\delta_0$. Equation (55) reflects that shareholders provide an amount equal to their expected payoff at $t = 1$. Recall from above that in the good state at $t = 1$, shareholders will receive the share $1 - \lambda$ of the cash flow $\omega_{1,g}l_0 > 0$. In the bad state, in which the cash flow is negative, they will receive nothing. The banker's expected profit, π_0, is given by equation (52). With probability p_1, the economic conditions will be good at $t = 1$ and the banker's expected profit is $\pi_{1,g}(l^*_{1,g})$, as specified in Lemma 1. Otherwise the economic conditions are bad and the banker's expected profit equals $\pi_{1,b}(l^*_{1,b})$, as specified in Lemma 2. Granting loans again imposes private costs, $c(l_0)$, on the banker, depending on the volume of first-period loans, l_0.

A.3.2 Determination of Reduced Forms

Recall from Lemma 1 that the banker will always operate in the safe mode if economic conditions are good at $t = 1$. Therefore, we only have to consider all combinations feasible based on the modes available in the first period and in the bad state at $t = 1$.

A.3.2.1 Safe Mode $m = \mathcal{S}$ Suppose the banker operates in the safe mode independent of the date or state of the economy, so that $m_0 = s$ and $m^*_{1,b} = s$, or in short $m = \mathcal{S}$.

Inserting (54) and (55) in (53), solving for δ_0 and inserting the result in the definition of $\omega_{1,g} := v_g - \frac{\delta_0 - a_0}{l_0}$ and $\omega_{1,b} := -\frac{\delta_0 - a_0}{l_0}$ yields

$$\omega_{1,g} = \frac{v_g - 1}{1 - (1-\lambda)\, p_1} > 0, \tag{56}$$

$$\omega_{1,b} = -\frac{1 - (1-\lambda)\, p_1 v_g}{1 - (1-\lambda)\, p_1} < 0. \tag{57}$$

Moreover, inserting $\pi^*_{1,g}$ as defined in Lemma (1) and $\pi^*_{1,b}$ for $m^*_{1,b} = s$ as defined in Lemma (2) as well as $\omega_{1,g}$ and $\omega_{1,b}$ in (52) and $l_1^{\max}$ as defined in (50) yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{S}}(l_0) = \phi_0(l_0) + p_1 \phi_{1,g}(l^{\text{fb}}_{1,g}) + (1-p_1)\phi_{1,b}(\min\{l^{\text{fb}}_{1,b}, l_1^{\max}(l_0)\}). \tag{58}$$

$$\text{with} \quad l_1^{\max} = \frac{\mu - 1 - \lambda p_1 \Delta}{[1-(1-\lambda)p_1][1-(1-\lambda)p_2 r_b]} l_0 =: \psi l_0. \tag{59}$$

A.3.2.2 Risky Mode $m = \mathcal{R}$ Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if economic conditions are bad at $t = 1$, so that $m_0 = s$ and $m^*_{1,b} = r$, or in short $m = \mathcal{R}$. Inserting $\pi^*_{1,g}$ as defined in Lemma (1) and $\pi^*_{1,b}$ for $m^*_{1,b} = r$ as defined in Lemma (2) as well as $\omega_{1,g}$ and $\omega_{1,b}$ in (52) and in the restriction on l_0, $l_0^{\max}$, as defined in (49) yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{R}}(l_0) = \phi_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta) l_0$$

$$+ p_1 \phi_{1,g}(l^{\text{fb}}_{1,g}) + (1-p_1)\phi_{1,b}(l^{\text{fb}}_{1,b}) \tag{60}$$

$$\text{s.t.} \quad l_0 \leq \frac{\phi_{1,b}\left(l^{\text{fb}}_{1,b}\right)}{\frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1} - p_2(\mu - p_1\Delta)} =: l_0^{\max}. \tag{61}$$

A.3.2.3 Failure Mode $m = \mathcal{F}$ Suppose the banker operates in the risky mode straight away in the first period, which results in a bank run in the bad state at $t = 1$, so that $m_0 = r$ and $m^*_{1,b} = f$, or in short $m = \mathcal{F}$. Inserting (54) and (55) in (53), solving for δ_0 and inserting the result in the definition of $\omega_{1,g} := v_g - \frac{\delta_0 - a_0}{l_0}$ yields

$$\omega_{1,g} = \frac{p_1 v_g - 1}{p_1 \lambda} - \frac{(1-p_1)a_0}{l_0 \lambda} > 0. \tag{62}$$

Moreover, inserting $\pi^*_{1,g}$ as defined in Lemma (1) and $\pi^*_{1,b}$ for $m^*_{1,b} = f$ as defined in Lemma (2) as well as $\omega_{1,g}$ in (52) yields

$$\max_{l_0,a_0\in\mathbb{R}^+} \pi_0^{\mathcal{F}}(l_0) = \phi_0(l_0) - (1-p_1)(\mu - p_1\Delta)l_0 - (1-p_1)a_0 + p_1\phi_{1,g}(l^{\text{fb}}_{1,g}) \tag{63}$$

$$\text{s.t.}\;\; l_0 > l_0^{\max}. \tag{64}$$

A.3.3 Determination of Optimal Loan Volumes at $t = 0$

A.3.3.1 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{A}$ Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{S}$. It follows from (58) that $\frac{\partial\pi_0^{\mathcal{S}}}{\partial l_0} = \phi_0'(l_0)$, 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 risk Δ affect the optimal loan volumes. Due to the mean preserving spread we can conclude that $\frac{\partial l_0^{\text{fb}}}{\partial\Delta} = 0$.

A.3.3.2 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{B}$ 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 state at $t = 1$, i.e. (59) becomes binding. It follows from (58) that

$$\frac{\partial\pi_0^{\mathcal{S}}}{\partial l_0} = \phi_0'(l_0) + (1-p_1)\phi_{1,b}'(l_1^{\max})\frac{\partial l_1^{\max}}{\partial l_0}. \tag{65}$$

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 bad state at $t = 1$ 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 (65) 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 risk Δ affect the optimal loan volume $l_0^{\mathcal{S}}$, i.e. $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta}$, we define the function, $F^{\mathcal{B}}$, as the first order condition of $\pi_0^{\mathcal{S}}(l_0)$ with respect to l_0:

$$F^{\mathcal{B}} := \left[\mu - 1 - \frac{\partial c}{\partial l_0^{\mathcal{S}}}\right] + (1-p_1)\left[p_2 r_b - 1 - \frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}\right]\psi = 0. \tag{66}$$

Applying the implicit function theorem yields $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta} = -\frac{\frac{\partial F^{\mathcal{B}}}{\partial \Delta}}{\frac{\partial F^{\mathcal{B}}}{\partial l_0^{\mathcal{S}}}}$. It follows that $\frac{\partial F^{\mathcal{B}}}{\partial \Delta} = (1-p_1)\phi'_{1,b}(l_1^{\max})\frac{\partial \psi}{\partial \Delta} - (1-p_1)\psi\frac{\partial c(l_1^{\max})}{\partial l_1^{\max}}\frac{\partial l_1^{\max}}{\partial \Delta}$ 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 risks are small, $\frac{\partial F^{\mathcal{B}}}{\partial \Delta}$ will be positive. For small risks the first term is negative due to $\frac{\partial \psi}{\partial \Delta} < 0$ but close to zero as $l_1^{\max}$ is close to $l_{1,b}^{\text{fb}}$, while the second term is positive due to $\frac{\partial l_1^{\max}}{\partial \Delta} < 0$ and sufficiently large as ψ is large for small risks. If the risk is, however, high, then $\frac{\partial F^{\mathcal{B}}}{\partial \Delta}$ will be negative. For larger 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 $l_{1,b}^{\text{fb}}$ increases. We can thus conclude that $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta}$ is positive for smaller risks and negative for larger risks.

A.3.3.3 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{C}$ Suppose the banker operates according to strategy $\mathcal{C}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{R}$. It follows from (60) that

$$\frac{\partial \pi_0^{\mathcal{R}}}{\partial l_0} = [1-(1-p_1)(1-p_2)]\mu + (1-p_1)(1-p_2)p_1\Delta - 1 - c'(l_0), \tag{67}$$

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 risk, Δ, affect the optimal loan volume, l_0^*, i.e. $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta}$, we define the function, $F^{\mathcal{C}}$, as the first order condition of $\pi_0^{\mathcal{R}}(l_0)$ with respect to l_0 for $l_0^{\mathcal{R}}$:

$$F^{\mathcal{C}} := [1-(1-p_1)(1-p_2)]\mu + (1-p_1)(1-p_2)p_1\Delta - 1 - c'(l_0^{\mathcal{R}}) = 0. \tag{68}$$

Applying the implicit function theorem yields $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta} = -\frac{\frac{\partial F^{\mathcal{C}}}{\partial \Delta}}{\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{R}}}}$. As $\frac{\partial F^{\mathcal{C}}}{\partial \Delta} = (1-p_1)(1-p_2)p_1 > 0$ and $\frac{\partial F^{\mathcal{C}}}{\partial l_0^{\mathcal{R}}} = -c''(l_0^{\mathcal{R}}) < 0$, we can conclude that $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta} > 0$.

A.3.3.4 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{D}$ Suppose the banker operates according to strategy $\mathcal{D}$, i.e. he faces a restriction on bank loan supply when operating according to $m = \mathcal{R}$, as (61) becomes binding. Hence the optimal loan volume is $l_0^* = l_0^{\max}$. It follows directly from (61) that $\frac{\partial l_0^{\max}}{\partial \Delta} < 0$, as $\lambda \in [0.5, 1)$ and $p_1, p_2 \in [0.6, 1)$.[19]

A.3.3.5 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}$ 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 economic conditions are bad at $t = 1$. It follows from (63) that $\frac{\partial \pi_0^{\mathcal{F}}}{\partial l_0} = \phi_0'(l_0) - (1 - p_1)(\mu - p_1 \Delta)$, which decreases in l_0 and is equal to zero for $l_0 = l_0^{\mathcal{F}}$. Hence the optimal loan volume is $l_0^* = l_0^{\mathcal{F}}$.

In order to determine how changes of the risk, Δ, affect the optimal loan volume $l_0^{\mathcal{F}}$, i.e. $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta}$, we define the function, $F^{\mathcal{E}}$, as the first order condition of $\pi_0^{\mathcal{F}}(l_0)$ with respect to l_0:

$$F^{\mathcal{E}} := p_1 \left(\mu + (1 - p_1)\,\Delta\right) - 1 - c'(l_0^{\mathcal{F}}) = 0. \tag{69}$$

Applying the implicit function theorem yields $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} = -\frac{\frac{\partial F^{\mathcal{E}}}{\partial \Delta}}{\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{F}}}}$. As $\frac{\partial F^{\mathcal{E}}}{\partial \Delta} = (1 - p_1)p_1 > 0$ and $\frac{\partial F^{\mathcal{E}}}{\partial l_0^{\mathcal{F}}} = -c''(l_0^{\mathcal{F}}) < 0$, we can conclude that $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} > 0$.

A.3.4 Critical Values of Δ

In a next step, we determine the optimal behavior of the banker for a given risk, Δ.

1. We denote $\Delta^{\mathcal{A}}$ 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 bad state at $t = 1$ as long as $l_0^{\text{fb}} \geq \frac{l_{1,b}^{\text{fb}}}{\psi}$. As the first best

[19] If the good state at $t = 1$ and $t = 2$ were quite unlikely, i.e. p_1 and p_2 were small, $\frac{\partial l_0^{\max}}{\partial \Delta}$ would be positive. For these risks, the restriction on bank loan supply 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, f, in the bad state at $t = 1$.

loan volumes l_0^{fb} and $l_{1,b}^{\text{fb}}$ are independent of Δ while ψ decreases in Δ, there exists a $\Delta^{\mathcal{A}}$ so that $\psi l_0^{\text{fb}} = l_{1,b}^{\text{fb}}$, which is given by

$$\Delta^{\mathcal{A}} := \frac{[(1-\lambda)p_2 r_b - 1][1-(1-\lambda)p_1]}{\lambda p_1} \frac{l_{1,b}^{\text{fb}}}{l_0^{\text{fb}}} + \frac{\mu - 1}{\lambda p_1}. \tag{70}$$

As $\pi_0^{\mathcal{S}}(l_0^{\text{fb}}) \geq \pi_0^{\mathcal{S}}(l_0) > \pi_0^{\mathcal{R}}(l_0) > \pi_0^{\mathcal{F}}(l_0)$, it is never optimal for the banker to switch to another strategy for all $\Delta \leq \Delta^{\mathcal{A}}$.

2. We denote $\Delta^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}$ and strategy $\mathcal{C}$. For $\Delta = \Delta^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{S}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{R}}(l_0) > \pi_0^{\mathcal{F}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\text{fb}})}{\partial \Delta} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta} = 0$, the expected profit from strategy $\mathcal{B}$ decreases in Δ, as (58) shows. It follows that $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} \frac{\partial l_0^{\mathcal{S}}}{\partial \Delta} + \frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} \frac{\partial l_1^{\max}}{\partial \Delta} < 0$, as $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} = 0$, $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} > 0$ and $\frac{\partial l_1^{\max}}{\partial \Delta} < 0$. Moreover, it follows from (60) that $\frac{\partial \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_0^{\mathcal{R}} > 0$, as $\frac{\partial \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} = 0$. Accordingly, if there exists a unique $\Delta^{\mathcal{B}'} > \Delta^{\mathcal{A}}$ for which $\pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) = \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}})$, then the banker will prefer strategy $\mathcal{B}$ over strategies $\mathcal{C}$, $\mathcal{D}$ and $\mathcal{E}$ as $\pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) \geq \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}}) > \pi_0^{\mathcal{R}}(l_0^{\max}) > \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$ for all $\Delta \leq \Delta^{\mathcal{B}'}$, while for all $\Delta > \Delta^{\mathcal{B}'}$, the banker prefers strategy $\mathcal{C}$ over strategy $\mathcal{B}$ as $\pi_0^{\mathcal{R}}(l_0^{\mathcal{R}}) > \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})$. If such a $\Delta^{\mathcal{B}'}$ does not exist within $(\Delta^{\mathcal{A}}, \Delta^{\psi}]$, e.g. as $l_0^{\max}$ becomes binding for a $\Delta \leq \Delta^{\psi}$, the banker prefers strategy $\mathcal{B}$ as long as the safe mode is available in the bad state at $t = 1$, i.e. for all $\Delta \in (\Delta^{\mathcal{A}}, \Delta^{\psi}]$ so that

$$\Delta^{\mathcal{B}} := \min\{\Delta^{\mathcal{B}'}, \Delta^{\psi}\}. \tag{71}$$

3. We denote $\Delta^{\mathcal{C}}$ 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 loan supply is not restricted when operating according to $m = \mathcal{R}$. It follows from the definitions of $l_0^{\max}$ and v_b that the banker is indifferent between the two strategies if $l_0^{\mathcal{R}} = l_0^{\max}$, or if

$$\Delta^{\mathcal{C}} := \frac{\phi_{1,b}^r(l_{1,b}^{\text{fb}})[1-(1-\lambda)p_1]}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]l_0^{\mathcal{R}}} + \frac{\mu[p_2 + (1-\lambda)p_1(1-p_2)] - 1}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]}. \tag{72}$$

As long as $l_0^{\mathcal{R}} < l_0^{\max}$ it follows that $\pi_0^{\mathcal{R}}(l_0^{\mathcal{R}}) > \pi_0^{\mathcal{R}}(l_0^{\max}) > \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$ so that the banker prefers strategy $\mathcal{C}$ over strategies $\mathcal{D}$ and $\mathcal{E}$ for all $\Delta \leq \Delta^{\mathcal{C}}$. For all $\Delta > \Delta^{\mathcal{C}}$ strategy $\mathcal{C}$ is not feasible.

4. We denote $\Delta^{\mathcal{D}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}$ and strategy $\mathcal{E}$. It follows from (60) that $\frac{\partial \pi_0^{\mathcal{R}}(l_0^{\max})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{R}}(l_0^{\max})}{\partial l_0^{\max}} \frac{\partial l_0^{\max}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_0^{\max}$, which is negative for larger risks due to $\frac{\partial \pi_0^{\mathcal{R}}(l_0^{\max})}{\partial l_0^{\max}} > 0$ and $\frac{\partial l_0^{\max}}{\partial \Delta} < 0$. Moreover, it follows from (63) that $\frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} \frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} + p_1(1-p_1)l_0^{\mathcal{F}} > 0$ as $\frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} = 0$. Hence, there exists a unique $\Delta^{\mathcal{D}} > \Delta^{\mathcal{C}} > \Delta^{\mathcal{B}} > \Delta^{\mathcal{A}}$ for which $\pi_0^{\mathcal{R}}(l_0^{\max}) = \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$ so that for all $\Delta \leq \Delta^{\mathcal{D}}$, the banker prefers strategy $\mathcal{D}$ over strategy $\mathcal{E}$ as $\pi_0^{\mathcal{R}}(l_0^{\max}) > \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$, while for all $\Delta > \Delta^{\mathcal{D}}$, the banker prefers $\mathcal{E}$ over $\mathcal{D}$ due to $\pi_0^{\mathcal{F}}(l_0^{\mathcal{F}}) > \pi_0^{\mathcal{R}}(l_0^{\max})$.

B Proof of Proposition 2

This proof proceeds in the same three steps as the proof of Proposition 1, whereas Lemma 3 reflects the banker's optimal behavior in the good state at $t = 1$ and Lemma 4 the one of the bad state. However, for each step we can skip the banker's optimization problem as these are given in the proof of Proposition 1.

B.1 Second Period ($t = 1$), Good State

As the regulator is able to identify that the economy is in the good state, the risk weight for all loans are zero so that the risk-weighted capital-to-asset ratio becomes irrelevant. The banker's behavior is thus identical to the benchmark scenario, see the proof of Lemma 1. We obtain

Lemma 3: *Let* $\mathbb{K} := \left[1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}, \min\left\{1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}, 1 - \frac{1-(1-\lambda)p_1\mu_1}{1-(1-\lambda)p_1}\right\}\right]$. *If the economy is in the good state at date* $t = 1$ *and* $\mathbb{K} \neq \emptyset$,[20] *the banker's optimal response to CAR for all* $\kappa \in \mathbb{K}$ *is characterized by*

$$m_{1,g}^* = s, \quad l_{1,g}^* = l_{1,b}^{fb}, \quad \pi_{1,g}^* = \pi_{1,g}^{s*} \quad \forall\ l_0. \tag{73}$$

[20]As long as μ is sufficiently larger than r_b, $\mathbb{K}$ is non-empty.

where $\pi_{1,g}^{s*}$ *is defined by* (25).

B.2 Second Period ($t = 1$), Bad State

B.2.1 Determination of Reduced Forms

B.2.1.1 Safe Mode Suppose the banker operates in the safe mode $m_{1,g} = s$. The regulator aims to impose capital requirements, which will not affect bank loan supply given that the bank is already stable. The capital requirement imposes a restriction

$$\delta_{1,b} \leq (1-\kappa)(l_0 + l_{1,b}) + a_{1,b} \tag{74}$$

on the face value of deposits. Inserting (31) and (32) in (30), solving for $\delta_{1,b}$, and inserting the result in (74) yields

$$[1-(1-\lambda)p_2 r_b - \lambda(1-\kappa)]l_{1,b} \leq [(1-\lambda)v_b + \lambda(1-\kappa) + \omega_{1,b})]\, l_0. \tag{75}$$

We will show below that as long as $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu}{1-(1-\lambda)p_1}$, the RHS of (75) is positive. Moreover, restricting the capital ratio to $\kappa < 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda}$ results in a negative LHS of (75). Hence, (75) never binds and the relevant restriction for the face value of deposits, when operating in the safe mode, is still $\delta_{1,b} \leq v_b l_0 + a_{1,b}$. Inserting (31) and (32) in (30), solving for $\delta_{1,b}$, and inserting the result in (29) and the restriction on $\delta_{1,b}$ in (31) thus yields again

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi_{1,b}^{s} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) \tag{76}$$

$$\text{s. t.} \quad [1-(1-\lambda)p_2 r_b]l_{1,b} \leq (v_b + \omega_{1,b})l_0. \tag{77}$$

B.2.1.2 Risky Mode Suppose the banker operates in the risky mode. The regulator aims to impose a binding restriction on bank loan supply for this mode. The capital requirement imposes a restriction (74) on the face value of deposits. Inserting (31) and (32) in (30), solving for $\delta_{1,b}$, and inserting the result in (29) and (74) yields

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^r_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) - (1-p_2)a_{1,b} \tag{78}$$

$$\text{s. t.} \quad [1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)]\, l_{1,b} \leq [(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}]\, l_0. \tag{79}$$

B.2.1.3 Failure Mode Suppose the banker operates in the failure mode by closing the bank already in the bad state at $t = 1$. Then it follows that

$$\pi^f_{1,b} = 0. \tag{80}$$

B.2.2 Determination of Optimal Loan Volumes at $t = 1$

B.2.2.1 Safe Mode Suppose the banker operates in the safe mode. It follows from (76) that $\frac{\partial \pi^s_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}\,(l_{1,b})$, 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 loan supply (77), we can conclude that the optimal loan volume $l^{s*}_{1,b}$ and the expected profit $\pi^{s*}_{1,b}$ will have the following properties:

$$l^{s*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}, \tag{81}$$

$$\pi^{s*}_{1,b} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}\right), \tag{82}$$

where $l^{\max}_1$ is defined by (40).

B.2.2.2 Risky Mode Suppose the banker operates in the risky mode. It follows from (78) that $\frac{\partial \pi^r_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}\,(l_{1,b})$, which decreases in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. If $\kappa > 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}$, bank loan supply will potentially be restricted. Considering this restriction (79), we can conclude that the optimal loan volume $l^{r*}_{1,b}$ and the expected profit $\pi^{r*}_{1,b}$ will have the following properties:

$$l^{r*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\}, \tag{83}$$

$$\pi^{r*}_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\}\right). \tag{84}$$

with

$$l_{1,\kappa}^{\max} := \frac{[(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}]}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)} l_0. \tag{85}$$

B.2.2.3 Failure Mode Suppose the banker operates in the failure mode. By definition, the optimal loan volume $l_{1,b}^{f*}$ and the expected profit $\pi_{1,b}^{f*}$ will have the following properties:

$$l_{1,b}^{f*} = 0, \tag{86}$$

$$\pi_{1,b}^{f*} = 0. \tag{87}$$

B.2.3 Critical Values of l_0

1. If $v_b + \omega_{1,b} \geq 0$, it follows from (82) and (87) that $\pi_{1,b}^{s*} \geq \pi_{1,b}^{f*}$ so that the failure mode is never optimal. Comparing $\pi_{1,b}^{s*}$ as defined in (82) and $\pi_{1,b}^{r*}$ as defined in (84) yields $\pi_{1,b}^{s*} \geq \pi_{1,b}^{r*}$ if

$$(1-p_2)v_b l_0 + \phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_1^{\max}(l_0)\right\}\right) \geq \phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}(l_0)\right\}\right). \tag{88}$$

   As both $l_1^{\max}$ and $l_{1,\kappa}^{\max}$ increase in l_0, this condition holds for all $l_0 \geq l_{0,\kappa}^{\min}$, as defined below in (94). For all $l_0 \in (0, l_{0,\kappa}^{\min})$ it thus follows that $\pi_{1,b}^{r*} > \pi_{1,b}^{s*} > \pi_{1,b}^{f*}$. For $l_0 = 0$ neither the safe mode nor the risky mode is available with a positive loan volume. The banker thus grants no loans at all so that $\pi_{1,b}^{s*} = 0$.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that granting loans in the safe mode is not available. Comparing $\pi_{1,b}^{r*}$ as defined in (84) and $\pi_{1,b}^{f*}$ as defined in (87) yields that $\pi_{1,b}^{r*} \geq \pi_{1,b}^{f*}$ if

$$(p_2 v_b + \omega_{1,b})\, l_0 \geq -\phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\right\}\right). \tag{89}$$

   Hence, this condition holds for all $l_0 \in (0, l_{0,\kappa}^{\max}]$, with $l_{0,\kappa}^{\max}$ defined below in (92). For all $l_0 > l_{0,\kappa}^{\max}$ it follows that $\pi_{1,b}^{f*} > \pi_{1,b}^{r*}$. 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 safe mode and $\pi^{s*}_{1,b} = 0$.

We obtain

Lemma 4: *If the economy is in the bad state at date $t = 1$ and CAR with $k \in \mathbb{K} \neq \emptyset$ is in place, the banker's decision on the mode of operation, $m^*_{1,b}$, bank loan supply, $l^*_{1,b}$, and his expected profit $\pi^*_{1,b}$ will have the following properties:*

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

$$\begin{aligned}
&m^*_{1,b} = s, \quad l^*_{1,b} = l^{fb}_{1,b}, && \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if} \quad l_0 \geq \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\
&m^*_{1,b} = s, \quad l^*_{1,b} = l^{max}_1, && \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if} \quad l_0 \in [l^{min}_{0,\kappa}, \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\
&m^*_{1,b} = r, \quad l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}\}, && \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \text{if} \quad l_0 \in (0, l^{min}_{0,\kappa}), \\
&m^*_{1,b} = s, \quad l^*_{1,b} = 0, && \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if} \quad l_0 = 0,
\end{aligned} \tag{90}$$

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

$$\begin{aligned}
&m^*_{1,b} = s, \quad l^*_{1,b} = 0, && \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if} \quad l_0 = 0, \\
&m^*_{1,b} = r, \quad l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}\}, && \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \text{if} \quad l_0 \in (0, l^{max}_{0,\kappa}], \\
&m^*_{1,b} = f, \quad l^*_{1,b} = 0, && \pi^*_{1,b} = \pi^{f*}_{1,b} \quad \text{if} \quad l_0 > l^{max}_{0,\kappa},
\end{aligned} \tag{91}$$

where $\pi^{s*}_{1,b}$, $\pi^{s*}_{1,b}$ and $\pi^{s*}_{1,b}$ are defined by (82)*,* (84) *and* (87)*, respectively,*

$$l^{max}_{0,\kappa} := -\frac{\phi_{1,b}\left(\min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}\}\right)}{p_2 v_b + \omega_{1,b}}, \tag{92}$$

$$l^{max}_{1,\kappa} := \frac{(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)} l_0, \tag{93}$$

and where $l^{min}_{0,\kappa}$ is implicitly defined by

$$(1 - p_2)v_b l_0 + \phi_{1,b}\left(l^{max}_1(l_0)\right) = \phi_{1,b}(\min\{l^{fb}_{1,b}, l^{max}_{1,\kappa}(l_0)\}). \tag{94}$$

B.3 First Period

B.3.1 Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in the good state at $t = 1$, we again only have to consider all combinations feasible based on the modes available in the first period and in the bad state at $t = 1$.

B.3.1.1 Safe Mode $m = \mathcal{S}$ Suppose the banker operates in the safe mode independent of the date or state of the economy, so that $m_0 = s$ and $m^*_{1,b} = s$, or in short $m = \mathcal{S}$. We stated in the text that capital requirements impose no additional restriction on bank loan supply in the safe mode. Capital requirements will impose an additional restriction on the face value of the deposits if (11) becomes binding. In this case, inserting this restriction on deposits, as well as the amount provided by depositors (54) and shareholders (55) into the budget constraint (53), yields

$$\frac{1-(1-\lambda)p_1 v_g}{1-(1-\lambda)p_1} l_0 \leq (1-\kappa) l_0. \tag{95}$$

As $v_g = \mu + (1-p_1)\Delta$, this condition will hold for all risks if $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu}{1-(1-\lambda)p_1}$. Therefore capital requirements impose no restriction on bank loan supply and the reduced form of the optimization problem, when operating according to $m = \mathcal{S}$, is identical to (58) and (59).

B.3.1.2 Risky Mode $m = \mathcal{R}$ Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if economic conditions are bad at $t = 1$, so that $m = \mathcal{R}$. In conjunction with Lemma 3 and 4, inserting the funds provided by depositors (54) and shareholders (55) into the budget constraint (53), and making use of the definition of ϕ_t and (2) when applying the budget constraint to the expected profit (52), yields

$$\max_{l_0,a_0\in\mathbb{R}^+} \pi^{\mathcal{R}}_{0,\kappa}(l_0) = \phi_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta)l_0$$

$$+ p_1\phi_{1,g}(l^{\text{fb}}_{1,g}) + (1-p_1)\phi_{1,b}(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\}) \tag{96}$$

$$\text{s.t.}\ \ l_0 \leq \frac{\phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\}\right)}{\frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1} - p_2(\mu - p_1\Delta)} =: l^{\max}_{0,\kappa} \tag{97}$$

with

$$l^{\max}_{1,\kappa} := \psi_\kappa l_0 \tag{98}$$

and

$$\psi_\kappa := \frac{\frac{(1-\lambda)(p_1+p_2[1-(1-\lambda)p_1])\mu+(1-\lambda)p_1(1-p_1-p_2[1-(1-\lambda)p_1])\Delta-1}{1-(1-\lambda)p_1} + \lambda p_2(1-\kappa)}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)}. \tag{99}$$

B.3.1.3 Failure Mode $m = \mathcal{F}$ Suppose the banker operates in the risky mode in the first period, which results in a bank run in the bad state at $t = 1$, so that $m = \mathcal{F}$. 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 (54) and shareholders (55) into the budget constraint (53), yields

$$[1 - (1-\lambda)p_1 v_g - \lambda p_1(1-\kappa)]l_0 \leq 0. \tag{100}$$

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 $\kappa < 1 - \frac{1-(1-\lambda)p_1[\mu+(1-p_1)\Delta]}{\lambda p_1}$, a sufficient amount of deposits will be issued so that bank loan supply is feasible and unrestricted. As this threshold depends on the risk, Δ, imposing a regulatory capital ratio, κ, implies that the risky mode at $t = 0$ is feasible for all

$$\Delta \geq \frac{1 - \lambda p_1 - (1-\lambda)p_1\mu + \lambda p_1\kappa}{(1-\lambda)p_1(1-p_1)} =: \Delta^{\mathcal{E}}_\kappa. \tag{101}$$

For all these risks the reduced form changed only slightly compared with (63) and (64). In conjunction with Lemma 3 and 4, inserting the funds provided by depositors (54) and shareholders (55) into the budget constraint (53), and making use of the definition of ϕ_t when applying the budget constraint to the expected profit (52), yields

$$\max_{l_0,a_0\in\mathbb{R}^+} \pi_0^{\mathcal{F}}(l_0) = \phi_0(l_0) - (1-p_1)(\mu - p_1\Delta)l_0 - (1-p_1)a_0 + p_1\phi_{1,g}(l_{1,g}^{\text{fb}}) \tag{102}$$

$$\text{s.t.} \quad l_0 > l_{0,\kappa}^{\max}. \tag{103}$$

B.3.2 Determination of Optimal Loan Volumes at $t = 0$

B.3.2.1 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{A}$ Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{S}$. As the reduced form is identical to (58) we can likewise conclude that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta} = 0$.

B.3.2.2 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{B}_{CAR}$ Suppose the banker operates according to strategy $\mathcal{B}_{CAR}$, i.e. the restriction on bank loan supply becomes binding when operating according to $m = \mathcal{S}$. As the reduced form is identical to (58) and (59), 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 $\frac{\partial \pi_0^{\mathcal{S}}}{\partial l_0}$ 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 risk if Δ is small but will decrease if Δ is large.

B.3.2.3 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{X}_{CAR}$ Suppose the banker operates according to strategy $\mathcal{X}_{CAR}$, i.e. bank loan supply is so heavily restricted when operating according to $m = \mathcal{S}$ that he cannot grant any loans neither in the first period nor in the bad state at $t = 1$. By definition this implies that the optimal loan volume is $l_0^* = 0$.

B.3.2.4 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{C}_{CAR}$ Suppose the banker operates according to strategy $\mathcal{C}_{CAR}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{R}$. It follows from (96) that

$$\begin{aligned}\frac{\partial \pi_0^{\mathcal{R}}}{\partial l_0} &= \phi_0'(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta) \\ &\quad + (1-p_1)\phi_{1,b}'(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\})\frac{\partial \min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}}{\partial l_0}. \qquad (104)\end{aligned}$$

Note that the first two terms decrease in l_0. The third term is equal to zero as long as bank loan supply is not restricted in the bad state at $t = 1$. If bank loan supply is restricted in this bad state, 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 $l_0 = l_0^{\mathcal{R}}$, 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 bad state at $t = 1$ for $l_0^{\text{fb}} < \frac{l_{1,b}^{\text{fb}}}{\psi_\kappa}$. Consequently, there exists a $l_{0,\kappa}^{\mathcal{R}}$ with $l_{0,\kappa}^{\mathcal{R}} \in \left[l_0^{\mathcal{R}}, \frac{l_{1,b}^{\text{fb}}}{\psi_\kappa}\right]$ for which (104) is equal to zero, so that the optimal loan volume is $l_0^* = l_{0,\kappa}^{\mathcal{R}}$.

In order to determine how changes of the risk, Δ, affect the optimal loan volume, $l_{0,\kappa}^{\mathcal{R}}$, i.e. $\frac{\partial l_{0,\kappa}^{\mathcal{R}}}{\partial \Delta}$, we can conclude from (68) that $\frac{\partial l_{0,\kappa}^{\mathcal{R}}}{\partial \Delta} > 0$ as long as $l_{0,\kappa}^{\mathcal{R}} = l_0^{\mathcal{R}}$. If bank loan supply is restricted in the bad state at $t = 1$, we define the function, $F_\kappa^{\mathcal{C}}$, as the first order condition of $\pi_{0,\kappa}^{\mathcal{R}}(l_0)$ with respect to l_0 for $l_{0,\kappa}^{\mathcal{R}}$:

$$\begin{aligned}F_\kappa^{\mathcal{C}} &:= [1-(1-p_1)(1-p_2)]\mu + (1-p_1)(1-p_2)p_1\Delta - 1 - \frac{\partial c}{\partial l_{0,\kappa}^{\mathcal{R}}} \\ &\quad + (1-p_1)\left[p_2 r_b - 1 - \frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}\right]\psi = 0. \qquad (105)\end{aligned}$$

Applying the implicit function theorem yields $\frac{\partial l_{0,\kappa}^{\mathcal{R}}}{\partial \Delta} = -\frac{\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta}}{\frac{\partial F_\kappa^{\mathcal{C}}}{\partial l_{0,\kappa}^{\mathcal{R}}}}$. It follows that $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta} = (1-p_1)(1-p_2)p_1 + (1-p_1)\phi_{1,b}'(l_{1,\kappa}^{\max})\frac{\partial \psi_\kappa}{\partial \Delta} - (1-p_1)\psi_\kappa \frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}\frac{\partial l_{1,\kappa}^{\max}}{\partial \Delta}$ and $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial l_{0,\kappa}^{\mathcal{R}}} = -\frac{\partial^2 c(l_{0,\kappa}^{\mathcal{R}})}{\partial {l_{0,\kappa}^{\mathcal{R}}}^2} - (1-p_1)\frac{\partial c(l_{1,\kappa}^{\max})}{\partial l_{1,\kappa}^{\max}}\frac{\partial l_{1,\kappa}^{\max}}{\partial l_{0,\kappa}^{\mathcal{R}}}\psi_\kappa < 0$. If Δ is small, $\frac{\partial F_\kappa^{\mathcal{C}}}{\partial \Delta}$ will positive. For small risks the second term is negative due to $\frac{\partial \psi_\kappa}{\partial \Delta} < 0$ but close to zero, as $l_{1,\kappa}^{\max}$ is close to $l_{1,b}^{\text{fb}}$, while the third is positive due to $\frac{\partial l_{1,\kappa}^{\max}}{\partial \Delta} < 0$ and sufficiently large, as ψ_κ is large for small risks. The first term is always positive and constant. If the risks are large, $\frac{\partial F_{\kappa}^{\mathcal{C}}}{\partial \Delta}$ will be negative. For larger 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 $\frac{\partial l_{0,\kappa}^{\mathcal{R}}}{\partial \Delta}$ is positive for smaller risks and negative for larger risks.

B.3.2.5 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{D}_{CAR}$ Suppose the banker operates according to strategy $\mathcal{D}_{CAR}$, i.e. he faces a restriction on bank loan supply when operating according to $m = \mathcal{R}$, as (97) becomes binding. Hence the optimal loan volume is $l_0^* = l_{0,\kappa}^{\max}$. Due to $\frac{\partial l_{1,\kappa}^{\max}}{\partial \Delta} < 0$ and the results from the proof of Proposition 1 that $\frac{\partial l_0^{\max}}{\partial \Delta} < 0$, we can directly conclude that $\frac{\partial l_{0,\kappa}^{\max}}{\partial \Delta} < 0$. Strategy $\mathcal{D}_{CAR}$ is feasible as long as $\psi_{\kappa} \geq 0$. In analogy to Δ^{ψ}, we define the risk for which $\psi_{\kappa} = 0$ as Δ_{κ}^{ψ}.

B.3.2.6 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}_{CAR}$ Suppose the banker operates according to strategy $\mathcal{E}_{CAR}$, i.e. he operates according to $m = \mathcal{F}$. As long as strategy $\mathcal{E}_{CAR}$ is feasible, i.e. for all $\Delta \geq \Delta_{\kappa}^{\mathcal{E}}$, (102) is identical to (63) so that the optimal loan volume is $l_0^* = l_0^{\mathcal{F}}$ with $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} > 0$.

B.3.3 Critical Values of Δ

In a next step, we determine the optimal behavior of the banker for a given risk Δ.

1. We have defined $\Delta^{\mathcal{A}}$ already in (70).

2. We denote $\Delta_{\kappa}^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}_{CAR}$ and strategy $\mathcal{C}_{CAR}$. Recall that for $\Delta = \Delta^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{S}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{R}}(l_0) > \pi_0^{\mathcal{F}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\text{fb}})}{\partial \Delta} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta} = 0$, the expected profit from strategy $\mathcal{B}_{CAR}$ decreases in Δ, i.e. $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial \Delta} < 0$. Moreover, it follows from (96) that $\frac{\partial \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}})}{\partial \Delta} = \frac{\partial \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}})}{\partial l_{0,\kappa}^{\mathcal{R}}} \frac{\partial l_{0,\kappa}^{\mathcal{R}}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_{0,\kappa}^{\mathcal{R}} > 0$, as $\frac{\partial \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}})}{\partial l_{0,\kappa}^{\mathcal{R}}} = 0$. Accordingly, if there exists a unique $\Delta_{\kappa}^{\mathcal{B}'} > \Delta^{\mathcal{A}}$ for which $\pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) = \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}})$, then the banker will prefer strategy $\mathcal{B}_{CAR}$ over strategies $\mathcal{C}_{CAR}$, $\mathcal{D}_{CAR}$ and $\mathcal{E}_{CAR}$ as $\pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) \geq \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}}) > \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max}) > \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$ for all $\Delta \leq \Delta_{\kappa}^{\mathcal{B}'}$, while for all $\Delta > \Delta_{\kappa}^{\mathcal{B}'}$, the banker prefers strategy $\mathcal{C}_{CAR}$ over strategy $\mathcal{B}_{CAR}$ as $\pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}}) > \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})$. If such a $\Delta_{\kappa}^{\mathcal{B}'}$ does not exist within $(\Delta^{\mathcal{A}}, \Delta^{\psi}]$, e.g. as $l_{0,\kappa}^{\max}$ becomes binding for a $\Delta \leq \Delta^{\psi}$, the banker prefers

strategy $\mathcal{B}_{CAR}$ as long as the safe mode is available in the bad state at $t=1$, i.e. for all $\Delta \in (\Delta^{\mathcal{A}}, \Delta^{\psi}]$ so that

$$\Delta_\kappa^{\mathcal{B}} := \min\{\Delta_\kappa^{\mathcal{B}'}, \Delta^{\psi}\}. \tag{106}$$

3. We denote $\Delta_\kappa^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}_{CAR}$ and strategy $\mathcal{D}_{CAR}$, i.e. the highest risk level for which bank loan supply is not restricted when operating according to $m=\mathcal{R}$. It follows from the definitions of $l_{0,\kappa}^{\max}$ and v_b that the banker will be indifferent between the two strategies if $l_{0,\kappa}^{\mathcal{R}} = l_{0,\kappa}^{\max}$ or if

$$\Delta_\kappa^{\mathcal{C}} := \frac{\phi_{1,b}(\min\{l_{1,b}^{\mathrm{fb}}, l_{1,\kappa}^{\max}\})[1-(1-\lambda)p_1]}{p_1[p_2-(1-\lambda)(1-p_1(1-p_2))]l_{0,\kappa}^{\mathcal{R}}} + \frac{\mu[p_2+(1-\lambda)p_1(1-p_2)]-1}{p_1[p_2-(1-\lambda)(1-p_1(1-p_2))]}. \tag{107}$$

As long as $l_{0,\kappa}^{\mathcal{R}} < l_{0,\kappa}^{\max}$ it follows that $\pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\mathcal{R}}) > \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max}) > \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$ so that the banker prefers strategy $\mathcal{C}_{CAR}$ over strategies $\mathcal{D}_{CAR}$ and $\mathcal{E}_{CAR}$ for all $\Delta \le \Delta_\kappa^{\mathcal{C}}$. For all $\Delta > \Delta_\kappa^{\mathcal{C}}$ strategy $\mathcal{C}_{CAR}$ is not feasible.

4. We denote $\Delta_\kappa^{\mathcal{D}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}_{CAR}$ and strategy $\mathcal{E}_{CAR}$. It follows from (96) that $\frac{\partial \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max})}{\partial \Delta} = \frac{\partial \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max})}{\partial l_{0,\kappa}^{\max}} \frac{\partial l_{0,\kappa}^{\max}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_{0,\kappa}^{\max}$, which is negative for sufficiently large Δ as $\frac{\partial \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max})}{\partial l_{0,\kappa}^{\max}} > 0$ and $\frac{\partial l_{0,\kappa}^{\max}}{\partial \Delta} < 0$. Recall from (63) in the proof of Proposition 1 that $\frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} \frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} + p_1(1-p_1)l_0^{\mathcal{F}} > 0$ as $\frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} = 0$. Accordingly, if there exists a unique $\Delta_\kappa^{\mathcal{D}} > \Delta_\kappa^{\mathcal{C}} > \Delta_\kappa^{\mathcal{B}} > \Delta^{\mathcal{A}}$ for which $\pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max}) = \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$, the banker will prefer strategy $\mathcal{D}_{CAR}$ over strategy $\mathcal{E}_{CAR}$ as $\pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max}) > \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})$ for all $\Delta \le \Delta_\kappa^{\mathcal{D}}$, while for all $\Delta > \Delta_\kappa^{\mathcal{D}}$, the banker prefers $\mathcal{E}_{CAR}$ over $\mathcal{D}_{CAR}$ due to $\pi_0^{\mathcal{F}}(l_0^{\mathcal{F}}) > \pi_{0,\kappa}^{\mathcal{R}}(l_{0,\kappa}^{\max})$. If such a $\Delta_\kappa^{\mathcal{D}}$ does not exist within $(\Delta_\kappa^{\mathcal{C}}, \Delta_\kappa^{\psi}]$, e.g. as capital requirements are so strict that $\Delta_\kappa^{\psi} < \Delta_\kappa^{\mathcal{E}}$, the banker will prefer strategy $\mathcal{D}_{CAR}$ as long as the risky mode is available in the bad state at $t=1$, i.e. for all $\Delta \in (\Delta_\kappa^{\mathcal{C}}, \Delta_\kappa^{\psi}]$. In this case, the banker will prefer strategy $\mathcal{X}_{CAR}$ for all $\Delta \in (\Delta_\kappa^{\psi}, \Delta_\kappa^{\mathcal{E}})$ and strategy $\mathcal{E}_{CAR}$ as soon as this strategy is feasible, i.e. for all $\Delta > \Delta_\kappa^{\mathcal{E}}$.

C Proof of Proposition 3

As this proof is to large extent a combination of the proofs of Propositions 1 and 2, we shorten this proof accordingly. The banker's optimal behavior in the good state at $t = 1$ is given by Lemma 3 whereas his optimal behavior in the bad state at $t = 1$ is given by Lemma 2. Therefore, we will only focus on the first period.

C.1 Determination of Reduced Forms

C.1.1 Safe Mode $m = \mathcal{S}$

Suppose the banker operates in the safe mode independent of the date or state of the economy, so that $m_0 = s$ and $m^*_{1,b} = s$, or in short $m = \mathcal{S}$. While $\kappa_b = 0$ implies that capital requirements impose no additional restriction on the face value of deposits in the bad state at $t = 1$, $\kappa_g > \kappa$ will result in a restriction on the face value in the first period if (11) becomes binding. It follows from (95) that the safe mode will be feasible if $\omega_{1,b} \leq 1 - \kappa$. Given that $\omega_{1,b} = \frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1}$, a countercyclical capital buffer $\kappa_g > 1 - \frac{1-(1-\lambda)p_1\mu}{1-(1-\lambda)p_1}$ implies that operating in the safe mode in the first period will only be feasible if

$$\Delta \geq \frac{1 - (1-\lambda)p_1\mu - [1-(1-\lambda)p_1](1-\kappa_g)]}{(1-\lambda)p_1(1-p_1)} =: \Delta^{\mathcal{Y}}_{\kappa_g}. \tag{108}$$

As long as this condition is fulfilled, the reduced form when operating according to $m = \mathcal{S}$ is identical to (60) and (61).

C.1.2 Risky Mode $m = \mathcal{R}$

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 bad state at $t = 1$, so that $m = \mathcal{R}$. Operating in the safe mode in the first period will only be feasible if $\Delta \geq \Delta^{\mathcal{Y}}_{\kappa_g}$. As the countercyclical capital requirements impose no restriction in the bad state at $t = 1$, we can conclude that the reduced form when operating according to $m = \mathcal{R}$ is identical to (60) and (61).

C.1.3 Safe Mode $m = \mathcal{F}$

Suppose the banker operates in the risky mode in the first period, which results in a bank run in the bad state at $t = 1$, so that $m = \mathcal{F}$. We obtained, in the proof of Proposition 2, the result that operating in the risky mode in the first period will be feasible if the risk, Δ, is sufficiently large. Replacing κ with κ_g, operating according to $m = \mathcal{F}$ is feasible for all $\Delta \geq \Delta^{\mathcal{E}}_{\kappa_g}$ with

$$\Delta^{\mathcal{E}}_{\kappa_g} := \frac{1 - \lambda p_1 - (1-\lambda)p_1\mu + \lambda p_1 \kappa_g}{(1-\lambda)p_1(1-p_1)}. \tag{109}$$

For all these risks, the reduced form is identical to (63) and (64), as bank loan supply is not restricted when the economy is in the bad state at $t = 1$.

C.2 Determination of Optimal Loan Volumes at $t = 0$

C.2.1 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{A}$

Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{S}$. As long as strategy $\mathcal{A}$ is feasible, the reduced form is identical to (58). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta} = 0$.

C.2.2 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{B}_{CCB}$

Suppose the banker operates according to strategy $\mathcal{B}_{CCB}$, i.e. the restriction on bank loan supply becomes binding when operating according to $m = \mathcal{S}$. As long as strategy $\mathcal{B}_{CCB}$ is feasible, the reduced form is identical to (58) and (59). 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 $\frac{\partial \pi_0^{\mathcal{S}}}{\partial l_0}$ 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 risk if Δ is small but will decrease if Δ is large.

C.2.3 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{C}_{CCB}$

Suppose the banker operates according to strategy $\mathcal{C}_{CCB}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{R}$. As long as strategy $\mathcal{C}_{CCB}$ is feasible, the reduced form is identical to (60) and (61). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\mathcal{R}}$ with $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta} > 0$.

C.2.4 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{D}_{CCB}$

Suppose the banker operates according to strategy $\mathcal{D}_{CCB}$, i.e. he faces a restriction on bank loan supply when operating according to $m = \mathcal{R}$, as (97) becomes binding. As long as strategy $\mathcal{D}_{CCB}$ is feasible, the reduced form is identical to (60) and (61). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\max}$ with $\frac{\partial l_0^{\max}}{\partial \Delta} < 0$.

C.2.5 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{Y}_{CCB}$

Suppose the banker operates according to strategy $\mathcal{Y}_{CCB}$, i.e. he cannot grant any loans when operating according to $m = \mathcal{R}$. Recall from Lemma 2 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 $l_0^* = 0$.

C.2.6 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}_{CCB}$

Suppose the banker operates according to strategy $\mathcal{E}_{CCB}$, i.e. he operates according to $m = \mathcal{F}$. As long as strategy $\mathcal{E}_{CCB}$ is feasible, the reduced form is identical to (63). We can thus likewise conclude that the optimal loan volume is $l_0^* = l_0^{\mathcal{F}}$ with $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} > 0$.

C.3 Critical Values of Δ

While $\Delta^{\mathcal{A}}$, $\Delta^{\mathcal{B}}$, $\Delta^{\mathcal{C}}$ and $\Delta^{\mathcal{D}}$ are defined in the proof of Proposition 1, it follows from the fact that $\Delta_{\kappa_g}^{\mathcal{Y}} < \Delta_{\kappa_g}^{\mathcal{E}}$ that the banker will have to operate according to strategy $\mathcal{Y}_{CCB}$ for all $\Delta \leq \Delta_{\kappa_g}^{\mathcal{Y}}$. Moreover, it follows from the definition of $\Delta_{\kappa_g}^{\mathcal{E}}$ that the banker will prefer to operate according to strategy $\mathcal{E}_{CCB}$ if both $\pi_0^{\mathcal{F}}(l_0^{\mathcal{F}}) > \pi_0^{\mathcal{R}}(l_0^{\max})$ and $\Delta \geq \Delta_{\kappa_g}^{\mathcal{E}}$.

D Proof of Proposition 4

This proof proceeds in the same three steps as the proof of Proposition 2.

D.1 Second Period ($t = 1$), Good State

The liquidity coverage ratio imposes no restriction on bank loan supply when operating in the safe mode. As in this case the risk-free asset yields a zero net return while depositors require a zero net return, the banker can fulfill any LCR by a balance sheet extension. As his optimal behavior in the safe mode with respect to granting loans remains unchanged, we can conclude

Lemma 5: *If the economy is in the good state at date $t = 1$, the banker's optimal response to LCR is characterized by*

$$m^*_{1,g} = s, \quad l^*_{1,g} = l^{fb}_{1,b}, \quad \pi^*_{1,g} = \pi^{s*}_{1,g} \quad \forall\ l_0, \tag{110}$$

where $\pi^{s*}_{1,g}$ is defined by (25).

D.2 Second Period ($t = 1$), Bad State

D.2.1 Determination of Reduced Forms

D.2.1.1 Safe Mode Suppose the banker operates in the safe mode. The liquidity coverage ratio will result in a restriction on the face value of deposits if

$$\frac{a_{1,b}}{\eta} \leq v_b l_0 + a_{1,b}. \tag{111}$$

Limiting the liquidity coverage ratio to $\eta \in (0, 1)$ implies that such a restriction is never binding. It follows from (33) 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 (111) 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. As in (33) and (34), the expected profit and the restriction on bank loan supply reads

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^s_{1,b} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) \tag{112}$$

$$\text{s.t.}\quad [1-(1-\lambda)p_2 r_b] l_{1,b} \leq (v_b + \omega_{1,b}) l_0. \tag{113}$$

D.2.1.2 Risky Mode 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 (35). 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 (31) and shareholders (32) into the budget constraint (30), and making use of (16) when applying the budget constraint to the expected profit (29), yields

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^r_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) - (1-p_2) a_{1,b} \tag{114}$$

$$\text{s.t.}\quad [1-(1-\lambda)p_2 r_b]\, l_{1,b} \leq [(1-\lambda)p_2 v_b + \omega_{1,b}]\, l_0 + \left[\frac{1-\eta}{\eta} - (1-p_2)\right] a_{1,b}. \tag{115}$$

D.2.1.3 Failure Mode Suppose the banker operates in the failure mode by closing the bank already in the bad state at $t = 1$. Then it follows again that

$$\pi^f_{1,b} = 0. \tag{116}$$

D.2.2 Determination of Optimal Loan Volumes at $t = 1$

D.2.2.1 Safe Mode Suppose the banker operates in the safe mode. We can thus directly conclude from the proof of Lemma 2 that the optimal loan volume $l^{s*}_{1,b}$ and the expected profit $\pi^{s*}_{1,b}$ will have the following properties:

$$l^{s*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}, \tag{117}$$

$$\pi^{s*}_{1,b} = (v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}\right). \tag{118}$$

D.2.2.2 Risky Mode Suppose the banker operates in the risky mode. It follows from (114) that $\frac{\partial \pi^r_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}(l_{1,b})$, 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 loan supply (115), the optimal loan volume $l^{r*}_{1,b}$ and the expected profit $\pi^{r*}_{1,b}$ will have the following properties:

$$l^{r*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}, \tag{119}$$

$$\pi^{r*}_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}\right) - (1-p_2)a_{1,b}, \tag{120}$$

with

$$l^{\max}_{1,\eta} := \psi_\eta l_0 + \xi_\eta a_{1,b} \tag{121}$$

where

$$\psi_\eta := \frac{(1-\lambda)p_2 v_b + \omega_{1,b}}{1-(1-\lambda)p_2 r_b} \tag{122}$$

and

$$\xi_\eta := \frac{\frac{1-\eta}{\eta}\lambda p_2 - (1-p_2)}{1-(1-\lambda)p_2 r_b}. \tag{123}$$

Comparing (122) with (40), 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 loan supply 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 loan supply. As this investment still corresponds with a negative expected profit, the optimal investment is determined by its first order condition

$$\frac{\partial \pi^r_{1,b}}{\partial a_{1,b}} = \phi'_{1,b}\left(l^{\max}_{1,\eta}\right)\frac{\partial l^{\max}_{1,\eta}}{\partial a_{1,b}} - (1-p_2). \tag{124}$$

In this case, the risky mode is feasible and the optimal loan volume is $l^*_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}$.

D.2.2.3 Failure Mode Suppose the banker operates in the failure mode. By definition, the optimal loan volume $l_{1,b}^{f*}$ and the expected profit $\pi_{1,b}^{f*}$ will have the following properties:

$$l_{1,b}^{f*} = 0, \tag{125}$$

$$\pi_{1,b}^{f*} = 0. \tag{126}$$

D.2.3 Critical Values of l_0

1. If $v_b + \omega_{1,b} \geq 0$, it follows from (118) and (126) that $\pi_{1,b}^{s*} \geq \pi_{1,b}^{f*}$, so that the failure mode is never optimal. Comparing $\pi_{1,b}^{s*}$ as defined in (118) and $\pi_{1,b}^{r*}$ as defined in (120) yields $\pi_{1,b}^{s*} \geq \pi_{1,b}^{r*}$ if

$$(1-p_2)(v_b l_0 + a_{1,b}) + \phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_1^{\max}\right\}\right) \geq \phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\right\}\right). \tag{127}$$

   As both $l_1^{\max}$ and $l_{1,\eta}^{\max}$ increase in l_0, this condition holds for all $l_0 \geq l_{0,\eta}^{\min}$, defined below in (133). For all $l_0 < l_{0,\eta}^{\min}$ it follows that $\pi_{1,b}^{r*} > \pi_{1,b}^{s*} > \pi_{1,b}^{f*}$.

2. If $v_b + \omega_{1,b} < 0$, it follows, due to $l_1^{\max} < 0$, that the safe mode is not available. Comparing $\pi_{1,b}^{r*}$ as defined in (120) and $\pi_{1,b}^{f*}$ as defined in (126) yields that $\pi_{1,b}^{r*} \geq \pi_{1,b}^{f*}$ if

$$(p_2 v_b + \omega_{1,b}) l_0 \geq -\phi_{1,b}\left(\min\left\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\right\}\right) + (1-p_2)a_{1,b}. \tag{128}$$

   Hence this condition holds for all $l_0 \leq l_{0,\eta}^{\max}$, defined below in (131). For all $l_0 > l_{0,\eta}^{\max}$ it follows that $\pi_{1,b}^{f*} > \pi_{1,b}^{r*}$.

We obtain

Lemma 6: *If the economy is in the bad state at date $t = 1$ and a LCR with $\eta < \frac{\lambda p_2}{1-(1-\lambda)p_2}$ is in place, the banker's optimal decision on the mode of operation, $m_{1,b}^*$, bank loan supply, $l_{1,b}^*$, and his expected profit $\pi_{1,b}^*$ will have the following properties:*

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

$$
\begin{aligned}
&m^*_{1,b} = s, \quad l^*_{1,b} = l^{fb}_{1,b}, && \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \textit{if} \;\; l_0 \geq \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\
&m^*_{1,b} = s, \quad l^*_{1,b} = l^{max}_{1}, && \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \textit{if} \;\; l_0 \in [l^{min}_{0,\eta}, \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\
&m^*_{1,b} = r, \quad l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\eta}\}, && \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \textit{if} \;\; l_0 \leq l^{min}_{0,\eta},
\end{aligned}
\tag{129}
$$

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

$$
\begin{aligned}
&m^*_{1,b} = r, \quad l^*_{1,b} = \min\{l^{fb}_{1,b}, l^{max}_{1,\eta}\}, && \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \textit{if} \;\; l_0 \leq l^{max}_{0,\eta}, \\
&m^*_{1,b} = f, \quad l^*_{1,b} = 0, && \pi^*_{1,b} = \pi^{f*}_{1,b} \quad \textit{if} \;\; l_0 > l^{max}_{0,\eta},
\end{aligned}
\tag{130}
$$

where $\pi^{s*}_{1,b}$, $\pi^{s*}_{1,b}$ and $\pi^{s*}_{1,b}$ are defined by (118), (120) *and* (126), *respectively,*

$$
l^{max}_{0,\eta} := -\frac{\phi_{1,b}\left(\min\{l^{fb}_{1,b}, l^{max}_{1,\eta}\}\right) - (1-p_2)a_{1,b}}{p_2 v_b + \omega_{1,b}}, \tag{131}
$$

$$
l^{max}_{1,\eta} := \frac{(1-\lambda)p_2 v_b + \omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0 + \frac{\frac{1-\eta}{\eta} - (1-p_2)}{1-(1-\lambda)p_2 r_b} a_{1,b}, \tag{132}
$$

and where $l^{min}_{0,\eta}$ is implicitly defined by

$$
(1-p_2)(v_b l_0 + a_{1,b}) + \phi_{1,b}\left(l^{max}_{1}(l_0)\right) = \phi_{1,b}(\min\{l^{fb}_{1,b}, l^{max}_{1,\eta}(l_0)\}). \tag{133}
$$

D.3 First Period

D.3.1 Determination of Reduced Forms

As the banker will always operate in the safe mode if the economy is in the good state at $t = 1$, we again only have to consider all combinations feasible based on the modes available in the first period and in the bad state at $t = 1$.

D.3.1.1 Safe Mode $m = \mathcal{S}$ Suppose the banker operates in the safe mode independent of the date or state of the economy, so that $m_0 = s$ and $m^*_{1,b} = s$, or in short $m = \mathcal{S}$. As the expected profit (58) 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 $m = \mathcal{S}$ is identical to (58) and (59).

D.3.1.2 Risky Mode $m = \mathcal{R}$ Suppose the banker still operates in the safe mode in the first period but will switch to the risky mode if economic conditions are bad at $t = 1$, so that $m = \mathcal{R}$. In conjunction with Lemma 5 and 6, inserting the funds provided by depositors (54) and shareholders (55) into the budget constraint (53), and making use of the definition of ϕ_t and (2) when applying the budget constraint to the expected profit (52), yields

$$\begin{aligned} \max_{l_0, a_0 \in \mathbb{R}^+} \pi^{\mathcal{R}}_{0,\eta}(l_0) = {} & \phi_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta)l_0 \\ & + p_1\phi_{1,g}(l^{\text{fb}}_{1,g}) + (1-p_1)\left[\phi_{1,b}(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}) - (1-p_2)a_{1,b}\right] \end{aligned} \tag{134}$$

$$\text{s.t.}\ \ l_0 \leq \frac{\phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}\right) - (1-p_2)a_{1,b}}{\frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1} - p_2(\mu - p_1\Delta)} =: l^{\max}_{0,\eta\mathcal{R}} \tag{135}$$

with

$$l^{\max}_{1,\eta} := \psi_\eta l_0 + \xi_\eta a_{1,b} \tag{136}$$

and

$$\psi_\eta := \frac{(1-\lambda)p_2(\mu - p_1\Delta) + \frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1}}{1-(1-\lambda)p_2 r_b}, \tag{137}$$

while ξ_η is defined in (123).

D.3.1.3 Failure Mode $m = \mathcal{F}$ Suppose the banker operates in the risky mode straight away in the first period which results in a bank run in the bad state at $t = 1$, so that $m = \mathcal{F}$. In this case the expected profit of the risk-free asset is $p_1 - 1 < 0$, see (63). 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 5 and 6, considering this restriction on deposits when inserting the funds provided by depositors (54) and shareholders (55) into the budget constraint (53), and making use of the definition of ϕ_t when applying the budget constraint to the expected profit (52), yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi^{\mathcal{F}}_{0,\eta}(l_0) = \phi_0(l_0) - (1-p_1)(\mu - p_1\Delta)l_0 - (1-p_1)a_0 + p_1\phi_{1,g}(l^{\text{fb}}_{1,g}) \tag{138}$$

$$\text{s.t.} \quad l_0 \leq \frac{\frac{1-\eta}{\eta}\lambda p_1 - (1-p_1)}{1-(1-\lambda)p_1[\mu + (1-p_1)\Delta]} a_0 =: l^{\max}_{0,\eta_{\mathcal{F}}}. \tag{139}$$

D.3.2 Determination of Optimal Loan Volumes at $t = 0$

D.3.2.1 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{A}$ Suppose the banker operates according to strategy $\mathcal{A}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{S}$. As the reduced form is identical to (58) we can likewise conclude that the optimal loan volume is $l^*_0 = l^{\text{fb}}_0$ with $\frac{\partial l^{\text{fb}}_0}{\partial \Delta} = 0$.

D.3.2.2 Safe Mode $m = \mathcal{S}$, Strategy $\mathcal{B}_{LCR}$ Suppose the banker operates according to strategy $\mathcal{B}_{LCR}$, i.e. the restriction on bank loan supply becomes binding when operating according to $m = \mathcal{S}$. As the reduced form is identical to (58) and (59), we can likewise conclude that there exists a $l^{\mathcal{S}}_0$ with $l^{\mathcal{S}}_0 \in \left[l^{\text{fb}}_0, \frac{l^{\text{fb}}_{1,b}}{\psi}\right]$ for which $\frac{\partial \pi^{\mathcal{S}}_0}{\partial l_0}$ is equal to zero so that the optimal loan volume is $l^*_0 = l^{\mathcal{S}}_0$. Again it follows that $l^{\mathcal{S}}_0$ will increase in the risk if Δ is small but will decrease if Δ is large.

D.3.2.3 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{C}_{LCR}$ Suppose the banker operates according to strategy $\mathcal{C}_{LCR}$, i.e. he faces no restriction on bank loan supply when operating according to $m = \mathcal{R}$. It follows from (134) that

$$\begin{aligned} \frac{\partial \pi^{\mathcal{R}}_0}{\partial l_0} &= \phi'_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta) \\ &\quad + (1-p_1)\phi'_{1,b}(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}) \frac{\partial \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}}{\partial l_0}. \end{aligned} \tag{140}$$

Note that the first two terms decrease in l_0. The third term is equal to zero as long as bank loan supply is not restricted in the bad state at $t = 1$. If bank loan supply is restricted in this bad state, the third term will decrease in l_0 as $\frac{\partial c(l^{\max}_{1,\eta})}{\partial l^{\max}_{1,\eta}}$ increases in $l^{\max}_{1,\eta}$, 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 $l_0 = l_0^{\mathcal{R}}$, 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 bad state at $t = 1$ 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 $l_{0,\eta}^{\mathcal{R}}$ with $l_{0,\eta}^{\mathcal{R}} \in \left[l_0^{\mathcal{R}}, \frac{l_{1,b}^{\text{fb}} - \xi_\eta a_{1,b}}{\psi_\eta}\right]$ for which (140) is equal to zero. For $\psi_\eta < 0$ there exists a $l_{0,\eta}^{\mathcal{R}}$ with $l_{0,\eta}^{\mathcal{R}} < l_0^{\mathcal{R}}$ for which (140) is equal to zero. The optimal loan volume is thus $l_0^* = l_{0,\eta}^{\mathcal{R}}$.

In order to determine how changes of the risk, Δ, affect the optimal loan volume $l_{0,\eta}^{\mathcal{R}}$, i.e. $\frac{\partial l_{0,\eta}^{\mathcal{R}}}{\partial \Delta}$, we can conclude from (68) that $\frac{\partial l_{0,\eta}^{\mathcal{R}}}{\partial \Delta} > 0$ as long as $l_{0,\eta}^{\mathcal{R}} = l_0^{\mathcal{R}}$. Given that bank loan supply is restricted in the bad state at $t = 1$, we define the function, $F_\eta^{\mathcal{C}}$, as the first order condition of $\pi_{0,\eta}^{\mathcal{R}}(l_0)$ with respect to l_0 for $l_{0,\eta}^{\mathcal{R}}$:

$$
\begin{aligned}
F_\eta^{\mathcal{C}} :=& [1 - (1 - p_1)(1 - p_2)]\mu + (1 - p_1)(1 - p_2)p_1\Delta - 1 - \frac{\partial c}{\partial l_{0,\eta}^{\mathcal{R}}} \\
&+ (1 - p_1)\left[p_2 r_b - 1 - \frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}}\right]\psi_\eta = 0. \qquad (141)
\end{aligned}
$$

Applying the implicit function theorem yields $\frac{\partial l_{0,\eta}^{\mathcal{R}}}{\partial \Delta} = -\frac{\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta}}{\frac{\partial F_\eta^{\mathcal{C}}}{\partial l_{0,\eta}^{\mathcal{R}}}}$. It follows that $\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta} = (1-p_1)(1-p_2)p_1 + (1-p_1)\phi_{1,b}'(l_{1,\eta}^{\max})\frac{\partial \psi_\eta}{\partial \Delta} - (1-p_1)\psi_\eta \frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}} \frac{\partial l_{1,\eta}^{\max}}{\partial \Delta}$ and $\frac{\partial F_\eta^{\mathcal{C}}}{\partial l_{0,\eta}^{\mathcal{R}}} = -\frac{\partial^2 c(l_{0,\eta}^{\mathcal{R}})}{\partial {l_{0,\eta}^{\mathcal{R}}}^2} - (1-p_1)\frac{\partial c(l_{1,\eta}^{\max})}{\partial l_{1,\eta}^{\max}} \frac{\partial l_{1,\eta}^{\max}}{\partial l_{0,\eta}^{\mathcal{R}}}\psi_\eta < 0$. If the risk is small, $\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta}$ will be positive. For small risks the second term is negative due to $\frac{\partial \psi_\eta}{\partial \Delta} < 0$ but close to zero as $l_{1,\eta}^{\max}$ is close to $l_{1,b}^{\text{fb}}$, while the third is positive, due to $\frac{\partial l_{1,\eta}^{\max}}{\partial \Delta} < 0$, and sufficiently large as ψ_η is large for small risks. The first term is always positive and constant. If risks are large, $\frac{\partial F_\eta^{\mathcal{C}}}{\partial \Delta}$ will be negative. For larger 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 $\frac{\partial l_{0,\eta}^{\mathcal{R}}}{\partial \Delta}$ is positive for smaller risks and negative for larger risks.

D.3.2.4 Risky Mode $m = \mathcal{R}$, Strategy $\mathcal{D}_{LCR}$ Suppose the banker operates according to strategy $\mathcal{D}_{LCR}$, i.e. he faces a restriction on bank loan supply when operating according to $m = \mathcal{R}$, as (135) becomes binding. Hence the optimal loan volume is $l_0^* = l_{0,\eta_{\mathcal{R}}}^{\max}$.

Due to $\frac{\partial l_{1,\eta}^{\max}}{\partial \Delta} < 0$ and the results from the proof of Proposition 1 that $\frac{\partial l_0^{\max}}{\partial \Delta} < 0$, we can directly conclude that $\frac{\partial l_{0,\eta\mathcal{R}}^{\max}}{\partial \Delta} < 0$.

D.3.2.5 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}_{LCR}$ Suppose the banker operates according to strategy $\mathcal{E}_{LCR}$, i.e. he operates according to $m = \mathcal{F}$. It follows from (139) 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 loan supply. However, this investment corresponds with a negative expected profit, so that the optimal investment is determined by its first order condition

$$\frac{\partial \pi_{0,\eta}^{\mathcal{F}}}{\partial a_0} = \left[\phi_0' \left(l_{0,\eta\mathcal{F}}^{\max}\right) - (1-p_1)(\mu - p_1\Delta)\right] \frac{\partial l_{0,\eta\mathcal{F}}^{\max}}{\partial a_0} - (1-p_1). \tag{142}$$

The optimal loan volume is thus $l_0^* = \min\{l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{\max}\}$. It follows directly from (63) that $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} > 0$. Moreover, it follows from (139) that $\frac{\partial l_{0,\eta\mathcal{F}}^{\max}}{\partial \Delta} > 0$.

D.3.3 Critical Values of Δ

1. We have defined $\Delta^{\mathcal{A}}$ in (70).

2. We denote $\Delta_\eta^{\mathcal{B}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{B}_{LCR}$ and strategy $\mathcal{C}_{LCR}$. Recall that for $\Delta = \Delta^{\mathcal{A}}$ it follows that $\pi_0^{\mathcal{S}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{R}}(l_0) > \pi_0^{\mathcal{F}}(l_0)$. While $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\text{fb}})}{\partial \Delta} = 0$ because of $\frac{\partial l_0^{\text{fb}}}{\partial \Delta} = 0$, the expected profit from strategy $\mathcal{B}_{LCR}$ decreases in Δ, i.e. $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial \Delta} < 0$. Moreover, it follows from (134) that $\frac{\partial \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}})}{\partial \Delta} = \frac{\partial \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}})}{\partial l_{0,\eta}^{\mathcal{R}}} \frac{\partial l_{0,\eta}^{\mathcal{R}}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_{0,\eta}^{\mathcal{R}} > 0$, as $\frac{\partial \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}})}{\partial l_{0,\eta}^{\mathcal{R}}} = 0$. Accordingly, if there exists a unique $\Delta_\eta^{\mathcal{B}'} > \Delta^{\mathcal{A}}$ for which $\pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) = \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}})$, the banker will prefer strategy $\mathcal{B}_{LCR}$ over strategies $\mathcal{C}_{LCR}$, $\mathcal{D}_{LCR}$ and $\mathcal{E}_{LCR}$ as $\pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) \geq \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}}) > \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max}) > \pi_{0,\eta}^{\mathcal{F}}(\min l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{\max}\})$ for all $\Delta \leq \Delta_\eta^{\mathcal{B}'}$, while for all $\Delta > \Delta_\eta^{\mathcal{B}'}$, the banker prefers strategy $\mathcal{C}_{LCR}$ over strategy $\mathcal{B}_{LCR}$ as $\pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}}) > \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})$. If such a $\Delta_\eta^{\mathcal{B}'}$ does not exist within $(\Delta^{\mathcal{A}}, \Delta^\psi]$, e.g. as $l_{0,\eta\mathcal{R}}^{\max}$ becomes binding for a $\Delta \leq \Delta^\psi$, the banker will prefer strategy $\mathcal{B}_{LCR}$ as long as the safe mode is available in the bad state at $t = 1$, i.e. for all $\Delta \in (\Delta^{\mathcal{A}}, \Delta^\psi]$ so that

$$\Delta_\eta^{\mathcal{B}} := \min\{\Delta_\eta^{\mathcal{B}'}, \Delta^\psi\}. \tag{143}$$

3. We denote $\Delta_\eta^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}_{LCR}$ and strategy $\mathcal{D}_{LCR}$, i.e. the highest risk level for which bank loan supply is not restricted when operating according to $m = \mathcal{R}$. It follows from the definitions of $l_{0,\eta\mathcal{R}}^{\max}$ and v_b that the banker is indifferent between the two strategies if $l_{0,\eta}^{\mathcal{R}} = l_{0,\eta\mathcal{R}}^{\max}$ or if

$$\begin{aligned}\Delta_\eta^{\mathcal{C}} := & \frac{[\phi_{1,b}(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}) - (1-p_2)a_{2,b}][1-(1-\lambda)p_1]}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]l_{0,\eta}^{\mathcal{R}}} \\ & + \frac{\mu[p_2 + (1-\lambda)p_1(1-p_2)] - 1}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]}. \end{aligned} \tag{144}$$

As long as $l_{0,\eta}^{\mathcal{R}} < l_{0,\eta\mathcal{R}}^{\max}$ it follows that $\pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta}^{\mathcal{R}}) > \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max}) > \pi_{0,\eta}^{\mathcal{F}}(\min l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{\max}\})$ so that the banker prefers strategy $\mathcal{C}_{LCR}$ over strategy $\mathcal{D}_{LCR}$ and $\mathcal{E}_{LCR}$ for all $\Delta \leq \Delta_\eta^{\mathcal{C}}$. For all $\Delta > \Delta_\eta^{\mathcal{C}}$ strategy $\mathcal{C}_{LCR}$ is not feasible.

4. We denote $\Delta_\eta^{\mathcal{D}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{D}_{LCR}$ and strategy $\mathcal{E}_{LCR}$. It follows from (134) that $\frac{\partial \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max})}{\partial \Delta} = \frac{\partial \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max})}{\partial l_{0,\eta\mathcal{R}}^{\max}} \frac{\partial l_{0,\eta\mathcal{R}}^{\max}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_{0,\eta\mathcal{R}}^{\max}$, which is negative for sufficiently large Δ as $\frac{\partial \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max})}{\partial l_{0,\eta\mathcal{R}}^{\max}} > 0$ and $\frac{\partial l_{0,\eta\mathcal{R}}^{\max}}{\partial \Delta} < 0$. It follows from (138) that $\frac{\partial \pi_{0,\eta}^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial \Delta} = \frac{\partial \pi_{0,\eta}^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} \frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} + p_1(1-p_1)l_0^{\mathcal{F}} > 0$ as $\frac{\partial \pi_{0,\eta}^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} = 0$. Moreover, it follows from (138) that $\frac{\partial \pi_{0,\eta}^{\mathcal{F}}(l_{0,\eta\mathcal{F}}^{\max})}{\partial \Delta} = \frac{\partial \pi_{0,\eta}^{\mathcal{F}}(l_{0,\eta\mathcal{F}}^{\max})}{\partial l_{0,\eta\mathcal{F}}^{\max}} \frac{\partial l_{0,\eta\mathcal{F}}^{\max}}{\partial \Delta} + p_1(1-p_1)l_{0,\eta\mathcal{F}}^{\max} > 0$ as $\frac{\partial \pi_{0,\eta}^{\mathcal{F}}(l_{0,\eta\mathcal{F}}^{\max})}{\partial l_{0,\eta\mathcal{F}}^{\max}} > 0$ and $\frac{\partial l_{0,\eta\mathcal{F}}^{\max}}{\partial \Delta} > 0$. Accordingly, there exists a unique $\Delta_\eta^{\mathcal{D}} > \Delta_\eta^{\mathcal{C}} > \Delta_\eta^{\mathcal{B}} > \Delta^{\mathcal{A}}$ for which $\pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max}) = \pi_{0,\eta}^{\mathcal{F}}(\min l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{\max}\})$, so that for all $\Delta \leq \Delta_\eta^{\mathcal{D}}$, the banker prefers strategy $\mathcal{D}_{LCR}$ over strategy $\mathcal{E}_{LCR}$ as $\pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max}) > \pi_{0,\eta}^{\mathcal{F}}(\min l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{\max}\})$, while for all $\Delta > \Delta_\eta^{\mathcal{D}}$, the banker prefers $\mathcal{E}_{LCR}$ over $\mathcal{D}_{LCR}$ due to $\pi_{0,\eta}^{\mathcal{F}}(\min l_0^{\mathcal{F}}, l_{0,\eta\mathcal{F}}^{\max}\}) > \pi_{0,\eta}^{\mathcal{R}}(l_{0,\eta\mathcal{R}}^{\max})$.

Proof of Proposition 5

For this proof it is only important that the banker cannot raise additional equity once he chooses the risky mode, as shareholders participation constraint is fulfilled with equality. As the bank might default at the end of the period, the CDS price becomes positive resulting in a take over and thus in a negative expected return for the banker. Accordingly, operating in the risky mode is never beneficial so that the banker will always operate in the safe mode, whereat bank loan supply might be restricted or not feasible at all.