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Implications of bank regulation for loan supply and bank stability: A dynamic perspective

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Non-technical summary

Research Question

Banks finance their loans and other assets with a combination of external finance in form of deposits and external equity as well as internal finance by gaining internal funds. Whereas the two types of external finance typically generate a trade-off between bank stability and loan supply due to different costs, we are interested in the impact of internal finance. Like external equity, internal funds improve the stability of banks, but unlike equity they are the outcome of a bank's past decisions on loan supply and capital structure. These decisions thus not only determine a bank's current stability, it also predetermines the future availability of internal funds, the future costs of external finance with deposits and external equity and a bank's vulnerability to future risks. Vice versa, expected future difficulties with respect to funding might affect a bank's lending and capital structure decision today. This paper sets out to understand the role of internal funds in this intertemporal link and the influence of bank regulation on the dynamics of loan supply and bank stability.

Contribution

In a theoretical partial equilibrium model, we study the decisions of a forward-looking bank over time with respect to its investment and capital structure. Taking the advantages of regulatory intervention as given, our approach is to identify the conditions under which different regulatory instruments can achieve bank stability and to assess the costs of doing so in terms of loan supply. We analyze the effects of risk-weighted capital-to-asset ratios and liquidity coverage ratios as well as regulatory margin calls, which is a theoretical proposal by Hart and Zingales (2011).

Results

Credit risk and financial frictions that cause debt to be cheaper than equity create an intratemporal and intertemporal trade-off between the stability of a bank and the efficiency of its loan supply. Internal funds may overcome this trade-off, but their availability is restricted. In this model framework, all regulatory instruments may increase bank stability for certain credit risks, but have distinctively different effects on loan supply. According to our model, risk-weighted capital-to-asset ratios may increase the volatility in loan supply. Liquidity coverage ratios may increase the volatility in loan supply as well, but in contrast to risk-weighted capital-to-asset ratios they never impose an additional restriction on loan supply of an already stable bank. Regulatory margin calls will also never change the loan supply if the bank chooses a safe capital structure. However, for high credit risks, it stops credit intermediation.

Nichttechnische Zusammenfassung

Fragestellung

Banken finanzieren ihre Kredite und andere Aktiva mit einer Kombination von Außenfinanzierung durch Eigen- und Fremdkapital sowie Innenfinanzierung, d.h. durch die Gewinnung interner Mittel. Während die beiden Außenfinanzierungsformen aufgrund unterschiedlicher Kosten typischerweise einen Zielkonflikt zwischen der Stabilität der Bank und ihrem Kreditangebot generieren, sind wir an dem Effekt der Innenfinanzierung interessiert. Interne Mittel unterstützen wie externes Eigenkapital die Stabilität der Bank, werden aber durch Bankentscheidungen der Vergangenheit bezüglich Kreditangebot und Kapitalstruktur bestimmt. Diese beeinflussen daher nicht nur die derzeitige Stabilität der Bank, sondern auch die zukünftige Verfügbarkeit interner Mittel sowie die Kosten der externen Finanzierung mit Eigen- und Fremdkapital und damit die zukünftige Stabilität der Bank. Darüber hinaus beeinflussen erwartete zukünftige Finanzierungsschwierigkeiten jetzige Bankentscheidungen. Dieses Papier untersucht die Rolle interner Mittel in diesem intertemporalen Zusammenhang und den Einfluss, den regulatorische Instrumente auf die Dynamik von Kreditangebot und Bankstabilität haben können.

Beitrag

Im Rahmen eines theoretischen Partialmodells wird untersucht, wie sich eine vorrausschauende Bank im Zeitverlauf bezüglich ihrer Investitions- und Kapitalstruktur entscheidet. Während die Vorteile einer Regulierung als gegeben angenommen werden, untersucht dieses Papier, unter welchen Voraussetzungen verschiedene regulatorische Instrumente Bankstabilität bewirken können und welche Kosten in Form von Veränderungen des Kreditangebots anfallen. Neben risikogewichteten Eigenmittelanforderungen und Liquiditätsdeckungsquoten wird auch ein theoretischer Vorschlag - regulatorische Nachschusspflichten à la Hart und Zingales (2011) - untersucht.

Ergebnisse

Durch die Berücksichtigung von Kreditrisiken und Finanzfriktionen, die dazu führen, dass Eigenkapital teurer als Fremdkapital ist, entsteht ein intratemporaler und intertemporaler Zielkonflikt zwischen effizientem Kreditangebot und der Stabilität der Bank. Die Verwendung interner Mittel kann diesen Zielkonflikt lösen, diese sind aber nur begrenzt verfügbar. Im vorliegenden Modellrahmen können alle Regulierungsinstrumente die Stabilität der Bank gegenüber bestimmten Kreditrisiken verbessern, sie unterscheiden sich jedoch in ihrer Wirkung auf das Kreditangebot. Risikogewichtete Eigenmittelanforderungen können in diesem Modell zu einer höheren Volatilität des Kreditangebots führen. Liquiditätsdeckungsquoten können zwar ebenfalls die Volatilität des Kreditangebots erhöhen, führen aber im Gegensatz zu risikogewichteten Eigenmittelanforderungen zu keiner zusätzlichen Verknappung des Kreditangebots einer ohnehin stabilen Bank. Regulatorische Nachschusspflichten verändern das Kreditangebot bei sicherer Kapitalstruktur ebenfalls nicht. Allerdings kann die Bank bei dieser Regulierung ihrer Kreditintermediationsfunktion bei höheren Kreditrisiken nicht mehr nachkommen.

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Implications of Bank Regulation for Loan Supply and Bank Stability: A Dynamic Perspective*

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Abstract

A bank's decision on loan supply and capital structure determines its immediate bankruptcy risk as well as the future availability of internal funds. These internal funds in turn determine a bank's future costs of external finance and future vulnerability to bankruptcy risks. We study these intra- and intertemporal links and analyze the influence of risk-weighted capital-to-asset ratios, liquidity coverage ratios and regulatory margin calls on the dynamics of loan supply and bank stability. Only regulatory margin calls or large liquidity coverage ratios achieve bank stability for all risk levels, but for large risks a bank will stop credit intermediation.

Keywords: bank lending, banking crisis, bank capital regulation, liquidity regulation

JEL classification: G01, G21, G28, E32.

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1 Introduction

A major objective of bank regulation is to promote the stability of the banking system. Regulators pursue this objective indirectly, primarily through influencing the decisions of banks to grant loans and to take risks. Studies of the effects of regulations on these decisions typically focus on the differences between equity and debt, particularly uninsured deposits and other short-term debt. Such debt serves the liquidity needs of investors but may expose banks to the risk of bankruptcy.[1] Equity makes banks less vulnerable to risks but either impairs the provision of liquidity services by banks or increases their costs.[2] As a bank's ability to raise funds for granting risky loans depends on the value of the liquidity services it provides, a bank with more equity assumes lower bankruptcy risks but also grants fewer loans.

This trade-off is a key concern for regulators. However, the account is incomplete as equity is not only associated with funds raised externally from shareholders. Internal funds are another form of equity funding. They are the financial resources a bank can command through managing assets originated in a previous period. These resources correspond either to the current returns of these assets or to the amount a bank can raise externally against their future returns, net of any debt immediately due for payment. In the present paper we develop a dynamic model of a banking firm which can use internal funds in addition to funds raised externally from depositors and shareholders. We argue that internal funds are a form of equity that renders the trade-off between bank stability and loan supply more subtle, with some important implications for the effects of regulatory instruments on banks' risk taking and loan supply.

We show that, provided loans exhibit only moderate risks, they generate some internal funds in the future even when financial conditions turn out to bad. Granting more loans than justified by their net present value today will boost internal funds available tomorrow. This eases a possible future financial constraint and allows the bank to be safe at all times. Such excess loan supply today followed by a credit crunch tomorrow if conditions get worse are jointly caused by the possibility of future funding problems.[3]

Provided loans exhibit considerable risks, the bank will face strong funding problems should loans perform poorly in the future. This is because internal funds will be negative, implying a debt overhang. Even a forward-looking bank will cope with these funding problems only when they materialize. The bank will then adopt a fragile capital structure, raising funds primarily via new deposits. However, the risk of a bank run as a result of implementing such a capital structure in the future may already reduce the value of

[1] Bankruptcy for liquidity providing banks is often associated with bank runs (Diamond and Dybvig, 1983; Diamond and Rajan, 2001; Allen and Gale, 2004). Such bank runs can be very costly for society (Dell'Ariccia, Detragiache, and Rajan, 2008).

[2] Typically, it is not crucial why equity makes liquidity provision more costly from an individual bank's perspective. In Diamond and Rajan (2000) it is because banks can exploit informational rents from shareholders but not depositors. 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, Carletti, and Marquez (2015) 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, DeMarzo, Hellwig, and Pfleiderer (2014).

[3] 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 Jordi, Schularick, and Taylor, 2013).

loans granted today. Therefore a bank grants fewer loans today than justified by their net present value. If these loans perform poorly in the future, the bank will gamble for resurrection.

Against this background, we consider three regulatory instruments and their effects on a bank's decision on capital structure and loan supply: risk-weighted capital-to-asset ratios (CAR), liquidity coverage ratios (LCR) and regulatory margin calls (RMC). Provided credit risks are not too large, CAR amplify the volatility of loan supply. The regulation lowers the funding liquidity of loans, especially in times that are already financially difficult. A bank then makes provisions today by aiming at generating more internal funds for the future. This implies supplying even more loans today. A more pronounced credit crunch in bad times following a stronger loan supply in good times occurs even with risk-weights being constant over time and financial conditions.[4] With considerable credit risks, boosting internal funds may be too costly though such that the bank either adopts a fragile capital structure at all dates or stops credit intermediation altogether.

LCR do not affect loan supply as long as the bank chooses a safe capital structure. To meet the regulatory requirement, it can simply issue additional deposits to be invested in a risk-free asset until the required ratio is achieved. Risk-taking becomes less attractive though with LCR because loans become less valuable in building-up internal funds with a fragile capital structure. 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, LCR tend to increase bank stability at the cost of a higher volatility of loan supply. Sufficiently large LCR may induce the bank to choose a safe capital structure even for large credit risks.

RMC have been suggested by Hart and Zingales (2011) and work as follows. When the markets' assessment of a bank's probability of default increases above a threshold set by the regulator, shareholders have to recapitalize their bank. If they don't, the regulator performs a stress test and, if this test confirms a risk to the bank's stability, takes over the bank, replaces its management and wipes out shareholders. Given these supervisory consequences, bank and shareholders share the incentive to eliminate the risk of default at all times. In the context of our model, bank stability will thus prevail for all credit risks. The downside of RMC is that the banker grants loans only as long as their funding liquidity is still sufficiently large. Therefore, RMC do not alter the volatility in loan supply for moderate credit risks. For considerable credit risks, however, RMC increase bank stability at the cost of a stop in credit intermediation.

The analytical backbones of our model are taken from dynamic banking models such as Bucher, Dietrich, and Hauck (2013), which we have augmented for our purpose by including external equity capital. With its focus on banks using deposits, external equity as well as internal funds to make loans in a dynamic setting, our paper is most closely related to Repullo and Suarez (2013) and Hyun and Rhee (2011). Using an infinite horizon model with overlapping generations, Repullo and Suarez (2013) discuss the dynamic implications of capital structure decisions for a bank's future ability to supply credit. In Hyun and Rhee (2011), deposits as well as internal funds are exogenous leaving no room for strategic action to boost future loan supply. Both papers concentrate on the effects

[4] Others have attributed such effects of bank capital regulation to variations in risk-weights over the business cycle, see Repullo and Suarez (2013), Ferri, Liu, and Majnoni (2001) and Mulder and Montfort (2000). See Allen and Saunders (2004) for a survey on pro-cyclicality.

of capital requirements. We add to these papers in two ways. First, we investigate a scenario in which banks not only vary their capital structure but also the volume of their loan supply to strategically improve future funding conditions. Second, we evaluate the consequences of a richer set of regulatory instruments.

Our model predicts that loan supply can be volatile and excessive at times. This prediction can also be found in Lorenzoni (2008). In contrast to this paper, we explicitly consider credit intermediation by banks. Finally, Dietrich and Hauck (2012) analyze the impact of different bail-out schemes on bank loan supply and risk-taking while Blum (2008) compares risk-weighted capital-to-asset ratios with a leverage ratio, showing that the latter may rectify disincentives for banks misreporting their risks to the supervisor. In contrast to ours, these frameworks feature a one-period world, in which banks are not able to strategically acquire internal funds over time.

The objective of our paper is to identify the conditions under which a regulatory instrument changes a bank's decision on capital structure and loan supply and in which way, holding everything else equal. Therefore, we do not consider an explicit welfare measure. We also deliberately turn 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.[5] 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. Section 4 explores the effects of CAR, LCR and RMC. Section 5 concludes.

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.[6] 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

[5] See Arnold, Borio, Ellis, and Moshirian (2012) for a survey of the role of systemic risk for macro-prudential bank regulation.

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

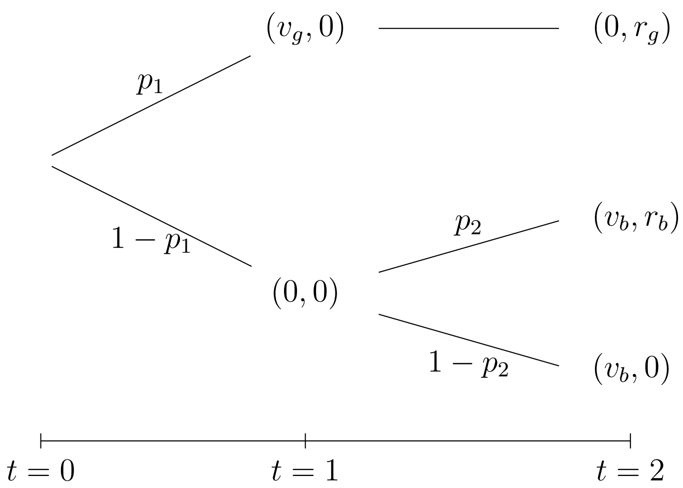

Figure 1: Loan earnings (per unit).
Note: At each node, the first entry refers to loans granted at $t = 0$ and the second entry to loans granted at $t = 1$.

$\Delta := v_g - v_b$, and let $\mu := p_1 v_g + (1 - p_1) v_b$ be the expected return of first-period loans.[7] 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.[8]

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 $t = 2$.[9] 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.[10] We let the expected net returns of second-period loans be positive even in the bad state, i.e. $p_2 r_b > 1$.

Investors can buy bank equity shares or hold uninsured deposits. The difference between them 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), uninsured demandable deposits eliminate this incentive as any attempt to renegotiate repayments to depositors would trigger an immediate bank run destroying

[7] The returns thus exhibit persistent and mean reverting shocks, which is a common assumption in macromodels, cf. Aghion, Angeletos, Banerjee, and Manova (2010).

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

[9] From a regulatory perspective, an explicit analysis of a risky loan supply following an initial good return is obsolete as it does not create a failure issue, see e.g. Bucher et al. (2013).

[10] Restricting attention to $p_1, p_2 \geq 0.6$ reduces complexity, as it ensures that for sufficiently large credit risk the banker always puts the bank at risk already in the first period.

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.[11]

To prevent such runs, a banker can issue equity shares.[12] 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.

In our model, we account for these 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. At $t = 1$, the banker additionally commands internal funds depending on the outcome of his investment decisions in the first period and the state of the economy. 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. That all assets, including the safe asset will lose their value to a investors in a run can be justified in several ways. A standard explanation is bankruptcy cost. Another explanation is that bank failures are systemic events. Then, a system-wide dry-up of market liquidity makes these assets temporarily worth less. Alternatively, the safe asset could be considered as interbank claims on another bank which also loses value when interbank markets freeze in a crisis.

Provided 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.

[11]Large uninsured deposits and similar short-term claims on banks are typically held by institutional investors. But even insured depositors have an incentive to join a bank run as the Northern Rock example has proved in autumn 2007.

[12]Considering internal funds as the only form of equity does not change our benchmark results qualitatively, see Bucher et al. (2013). In this setup, we however want to leave the decision on the type of equity with the banker, as we regard a more general decision to be useful for evaluating capital requirements.

As everyone is risk neutral, the 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.[13] We thus disregard the safe asset in the benchmark situation.

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,

[13]Storage can thus not serve a precautionary function, as an investment in the risk-free asset always has to be funded by an equivalent amount of deposits, which always need to be paid off at the end of each period.

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 $t = 1$. By definition, there are no internal funds at this stage.

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 the failure 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 $l_0^{\mathcal{F}} < l_0^{\mathcal{R}}$.[14]

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 and failure 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 or failure 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,

[14] Independent of the optimal strategy, our findings are thus in line with the pecking order theory, as the banker prefers internal funds over deposits over external equity.

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 failure mode less attractive at $t = 0$ when the constraint on deposits is binding for a bank choosing a risky capital structure 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 staying 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*

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

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 and failure 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. 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 (failure mode), 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 bank stability but at a very high cost in terms of credit disintermediation.

4.2 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 100% to guarantee bank stability.[15]

Just like CAR, LCR implies an upper bound on deposits. Unlike CAR, LCR does never affect loans for banks in the safe mode, 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.

Only loan supply by banks in the risky or failure 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 or failure mode, 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 the respective period. In our benchmark this is exactly the reason why a bank operating in the risky or failure 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 or failure mode would not be restricted in refinancing loans with deposits. In the risky mode, this holds true for both, new and legacy loans if economic conditions are bad at $t = 1$. 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

[15] Basel III is based on the notion that not all depositors will withdraw their funds within that time period so that the actual LCR which is set to be at least 100% is not comparable in size with the LCR determined in our model.

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 and failure mode. Therefore, LCR makes both of these modes 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 the risky mode.

This leads us to the following conclusion.

Proposition 3. *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*

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

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 period (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 $\eta > \max\left\{\frac{\lambda p_1}{1-(1-\lambda)p_1}, \frac{\lambda p_2}{1-(1-\lambda)p_2}\right\}$, both the risky and failure mode are 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]

4.3 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 or failure 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 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 or failure 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 or failure mode, 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

[16] A similar argument has been made by De Nicolò, Gamba, and Lucchetta (2014).

[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.

[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.

Proposition 4. *The banker's optimal response to RMC is characterized by*

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

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 or failure mode. 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 putting the bank at risk with the risky or failure 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 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 first-best 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 explanation 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 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 out to be bad becomes less attractive relative to building up internal funds prior to potential financial problems.

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 choose a risky capital structure. 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 an effect on loan supply.

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.

Appendix

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 bad state at $t = 1$ in section A.1 that includes Lemma 1. Second, we consider the good state at $t = 1$ in section A.2 and Lemma 2. Finally, we determine the banker's optimal behavior at $t = 0$ in section A.3.

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 ($t = 1$), Bad State

In analogy to the modes $m \in \{\mathcal{S}, \mathcal{R}, \mathcal{F}\}$ identified in the paper, we use the modes $m_{1,b} = \{s, r, f\}$ that the banker can implement from $t = 1$ in the bad state onwards.

A.1.1 Optimization Problem

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

$$\max_{l_{1,b}, a_{1,b}, \delta_{1,b} \in \mathbb{R}^+} \pi_{1,b} = \lambda E\left[\max\left\{v_b l_0 + r_j l_{1,b} + a_{1,b} - \delta_{1,b}, 0\right\}\right] - c(l_{1,b}) \tag{17}$$

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

$$d_{1,b} = \begin{cases} \delta_{1,b} & \text{if} \quad m_{1,b} = s: \ \delta_{1,b} \leq v_b l_0 + a_{1,b}, \\ p_2 \delta_{1,b} & \text{if} \quad m_{1,b} = r: \ \delta_{1,b} \in (v_b l_0 + a_{1,b}, v_b l_0 + r_b l_{1,b} + a_{1,b}], \end{cases} \tag{19}$$

$$e_{1,b} = (1 - \lambda) E\left[\max\left\{v_b l_0 + r_j l_{1,b} + a_{1,b} - \delta_{1,b}, 0\right\}\right], \tag{20}$$

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 (40).

Equation (17) reflects the banker's expected profit in the bad state. Equation (18) gives the bank's budget constraint. The decision of depositors and shareholders to provide funds depends on the mode of operation and their respective expected payoff (see equation 19 and 20).

A.1.2 Determination of Reduced Forms and Optimal Loan Volumes

A.1.2.1 Safe Mode Suppose the banker chooses $m_{1,b} = s$. Inserting (19) and (20) in (18), solving for $\delta_{1,b}$, and inserting the result in (17) and the restriction on $\delta_{1,b}$ in (19) yields

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

$$\text{s. t.} \quad [1-(1-\lambda)p_2 r_b]l_{1,b} \leq (v_b+\omega_{1,b})l_0. \tag{22}$$

It follows from (21) that $\frac{\partial \pi^s_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}\,(l_{1,b})$, which is decreasing in $l_{1,b}$ and equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. The optimal loan volume $l^{s*}_{1,b}$ and the expected profit $\pi^{s*}_{1,b}$ thus read

$$l^{s*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_1\} \quad \text{and} \quad \pi^{s*}_{1,b} = (v_b+\omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_1\}\right), \tag{23}$$

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

$$l^{\max}_1 := \frac{v_b+\omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0. \tag{24}$$

A.1.2.2 Risky Mode Suppose the banker chooses $m_{1,b} = r$ so that the reduced form is given by

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^r_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) - (1-p_2)a_{1,b} \tag{25}$$

$$\text{s. t.} \quad [p_2 r_b - 1]l_{1,b} \geq -p_2 v_b l_0 - \omega_{1,b} l_0 + (1-p_2)a_{1,b}. \tag{26}$$

It follows from (25) that $\frac{\partial \pi^r_{1,b}}{\partial l_{1,b}} = \phi'_{1,b}\,(l_{1,b})$, which is decreasing in $l_{1,b}$ and is equal to zero for $l_{1,b} = l^{\text{fb}}_{1,b}$. The optimal loan volume $l^{r*}_{1,b}$ and the expected profit $\pi^{r*}_{1,b}$ thus read

$$l^{r*}_{1,b} = l^{\text{fb}}_{1,b} \quad \text{and} \quad \pi^{r*}_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(l^{\text{fb}}_{1,b}\right). \tag{27}$$

A.1.2.3 Failure Mode Suppose the banker chooses $m_{1,b} = f$ by closing the bank in the bad state at $t = 1$. By definition, the optimal loan volume $l^{f*}_{1,b}$ and the expected profit $\pi^{f*}_{1,b}$ are given by

$$l^{f*}_{1,b} = 0 \quad \text{and} \quad \pi^{f*}_{1,b} = 0. \tag{28}$$

A.1.3 Comparison

Comparing expected profits, we obtain

Lemma 1. *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*

$$\begin{aligned} m^*_{1,b} &= s, \quad l^*_{1,b} = l^{fb}_{1,b}, \quad \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if} \;\; l_0 \geq \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}, \\ m^*_{1,b} &= s, \quad l^*_{1,b} = l^{max}_1, \quad \pi^*_{1,b} = \pi^{s*}_{1,b} \quad \text{if} \;\; l_0 \in [l^{min}_0, \tfrac{1-(1-\lambda)p_2 r_b}{v_b+\omega_{1,b}} l^{fb}_{1,b}), \\ m^*_{1,b} &= r, \quad l^*_{1,b} = l^{fb}_{1,b}, \quad \pi^*_{1,b} = \pi^{r*}_{1,b} \quad \text{if} \;\; l_0 < l^{min}_0, \end{aligned} \tag{29}$$

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

$$\begin{array}{llll} m^*_{1,b} = r, & l^*_{1,b} = l^{fb}_{1,b}, & \pi^*_{1,b} = \pi^{r*}_{1,b} & \text{if } \ l_0 \leq l_0^{max}, \\ m^*_{1,b} = f, & l^*_{1,b} = 0, & \pi^*_{1,b} = \pi^{f*}_{1,b} & \text{if } \ l_0 > l_0^{max}, \end{array} \tag{30}$$

where $\pi^{s*}_{1,b}$, $\pi^{r*}_{1,b}$ *and* $\pi^{f*}_{1,b}$ *are defined by* (23), (27) *and* (28), *respectively,*

$$l_0^{max} := -\frac{\phi_{1,b}\left(l^{fb}_{1,b}\right)}{p_2 v_b + \omega_{1,b}}, \tag{31}$$

$$l_1^{max} := \frac{v_b + \omega_{1,b}}{1-(1-\lambda)p_2 r_b} l_0, \tag{32}$$

and where l_0^{min} *is implicitly defined by*

$$(1-p_2)v_b l_0 + \phi_{1,b}\left(l_1^{max}(l_0)\right) = \phi_{1,b}(l^{fb}_{1,b}). \tag{33}$$

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

The banker's behavior in the good state can be determined analogously. As granting loans is not restricted in the safe mode, we obtain

Lemma 2. *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:*

$$m^*_{1,g} = s, \quad l^*_{1,g} = l^{fb}_{1,g}, \quad \pi^*_{1,g} = \pi^{s*}_{1,g} \quad \forall \ l_0, \tag{34}$$

where $\pi^{s*}_{1,g} = \lambda\omega_{1,g} l_0 + \phi_{1,g}\left(l^{fb}_{1,g}\right)$ *and* $\omega_{1,g} := v_g - \frac{\delta_0 - a_0}{l_0}$.

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

$$\max_{l_0, a_0, \delta_0 \in \mathbb{R}^+} \pi_0 = p_1 \pi_{1,g}(l^*_{1,g}) + (1-p_1)\,\pi_{1,b}(l^*_{1,b}) - c(l_0) \tag{35}$$

$$\text{s.t.} \quad l_0 + a_0 = d_0 + e_0, \tag{36}$$

$$d_0 = \begin{cases} \delta_0 & \text{if} \quad m_0 = s: \ m^*_{1,b} \neq f \\ p_1\delta_0 & \text{if} \quad m_0 = r: \ m^*_{1,b} = f \end{cases}, \tag{37}$$

$$e_0 = (1-\lambda)p_1\omega_{1,g} l_0. \tag{38}$$

The banker anticipates his optimal behavior in the future when maximizing his expected profit, π_0, at the beginning of the first period, see (35). He considers the budget constraint (36), depositors' willingness to provide funds (37) and shareholders' expected payoff (38).

A.3.2 Determination of Reduced Forms and Optimal Loan Volumes

Recall from Lemma 2 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 chooses $m_0 = s$ and $m^*_{1,b} = s$, or in short $m = \mathcal{S}$. Inserting (37) and (38) in (36), solving for δ_0 and inserting the result in the definition of $\omega_{1,g}$ and $\omega_{1,b}$ yields

$$\omega_{1,g} = \frac{v_g - 1}{1 - (1-\lambda)\,p_1} > 0, \tag{39}$$

$$\omega_{1,b} = -\frac{1 - (1-\lambda)\,p_1 v_g}{1 - (1-\lambda)\,p_1} < 0. \tag{40}$$

Moreover, inserting $\pi^*_{1,g}$ as defined in Lemma 2 and $\pi^*_{1,b}$ for $m^*_{1,b} = s$ as defined in Lemma 1 as well as $\omega_{1,g}$ and $\omega_{1,b}$ in (35) and $l_1^{\max}$ as defined in (32) yields

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{S}}(l_0) = \phi_0(l_0) + p_1 \phi_{1,g}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}(\min\{l_{1,b}^{\text{fb}}, l_1^{\max}(l_0)\}) \tag{41}$$

$$\text{with} \quad l_1^{\max} = \frac{\mu - 1 - \lambda p_1 \Delta}{[1-(1-\lambda)p_1][1-(1-\lambda)p_2 r_b]} l_0 =: \psi l_0. \tag{42}$$

Strategy $\mathcal{A}$: If (42) is not binding, it follows from (41) 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 $l_0^* = l_0^{\text{fb}}$ with $\frac{\partial l_0^{\text{fb}}}{\partial \Delta} = 0$ due to the mean preserving spread.

Strategy $\mathcal{B}$: If (42) is binding, it follows from (41) that

$$\frac{\partial \pi_0^{\mathcal{S}}}{\partial l_0} = \phi_0'(l_0) + (1-p_1)\phi_{1,b}'(l_1^{\max})\frac{\partial l_1^{\max}}{\partial l_0}. \tag{43}$$

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 (43) is equal to zero so that the optimal loan volume is $l_0^* = l_0^{\mathcal{S}}$. Applying the implicit function theorem on the first order condition of $\pi_0^{\mathcal{S}}(l_0)$ with respect to l_0 yields that $\frac{\partial l_0^{\mathcal{S}}}{\partial \Delta}$ is positive for smaller risks and negative for larger risks.

A.3.2.2 Risky Mode $m = \mathcal{R}$ Suppose the banker chooses $m_0 = s$ and $m_{1,b}^* = r$, or in short $m = \mathcal{R}$ so that the reduced form reads

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{R}}(l_0) = \phi_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta)l_0 + p_1\phi_{1,g}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}(l_{1,b}^{\text{fb}}) \quad (44)$$

$$\text{s. t.} \quad l_0 \leq \frac{\phi_{1,b}\left(l_{1,b}^{\text{fb}}\right)}{\frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1} - p_2(\mu - p_1\Delta)} =: l_0^{\max}. \quad (45)$$

Strategy $\mathcal{C}$: If (45) is not binding, it follows from (44) that

$$\frac{\partial \pi_0^{\mathcal{R}}}{\partial l_0} = [1 - (1-p_1)(1-p_2)]\mu + (1-p_1)(1-p_2)p_1\Delta - 1 - c'(l_0), \quad (46)$$

which decreases in l_0 and is equal to zero for $l_0 = l_0^{\mathcal{R}}$. Hence the optimal loan volume is $l_0^* = l_0^{\mathcal{R}}$. Applying the implicit function theorem on the first order condition of $\pi_0^{\mathcal{R}}(l_0)$ with respect to l_0 yields that $\frac{\partial l_0^{\mathcal{R}}}{\partial \Delta} > 0$ due to $c''(l_0^{\mathcal{R}}) > 0$.

Strategy $\mathcal{D}$: If (45) is binding, the optimal loan volume is $l_0^* = l_0^{\max}$ with $\frac{\partial l_0^{\max}}{\partial \Delta} < 0$, as $\lambda \in [0.5, 1)$ and $p_1, p_2 \in [0.6, 1)$.[19]

A.3.2.3 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}$ Suppose the banker chooses $m_0 = r$ and $m_{1,b}^* = f$, or in short $m = \mathcal{F}$. Inserting (37) and (38) in (36), solving for δ_0 and inserting the result in the definition of $\omega_{1,g}$ yields

$$\omega_{1,g} = \frac{p_1 v_g - 1}{p_1 \lambda} - \frac{(1-p_1)a_0}{l_0 \lambda} > 0. \quad (47)$$

Thus, the reduced form reads

$$\max_{l_0, a_0 \in \mathbb{R}^+} \pi_0^{\mathcal{F}}(l_0) = \phi_0(l_0) - (1-p_1)(\mu - p_1\Delta)l_0 - (1-p_1)a_0 + p_1\phi_{1,g}(l_{1,g}^{\text{fb}}) \quad (48)$$

$$\text{s. t.} \quad l_0 > l_0^{\max}. \quad (49)$$

It follows from (48) 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 $l_0^* = l_0^{\mathcal{F}}$. Applying the implicit function theorem on the first order condition of $\pi_0^{\mathcal{F}}(l_0)$ with respect to l_0 yields $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} > 0$.

A.3.3 Critical Values of Δ

In the final 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. As the first best loan volumes l_0^{fb}

[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 choose $m_{1,b}^* = f$.

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

$$\Delta^{\mathcal{A}} := \frac{[(1-\lambda)p_2 r_b - 1][1-(1-\lambda)p_1]}{\lambda p_1} \frac{l_{1,b}^{\text{fb}}}{l_0^{\text{fb}}} + \frac{\mu - 1}{\lambda p_1}. \tag{50}$$

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 $\pi_0^{\mathcal{S}}(l_0^{\text{fb}}) = \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}}) > \pi_0^{\mathcal{R}}(l_0) > \pi_0^{\mathcal{F}}(l_0)$. It follows from (41) that the expected profit from strategy $\mathcal{B}$ decreases in Δ, as $\frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial l_0^{\mathcal{S}}} \frac{\partial l_0^{\mathcal{S}}}{\partial \Delta} + \frac{\partial \pi_0^{\mathcal{S}}(l_0^{\mathcal{S}})}{\partial l_1^{\max}} \frac{\partial l_1^{\max}}{\partial \Delta} < 0$. Moreover, it follows from (44) that $\frac{\partial \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{R}}(l_0^{\mathcal{R}})}{\partial l_0^{\mathcal{R}}} \frac{\partial l_0^{\mathcal{R}}}{\partial \Delta} + (1-p_1)(1-p_2)p_1 l_0^{\mathcal{R}} > 0$. 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

$$\Delta^{\mathcal{B}} := \min\{\Delta^{\mathcal{B}'}, \Delta^{\psi}\}. \tag{51}$$

3. We denote $\Delta^{\mathcal{C}}$ as the risk level for which the banker is indifferent between strategy $\mathcal{C}$ and strategy $\mathcal{D}$. 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

$$\Delta^{\mathcal{C}} := \frac{\phi_{1,b}^{r}(l_{1,b}^{\text{fb}})[1-(1-\lambda)p_1]}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))] l_0^{\mathcal{R}}} + \frac{\mu[p_2 + (1-\lambda)p_1(1-p_2)] - 1}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]}. \tag{52}$$

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 (44) 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 (48) that $\frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial \Delta} = \frac{\partial \pi_0^{\mathcal{F}}(l_0^{\mathcal{F}})}{\partial l_0^{\mathcal{F}}} \frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} + p_1(1-p_1) l_0^{\mathcal{F}} > 0$. 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 analogously to the proof of Proposition 1. In the following, we only present deviations from the previous proof.

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

B.1.1 Determination of Reduced Forms and Optimal Loan Volumes

B.1.1.1 Safe Mode The regulator aims at imposing capital requirements, which will not affect bank loan supply given that the bank is already stable. The capital requirement imposes a restriction

$$\delta_{1,b} \leq (1-\kappa)(l_0 + l_{1,b}) + a_{1,b} \tag{53}$$

on the face value of deposits. Inserting (19) and (20) in (18), solving for $\delta_{1,b}$, and inserting the result in (53) yields

$$[1-(1-\lambda)p_2 r_b - \lambda(1-\kappa)]l_{1,b} \leq [(1-\lambda)v_b + \lambda(1-\kappa) + \omega_{1,b})]\, l_0. \tag{54}$$

As $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu}{1-(1-\lambda)p_1}$, the RHS of (54) 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 (54). Hence, (54) never binds and the relevant restriction for the face value of deposits, when operating in the safe mode, remains to be $\delta_{1,b} \leq v_b l_0 + a_{1,b}$ so that the optimal loan volume $l^{s*}_{1,b}$ and the expected profit $\pi^{s*}_{1,b}$ are given by (27).

B.1.1.2 Risky Mode The regulator aims to impose a binding restriction on bank loan supply for the risky mode. The capital requirement imposes a restriction (53) on the face value of deposits. The reduced form thus reads

$$\max_{l_{1,b},a_{1,b}\in\mathbb{R}^+} \pi^r_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\,(l_{1,b}) - (1-p_2)a_{1,b} \tag{55}$$

$$\text{s.t.} \quad [1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)]\, l_{1,b} \leq [(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}]\, l_0. \tag{56}$$

If $\kappa > 1 - \frac{1-(1-\lambda)p_2 r_b}{\lambda p_2}$, bank loan supply will potentially be restricted. Considering this restriction (56), we can conclude that the optimal loan volume $l^{r*}_{1,b}$ and the expected profit $\pi^{r*}_{1,b}$ read

$$l^{r*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\} \quad \text{and} \quad \pi^{r*}_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\kappa}\}\right) \tag{57}$$

with

$$l^{\max}_{1,\kappa} := \frac{[(1-\lambda)p_2 v_b + \lambda p_2(1-\kappa) + \omega_{1,b}]}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)} l_0. \tag{58}$$

B.1.2 Comparison

Comparing expected profits, leads to a similar result as Lemma 1. The two main differences are that operating in the risky mode may be restricted by $l^{\max}_{1,\kappa}$ and that operating in the safe mode is feasible if the banker grants no loans neither in the first nor in the second period. This results in slightly different intervals for the respective modes of operation. Note that $\mathbb{K}$ is non-empty as long as μ is sufficiently larger than r_b.

B.2 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 loans are zero so that CAR becomes irrelevant. The banker's behavior is thus identical to the benchmark scenario, see Lemma 2.

B.3 First Period

B.3.1 Determination of Reduced Forms and Optimal Loan Volumes

B.3.1.1 Safe Mode $m = \mathcal{S}$ 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 (37) and (38) into (36), yields

$$\frac{1-(1-\lambda)p_1 v_g}{1-(1-\lambda)p_1} l_0 \leq (1-\kappa) l_0. \tag{59}$$

As $v_g = \mu + (1-p_1)\Delta$, this condition holds for all risks if $\kappa < 1 - \frac{1-(1-\lambda)p_1\mu}{1-(1-\lambda)p_1}$. Therefore a CAR $k \in \mathbb{K}$ imposes no additional restriction on bank loan supply so that (41), (42) and thus strategy $\mathcal{A}$ remain unchanged. **Strategy** $\mathcal{B}_{CAR}$ differs from strategy $\mathcal{B}$ in the sense that its upper bound may be larger. Moreover, **strategy** $\mathcal{X}_{CAR}$ implies that bank loan supply is so heavily restricted when choosing $m = \mathcal{S}$ that no loans can be granted neither in the first period nor in the bad state at $t = 1$. By definition this results in $l_0^* = 0$.

B.3.1.2 Risky Mode $m = \mathcal{R}$ Considering the results of the second period, the reduced form changes to

$$\begin{aligned} \max_{l_0, a_0 \in \mathbb{R}^+} \pi_{0,\kappa}^{\mathcal{R}}(l_0) = &\ \phi_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta) l_0 \\ &+ p_1 \phi_{1,g}(l_{1,g}^{\text{fb}}) + (1-p_1)\phi_{1,b}(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}) \end{aligned} \tag{60}$$

$$\text{s.t.}\quad l_0 \leq \frac{\phi_{1,b}\left(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}\right)}{\frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1} - p_2(\mu - p_1\Delta)} =: l_{0,\kappa}^{\max} \tag{61}$$

with

$$l_{1,\kappa}^{\max} := \psi_\kappa l_0 \quad \text{and} \quad \psi_\kappa := \frac{\frac{(1-\lambda)(p_1+p_2[1-(1-\lambda)p_1])\mu + (1-\lambda)p_1(1-p_1-p_2[1-(1-\lambda)p_1])\Delta - 1}{1-(1-\lambda)p_1} + \lambda p_2(1-\kappa)}{1-(1-\lambda)p_2 r_b - \lambda p_2(1-\kappa)}. \tag{62}$$

Strategy $\mathcal{C}_{CAR}$: If (61) is not binding, it follows from (60) that

$$\frac{\partial \pi_0^{\mathcal{R}}}{\partial l_0} = \phi_0'(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta) + (1-p_1)\phi_{1,b}'(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\})\frac{\partial \min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\}}{\partial l_0}. \tag{63}$$

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 (63) is equal to zero, so that the optimal loan volume is $l_0^* = l_{0,\kappa}^{\mathcal{R}}$. Applying the implicit function theorem on the first order condition of $\pi_{0,\kappa}^{\mathcal{R}}(l_0)$ with respect to l_0 yields that $\frac{\partial l_{0,\kappa}^{\mathcal{R}}}{\partial \Delta}$ is positive for smaller risks and negative for larger risks.

Strategy $\mathcal{D}_{CAR}$: If (61) is binding, the optimal loan volume is $l_0^* = l_{0,\kappa}^{\max}$ with $\frac{\partial l_{0,\kappa}^{\max}}{\partial \Delta} < 0$. 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.3.1.3 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}_{CAR}$

Capital requirements will always impose a restriction on the face value of deposits as $(1-\kappa)l_0 + a_0 < v_g l_0 + a_0$ is always fulfilled. Considering this restriction when inserting (37) and (38) into (36), yields

$$[1 - (1-\lambda)p_1 v_g - \lambda p_1(1-\kappa)]l_0 \leq 0. \tag{64}$$

In consequence, this 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 Δ, imposing a certain κ implies that this mode is feasible for all

$$\Delta \geq \frac{1 - \lambda p_1 - (1-\lambda)p_1\mu + \lambda p_1 \kappa}{(1-\lambda)p_1(1-p_1)} =: \Delta_\kappa^{\mathcal{E}}. \tag{65}$$

Strategy $\mathcal{E}_{CAR}$ thus also only differs from strategy $\mathcal{E}$ with respect to its interval.

B.3.2 Critical Values of Δ

$\Delta_\kappa^{\mathcal{B}}$, $\Delta_\kappa^{\mathcal{C}}$ and $\Delta_\kappa^{\mathcal{D}}$ are obtained analogously to $\Delta^{\mathcal{B}}$, $\Delta^{\mathcal{C}}$ and $\Delta^{\mathcal{D}}$, as the indifference between strategy $\mathcal{B}_{CAR}$ and $\mathcal{C}_{CAR}$, strategy $\mathcal{C}_{CAR}$ and $\mathcal{D}_{CAR}$, as well as $\mathcal{D}_{CAR}$ and $\mathcal{E}_{CAR}$ with

$$\Delta_\kappa^{\mathcal{C}} := \frac{\phi_{1,b}(\min\{l_{1,b}^{\text{fb}}, l_{1,\kappa}^{\max}\})[1-(1-\lambda)p_1]}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]l_{0,\kappa}^{\mathcal{R}}} + \frac{\mu[p_2 + (1-\lambda)p_1(1-p_2)] - 1}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]}. \tag{66}$$

If $\Delta_\kappa^{\mathcal{D}}$ 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

This proof proceeds analogously to the proof of Proposition 1 so that we only show deviations from the previous proofs.

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

C.1.1 Determination of Reduced Forms and Optimal Loan Volumes

C.1.1.1 Safe Mode The LCR will result in a restriction on the face value of deposits if

$$\frac{a_{1,b}}{\eta} \leq v_b l_0 + a_{1,b}. \tag{67}$$

Limiting the LCR to $\eta \in (0,1)$ implies that such a restriction is never binding. In order to fulfill the LCR, the banker can simply issue more deposits that are invested in the risk-free asset. This increases the LHS of (67) to a larger extent than the RHS. Accordingly there exists a critical $a_{1,b}$ for which the LCR imposes no additional restriction on the face value of deposits so that the optimal loan volume and the expected profit are given by (23).

C.1.1.2 Risky Mode The expected profit of the risk-free asset in the risky mode is $p_2 - 1 < 0$, see (25). Therefore, the LCR will always impose a restriction on the face value of deposits, i.e. $\delta_{1,b} \leq \frac{a_{1,b}}{\eta}$ becomes binding. Considering this new restriction on deposits the reduced form reads

$$\max_{l_{1,b}, a_{1,b} \in \mathbb{R}^+} \pi^r_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}(l_{1,b}) - (1-p_2) a_{1,b} \tag{68}$$

$$\text{s.t.} \quad [1 - (1-\lambda) p_2 r_b]\, l_{1,b} \leq [(1-\lambda) p_2 v_b + \omega_{1,b}]\, l_0 + \left[\frac{1-\eta}{\eta} - (1-p_2)\right] a_{1,b}, \tag{69}$$

so that the optimal loan volume $l^{r*}_{1,b}$ and the expected profit $\pi^{r*}_{1,b}$ are given by

$$l^{r*}_{1,b} = \min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\} \quad \text{and} \quad \pi^{r*}_{1,b} = (p_2 v_b + \omega_{1,b})\, l_0 + \phi_{1,b}\left(\min\{l^{\text{fb}}_{1,b}, l^{\max}_{1,\eta}\}\right) - (1-p_2) a_{1,b}, \tag{70}$$

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

$$\psi_\eta := \frac{(1-\lambda) p_2 v_b + \omega_{1,b}}{1 - (1-\lambda) p_2 r_b} < \psi \quad \text{and} \quad \xi_\eta := \frac{\frac{1-\eta}{\eta} \lambda p_2 - (1-p_2)}{1 - (1-\lambda) p_2 r_b}. \tag{71}$$

As long as $\xi_\eta < 0$ investing in the risk-free asset $a_{1,b}$ results in a negative expected profit so that $a^*_{1,b} = 0$. This implies, however, that the banker cannot issue any new deposits and the risky mode is technically not feasible.

For all $\xi_\eta > 0$, i.e. for all $\eta < \frac{\lambda p_2}{1-(1-\lambda)p_2}$, $a^*_{1,b}$ is determined by

$$\frac{\partial \pi^r_{1,b}}{\partial a_{1,b}} = \phi'_{1,b}\left(l^{\max}_{1,\eta}\right) \frac{\partial l^{\max}_{1,\eta}}{\partial a_{1,b}} - (1-p_2). \tag{72}$$

C.1.2 Comparison

Comparing expected profits, leads to a similar result as Lemma 1. The main difference is that operating in the risky mode may be restricted by $l_{1,\eta}^{\max}$. This results in slightly different intervals for the respective modes of operation.

C.2 Second Period ($t = 1$), Good State

As the LCR imposes no restriction on bank loan supply when operating in the safe mode, Lemma 2 remains unchanged.

C.3 First Period

C.3.1 Determination of Reduced Forms and Optimal Loan Volumes

C.3.1.1 Safe Mode $m = \mathcal{S}$ As the reduced form is identical to (41) and (42), **strategy $\mathcal{A}$** remain unchanged. **Strategy $\mathcal{B}_{LCR}$** differs from strategy $\mathcal{B}$ in the sense that its upper bound may be larger.

C.3.1.2 Risky Mode $m = \mathcal{R}$ Considering the results of the second period, the reduced form reads

$$\max_{l_0, a_0 \in \mathbb{R}+} \pi_{0,\eta}^{\mathcal{R}}(l_0) = \phi_0(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta)l_0 \tag{73}$$

$$+ p_1\phi_{1,g}(l_{1,g}^{\text{fb}}) + (1-p_1)\left[\phi_{1,b}(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}) - (1-p_2)a_{1,b}\right]$$

$$\text{s.t.} \quad l_0 \le \frac{\phi_{1,b}\left(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}\right) - (1-p_2)a_{1,b}}{\frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1} - p_2(\mu - p_1\Delta)} =: l_{0,\eta\mathcal{R}}^{\max} \tag{74}$$

with

$$l_{1,\eta}^{\max} := \psi_\eta l_0 + \xi_\eta a_{1,b} \quad \text{and} \quad \psi_\eta := \frac{(1-\lambda)p_2(\mu - p_1\Delta) + \frac{1-(1-\lambda)p_1(\mu+(1-p_1)\Delta)}{1-(1-\lambda)p_1}}{1-(1-\lambda)p_2 r_b}, \tag{75}$$

while ξ_η is defined in (71).

Strategy $\mathcal{C}_{LCR}$: If (74) is not binding, it follows from (73) that

$$\frac{\partial \pi_0^{\mathcal{R}}}{\partial l_0} = \phi_0'(l_0) - (1-p_1)(1-p_2)(\mu - p_1\Delta)$$

$$+ (1-p_1)\phi_{1,b}'(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\})\frac{\partial \min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}}{\partial l_0}, \tag{76}$$

which is equal to zero for $l_{0,\eta}^{\mathcal{R}}$ with $l_{0,\eta}^{\mathcal{R}} \in \left[l_0^{\mathcal{R}}, \frac{l_{1,b}^{\text{fb}} - \xi_\eta a_{1,b}}{\psi_\eta}\right]$ if $\psi_\eta > 0$ and $l_{0,\eta}^{\mathcal{R}}$ with $l_{0,\eta}^{\mathcal{R}} < l_0^{\mathcal{R}}$ if $\psi_\eta < 0$. The optimal loan volume is thus $l_0^* = l_{0,\eta}^{\mathcal{R}}$. Applying the implicit function theorem on the first order condition of $\pi_{0,\eta}^{\mathcal{R}}(l_0)$ with respect to l_0 yields that $\frac{\partial l_{0,\eta}^{\mathcal{R}}}{\partial \Delta}$ is positive for smaller risks and negative for larger risks.

Strategy $\mathcal{D}_{LCR}$: If (74) is binding, the optimal loan volume is $l_0^* = l_{0,\eta_\mathcal{R}}^{\max}$ with $\frac{\partial l_{0,\eta_\mathcal{R}}^{\max}}{\partial \Delta} < 0$.

C.3.1.3 Failure Mode $m = \mathcal{F}$, Strategy $\mathcal{E}_{LCR}$

As $p_1 - 1 < 0$, see (48), the LCR will always impose a restriction on the face value of deposits, i.e. $\delta_0 \leq \frac{a_0}{\eta}$ becomes binding. Considering this restriction, the reduced form reads

$$\max_{l_0, a_0 \in \mathbb{R}+} \pi_{0,\eta}^{\mathcal{F}}(l_0) = \phi_0(l_0) - (1-p_1)(\mu - p_1\Delta)l_0 - (1-p_1)a_0 + p_1\phi_{1,g}(l_{1,g}^{\text{fb}}) \tag{77}$$

$$\text{s. t.} \quad l_0 \leq \frac{\frac{1-\eta}{\eta}\lambda p_1 - (1-p_1)}{1-(1-\lambda)p_1[\mu + (1-p_1)\Delta]} a_0 =: l_{0,\eta_\mathcal{F}}^{\max}. \tag{78}$$

It follows from (78) 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 a_0^* is determined by

$$\frac{\partial \pi_{0,\eta}^{\mathcal{F}}}{\partial a_0} = \left[\phi_0'\left(l_{0,\eta_\mathcal{F}}^{\max}\right) - (1-p_1)(\mu - p_1\Delta)\right] \frac{\partial l_{0,\eta_\mathcal{F}}^{\max}}{\partial a_0} - (1-p_1). \tag{79}$$

The optimal loan volume is thus $l_0^* = \min\{l_0^{\mathcal{F}}, l_{0,\eta_\mathcal{F}}^{\max}\}$ with $\frac{\partial l_0^{\mathcal{F}}}{\partial \Delta} > 0$ and $\frac{\partial l_{0,\eta_\mathcal{F}}^{\max}}{\partial \Delta} > 0$.

C.3.2 Critical Values of Δ

$\Delta_\eta^\mathcal{B}$, $\Delta_\eta^\mathcal{C}$ and $\Delta_\eta^\mathcal{D}$ are obtained analogously to $\Delta^\mathcal{B}$, $\Delta^\mathcal{C}$ and $\Delta^\mathcal{D}$, as the indifference between strategy $\mathcal{B}_{LCR}$ and $\mathcal{C}_{LCR}$, strategy $\mathcal{C}_{LCR}$ and $\mathcal{D}_{LCR}$, as well as $\mathcal{D}_{LCR}$ and $\mathcal{E}_{LCR}$ with

$$\begin{aligned}\Delta_\eta^\mathcal{C} := &\frac{[\phi_{1,b}(\min\{l_{1,b}^{\text{fb}}, l_{1,\eta}^{\max}\}) - (1-p_2)a_{2,b}][1-(1-\lambda)p_1]}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]l_{0,\eta}^{\mathcal{R}}} \\ &+ \frac{\mu[p_2 + (1-\lambda)p_1(1-p_2)] - 1}{p_1[p_2 - (1-\lambda)(1-p_1(1-p_2))]}.\end{aligned} \tag{80}$$

D Proof of Proposition 4

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.

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