Interest Rates, Market Power, and Financial Stability

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Abstract

This paper shows that market power is key to assessing the effects of safe rates on banks' risk-taking. We construct a model where banks are partially funded with insured deposits, have market power in lending, and privately monitor loans, which reduces their probability of default. We show that lower safe rates lead to lower margins and higher risk-taking in competitive markets, but the result reverses in monopolistic markets. We also show that high deposit insurance makes it more likely that lower safe rates translate into lower risk-taking. The results are robust to introducing market power in deposits and endogenous leverage.

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1 Introduction

This paper analyzes, from a theoretical perspective, how changes in interest rates affect the risk-taking decisions of financial intermediaries, and how this relationship depends on the market structure of the financial sector. Our central contribution is to show that banks' market power and the composition of their liabilities are key determinants of whether lower safe rates lead to higher or lower risk-taking.

We model a one-period risk-neutral economy in which a fixed number of banks raise insured and uninsured deposits and compete à la Cournot in providing loans to penniless entrepreneurs. Banks privately choose the monitoring intensity of their loans, where higher monitoring results in lower probabilities of default. Crucially, we assume that the monitoring decision is costly and unobservable, which creates a moral hazard problem between the banks and their uninsured depositors. The expected return that both types of depositors require for their funds is assumed to be equal to an exogenous safe rate.

In this environment banks' monitoring incentives are determined by their intermediation margin, defined as the difference between loan rates and funding costs. We show how a change in the safe rate affects intermediation margins through two distinct forces. First, there is a direct *funding cost effect*: higher safe rates increase the cost of both insured and uninsured deposits, compressing intermediation margins and reducing incentives to monitor, holding loan rates fixed. Second, there is an indirect *loan rate effect*: higher safe rates reduce equilibrium lending, which results in higher loan rates, increasing intermediation margins and monitoring incentives, holding funding costs fixed.

Market power governs the relative strength of these two forces by determining the pass-through from funding costs to loan rates and in doing so determines the overall effect of safe rates on risk-taking. In competitive loan markets, the pass-through is strong, so higher safe rates increase intermediation margins and lead to lower probabilities of loan default. In contrast, in monopolistic loan markets the pass-through is weak, so higher safe rates reduce intermediation margins, resulting in higher probabilities of default.

At the same time, deposit insurance plays a key role in the determination of intermediation margins and their response to changes in safe rates. In contrast with insured deposits, uninsured deposits benefit from banks' monitoring as it increases their expected payoffs. Thus, an increase in the proportion of insured deposits reduces the funding cost effect, so the loan rate effect becomes relatively more important. This implies that the critical number of banks for which the sign of the relationship between the safe rate and the probability of loan default flips sign (from positive to negative) is increasing in the proportion of insured deposits. We conclude that *high safe rates reduce banks' risk-taking when their market power and the proportion of insured deposits is low, but increase risk-taking when their market power and the proportion of insured deposits is high.*

We next consider three extensions of the model. First, we analyze the effect of introducing heterogeneity in banks' monitoring costs. We assume that there are two observable types of banks characterized by high and low cost of monitoring entrepreneurs and show how in equilibrium, banks with high monitoring costs have lower market shares and their loans have higher probabilities of default. We show that higher safe rates reduce the market share of high monitoring cost banks, as their funding costs are more sensitive to the change in safe rates, leading to a *composition effect* which reduces the average probability of loan default.

Second, we consider a situation in which entrepreneurs also have the possibility of being directly funded by competitive investors that do not monitor their projects.[1] This extension allows us to analyze how the loan rate effect can be affected, in a non-linear way, by the presence of an outside funding option. In such situation market finance imposes a constraint that limits the loan rates that banks can charge and reduces their intermediation margins. We show that this constraint is more likely to bind in monopolistic loan markets and when

[1] We can think of these investors as unsophisticated bond financiers, as in Holmström and Tirole (1997).

the safe rate is low, which implies that these markets exhibit a U-shaped relationship between the safe rate and the probability of loan default.

Third, we analyze the effects of changes in safe rates when intermediaries also compete à la Cournot in the deposit market. This extension allows for an incomplete pass-through of safe rates to both loan and deposit rates, which affects the intensity of the funding cost effect. We show that the results are qualitatively similar to those of the original model: high safe rates reduce (increase) the probability of loan default when banks' market power is low (high)

Finally, we examine the relevance of inside equity capital, i.e. funds provided by those responsible for the monitoring decisions, in a dynamic extension of our model setup.[2] Higher inside equity, by increasing banks' skin in the game, plays an important role in determining their monitoring incentives. We assume that inside shareholders are risk-neutral long-lived agents that require a spread over the safe rate (a standard excess cost of capital) and take into account the loss of the bank's charter if their bank fails. We show that in this setup higher safe rates have two opposite effects. On the one hand, there is a *leverage effect* that follows from the fact that shareholders have higher incentives to use relatively cheaper equity. Thus, higher rates leads to lower leverage, higher intermediation margins and higher monitoring incentives. On the other hand, there is a *charter value effect* that follows from the fact that charter values go down, leading to lower monitoring incentives. While the latter effect dominates in monopolistic markets, the former dominates in competitive markets. Hence, we conclude that our results are robust to the introduction of endogenous leverage.

It is important to note that the model is silent about what drives changes in the safe rate. It may be real factors (such as a savings glut) or it may be monetary policy (as in the literature on the "risk-taking channel" reviewed below).

[2]In our setup, outside equity capital plays essentially the same role as uninsured deposits.

Suggestive evidence Before going into our model, it is worth presenting some suggestive evidence on the relevance of bank competition for the transmission of safe rates to loan rates and intermediation margins, which is key for our results. Following Dreschler et al. (2017), we estimate the sensitivity of loan rates and intermediation margins to changes in the Federal funds rate for different deciles of the distribution of banks' market power.

We use quarterly data from the U.S. Call Reports for the period 1994 to 2019 to obtain loan rates and intermediation margins for each bank. For loan rates we compute the interest and fee income on loans divided by total loans. For intermediation margins we compute the difference between loan rates and deposit rates, which are obtained as a weighted average of the rates for transaction accounts, savings deposits, and time deposits. We use the Federal funds target rate as the monetary policy rate.[3] Finally, as a proxy for market power, we use data on new mortgage lending by banks from the Home Mortgage Disclosure Act (HMDA) to compute an average Herfindahl index (HHI) for each bank.[4]

We divide the bank-quarter observations into 10 equal-sized bins from lowest to highest HHI, and run the following regression with quarterly data for each bin:

$$\Delta y_{bt} = \alpha_b + \beta_i \Delta FF_t + \varepsilon_{bt},$$

where Δy_{bt} is the change in either the loan rate or the intermediation margin of bank b that belongs to bin $i = 1, ..., 10$ at date t, ΔFF_t is the change in the Federal funds target rate at date t, and α_b are bank fixed effects. We refer to β_i as the sensitivity of loan rates or intermediation margins of banks belonging to bin i to changes in the Federal funds rate.

Figure 1 shows the results. Panel A plots the sensitivity of loan rates and Panel B the sensitivity of intermediation margins to changes in the Federal funds rate for each bin.

[3] After the introduction in 2008 of a target rate corridor we use the mid point of the target range.

[4] In particular, we first obtain for each year a county level HHI using new mortgages originated by banks. We then compute the weighted average of county HHIs across the counties in which a bank operates. Finally, we take the average HHI for each bank in all the years in the sample. Similar results obtain when we include mortgages originated by non-banks or we compute the HHI using data on deposits in bank branches from the Federal Deposit Insurance Corporation (FDIC).

Consistent with the mechanism in our theoretical model, we find a negative relationship in both cases. In other words, the higher the market power, the lower the effect of the policy rate on loan rates and intermediation margins. More importantly, and in line with the predictions of our model, the sensitivity of intermediation margins changes sign from positive to negative. In particular, for banks operating in competitive markets lower policy rates translate into lower margins, while for banks operating in monopolistic markets lower policy rates translate into higher margins. Since in our model monitoring incentives are driven by the intermediation margin, this evidence is consistent with our key result: lower rates lead to higher risk-taking when banks have low market power, and to lower risk-taking when banks have high market power.

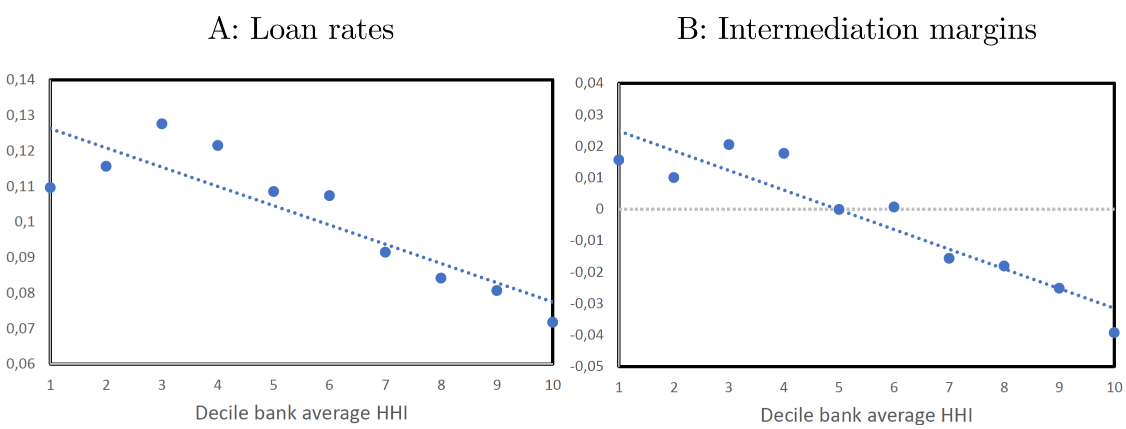

Figure 1. Sensitivities of loan rates and intermediation margins to the Federal funds rate for different levels of banks' market power

This figure shows the relationship between market power (from the lowest to the highest decile in banks' average Herfindahl index) and the sensitivity of loan rates (Panel A) and intermediation margins (Panel B) to changes in the Federal funds rate.

Related literature This paper is at the intersection of two strands of literature, one that analyzes the effect of competition on financial stability, and another one that analyzes the effect of monetary policy on banks' risk-taking incentives. Our main contribution is to provide a theoretical framework that shows that the competitive structure of the financial sector together with the level of interest rates and the extent of deposit insurance determine banks' intermediation margins and risk-taking incentives.

The relationship between bank competition and stability has been extensively examined, both theoretically and empirically. Seminal papers like Keeley (1990) or Allen and Gale (2000) provide theoretical models showing how, due to excessive risk-taking incentives, a more competitive banking sector results in higher probabilities of bank failure.[5] This relationship between bank competition and stability has also been investigated in many empirical papers; see for example the survey in Beck et al. (2006). We contribute to this literature by showing that different market structures, combining for example monitored bank and non-monitored bond finance, are relevant in shaping the relationship between interest rates and risk-taking.

Similarly, the relationship between deposit insurance and stability has received ample attention in the academic literature. In their seminal paper, Diamond and Dybvig (1983) highlight how deposit insurance can reduce depositor runs, and in so doing, enhance stability. However, this relationship can be more nuanced when banks' and investors' monitoring incentives are taken into account; see, for example, Allen et al. (2011). Empirical studies such as Demirgüç-Kunt and Detragiache (2002) and Demirgüç-Kunt and Huizinga (2004) provide evidence that deposit insurance has a negative impact on market discipline, thus increasing the likelihood of banking crises.[6] We contribute to this literature by showing how deposit insurance, combined with the extent of competition in the banking sector, is a relevant determinant of the impact of interest rates on risk-taking.

Our paper is also related to studies that highlight the importance of competition for

[5] A more recent strand of this literature builds on Stiglitz and Weiss (1981) to show how this relationship can be reversed when the risk-taking decisions are taken by the borrower instead of by the bank, and how a U-shaped relationship can arise under imperfect correlation of loan defaults; see Boyd and De Nicolo (2005) and Martinez-Miera and Repullo (2010).

[6] Relatedly, Ioannidou and Penas (2010) find that after the introduction of deposit insurance in 2001, Bolivian banks were more likely to initiate riskier loans.

assessing the effects of different policies on banks' risk-taking. Hellmann et al. (2000) show that, given the effect of competition on deposit rates, both capital and deposit rate regulations are needed in order to minimize risk-taking incentives. Repullo (2004) shows how the effect of bank capital regulation on risk-taking incentives depends on the competitive structure of the banking sector.

The papers more closely related to ours are Dell'Ariccia et al. (2014), which focusses on the relevance of leverage for the relationship between safe rates and banks' risk-taking, and Martinez-Miera and Repullo (2017), which studies the relationship between aggregate savings, safe rates, and risk-taking in an economy with a competitive financial sector.[7] While both papers provide models in which banks' risk-taking decisions are affected by safe rates, and show circumstances under which lower safe rates can lead to higher risk-taking, our paper emphasizes the effect of competition in shaping such relationship. We also highlight how features such as deposit insurance, heterogeneity in monitoring costs, and the presence of non-monitored bond finance affect the results.

Our modelling of endogenous leverage differs from that of Dell'Ariccia et al. (2014). They consider a static setup in which lower rates always lead to higher risk-taking irrespective of market power due to a *leverage effect*. This effect follows from the fact that with a fixed excess cost of capital, lower rates makes equity capital relatively more expensive than deposits, so banks have an incentive to increase their leverage, which leads them to decrease their monitoring. In contrast, we show that in a dynamic setup there is also a *charter value effect* that works in the opposite direction, since lower rates lead to higher charter values, so banks have an incentive to increase their monitoring in order to preserve their charter. Hence, we conclude that even with endogenous leverage market power is a key determinant of the effect of safe rates on risk-taking.

[7] See also Boissay et al. (2016) for a theoretical model on how safe rates affect risk-taking in the presence of informational asymmetries in the interbank market, and Dell'Ariccia et al. (2017) for empirical evidence on the connection between safe rates and banks' risk-taking.

Our focus on how interest rates affect banks' risk-taking in markets with financial frictions relates our work to the literature building on the seminal papers of Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) that highlights the importance of (information-driven) financial frictions for economic outcomes. More specifically, our paper is closely connected to papers analyzing the effects of monetary policy on banks' risk-taking incentives, the so-called "risk-taking channel" of monetary policy; see Adrian and Shin (2010), Borio and Zhu (2012), and Coimbra and Rey (2024), among many others. This literature provides evidence on how lax monetary policy conditions lead to higher risk-taking by banks; see Maddaloni and Peydro (2011), and Jimenez et al. (2014), among many others.[8]

The literature analyzing the transmission of monetary policy has emphasized the role of banks, the so-called "bank lending channel" of monetary policy, because of frictions arising in the deposit or more generally the funding markets; see the seminal studies by Bernanke and Blinder (1988) and Kashyap and Stein (1995). Research by Dreschler et al. (2017) has analyzed the effect of market power on the pass-through of monetary policy to deposit rates, with more competitive markets exhibiting a higher pass-through. We contribute to this literature by highlighting the importance of taking into account market power, as well as the extent of deposit insurance, in assessing the relationship between safe rates and financial stability.[9]

Structure Section 2 presents the static model of Cournot competition in the loan market. Section 3 presents the extensions of the model. Section 4 examines a dynamic version of the model that allows for endogenous leverage, and Section 5 contains our concluding remarks. The proofs of the analytical results are in the Appendix.

[8] Corbae and Levine (2018) provides empirical evidence on the relevance of competition for the effects of monetary policy on banks' probability of failure using branch deregulation shocks in the US.

[9] Other work has focussed on the effects of (unconventional) monetary policy on banks' risk-taking. For example, Chodorow-Reich (2014) shows that there is very little risk-taking response to expansionary monetary policy after 2009, while Heider et al. (2019) provide evidence on these effects in a negative interest rate environment.

2 Model of Bank Competition and Risk-taking

Consider an economy with two dates ($t = 0, 1$) with three types of risk-neutral agents: a continuum of *depositors*, a continuum of penniless *entrepreneurs*, and n identical *banks*. Depositors are characterized by an infinitely elastic supply of funds at an expected gross return R_0 (the safe rate). Each entrepreneur has an investment project that can only be funded by a single bank. Banks in turn have no capital and are funded by depositors. We assume that a proportion θ of a bank's deposits are insured (at zero cost) by a deposit insurance agency, while the rest are uninsured.

Entrepreneurs' projects require a unit investment at $t = 0$ and yield a stochastic return at $t = 1$ given by

$$\widetilde{R} = \begin{cases} R, & \text{with probability } 1 - p + m, \\ 0, & \text{with probability } p - m, \end{cases}$$

where $p \in (0, 1)$ is the probability of failure in the absence of monitoring, and $m \in [0, p]$ is the monitoring intensity of the lending bank. Monitoring is costly, and the cost function is

$$c(m) = \frac{\gamma}{2} m^2, \tag{1}$$

with $\gamma > 0$. While p is known, m is not observed by depositors, so there is a moral hazard problem between banks and uninsured depositors.

The outcome of entrepreneurs' projects is driven by a single aggregate risk factor z that is uniformly distributed in $[0, 1]$. A project monitored with intensity m will fail if and only if $z < p - m$. This assumption implies that the return of projects monitored with the same intensity will be perfectly correlated.[10]

The success return R is assumed to be a decreasing function of the aggregate investment of entrepreneurs.[11] Given that entrepreneurs only receive funding from banks, their aggregate

[10] This simplifying assumption is common in the banking literature; see, for example, Holmström and Tirole (1997), Allen and Gale (2000), and Boyd and De Nicolo (2005) among many others.

[11] This may be rationalized by assuming that the higher the investment and the output of entrepreneurs' projects (if successful), the lower the price that this output will command.

investment equals the aggregate supply of loans L. Thus, we can write the success return of a project as $R(L)$. We assume that this relationship is linear, so

$$R(L) = a - bL, \tag{2}$$

where $a > 0$ and $b > 0$. Free entry of entrepreneurs ensures that the success return $R(L)$ equals the rate at which they borrow from banks, which means that $R(L)$ is also the inverse loan demand function.

Banks compete à la Cournot for loans. Specifically, each bank $j = 1, ..., n$ chooses its supply of loans l_j, which determines the total supply of loans $L = \sum_{j=1}^{n} l_j$ and the loan rate $R(L)$. To fund its lending l_j, bank j offers a gross interest rate D_j to its insured depositors and a gross interest rate B_j to its uninsured depositors. Once the funding of its lending is arranged, bank j chooses the monitoring intensity of its loans m_j.

The objective of bank j is to maximize its expected profits, which are computed as follows: With probability $1 - p + m_j$ all loans are performing, so the bank gets $R(L)$ and pays $\theta D_j + (1-\theta)B_j$ per unit of loans, while with probability $p - m_j$ all loans default, so by limited liability the bank gets a zero return. Subtracting the monitoring costs per unit of loans (1), the problem of bank j may be written as

$$\max_{l_j, B_j, D_j, m_j} \left\{ l_j \left[(1 - p + m_j)(R(L) - \theta D_j - (1-\theta)B_j) - \frac{\gamma}{2} m_j^2 \right] \right\},$$

subject to the incentive compatibility constraint that determines its optimal choice of monitoring

$$m_j = \arg\max_m \left[(1 - p + m)(R(L) - \theta R_0 - (1-\theta)B_j) - \frac{\gamma}{2} m^2 \right],$$

and the participation constraints of the insured and uninsured depositors that are required to secure their funding

$$\begin{aligned} D_j &\geq R_0, \\ (1 - p + m_j)B_j &\geq R_0. \end{aligned}$$

The insured depositors get D_j from the bank with probability $1 - p + m_j$ and D_j from the deposit insurance agency with probability $p - m_j$, while the uninsured depositors get B_j from the bank with probability $1 - p + m_j$ and zero with probability $p - m_j$. With an infinitely elastic supply of funds at the rate R_0, the participation constraints of both types of depositors hold with equality.

To characterize the equilibrium of the model we proceed backwards. In Section 2.1 we determine the bank's uninsured borrowing rate B_j and monitoring intensity m_j as a function of the loan rate $R(L)$ determined by the banks' total lending L. Since at this point all banks face the same problem we can drop the subindex j and simply write $B(L)$ and $m(L)$. Then, in Section 2.2 we solve for the equilibrium total lending L.

2.1 Equilibrium Monitoring Decisions

Since banks choose the monitoring intensity of their loans $m(L)$ once the lending rate $R(L)$ and the uninsured funding rate $B(L)$ are set, their choice of monitoring is

$$m(L) = \arg\max_{m} \left[(1 - p + m)[R(L) - \theta R_0 - (1 - \theta)B(L)] - \frac{\gamma}{2} m^2 \right].$$

The first-order condition that characterizes an interior solution to this problem is

$$R(L) - \theta R_0 - (1 - \theta)B(L) = \gamma m(L). \tag{3}$$

Thus, in an interior solution banks' monitoring intensity $m(L)$ is proportional to the intermediation margin $R(L) - \theta R_0 - (1 - \theta)B(L)$. This is a fundamental property of our setup where banks' risk-taking is determined by intermediation margins.

The uninsured depositors' participation constraint is

$$[1 - p + m(L)]B(L) = R_0. \tag{4}$$

Note that we are implicitly assuming that the uninsured depositors correctly anticipate the monitoring intensity $m(L)$ chosen by the banks for any given borrowing rate $B(L)$. Solving for $B(L)$ in this constraint and substituting it into the first-order condition (3) gives the key equation that characterizes banks' choice of monitoring

$$\gamma m(L) + \theta R_0 + \frac{(1-\theta)R_0}{1-p+m(L)} = R(L). \tag{5}$$

Let us now define

$$\underline{R} = \min_{m\in[0,p]} \left(\gamma m + \theta R_0 + \frac{(1-\theta)R_0}{1-p+m}\right) = \gamma \underline{m} + \theta R_0 + \frac{(1-\theta)R_0}{1-p+\underline{m}}. \tag{6}$$

The following result that characterizes the feasible set of loan rates and their associated uninsured deposit rates and monitoring intensities.

Proposition 1 *Banks are able to fund a total supply of loans L if $R(L) \geq \underline{R}$, in which case*

$$m(L) = \max\left\{m \in [0,p] \mid \gamma m + \theta R_0 + \frac{(1-\theta)R_0}{1-p+m} \leq R(L)\right\}. \tag{7}$$

If $R(L) < \gamma p + R_0$, then $m(L) < p$ and the condition in (7) will be satisfied with equality.

Restricting attention to the case where $0 < m(L) < p$, Proposition 1 implies that $m(L)$ will be the highest solution to equation (5),[12] which is

$$m(L) = \frac{1}{2\gamma}\left[R(L) - \theta R_0 - \gamma(1-p) + \sqrt{[R(L) - \theta R_0 + \gamma(1-p)]^2 - 4\gamma(1-\theta)R_0}\right]. \tag{8}$$

From here it follows that an increase in total lending L, which according to (2) leads to a decrease in the loan rate $R(L)$, reduces the monitoring intensity of banks, so $m'(L) < 0$. This is because lower lending rates reduce the intermediation margin and hence banks' incentives to monitor. At the same time, (8) implies that an increase in the safe rate R_0, for a given value of the loan rate $R(L)$, also reduces monitoring. This is because higher safe rates translate into higher costs of funding, leading to a reduction in the intermediation margin and in banks' incentives to monitor. Finally, it can be checked that an increase in the proportion θ of insured deposits, for a given value of the loan rate $R(L)$, increases monitoring.[13] This

[12] The quadratic equation in $m(L)$ implied by (5) has in general two solutions that satisfy the bank's first-order condition (3) and the uninsured depositors' participation constraint (4), but the one with the highest monitoring intensity is the one preferred by the bank as it yields higher profits. Moreover, the bank can select it by simply offering to pay the uninsured depositors the rate corresponding to this solution.

[13] Differentiating (8) with respect to θ gives an expression that is positive if and only if $m(L) < p$.

is because a higher proportion of insured deposits reduce the costs of funding, leading to an increase in the intermediation margin and in banks' incentives to monitor.

It should be noted that this partial analysis of the effects of changes in the safe rate R_0 and in the proportion θ of insured deposits does not take into account the effect of such changes on the equilibrium supply of loans. To do so we now turn to the analysis of the banks' equilibrium lending decisions.

2.2 Equilibrium Lending Decisions

To compute the symmetric Cournot equilibrium of the loan market, note that the objective function of an individual bank is given by the product of its lending l by the profits per unit of loans, which are given by

$$\pi(L) = [1 - p + m(L)][R(L) - \theta R_0 - (1-\theta)B(L)] - \frac{\gamma}{2}[m(L)]^2. \tag{9}$$

In a Cournot equilibrium each bank maximizes its profits $l\pi(L)$ anticipating the decisions of the other $n-1$ banks. If the other $n-1$ banks choose to lend l^*, in a symmetric Cournot equilibrium the best response of any bank should be to choose l^*, which gives the condition

$$l^* = \arg\max_l \left[l\pi(l + (n-1)l^*) \right].$$

From here it follows that the symmetric Cournot equilibrium is characterized by the first-order condition $l^*\pi'(L^*) + \pi(L^*) = 0$, which multiplying by n gives

$$L^*\pi'(L^*) + n\pi(L^*) = 0, \tag{10}$$

where $L^* = nl^*$ is the equilibrium total lending.

Substituting the intermediation margin from (3) into the function $\pi(L)$ in (9) yields

$$\pi(L) = \gamma(1-p)m(L) + \frac{\gamma}{2}[m(L)]^2. \tag{11}$$

This implies that bank profits per unit of loans $\pi(L)$ will be positive whenever the intermediation margin is positive. Given that $m'(L) < 0$, this also implies

$$\pi'(L) = \gamma[1 - p + m(L)]m'(L) < 0. \tag{12}$$

However, the sign of $\pi''(L)$ is in principle ambiguous,[14] so in what follows we assume that parameter values are such that

$$L\pi''(L) + n\pi'(L) < 0. \tag{13}$$

Given that $\pi'(L) < 0$, this implies that the second-order condition for the symmetric Cournot equilibrium $L^*\pi''(L^*) + 2n\pi'(L^*) < 0$ is satisfied.

The equilibrium loan rate is $R^* = R(L^*)$, the rate at which banks borrow from the uninsured depositors is $B^* = B(L^*)$, and the rate at which banks borrow from the insured depositors is $D^* = R_0$. The probability of loan default is $PD = p - m^*$, where $m^* = m(L^*)$ is the banks' equilibrium monitoring intensity. Note that the assumption of a single aggregate risk factor implies that probability of loan default equals the probability of bank failure.

We are interested in analyzing the effect on the probability of default PD of changes in the safe rate R_0, and how this effect changes with the number of banks n, which measures (the inverse of) their market power, and with the proportion θ of insured deposits. To do this, we first analyze the effect of these variables on equilibrium total lending L^*.

Proposition 2 *If the equilibrium loan rate $R(L^*)$ is greater than the minimum feasible loan rate $\underline{R}$ defined in* (6)*, equilibrium total lending L^* satisfies*

$$\frac{\partial L^*}{\partial R_0} < 0, \ \frac{\partial L^*}{\partial \theta} > 0, \ \frac{\partial L^*}{\partial n} > 0.$$

The intuition behind these results is as follows. A lower safe rate R_0 and a higher proportion θ of insured deposits translate into a lower cost of funding for the banks, which

[14] The function $m(L)$ in (8) is strictly concave, but by (11) bank profits per unit of loans are strictly convex in $m(L)$. Thus, the sign of $\pi''(L)$ is ambiguous, although it is negative in all our numerical results.

in a Cournot equilibrium leads to higher lending L^*. And an increase in the intensity of competition implied by a higher number of banks n also leads to higher lending L^*.

2.3 Determinants of Bank Risk-taking

The effect of changes in the safe rate R_0 on the equilibrium monitoring intensity m^* is given by the following derivative

$$\frac{dm^*}{dR_0} = \frac{\partial m^*}{\partial L^*}\frac{\partial L^*}{\partial R_0} + \frac{\partial m^*}{\partial R_0}. \tag{14}$$

Using the expression for $m(L)$ in (8), we have shown that $\partial m/\partial L < 0$ and $\partial m/\partial R_0 < 0$. Given that by Proposition 2 we have $\partial L^*/\partial R_0 < 0$, the first term in the right-hand side of (14) is positive, while the second term is negative.

The negative term may be called the *funding cost effect*, and it follows from the fact that an increase in the safe rate R_0 increases the cost of both insured and uninsured depositors, and hence decreases the intermediation margin $R^* - \theta R_0 - (1-\theta)B^*$. The positive term may be called the *lending rate effect*, which comes from the fact that an increase in the safe rate R_0 reduces equilibrium lending L^*, which pushes up the loan rate R^* and the intermediation margin $R^* - \theta R_0 - (1-\theta)B^*$. Thus, one effect decreases the margin, while the other increases it. Since according to (3) the banks' monitoring intensity is proportional to the intermediation margin, in general we have an ambiguous effect on risk-taking.

In what follows we show that the sign of the derivative in (14) depends on the number of banks n. We proceed by first analyzing two extreme cases, namely the competitive case with a sufficiently large number of banks and the case with a single monopoly bank. Once we show that the sign of the derivative is different in both cases, we analyze how the relationship between safe rates and bank risk-taking depends on the number of banks.

In the competitive case, by Proposition 2 increasing the number of banks n increases equilibrium total lending L^* and reduces the equilibrium loan rate $R^* = R(L^*)$. There will be a high enough $\underline{n}$ for which the constraint $R^* \geq \underline{R}$ becomes binding.[15] In this case, by Proposition 1, the equilibrium monitoring intensity m^* equals the value $\underline{m}$ corresponding to the minimum feasible loan rate $\underline{R}$ defined in (6), which is

$$\underline{m} = \max\left\{\sqrt{\frac{(1-\theta)R_0}{\gamma}} - (1-p), 0\right\}. \tag{15}$$

Hence, when there is a significant proportion $(1-\theta) > \frac{\gamma}{R_0}(1-p)^2$ of uninsured deposits, we have $\underline{m} > 0$, and increases in the safe rate R_0 increase banks' equilibrium monitoring m^*. This condition is more likely to be satisfied when the safe rate R_0 is high, the cost of monitoring parameter γ is low, and the probability of failure in the absence of monitoring p is high. Otherwise, the monitoring intensity will be at the corner $m^* = 0$.

The intuition for this result is that the monitoring intensity $\underline{m}$ minimizes the convex function in (6). This minimum is characterized by equating the change in the marginal cost of monitoring to the change in the marginal benefit of monitoring. While the marginal cost does not depend on the safe rate R_0, the marginal benefit is increasing in R_0. This is because a higher safe increases the value of monitoring in terms of a reduction in the deposit rate required by the uninsured depositors. Thus, *for a large enough number of banks and a sufficient proportion of uninsured deposits higher safe rates lead to lower risk-taking.*

In the case of monopoly, the monopolist's objective function $\Pi(L) = L\pi(L)$ is decreasing in safe rate R_0, since $\pi(L)$ is monotonic in $m(L)$ by (11), and $m(L)$ is decreasing in R_0 by (8). Hence, the monopolist's equilibrium total profits Π^* is decreasing in R_0. Assuming that the monopolist's equilibrium profits per unit of loans π^* is also decreasing in R_0,[16] it follows by (11) that equilibrium monitoring m^* will be decreasing in R_0. Thus, *under monopoly higher safe rates lead to higher risk-taking.*

[15] Ignoring integer constraints, $\underline{n}$ satisfies the first-order condition $\underline{L}\pi'(\underline{L}) + \underline{n}\pi(\underline{L}) = 0$ for $\underline{L}$ such that $R(\underline{L}) = \underline{R}$. The equilibrium loan rates and risk-taking decisions will be the same for all $n > \underline{n}$.

[16] This is an assumption, since $dL^*/dR_0 < 0$ (by Proposition 2) implies that the sign of $d\ln\pi^*/dR_0 = d\Pi^*/dR_0 - dL^*/dR_0$ is in principle ambiguous, although it is negative in all our numerical results.

Our previous results show that for a large number of banks the relationship between the safe rate and the probability of loan default is negative when the proportion of uninsured deposits satisfies the condition $(1-\theta) > \frac{\gamma}{R_0}(1-p)^2$. Since the sign of the relationship is positive in the case of monopoly, this condition guarantees that the relationship flips sign (from positive to negative) with increases in the number of banks.

Figure 2 illustrates these results showing that an increase in the number of banks n leads to a reduction in the slope of the relationship between the safe rate R_0 (in the horizontal axis) and the probability of loan default PD (in the vertical axis).[17] For sufficiently high n the slope changes sign from positive to negative. Figure 2 also shows that an increase in the number of banks n increases the probability of default PD. This follows from the fact that, by Proposition 2, an increase in n increases equilibrium lending L^*, which using result $m'(L) < 0$ lowers equilibrium monitoring m^* and increases the probability of default PD. The intuition is clear: higher competition reduces intermediation margins and monitoring incentives.[18]

With regard to the effect of the proportion θ of insured deposits, the comparison between Panel A (for $\theta = 0.4$) and Panel B (for $\theta = 0.6$) of Figure 2 shows that higher deposit insurance increases risk-taking and makes it more likely that lower safe rates translate into higher intermediation margins and lower risk-taking. The intuition for the first effect is that deposit insurance induces banks to compete more aggressively for loans, since they are less concerned about the impact on the cost of uninsured deposits. To explain the intuition for the second effect we first prove the following result.

[17] Parameters used in this and the following figures are not intended to provide a calibration of the model; they are chosen to illustrate the qualitative results of the paper.

[18] This result is in line with the charter value view of the relationship between competition and financial stability, according to which higher competition results in higher risk-taking; See, for example, Keeley (1990), Allen and Gale (2000), Hellmann et al. (2000), and Repullo (2004).

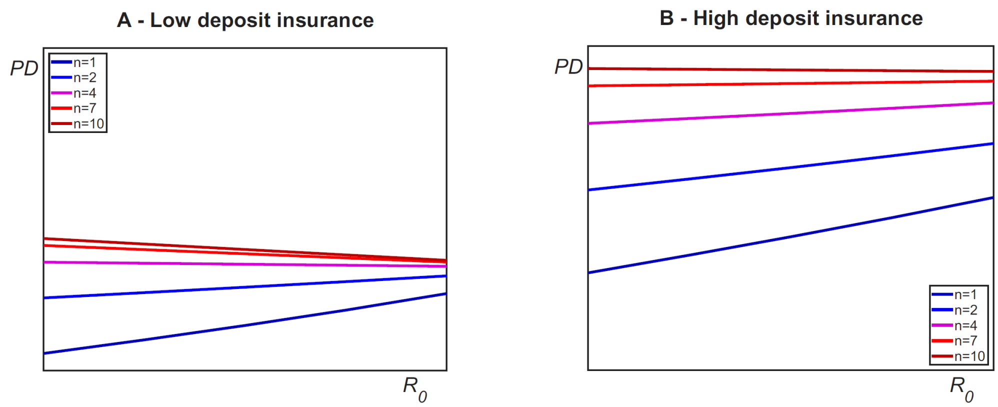

Figure 2. Effect of the safe rate on the probability of default

This figure shows the relationship between the safe rate (in the horizontal axis) and the probability of default (in the vertical axis) for loan markets with different number of banks and low (Panel A) and high (Panel B) proportion of insured deposits.

Proposition 3 *With full deposit insurance* ($\theta = 1$) *we have*

$$\frac{\partial m^*}{\partial R_0} < 0,$$

except when the number of banks n *is large in which case* $m^* = \underline{m} = 0$.

By continuity, this result implies that when the proportion θ of insured deposits is sufficiently large, increases in the safe rate R_0 lead to either increases in the probability of default PD, when banks have high market power (low n) or have no effect on the probability of default PD, when banks have low market power (high n). This latter result follows immediately from (15), because for sufficiently high θ we have $m^* = \underline{m} = 0$.

Away from these special cases, Figure 3 shows the effect of the number of banks n and the proportion θ of insured deposits on the slope of the relationship between the safe rate R_0 and the probability of default PD, that is the marginal effect on risk-taking. In the green area, which corresponds to low n and high θ, the slope is positive, so increases in the safe rate increase the probability of default. In the red area, which corresponds to high n and low θ, the slope is negative, so increases in the safe rate decrease the probability of default. From here it follows that the critical number of banks n for which the sign of the relationship between the safe rate and the probability of loan default flips sign (from positive to negative) is increasing in the proportion θ of insured deposits.[19]

The conclusion that follows from this analysis is that market power is key for assessing the effect of interest rates on banks' risk-taking. In particular, *low safe rates are detrimental to financial stability when banks' market power is low but beneficial when their market power is high*, except when there is a high proportion of insured deposits, in which case lower safe rates always decrease risk-taking.

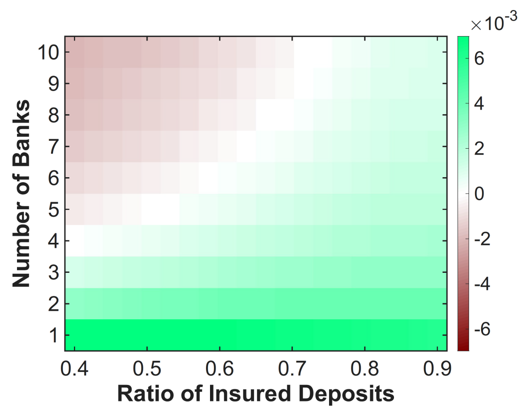

Figure 3. Marginal effect of the safe rate on the probability of default

This figure shows the slope of the relationship between the safe rate and the probability of default for different combinations of the proportion of insured deposits (in the horizontal axis) and the number of banks (in the vertical axis). The slope is positive in the green area and negative in the red area.

[19]It should be noted that in our setup outside equity, i.e. equity that is not provided by those responsible for the monitoring decisions, would be equivalent to uninsured deposits. Thus, higher amounts of outside equity, due for example to regulatory constraints, would tend to increase the slope of the relationship between the safe rate and the probability of loan default.

3 Three Extensions

This section discusses the robustness of our previous results to incorporating three relevant aspects of bank competition. First, we analyze the effect of introducing heterogeneity in banks' monitoring costs, which leads to different bank sizes. Second, we consider a variation of our model in which entrepreneurs can obtain funding for their projects from banks and also directly from competitive market investors. Finally, we analyze the effect of assuming that banks also compete à la Cournot in the deposit market.

3.1 Heterogeneous Monitoring Costs

Suppose that there are two types of banks that differ in the parameter γ of their monitoring cost function defined in (1): n_h banks have high monitoring costs, characterized by parameter γ_h, while $n_l = n - n_h$ banks have low monitoring costs, characterized by parameter $\gamma_l < \gamma_h$. Regardless of their type, it is assumed that a proportion θ of their deposits are insured, paying an interest rate equal to the safe rate R_0. Moreover, it is also assumed that a bank's type is observable to the uninsured depositors, so each type will pay a different uninsured deposit rate to secure their funding.

To characterize the equilibrium of the model with heterogeneous banks, note first that the critical values $\underline{R}_l$ and $\underline{R}_h$ which are defined by setting γ in (6) equal to γ_l and γ_h, respectively, satisfy $\underline{R}_l < \underline{R}_h$. From here it follows that whenever the total lending L is such that $\underline{R}_l \leq R(L) \leq \underline{R}_h$, only the low monitoring cost banks will operate, while when $\underline{R}_l < \underline{R}_h < R(L)$ both types of banks will operate.

By (8), if $R(L) \geq \underline{R}_j$ the monitoring intensity chosen by a bank of type $j = l, h$ in an interior solution is

$$m_j(L) = \frac{1}{2\gamma_j}\left[R(L) - \theta R_0 - \gamma_j(1-p) + \sqrt{[R(L) - \theta R_0 + \gamma_j(1-p)]^2 - 4\gamma_j(1-\theta)R_0}\right].$$

and the corresponding uninsured borrowing rate is

$$B_j(L) = \frac{R_0}{1 - p + m_j(L)}.$$

One can show that $m_l(L) > m_h(L)$,[20] which implies $B_l(L) < B_h(L)$. Thus, low monitoring cost banks choose a higher monitoring intensity, and consequently are able to borrow from the uninsured depositors at a lower rate.

A Cournot equilibrium is defined by a pair of strategies (l_l^*, l_h^*) for the two types of banks that satisfy

$$l_l^* = \arg\max_l \left[l\pi_l(l + (n_l - 1)l_l^* + n_h l_h^*) \right] \text{ and } l_h^* = \arg\max_l \left[l\pi_h(l + (n_h - 1)l_h^* + n_l l_l^*) \right].$$

The Cournot equilibrium is then characterized by the first-order conditions

$$L_l^* \pi_l'(L^*) + n_l \pi_l(L^*) = 0 \text{ and } L_h^* \pi_h'(L^*) + n_h \pi_h(L^*) = 0,$$

where $L_l^* = n_l l_l^*$, $L_h^* = n_h l_h^*$, and $L^* = L_l^* + L_h^*$.

Panel A of Figure 4 shows the effect of changes in the safe rate R_0 on lending by low and high monitoring cost banks, L_l^* and L_h^*, and total aggregate lending L^*. A first result is that $L_l^* > L_h^*$, so low monitoring cost banks are larger. A second result is that increases in the safe rate R_0 reduce lending by both types of banks, but the effect is more significant for high monitoring cost banks. In particular, the market share of low monitoring cost banks, denoted $\lambda = L_l^*/L^*$, increases with R_0, reaching 100% for high values of the safe rate for which it will not be profitable for the high monitoring cost banks to operate.

Panel B of Figure 4 shows the effect of changes in the safe rate R_0 on the probability of default of loans granted by low and high monitoring cost banks, $PD_l = p - m_l^*$ and $PD_h = p - m_h^*$, as well as on the average probability of loan default defined by

$$\overline{PD} = \lambda PD_l + (1 - \lambda) PD_h.$$

[20] This can be proved by total differentiation of (5), noting that by Proposition 1 the derivative of the left-hand side with respect to $m(L)$ is positive.

Increases in the safe rate R_0 increase the probability of default of loans granted by high monitoring cost banks, and have a negligible effect on the probability of default of loans granted by low monitoring cost banks, a result that follows from the fact that higher safe rates increase their comparative advantage relative to the high monitoring cost banks. Panel B also illustrates that there is a *composition effect*, due to the increase in the market share λ of the low monitoring cost banks, which reduces the average probability of default $\overline{PD}$, approaching PD_l for large values of R_0.

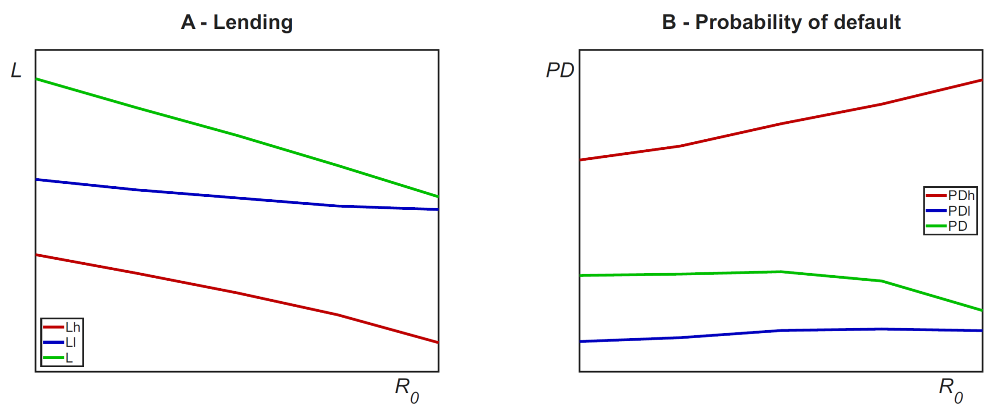

Figure 4. Effect of the safe rate on lending and the probability of default with heterogeneous monitoring costs

Panel A shows the relationship between the safe rate (in the horizontal axis) and lending (in the vertical axis) by low (in blue) and high (in red) monitoring cost banks, as well as total aggregate lending (in green). Panel B shows the relationship between the safe rate (in the horizontal axis) and the probability of default (in the vertical axis) of loans granted by low (in blue) and high (in red) monitoring cost banks, as well as the average probability of loan default (in green).

3.2 Competitive Bond Market

Suppose next that entrepreneurs can obtain funding for their projects from banks and also directly from competitive market investors. We assume that investors are not able to monitor entrepreneurs's projects (because they may be dispersed and subject to a free rider problem), and they are not covered by deposit insurance. Since they are competitive, they are willing to lend to entrepreneurs at a rate $\overline{R}$ that satisfies their participation constraint $(1-p)\overline{R} = R_0$.

The presence of market lenders imposes a constraint on banks, since the loan rate $R(L)$ cannot exceed the market rate $\overline{R}$. This means that the banks' inverse loan demand function (2) now becomes

$$R(L) = \min\{a - bL, \overline{R}\}.$$

The upper bound $\overline{R}$ will not be binding whenever the equilibrium in the absence of the bound is such that $R^* \leq \overline{R}$, but it will be binding when $R^* > \overline{R}$. In this case the candidate equilibrium lending will be $\overline{L} > L^*$ such that $R(\overline{L}) = a - b\overline{L} = \overline{R}$. By our previous results, the banks' borrowing rate and monitoring intensity will be $B(\overline{L})$ and $m(\overline{L})$, respectively.

Given that we focus on symmetric Nash equilibria, the question when $R^* > \overline{R}$ is: Will any bank j want to deviate from setting $l_j = \bar{l} = \overline{L}/n$ when the other $n-1$ banks choose to lend $\bar{l}$? To show that the answer is negative, note first that setting $l_j < \bar{l}$ is not profitable, since given the upper bound on loan rates the profits per unit of loans would not change from $\pi(\overline{L})$. Second, setting $l_j > \bar{l}$ is not profitable either since assumption (13) together with $\overline{L} > L^*$ implies

$$\frac{d}{dl}[l\pi(l + (n-1)\bar{l})]\bigg|_{l=\bar{l}} = \bar{l}\pi'(\overline{L}) + \pi(\overline{L}) < l^*\pi'(L^*) + \pi(L^*) = 0,$$

where the last equality is just the equilibrium condition in the absence of market finance. In other words, in such circumstance banks do not have an incentive to lend less, as they would not profit from higher loan rates given that they are set by market competitors, or to lend more, as this would reduce their overall profits.

Hence, whenever the upper bound $\overline{R}$ is binding, the equilibrium loan rate will be $\overline{R} = R_0/(1-p)$. Substituting this expression into (8) and rearranging yields

$$m^* = \frac{1}{2\gamma}\left[\frac{R_0}{1-p} - \theta R_0 - \gamma(1-p) + \sqrt{\left[\frac{R_0}{1-p} - \theta R_0 - \gamma(1-p)\right]^2 + 4\gamma p\theta R_0}\right],$$

which is increasing in the safe rate R_0. This is because when banks compete with market lenders, the loan rate effect dominates the funding cost effect, resulting in higher intermediation margins. We conclude that when the presence of market lenders binds the loan rate, increases in the safe rate R_0 increase the monitoring intensity m^* of the banks, and consequently reduce the probability of default of their loans.

Panel A of Figure 5 shows the effect of changes in the safe rate R_0 on equilibrium loan rates R^* in the presence of market finance. The solid lines show the relationship between R_0 and R^* for different values of the number of banks n. The dashed line shows the upper bound $\overline{R} = R_0/(1-p)$, which is binding in monopolistic markets (low n) and for low values of the safe rate R_0.

Panel B of Figure 5 shows the effect of changes in the safe rate R_0 on the probability of default $PD = p - m^*$ in the presence of market finance for different values of n. In competitive markets (high n), the relationship is still negative, that is lower safe rates translate into higher risk-taking. However, in contrast with the result in Section 2, *in monopolistic markets (low n) the relationship may be U-shaped, initially decreasing and then increasing banks' risk-taking*. This result follows from the fact that, as shown in Panel A, when the safe rate is low the equilibrium loan rate R^* in monopolistic markets equals the market rate $\overline{R}$, so lower rates reduce monitoring, thereby increasing the probability of default of bank loans.

3.3 Market Power in Deposits

We now consider the effects of changes in the safe rate when banks also have market power in raising deposits. In particular, we assume that banks compete à la Cournot in a deposit market characterized by a linear inverse supply function of the form

$$R_D(D) = R_0 - c + dD, \tag{16}$$

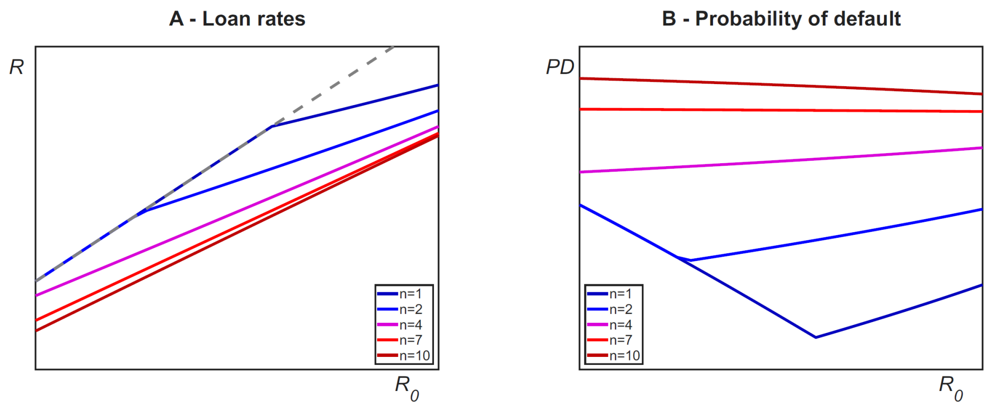

Figure 5. Effect of the safe rate on loan rates and the probability of default in the presence of market finance

Panel A shows the relationship between the safe rate (in the horizontal axis) and the equilibrium loan rates (in the vertical axis) for different number of banks. Panel B shows the relationship between the safe rate (in the horizontal axis) and the probability of default (in the vertical axis) for different number of banks.

where D is the aggregate supply of deposits and R_D is the required return of bank deposits, with $c > 0$ and $d > 0$. In this setup, the safe rate R_0 may be interpreted as the rate that depositors could obtain by investing in a safe asset such as government bonds.

The inverse supply function (16) can be derived from a model in which depositors differ in a liquidity premium associated with bank deposits. Specifically, suppose that there is a measure c of atomistic risk-neutral depositors with wealth $1/d$ characterized by a liquidity premium s associated with bank deposits that is uniformly distributed in $[0, c]$. An investor of type s will deposit her wealth in a bank offering an expected return R_D if $R_D + s \geq R_0$.

From here it follows that the aggregate supply of deposits D will be equal to the wealth of depositors with a liquidity premium $s \geq R_0 - R_D$, that is

$$D = \frac{c - (R_0 - R_D)}{d}.$$

Solving for R_D in this equation gives the inverse supply function (16).

We assume that banks compete à la Cournot for loans and deposits. Specifically, each bank $j = 1, ..., n$ chooses its supply of loans l_j and its demand for deposits d_j subject to the balance sheet constraint $l_j = d_j$. Given this constraint, in what follows we will simply denote by l_j the size of the balance sheet of bank j. As before, it is assumed that a proportion θ of bank deposits are insured.

The individual bank decisions determine the total supply of loans $L = \sum_{j=1}^{n} l_j$ and the loan rate $R(L)$, as well as the total demand for deposits $D = L$ and the required expected return of deposits $R_D(L)$. After $R(L)$ and $R_D(L)$ are determined, bank j offers a deposit rate $D_j = R_D(L)$ to its of insured deposits and a deposit rate B_j to its uninsured deposits. Finally, bank j chooses the monitoring intensity of its loans m_j. As before, we drop the subindex j and simply write $B(L)$ and $m(L)$.

To characterize the equilibrium of this model we first determine the banks' uninsured deposit rate $B(L)$ and monitoring intensity $m(L)$ as a function of the total supply of loans L (and demand for deposits $D = L$). The banks' choice of monitoring is given by

$$m(L) = \arg\max_{m} \left\{ (1 - p + m)[R(L) - \theta R_D(L) - (1 - \theta)B(L)] - \frac{\gamma}{2}m^2) \right\}.$$

and the uninsured depositors' participation constraint is now

$$[1 - p + m(L)]B(L) = R_D(L).$$

Following the same steps as in Section 2, one can show that if L is such that

$$R(L) \geq \min_{m \in [0,p]} \left(\gamma m + \theta R_D(L) + \frac{(1 - \theta)R_D(L)}{1 - p + m} \right),$$

we have

$$m(L) = \frac{1}{2\gamma} \left[R(L) - \theta R_D(L) - \gamma(1 - p) + \sqrt{[R(L) - \theta R_D(L) + \gamma(1 - p)]^2 - 4\gamma(1 - \theta)R_D(L)} \right] \tag{17}$$

and

$$B(L) = \frac{R_D(L)}{1 - p + m(L)} \tag{18}$$

By (17), the monitoring intensity $m(L)$ is increasing in the loan rate $R(L)$ and is decreasing in the required return of bank deposits $R_D(L)$. Since (2) and (16) imply $dR(L)/dL = -b < 0$ and $dR_D(D)/dD = dR_D(L)/dL = d > 0$, we conclude that

$$\frac{dm(L)}{dL} = -b\frac{\partial m(L)}{\partial R(L)} + d\frac{\partial m(L)}{\partial R_D(L)} < 0.$$

The second term in this expression is new, relative to our previous setup characterized by an infinitely elastic supply of funds at the safe rate R_0. This term amplifies the negative impact of total lending on bank monitoring, via the additional reduction in the intermediation margin, due to the increase in the required return of deposits $R_D(L)$.

A Cournot equilibrium is defined as in the base model, with $m(L)$ and $B(L)$ in (17) and (18) replacing the previous expressions in (9). Solving the first-order condition (10) gives the equilibrium amount of lending L^* (and deposit taking $D^* = L^*$). As before, the equilibrium loan rate is $R^* = R(L^*)$ and the probability of default is $PD = p - m(L^*)$.

Figure 6 shows that the qualitative effects of changes in the safe rate R_0 on the probability of loan default PD for different values of n are similar to the ones in Figure 2. Increasing the number of banks n leads to a reduction in the slope of the relationship between the safe rate R_0 and the probability of loan default PD. For sufficiently high n the the slope changes sign from positive to negative.

The conclusion is that *imperfect competition in the deposit market does not essentially change our initial results on the relationship between the safe rate and banks' risk-taking*: low interest rates have a negative impact on financial stability when banks' market power is low, and a positive impact when their market power is high.

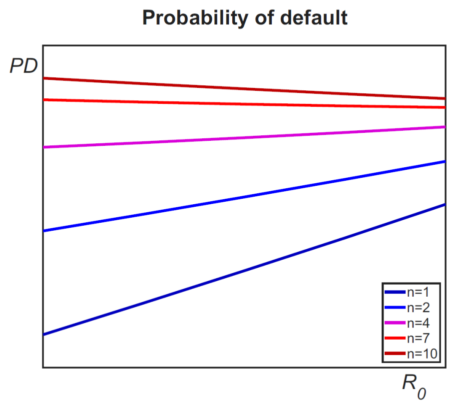

Figure 6. Effect of the safe rate on the probability of default with Cournot competition for deposits and loans

This figure shows the relationship between the safe rate (in the horizontal axis) and the probability of default (in the vertical axis) for different number banks that compete à la Cournot for both deposits and loans.

4 Endogenous Leverage

This section introduces inside equity capital, i.e. funds provided by those responsible for the monitoring decisions, and analyzes whether endogenizing leverage changes our previous results on the relationship between the safe rate and banks' risk-taking. For reasons that will be clear below, the analysis is conducted in a discrete-time infinite horizon dynamic setup.

It is assumed that the safe rate R_0 required by depositors is constant, and that equity capital is provided by long-lived investors with a discount rate $R_0 + \delta$, where $\delta > 0$ is a standard excess cost of capital. It is also assumed that when a bank fails, its charter is withdrawn and a new bank enters the market, so the total number of banks is always n.

The sequence of moves at any date is as follows: First, each bank $j = 1, ..., n$ chooses its supply of one-period loans l_j, which determines the total supply of loans $L = \sum_{j=1}^{n} l_j$ and the loan rate $R(L)$ for this date. Then, it chooses its capital per unit of loans k_j, which is assumed to be observable to depositors. Next, it offers an interest rate $D_j = R_0$ to its insured depositors and an interest rate B_j to its uninsured depositors to fund the remaining

$1 - k_j$ fraction of its loan portfolio. Finally, it chooses the monitoring intensity of its loans m_j.

To characterize the symmetric equilibrium of this model, we proceed backwards, dropping as before the subindex j. Consider a bank that has chosen to supply l loans and to have k capital per unit of loans in a market where the loan rate is $R(L)$. Let V denote the bank's charter value, which is lost with probability $p - m$, and $v = V/l$ the charter value per unit of loans. Then, the bank's uninsured borrowing rate $B(L, k, v)$ and monitoring intensity $m(L, k, v)$ are obtained by solving the bank's incentive compatibility constraint

$$m(L, v, k) =$$
$$\arg\max_m \left\{(1 - p + m)[R(L) + v - (1 - k)[\theta R_0 + (1 - \theta)B(L, k, v)]] - k(R_0 + \delta) - \frac{\gamma}{2}m^2\right\}$$

together with the uninsured depositors' participation constraint

$$[1 - p + m(L, k, v)]B(L, k, v) = R_0.$$

Hence, monitoring is determined not only by equilibrium loan rates, as in our static model, but also by banks' capital and charter values. Higher bank capital increases their skin in the game, leading to higher incentives to monitor. In a similar manner, higher charter values increase banks' incentive to survive, leading to higher monitoring. We now proceed to show how safe rates not only affect banks' funding costs and loan rates, but also banks' endogenous leverage and charter values.

Following the same steps as in Section 2, one can show that if

$$R(L) + v \geq \min_{m \in [0,p]} \left[\gamma m + (1 - k)\left(\theta R_0 + \frac{(1 - \theta)R_0}{1 - p + m}\right)\right],$$

then

$$\begin{aligned} m(L, v, k) &= \frac{1}{2\gamma}[R(L) + v - (1 - k)\theta R_0 - \gamma(1 - p)] \\ &\quad + \frac{1}{2\gamma}\sqrt{[R(L) + v - (1 - k)\theta R_0 + \gamma(1 - p)]^2 - 4\gamma(1 - k)(1 - \theta)R_0}\,. \end{aligned}$$

Given $m(L, v, k)$, we can proceed backwards to derive the banks' optimal capital per unit of loans, denoted $k(L, v)$. Then, the bank's one-period profits per unit of loans may be written as

$$\pi(L,v) = [1-p+m(L,v)]R(L)+[p-m(L,v)](1-k(L,v))\theta R_0 - R_0 - k(L,v)\delta - \frac{\gamma}{2}[m(L,v)]^2.$$

where $m(L, v) = m(L, v, k(L, v))$.

The symmetric Cournot equilibrium l^* of the dynamic game is obtained by solving

$$l^* = \arg\max_l \left[l\pi(l + (n-1)l^*, V^*/l) + (1 - p + m(l + (n-1)l^*, V^*/l))V^* \right],$$

where V^* satisfies the Bellman equation

$$V^* = \frac{1}{R_0 + \delta} \left[l^*\pi(L^*, V^*/l^*) + (1 - p + m(L^*, V^*/l^*))V^* \right].$$

The numerical solution to the dynamic model shows that a permanent reduction in the safe rate R_0 has two novel effects on monitoring incentives illustrated in Figure 7. The first in Panel A is a *leverage effect* that reduces the equilibrium capital per unit of loans k^*. The second in Panel B is a *charter value effect* that increases the equilibrium charter value per unit of loans v^*. The intuition for these effects is that lower safe rates increase the relative cost of bank capital, which leads to lower capital, and reduce the cost of deposit funding, which leads to higher charter values. The first effect reduces monitoring, because of the lower skin in the game, while the second increases it, because of the higher survival payoff.

Figure 8 shows that the dominant effect depends on the number of banks n. A higher number of banks n leads to a reduction in the slope of the relationship between the safe rate R_0 and the probability of loan default PD. For sufficiently high n the slope changes sign from positive to negative, as in the static model. We conclude that *endogeneizing leverage does not essentially change our results on the effect of safe rates on banks' risk-taking*: low interest rates have a negative impact on financial stability when banks' market power is low, and a positive impact when their market power is high.

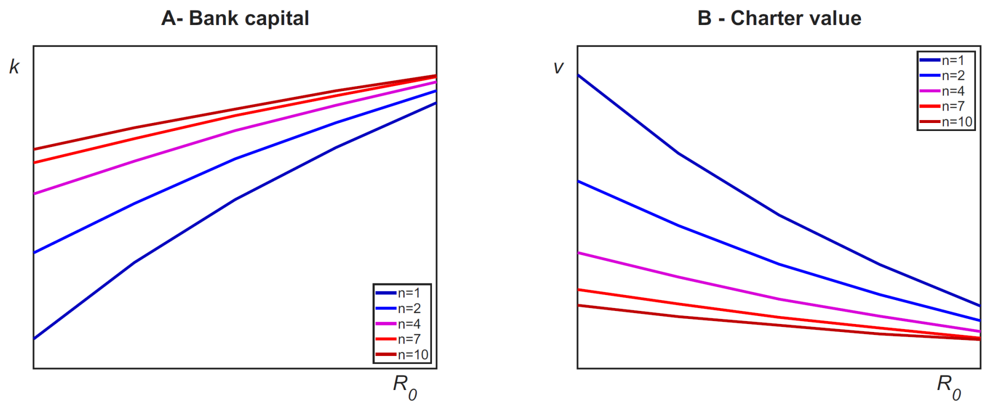

Figure 7. Effect of the safe rate on bank leverage and charter values in the dynamic model

This figure shows the relationship between the safe rate (in the horizontal axis) and the equilibrium bank capital (Panel A) and charter value (Panel B) in the dynamic model with endogenous leverage for loan markets with different number of banks.

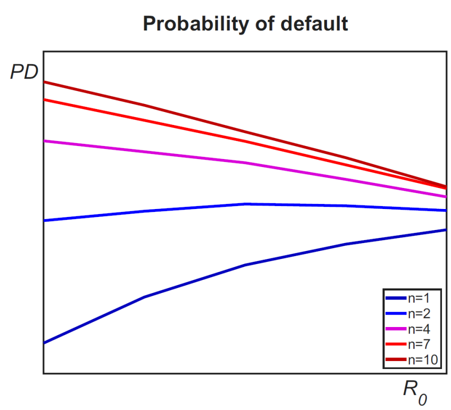

Figure 8. Effect of the safe rate on the probability of default in the dynamic model

This figure shows the relationship between the safe rate (in the horizontal axis) and the probability of default (in the vertical axis) in the dynamic model with endogenous leverage for loan markets with different number of banks.

5 Concluding Remarks

Are low interest rates conducive or detrimental to financial stability? This question has received ample attention both from academic and policy circles and generated a large, mostly empirical, literature. This paper addresses this question from a theoretical perspective.

Our model shows that risk-taking is driven by intermediation margins. In monopolistic loan markets the pass-through from funding costs to loan rates is weak, so lower safe rates result in higher intermediation margins and lower risk-taking. In contrast, in competitive markets the pass-through is strong, so lower safe rates result in lower intermediation margins and higher risk-taking. This implies that the slope of the relationship between the safe rate and probability of default goes down with an increase in the number of banks, changing from positive to negative as we move from monopolistic to competitive markets.

These results are robust to the introduction of (inside) equity capital, provided by long-lived shareholders that lose the bank's charter when it fails. We show that lower safe rates have two opposite effects. On the one hand, they increase leverage, which leads to higher risk-taking. On the other hand, they increase charter values, which leads to lower risk-taking. In monopolistic markets the charter value effect dominates, so lower rates translate into safer banks, while in competitive markets the leverage effect dominates, so lower rates translate into riskier banks.

Our analysis provides additional novel testable implications. First, when banks' market power is constrained by the possibility of firms borrowing directly from investors, we predict a U-shaped relationship between the safe rate and banks' risk-taking. Second, when banks are heterogeneous in their monitoring technologies, lower safe rates increase the market share of high monitoring costs banks. Third, we also predict that a higher proportion of insured liabilities leads to higher risk-taking and makes it more likely that lower safe rates translate into higher intermediation margins and lower risk-taking.

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Supplementary Material Appendix

Proof of Proposition 1 We have shown that the values of m that satisfy equation (5) are such that, for a given loan rate R, banks maximize their payoff and both insured and uninsured depositors get an expected return equal to the safe rate R_0. Since the function in the left-hand side of (5) is convex in m, there are three possible cases. If $R < \underline{R}$, equation (5) has no solution, so the banks will not able to fund their lending. If $R = \underline{R}$, m will be the unique solution to equation (5). And if $R > \underline{R}$, there will be one or two solutions to equation (5) for $m \geq 0$. If $\theta R_0 + (1-\theta)R_0/(1-p) < R$, m^* will be the unique positive solution to equation (5). If $\theta R_0 + (1-\theta)R_0/(1-p) \geq R$, let $\widehat{m}$ and m^* denote the two solutions to equation (5), with $\widehat{m} < m^*$. To show that the banks' payoff is higher with m^* it suffices to note that for $m < m^*$ we have

$$\frac{d}{dm}\left[(1-p+m)(R-\theta R_0)-(1-\theta)R_0-\frac{\gamma}{2}m^2\right] = R-\theta R_0-\gamma m > R-\theta R_0-\gamma m^* = (1-\theta)B^* > 0,$$

which implies

$$(1-p+\widehat{m})(R-\theta R_0)-(1-\theta)R_0-\frac{\gamma}{2}\widehat{m}^2 < (1-p+m^*)(R-\theta R_0)-(1-\theta)R_0-\frac{\gamma}{2}(m^*)^2,$$

as required. Finally, note that when $\gamma p + R_0 \geq R$ the solution will be at the corner $m^* = p$, while when $\gamma p + R_0 < R$ the solution will satisfy $m^* < p$. $\square$

Proof of Proposition 2 The effect of changes in variable $z = R_0, \theta, n$ on equilibrium lending L^* is obtained by differentiating the first-order condition (18), which gives

$$\frac{\partial L^*}{\partial z} = -\frac{\frac{\partial}{\partial z}[L^*\pi'(L^*) + n\pi(L^*)]}{L^*\pi''(L^*) + (n+1)\pi'(L^*)}.$$

Assumption (13) together with (12) imply $L^*\pi''(L^*) + (n+1)\pi'(L^*) < 0$, so the sign of $\partial L^*/\partial z$ will be that of the numerator.

For $z = R_0$ we need to show that

$$\frac{\partial}{\partial R_0}[L^*\pi'(L^*) + n\pi(L^*)] = L^*\frac{\partial \pi'(L^*)}{\partial R_0} + n\frac{\partial \pi(L^*)}{\partial R_0}$$
$$= \gamma L^*\left[[1-p+m(L^*)]\frac{\partial m'(L^*)}{\partial R_0} + m'(L^*)\frac{\partial m(L^*)}{\partial R_0}\right] + n\gamma[1-p+m(L^*)]\frac{\partial m(L^*)}{\partial R_0} < 0,$$

where we have used (11) and (12). Differentiating (8) gives

$$\frac{\partial m(L^*)}{\partial R_0} = \frac{\theta}{b}m'(L^*) - \frac{1-\theta}{F(L^*, R_0, \theta)},$$

and

$$\frac{\partial m'(L^*)}{\partial R_0} = \frac{\theta}{b}m''(L^*) - \frac{b(1-\theta)[R(L^*) - \theta R_0 + \gamma(1-p)]}{[F(L^*, R_0, \theta)]^3},$$

where

$$F(L^*, R_0, \theta) = \sqrt{[R(L^*) - \theta R_0 + \gamma(1-p)]^2 - 4\gamma(1-\theta)R_0}.$$

Substituting these results into the previous expression gives

$$\begin{aligned}\frac{\partial}{\partial R_0}[L^*\pi'(L^*) + n\pi(L^*)] \quad = \quad & \frac{\theta}{b}[L^*\pi''(L^*) + n\pi'(L^*)] \\ & -\gamma L^*[1-p+m(L^*)]\frac{b(1-\theta)[R(L^*) - \theta R_0 + \gamma(1-p)]}{[F(L^*, R_0, \theta)]^3} \\ & -\gamma L^* m'(L^*)\frac{1-\theta}{F(L^*, R_0, \theta)} - n\gamma[1-p+m(L^*)]\frac{1-\theta}{F(L^*, R_0, \theta)}.\end{aligned}$$

The first term in the right-hand-side of this expression is negative by assumption (13), and the other terms are also negative, except the third one (since $m'(L^*) < 0$). But given that

$$m'(L^*) = -\frac{b}{2\gamma}\left[1 + \frac{R(L^*) - \theta R_0 + \gamma(1-p)}{F(L^*, R_0, \theta)}\right] = -\frac{b[1-p+m(L^*)]}{F(L^*, R_0, \theta)},$$

adding the second and the third term gives

$$-\frac{\gamma L^* b(1-\theta)[1-p+m(L^*)]}{[F(L^*, R_0, \theta)]^2}\left[\frac{R(L^*) - \theta R_0 + \gamma(1-p)}{F(L^*, R_0, \theta)} - 1\right] < 0,$$

as required.

For $z = \theta$ we need to show that

$$\frac{\partial}{\partial\theta}[L^*\pi'(L^*) + n\pi(L^*)] = L^*\frac{\partial\pi'(L^*)}{\partial\theta} + n\frac{\partial\pi(L^*)}{\partial\theta}$$
$$= \gamma L^*\left[[1-p+m(L^*)]\frac{\partial m'(L^*)}{\partial\theta} + m'(L^*)\frac{\partial m(L^*)}{\partial\theta}\right] + n\gamma[1-p+m(L^*)]\frac{\partial m(L^*)}{\partial\theta} > 0,$$

where we have used (11) and (12). Differentiating (8) gives

$$\frac{\partial m(L^*)}{\partial\theta} = \frac{R_0[p-m(L^*)]}{F(L^*,R_0,\theta)} > 0.$$

Since $m'(L^*) < 0$, we need to show that

$$[1-p+m(L^*)]\frac{\partial m'(L^*)}{\partial\theta} + m'(L^*)\frac{\partial m(L^*)}{\partial\theta} = [1-p+m(L^*)]\left[\frac{\partial m'(L^*)}{\partial\theta} - \frac{b}{F(L^*,R_0,\theta)}\frac{\partial m(L^*)}{\partial\theta}\right] > 0.$$

But

$$\frac{\partial m'(L^*)}{\partial\theta} = -\frac{b}{F(L^*,R_0,\theta)}\frac{\partial m(L^*)}{\partial\theta} + \frac{b[1-p+m(L^*)]}{[F(L^*,R_0,\theta)]^2}\frac{\partial F(L^*,R_0,\theta)}{\partial\theta},$$

so the condition simplifies to

$$[1-p+m(L^*)]\frac{\partial F(L^*,R_0,\theta)}{\partial\theta} > 2F(L^*,R_0,\theta)\frac{\partial m(L^*)}{\partial\theta}.$$

Now

$$\frac{\partial m(L^*)}{\partial\theta} = \frac{1}{2\gamma}\left[\frac{\partial F(L^*,R_0,\theta)}{\partial\theta} - R_0\right]$$

implies

$$\frac{\partial F(L^*,R_0,\theta)}{\partial\theta} = 2\gamma\frac{\partial m(L^*)}{\partial\theta} + R_0.$$

Substituting this result into the previous expression gives the condition

$$[1-p+m(L^*)]\left(2\gamma\frac{\partial m(L^*)}{\partial\theta} + R_0\right) > 2F(L^*,R_0,\theta)\frac{\partial m(L^*)}{\partial\theta},$$

which simplifies to

$$[1-p+m(L^*)]R_0 > \left[1 - \frac{R(L^*) - \theta R_0 + \gamma(1-p)}{F(L^*,R_0,\theta)}\right]\frac{\partial m(L^*)}{\partial\theta}.$$

Since the term in brackets in the right-hand-side of this expression is negative and $\partial m(L^*)/\partial\theta > 0$, this implies the result.

Finally, for $z = n$ simply note that

$$\frac{\partial}{\partial n}[L^*\pi'(L^*) + n\pi(L^*)] = \pi(L^*) > 0.$$

as required. □

Proof of Proposition 3 With full deposit insurance ($\theta = 1$) and a large number of banks, (15) implies that the equilibrium monitoring intensity will be $m^* = \underline{m} = 0$, regardless of the safe rate R_0. With fewer banks, their choice of monitoring (3) simplifies to $m(L) = [R(L) - R_0]/\gamma$, which using (11) implies

$$\pi(L) = (1-p)[R(L) - R_0] + \frac{1}{2\gamma}[R(L) - R_0]^2.$$

From here it follows that the first-order condition (10) that characterizes equilibrium lending becomes

$$L^*\pi'(L^*) + n\pi(L^*) = -bL^*(1-p+m^*) + n\left[\gamma(1-p)m^* + \frac{\gamma}{2}(m^*)^2\right] = 0,$$

where $m^* = [R(L^*) - R_0]/\gamma$. Hence, we have

$$L^* = \frac{n\left[\gamma(1-p)m^* + \frac{\gamma}{2}(m^*)^2\right]}{b(1-p+m^*)},$$

which by Proposition 2 implies

$$\frac{\partial L^*}{\partial R_0} = \frac{n\gamma\left[(1-p)^2 + (1-p)m^* + \frac{1}{2}(m^*)^2\right]}{b(1-p+m^*)^2}\frac{\partial m^*}{\partial R_0} < 0,$$

so we conclude $\partial m^*/\partial R_0 < 0$. □