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INTEREST RATES, MARKET POWER, AND FINANCIAL STABILITY

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Abstract

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JEL Classification: G21, L13, E52

Keywords: Imperfect Competition, intermediation margins, Bank monitoring, bank risk-taking, monetary policy

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1 Introduction

Lax monetary conditions leading to low levels of interest rates have been identified as an important driver of risk-taking in the financial sector.[1] This paper analyzes, from a theoretical perspective, how interest rates affect the risk-taking decisions of financial intermediaries. Its key contribution is to highlight the relevance of the financial sector's market structure in shaping such relationship.

We model a one-period risk-neutral economy in which a fixed number of financial intermediaries raise uninsured funding from deep pocket investors and compete à la Cournot in providing loans to penniless entrepreneurs. Intermediaries 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 standard moral hazard problem between the financial intermediary and its investors. The expected return that investors require for their funds is assumed to be equal to an exogenous safe rate, which could be interpreted as a proxy for the stance of monetary policy.

We show that the effect of changes in the safe rate on the risk of the loan portfolios of financial intermediaries depends on their market power. In competitive loan markets the conventional prediction obtains: lower rates result in higher risk-taking by intermediaries. However, in monopolistic loan markets we the opposite prediction obtains: lower rates result in lower risk-taking. These contrasting results obtain because, although low interest rates lead to low funding costs for intermediaries, the intensity of the pass-through of financing rates to loan rates depends on their market power. Hence, lower safe rates can lead to either lower (in competitive markets) or higher (in monopolistic markets) intermediation margins, which in turn determine lower or higher monitoring incentives for financial intermediaries. We therefore conclude that the underlying market structure is key to assess the effects of the safe rate on the stability of the financial system.[2]

[1] See the discussion in Adrian and Liang (2018), as well as the empirical papers by Jimenez et al. (2014) and Ioannidou et al. (2015), among many others.

[2] Moreover, in line with the traditional (charter value) literature on competition and financial stability, we also show that higher competition results in higher risk-taking for any level of the safe rate; see, for example, Keeley (1990), Allen and Gale (2000), Hellmann et al. (2000), and Repullo (2004).

After stating our main results linking interest rates, market structure, and financial stability, we analyze three relevant aspects of competition in the loan market: (i) the possibility of direct market finance by investors that (unlike financial intermediaries) do not monitor entrepreneurs, (ii) monitoring cost asymmetries among intermediaries, and (iii) entry and exit decisions of intermediaries.

We first consider a situation in which entrepreneurs also have the possibility of being directly funded by competitive investors that do not monitor their projects.[3] In such situation we show that the equilibrium interest rate that intermediaries can charge is affected by the entrepreneurs' outside funding option. In particular, direct market finance imposes a constraint that limits the loan rates that intermediaries can charge and reduces their intermediation margins. We show that this constraint is more likely to bind in monopolistic loan markets and when the safe rate is low. This implies that, in the presence of direct market finance, monopolistic markets exhibit a U-shaped relationship between the safe rate and the intermediaries' risk-taking decisions. For low (high) levels of the safe rate decreasing such rate decreases (increases) intermediation margins and hence increases (decreases) the probability of loan default. In contrast, in competitive loan markets the results of the basic setup do not change. The reason being that in such markets direct market finance is not a competitive threat for financial institutions (as they already compete intensively among themselves), and therefore it does not affect the Cournot equilibrium outcomes.

We next analyze a situation in which financial intermediaries differ in their monitoring costs. We assume that there are two observable types of intermediaries: those with high and those with low cost of monitoring entrepreneurs. In equilibrium, intermediaries with high monitoring costs have lower market shares and their loans have higher probabilities of default. We show that lower safe rates increase (decrease) the market share of high (low) monitoring cost intermediaries and can decrease (increase) the probability of default of their loans. This is so because lower rates have a higher impact on the margins of high cost intermediaries. We conclude that, in the presence of heterogenous monitoring costs, lower

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

safe rates can have opposite effects on the risk of different intermediaries. We also highlight that, by increasing the market share of those intermediaries with higher cost of monitoring (which grant riskier loans), lower safe rates have an additional "composition effect" on the risk of the financial system, which makes the results closer to those of the competitive model.

We end our analysis of financial market structure by taking into account potential entry and exit decisions of intermediaries. We consider these decisions as a longer run phenomenon compared to the decisions to grant and monitor loans, with the aim of shedding light on the widespread view that interest rates that are "too low for too long" are detrimental to financial stability. We model entry decisions by assuming that intermediaries have to pay a fixed cost to operate. We show that, when entry is taken into account, lower safe rates induce higher competition in the loan market, adding an "entry effect" to our basic results on the effect of low safe rates, which increases risk-taking in the financial sector.[4]

We next analyze the three alternative funding scenarios for financial intermediaries: (i) replacing uninsured by insured deposits, (ii) introducing competition à la Cournot in the deposit market, and (iii) funding intermediaries with both equity capital and uninsured deposits.

Solving the model assuming insured deposits simplifies the analysis since intermediaries are then able to borrow at the safe rate. We show that in this case an increase in the safe rate always leads to an increase in the probability of loan default. The intuition for this result is that, in the perfect competition limit, insured deposits lead to zero intermediation margins and hence zero monitoring, so the relationship between the safe rate and the probability of loan default becomes flat. Away from this limit, i.e. when intermediaries have some market power, lower rates allow them to widen intermediation margins, which translates into higher monitoring and lower probabilities of default. Hence, the results for the model with insured deposits on the effect of safe rates on risk-taking are qualitatively similar to the results for the model with uninsured deposits when banks have significant market power. This highlights the importance of taking into account the composition of intermediaries' funding structure

[4]However, it should be noted that, by our previous results, in the presence of direct market finance lower rates can actually lead to exit.

in terms of insured and uninsured debt when analyzing the effects of safe rates on the risk of the financial system.

We next consider the effects of changes in safe rates when intermediaries also compete à la Cournot in the deposit market. In this case we show that the results are qualitatively similar to those of the basic model: low interest rates have a negative impact on financial stability when market power is low, and a positive impact when market power is high.

Finally, we consider what happens when intermediaries can also be funded with inside equity capital,[5] i.e. funds provided by those responsible for the monitoring decisions. As Dell'Ariccia et al. (2014) point out, a relevant determinant of intermediaries' risk-taking decisions is their capital structure, which can be affected by interest rates. We show that when the leverage of financial intermediaries is endogenously determined, market structure can still be a relevant variable in shaping how safe rates affect their risk-taking.

Our results differ from those of Dell'Ariccia et al. (2014) because, while they assume an infinitely elastic supply of equity capital at a constant spread above the safe rate, we also consider a situation in which equity capital is either fixed or increasingly costly to raise. In the case of an infinitely elastic supply of capital we get the same result as theirs: low safes rates are always detrimental to financial stability. The reason is that under this assumption low rates increase the cost of equity finance relative to the cost of debt finance, so banks react by increasing their leverage, thereby reducing their monitoring incentives. However, in the case of an inelastic supply of capital the results are qualitatively similar to those of the basic model: low safe rates are conducive (detrimental) to financial stability in monopolistic (competitive) markets. To the extent that inside equity may be in limited supply, we conclude that our benchmark results are robust to endogeneizing leverage, and point to relevant interactions between changes in interest rates, market structure and leverage.

Literature This paper is at the intersection of two strands of literature, the first one being those studies analyzing the relevance of market structure for financial stability, and the second one those studies analyzing the effects of low interest rates, which can be related to

[5] Outside equity capital plays essentially the same role as uninsured deposits.

lax monetary policy, on banks' risk-taking incentives. Our main contribution is to provide a unifying framework that shows that the competitive structure of the financial sector together with the level of interest rates determine banks' intermediation margins and risk-taking incentives. Our interest in how the transmission of lower rates is affected by market power relates our paper to a large literature analyzing the effects of financial frictions (in our case, moral hazard) on economic outcomes (including loan supply).

The relationship between competition and stability has been extensively examined, both theoretically and empirically. Seminal papers like Keeley (1990) or Allen and Gale (2000) provide theoretical setups showing how, due to excessive risk-taking incentives, a more competitive banking sector results in higher probabilities of bank failure.[6] This relationship between competition and stability has also been investigated in many empirical papers; see for example the survey in Beck et al. (2006). More recently, Jiang et al. (2018) find a positive relationship between bank competition and bank risk-taking, using a gravity-based measure of contestability during the branch deregulation period in the US. We contribute to this literature by showing how different market structures can not only affect risk-taking, but are also relevant in shaping the relationship between interest rates and risk-taking.

Our paper is also related to studies that highlight the relevance of competition for assessing the effects of different economic policies on banks' risk-taking. Hellmann et al. (2000) show how, given the incentives of competitive banking markets to increase 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 from a theoretical perspective are Dell'Ariccia et al. (2014), which focusses on the relevance of bank leverage for the relationship between safe rates and banks' risk-taking decisions, and Martinez-Miera and Repullo (2017), which studies the relationship between aggregate savings, safe rates and the structure and risk of the

[6] 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 when imperfect correlation of loan defaults is taken into account; see Boyd and De Nicolo (2005) and Martinez-Miera and Repullo (2010).

financial sector.[7] While both papers provide theoretical 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 study shows the relevance of market power in shaping such relationship. Crucially, we show that, when imperfect competition in the banking sector is taken on board, the previous results linking low rates with high risk-taking need not hold. Hence, our results complement previous work and provide novel testable predictions regarding how in certain market structures (for example those in which banks have high market power and are not exposed to competition by market lenders), lower rates can result in lower (and not higher) risk-taking by banks.

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 relevance of (information-driven) financial frictions for macroeconomic analysis. 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 (2017), among many others. This literature, predominantly empirical, 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). Recent research by Dreschler et al. (2017) has shown the relevance of deposit market competition for the pass-through of monetary policy to deposit rates. They find that more competitive markets exhibit a higher pass-through

[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 relevance of leverage for the connection between safe rates and banks' risk-taking.

[8] A recent study by Corbae and Levine (2020) provides empirical evidence on the relevance of competition in the banking sector for the effects of monetary policy on banks' probability of failure using branch deregulation shocks in the US.

(and higher growth in wages and employment following reductions in monetary policy rates). We contribute to this strand of the literature by highlighting the importance of taking into account imperfect competition in both the loan and the deposit markets, and showing the implications for the connection between interest rates and financial stability.[9]

Structure Section 2 presents the model of Cournot competition in the loan market with uninsured deposits and unobservable monitoring by intermediaries, and analyzes how market power affects the relationship between the safe rate and the equilibrium monitoring intensity, which determines the probability of default of the loans. Section 3 examines the robustness of our results when we incorporate three relevant aspects of competition in the loan market, namely the presence of competitive market lenders that do not monitor borrowers, heterogeneity in monitoring costs, and entry and exit decisions of financial intermediaries. Section 4 examines the robustness of our results when we consider three alternative funding scenarios, namely when intermediaries are funded with insured deposits, when they compete à la Cournot in the deposit market, and when they can also be funded with equity capital. Section 5 contains our concluding remarks. Proofs of the analytical results are in the Appendix.

2 Model

Consider an economy with two dates ($t = 0, 1$) populated by three types of risk-neutral agents: a continuum of deep pocket investors, a continuum of penniless entrepreneurs, and n identical financial intermediaries, which for brevity we refer to as banks.[10] Investors are characterized by an infinitely elastic supply of funds at an expected return equal to R_0 (the safe rate). Entrepreneurs have investment projects that can only be funded by banks. Banks

[9] Recent 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.

[10] We analyze the relevance of some features that characterize commercial banks such as deposit insurance and imperfect competition in the deposit market in Section 4.

in turn have no capital and are funded by investors.[11]

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

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

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.[12] While p is known, m is not observed by investors.

The success return R is assumed to be a linearly decreasing function of the aggregate investment of entrepreneurs. 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. The linearity in this relationship facilitates tractability.

Given that entrepreneurs only receive funding from banks, their aggregate investment equals the aggregate supply of loans L. Hence, we can write the success return of a project as

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

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.

We assume that 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.

Monitoring is costly, and the cost function is assumed to take the simple functional form

$$c(m) = \frac{\gamma}{2} m^2, \tag{3}$$

where $\gamma > 0$. Since monitoring is not observed by investors, there is a moral hazard problem between banks and investors.

[11] Section 4 also extends our basic framework to allow for banks raising (inside) equity capital.

[12] We are implicitly assuming that each firm is only funded by one bank.

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 $R = R(L)$. After R is determined, bank j offers an interest rate B_j to the (uninsured) investors, and once the lending and the funding rates are set it chooses the monitoring intensity of its loans m_j.

The objective of bank j is to maximize its expected profits, which can be computed as follows: With probability $1 - p + m_j$ all loans are performing, so the bank gets R and pays B_j, while with probability $p - m_j$ all loans default, so by limited liability the bank gets a zero return. Finally, we have to subtract the monitoring costs $c(m_j)$. Hence, the problem of bank j may be written as

$$\max_{(l_j, B_j, m_j)} \{l_j \left[(1 - p + m_j)(R - B_j) - c(m_j)\right]\}$$

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

$$m_j = \arg\max[(1 - p + m_j)(R - B_j) - c(m_j)]$$

and the participation constraint of the investors that is required to secure their funding[13]

$$(1 - p + m_j)B_j = R_0.$$

To characterize the equilibrium of the model we proceed backwards and in Section 2.1 determine the bank's borrowing rate B_j and monitoring intensity m_j as a function of the loan rate R. Notice that since the monitoring intensity m_j is not observed by investors, B_j cannot depend on m_j. Notice also that at this point all banks face the same problem so, since we focus on symmetric equilibria, we will drop the subindex j and simply write B and m. Finally, given that the loan rate R is a function of the total supply of loans L, we will write $R(L)$, $B(L)$ and $m(L)$, and then in Section 2.2 solve for the equilibrium supply of loans L.

[13] Having an infinetely elastic supply of funds at the safe rate R_0 implies the investors' participation constraint holds with equality.

2.1 Equilibrium monitoring decisions

Banks' choice of monitoring $m(L)$ for a given borrowing rate $B(L)$ is given by

$$m(L) = \arg\max_{m} \{(1 - p + m)[R(L) - B(L)] - c(m)\}. \tag{4}$$

By (3), the first-order condition that characterizes an interior solution to this problem is

$$R(L) - B(L) = \gamma m(L). \tag{5}$$

Thus, banks' monitoring intensity $m(L)$ will be proportional to the intermediation margin $R(L) - B(L)$.[14] In particular, when the intermediation margin is zero banks will not monitor their loans.

The investors' participation constraint is given by

$$[1 - p + m(L)]B(L) = R_0. \tag{6}$$

Solving for $B(L)$ in this constraint, substituting it into the first-order condition (5), and rearranging gives the key equation that characterizes the banks' monitoring intensity

$$\gamma m(L) + \frac{R_0}{1 - p + m(L)} = R(L). \tag{7}$$

The function in the left-hand side of (7) is convex in m. Let us then define

$$\underline{R} = \min_{m\in[0,p]} \left(\gamma m + \frac{R_0}{1 - p + m}\right) = \gamma \underline{m} + \frac{R_0}{1 - p + \underline{m}}. \tag{8}$$

We can now prove the following result.[15]

Proposition 1 *Banks are able to fund their lending L if $R(L) \geq \underline{R}$, in which case the optimal contract between banks and their investors is given by*

$$m(L) = \max\left\{m \in [0, p] \mid \gamma m + \frac{R_0}{1 - p + m} = R(L)\right\} \text{ and } B(L) = \frac{R_0}{1 - p + m(L)}. \tag{9}$$

[14] We implicitly assume that the marginal cost of monitoring γ is sufficiently high, so we do not reach the corner solution $m(L) = p$ in which bank loans are safe.

[15] The proof is almost identical to the proof of Proposition 1 in Martinez-Miera and Repullo (2017)

Proposition 1 implies that of the two possible solutions to equation (7), the one with higher monitoring characterizes the optimal contract. Thus, $m(L) \geq \underline{m}$, where $\underline{m}$ is defined in (8). Solving for $m(L)$ in (7), this implies

$$m(L) = \frac{1}{2\gamma}\left[R(L) - \gamma(1-p) + \sqrt{[R(L) + \gamma(1-p)]^2 - 4\gamma R_0}\right]. \tag{10}$$

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 $m'(L) < 0$. At the same time, (10) implies that an increase in the safe rate R_0, for a given value of L, reduces monitoring (since the coefficient of R_0 is negative).

Given that, as we will show below, equilibrium total lending is a decreasing function of the safe rate, we have two opposite effects of changes in the safe rates on banks' monitoring intensity, which can be called the *funding rate effect* and the *lending rate effect*. The former is a direct effect of higher safe rates, which makes borrowing more expensive and leads to lower margins and lower monitoring. The latter is an indirect effect of higher safe rates through total lending, which increases loan rates and leads to higher margins and higher monitoring. The combination of these two effects highlights that in order to understand the effects of changes in the safe rate on bank risk-taking, the intensity of the pass-through of the safe rate R_0 to the loan rate $R(L)$ is key.

2.2 Equilibrium lending decisions

To compute the Cournot equilibrium of the loan market, note that the objective function of an individual bank is given by the product $l\pi(L)$ of its lending l by the profits per unit of loans

$$\pi(L) = [1 - p + m(L)][R(L) - B(L)] - c(m(L)), \tag{11}$$

which depend on the lending of the other $n-1$ banks.

A symmetric Cournot equilibrium l^* is then defined by

$$l^* = \arg\max_l \left[l\pi(l + (n-1)l^*)\right], \tag{12}$$

and is characterized by the first-order condition

$$L^*\pi'(L^*) + n\pi(L^*) = 0, \tag{13}$$

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

Using (3) and (5), the function $\pi(L)$ in (11) may be written as

$$\pi(L) = (1-p)\gamma m(L) + \frac{\gamma}{2} m(L)^2, \tag{14}$$

which given the result $m'(L) < 0$ implies

$$\pi'(L) = \gamma[1 - p + m(L)]m'(L) < 0. \tag{15}$$

Although the sign of $\pi''(L)$ is in principle ambiguous, in what follows we assume that parameter values are such that $L\pi''(L) + (n+1)\pi'(L) < 0$,[16] so the second-order condition for the symmetric Cournot equilibrium $L^*\pi''(L^*) + 2n\pi'(L^*) < 0$ is satisfied.

The equilibrium loan rate is $R^* = R(L^*)$, and the rate at which banks borrow from investors is $B^* = B(L^*)$. 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, which is therefore the key driver of financial stability.

We are interested in analyzing the effect on the probability of default PD of changes in two parameter values, namely the expected return R_0 required by investors, and the number of banks n, which measures (the inverse of) their market power.

The effect of changes in the number of banks n is straightforward. Differentiating the first-order condition (13) and using the assumption $L\pi''(L) + (n+1)\pi'(L) < 0$ gives

$$\frac{\partial L^*}{\partial n} = -\frac{\pi(L^*)}{L^*\pi''(L^*) + (n+1)\pi'(L^*)} > 0. \tag{16}$$

Thus, increasing the number of banks n increases equilibrium total lending L^*. But since $m'(L) < 0$, this lowers the equilibrium monitoring intensity m^* and consequently increases the probability of default PD. This result is in line with the traditional (charter value) view

[16] This condition is satisfied in all of our numerical results.

of the relationship between competition and financial stability, according to which higher competition results in higher risk-taking.

In order to analyze the effect of changes in the safe rate R_0 on the probability of default PD, we first have to sign its effect on equilibrium lending L^*.

Proposition 2 *An increase in the safe rate R_0 always leads to a reduction in equilibrium lending L^*.*

As before, differentiating the first-order condition (13) gives

$$\frac{\partial L^*}{\partial R_0} = -\frac{\frac{\partial}{\partial R_0}[L^*\pi'(L^*) + n\pi(L^*)]}{L^*\pi''(L^*) + (n+1)\pi'(L^*)}.$$

Since we have assumed $L\pi''(L) + (n+1)\pi'(L) < 0$, the sign is that of the derivative in the numerator, which as we prove in the Appendix is negative. Thus, neither the endogenous monitoring decision of banks nor the Cournot competition among them alter the conventional result that a lower cost of funding implies higher lending.[17]

Interestingly, the effect of changes in the safe rate R_0 on the equilibrium monitoring intensity m^* is ambiguous. To see this, note that

$$\frac{dm^*}{dR_0} = \frac{\partial m^*}{\partial L^*}\frac{\partial L^*}{\partial R_0} + \frac{\partial m^*}{\partial R_0}. \tag{17}$$

Using the expression for $m(L)$ in (10), and the fact that by (2) we have $R'(L) = -b < 0$, it is immediate to show 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 (17) is positive, while the second is negative. The latter is the *funding rate effect* that comes from the fact that, by the investors' participation constraint (6), an increase in the safe rate R_0 increases the borrowing rate $B(L)$, and hence decreases the intermediation margin $R(L) - B(L)$ for any given L. The former is the *lending rate effect* that comes from the fact that an increase in the safe rate R_0 decreases equilibrium lending L^*, which increases the loan rate $R(L^*)$ and the intermediation margin $R(L^*) - B(L^*)$. Thus, the first effect pushes down the margin, while the second effect

[17] Thus, in this model there is no "reversal rate" as in Brunnermeier and Koby (2019), as lower safe rates translate into lower lending rates.

pushes it up. Since according to (5) the banks' monitoring intensity is proportional to the intermediation margin, we have an ambiguous effect on risk-taking.

In what follows we show that the sign of derivative in (17) depends on the number of banks n. In particular, when n is large the derivative is positive, so higher safe rates lead to lower risk-taking, while when n is small the derivative is negative, so higher safe rates lead to higher risk-taking. The following result deals with the limit cases of monopoly and perfect competition.

Proposition 3 *Under monopoly* ($n = 1$), *an increase in the safe rate* R_0 *leads to an increase in the equilibrium probability of loan default* $PD = p - m^*$. *Under perfect competition* ($n \to \infty$), *whenever monitoring is positive an increase in the safe rate* R_0 *leads to a decrease in the equilibrium probability of loan default* $PD = p - m^*$.

The intuition for the result in the monopoly case is as follows. Higher safe rates increase the monopolist's funding costs, which translates into lower profits per unit of loans and consequently lower monitoring incentives.

The intuition for the result in the perfect competition case is as follows. Increasing the number of banks n increases equilibrium lending L^* and reduces the equilibrium loan rate R^*. There will be a point in which the constraint $R(L) \geq \underline{R}$ becomes binding, in which case by Proposition 1 the equilibrium monitoring intensity m^* equals the value $\underline{m}$ defined in (9) that minimizes the convex function

$$\gamma m + \frac{R_0}{1 - p + m}.$$

The derivative with respect to m of the first term captures the effect on the marginal cost of monitoring, which is constant, while the derivative of the second term captures the effect on the marginal benefit of monitoring, in terms of a reduction in the borrowing rate

$$B = \frac{R_0}{1 - p + m},$$

which is increasing (in absolute value) in the safe rate R_0. Hence, when $\underline{m}$ is not at the corner with zero monitoring (which requires $\gamma < R_0/(1-p)^2$), increases in R_0 push $\underline{m}$ to the right, as the marginal benefit of monitoring is higher for higher safe rates, so the equilibrium monitoring intensity of competitive banks will increase.

Summing up, we have shown that under monopoly increases in the safe rate R_0 increase the probability of default of bank loans, while under perfect competition increases in the safe rate R_0 reduce it. These results suggest that the slope of the relationship between R_0 and PD changes from positive to negative as we increase the number of banks n, so that $\partial^2 PD/\partial R_0 \partial n < 0$.

Indeed, as Figure 1 illustrates, 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 equilibrium probability of loan default PD (in the vertical axis). For sufficiently high n the the slope changes sign from positive to negative. The conclusion is that market power matters for assessing the effect of interest rates on financial stability. In particular, *low interest rates are detrimental to financial stability when banks' market power is low, but beneficial when their market power is high.*

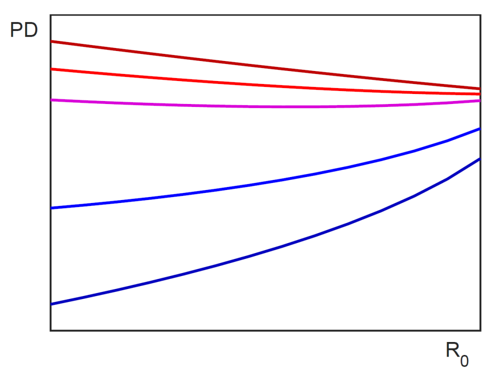

Figure 1. Effect of the safe rate on the probability of loan default

This figure shows the relationship between the safe rate and the probability of default for loan markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks.

The intuition for these results is as follows. A reduction in the safe rate reduces banks' funding costs which translates into lower loan rates. In monopolistic markets this pass-through from funding costs to loan rates is not very intense, as banks take into account the market-wide effect of their individual lending decisions, which results in higher intermediation margins, and hence higher monitoring incentives; see equation (5). In competitive markets the pass-through is more intense, as banks do not internalize the market-wide effect of their individual lending decisions, which results in lower intermediation margins and lower monitoring incentives. This is illustrated in Figure 2, where we show the effect of changes in the safe rate R_0 on equilibrium loan rates R^* (Panel A) and intermediation margins $R^* - B^*$ (Panel B) for different values of the number of banks n. The slopes of the lines in Panel A become steeper (a higher pass-through) with increases in n, which leads to the change in the slope of the lines in Panel B from positive (for high n) to negative (for low n).

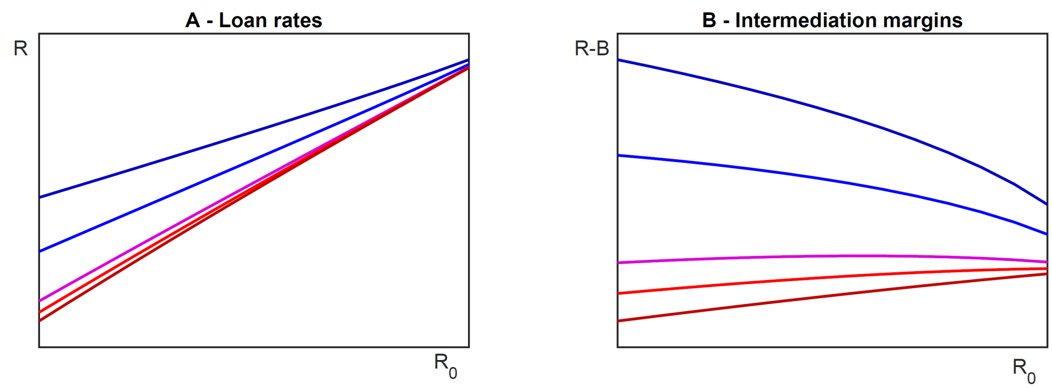

Figure 2. Effect of the safe rate on loan rates and intermediation margins

This figure shows the relationship between the safe rate and the equilibrium loan rates (Panel A) and intermediation margins (Panel B) for loan markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks.

3 Alternative Competition Scenarios

This section reviews our previous results on the relationship between the safe rate and banks' risk-taking decisions when we incorporate three relevant aspects of competition in the loan market. First, we consider the effect of introducing competitive market lenders that do not monitor borrowers, but can limit the monopoly rents that banks are able to capture. Second, we analyze at the effect of introducing heterogeneity in banks' monitoring costs. Finally, we discuss the long run effects that obtain when we allow for entry (or exit) of banks in the loan market.

3.1 Direct market finance

Consider a variation of our model in which entrepreneurs can obtain funding for their projects from banks and also directly from investors.[18] We assume that investors are not able to monitor entrepreneurs's projects (because they may be dispersed and subject to a free rider problem). They are also assumed to be competitive in the sense that they are willing to lend at a rate $\overline{R}$ that satisfies the participation constraint

$$(1-p)\overline{R} = R_0. \tag{18}$$

The presence of market lenders imposes a constraint on banks' lending, since the loan rate $R(L)$ cannot exceed the market rate $\overline{R}$.[19] This means that the inverse loan demand function (2) now becomes

$$R(L) = \min\{a - bL, \overline{R}\}. \tag{19}$$

The upper bound $\overline{R}$ will be binding whenever the original equilibrium (in the absence of the bound) is such that $R^* > \overline{R}$. In such case the candidate equilibrium lending will be $\overline{L} > L^*$ such $R(\overline{L}) = a - b\overline{L} = \overline{R}$. By our previous results, the banks' borrowing rate and monitoring intensity will be given by $B(\overline{L})$ and $m(\overline{L})$, respectively. The question is: will a bank j want to deviate from setting $l_j = \bar{l} = \overline{L}/n$ when the other $n-1$ banks choose to lend $\bar{l}$?

There are two cases to consider. First, note that setting $l_j < \bar{l}$ is not profitable, since given the upper bound in 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 the assumption $L\pi''(L) + (n+1)\pi'(L) < 0$ together with $\overline{L} > L^*$ implies

$$\frac{d}{dl}[l\pi(l + (n-1)\bar{l})]\bigg|_{l=\bar{l}} = \bar{l}\pi'(\overline{L}) + \pi(\overline{L}) < l^*\pi'(L^*) + \pi(L^*) = 0, \tag{20}$$

[18] This setup can be more suitable for large firms that can access bond markets. In contrast, our basic setup can be more relevant for smaller firms that do not have easy access to such markets.

[19] Note that if $R(L) > \overline{R}$, more entrepreneurs would enter the market, borrowing at the market rate $\overline{R}$, driving down the success return $R(L)$ until it coincides with $\overline{R}$.

where the last equality is just the equilibrium condition in the absence of direct market finance.

Hence, we conclude that whenever the upper bound $\overline{R}$ is binding, the equilibrium total lending by banks will be $\overline{L}$. Interestingly, although direct market finance is zero, it has a significant effect on equilibrium lending and interest rates by limiting banks' market power. It also has an effect on the relationship between the safe rate R_0 and the probability of loan default PD. In particular, substituting the loan rate $\overline{R} = R_0/(1-p)$ into (10) yields an equilibrium level of monitoring

$$m^* = \frac{R_0}{\gamma(1-p)} - (1-p), \tag{21}$$

which is increasing in R_0. Thus, 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.[20]

Figure 3 illustrates the effect of changes in the safe rate R_0 on equilibrium loan rates R^* (Panel A) and intermediation margins $R^* - B^*$ (Panel B) in the presence of direct market finance. The solid lines in Panel A show the relationship between R^* and R_0 for different values of n. The dashed line shows the upper bound $\overline{R} = R_0/(1-p)$, which is binding for monopolistic markets (low n) and for low values of the safe rate R_0. The lines in Panel B show the implied relationship between $R^* - B^*$ and R_0 for different values of n.

[20] Note that this implies that the lending rate effect that comes from the increase in $\overline{R}$ is stronger than the funding rate effect that comes from the increase in the borrowing rate $B(L)$.

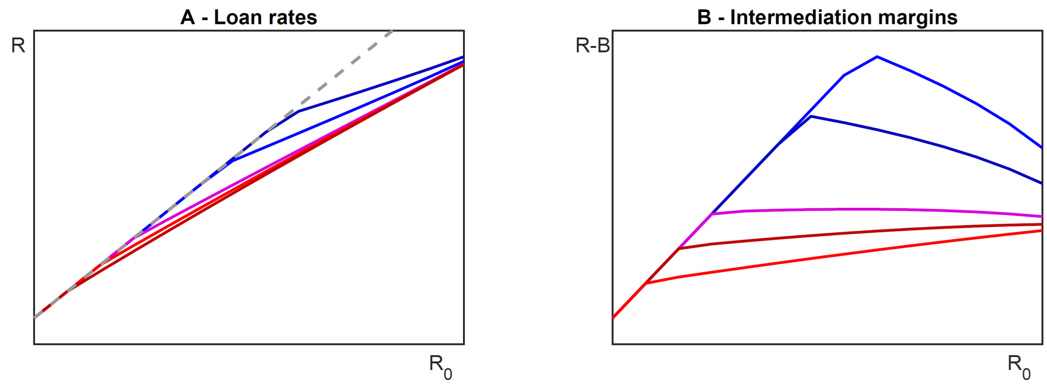

Figure 3. Effect of the safe rate on loan rates and intermediation margins in the presence of market finance

This figure shows the relationship between the safe rate and the equilibrium loan rates (Panel A) and intermediation margins (Panel B) in the presence of market finance for loan markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks. The dashed line in Panel A represents the loan rate under direct market finance.

Figure 4 shows the effect of introducing market finance on the equilibrium probability of loan default PD. The horizontal axis represents the safe rate R_0, and the vertical axis represents the probability of loan default PD. The different lines show the relationship between PD and R_0 for different values of n. For competitive markets (high n), the relationship is still negative, that is higher safe rates translate into lower risk-taking. However, in contrast with the result in Section 2, in monopolistic markets (low n) the effect is U-shaped: lower safe rates initially decrease banks' risk-taking, but below certain point they increase risk-taking. This result follows from the fact that, as shown in Figure 3, when the safe rate is low the equilibrium loan rate R^* in monopolistic markets equals the market rate $\overline{R}$, so by (21) lower rates reduce monitoring intensities, thereby increasing the probability of default of bank loans.

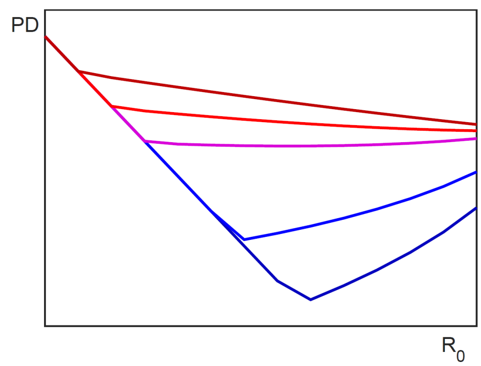

Figure 4. Effect of the safe rate on the probability of loan default in the presence of market finance

This figure shows the relationship between the safe rate and the probability of default for loan markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks in the presence of direct market finance.

3.2 Heterogenous monitoring costs

We next consider the effect of changes in the safe rate in a loan market in which banks may have different monitoring costs. Specifically, suppose that there are two types of banks that differ in the parameter γ of their monitoring cost function (3): n_1 banks have high monitoring costs, characterized by parameter γ_1, while $n_0 = n - n_1$ banks have low monitoring costs, characterized by parameter $\gamma_0 < \gamma_1$. It is assumed that a bank's type is observable to investors, so they can adjust the rates at which they are willing to fund them.

To characterize the equilibrium of the model with heterogeneous banks, note first that the critical values $\underline{R}_0$ and $\underline{R}_1$ which are defined by setting γ in (8) equal to γ_0 and γ_1, respectively, satisfy $\underline{R}_0 < \underline{R}_1$. From here it follows that whenever the total supply of loans L is such that $\underline{R}_0 < R(L) < \underline{R}_1$, only the low monitoring cost banks will operate.

By our results in Section 2, if $R(L) \geq \underline{R}_j$ the monitoring intensity chosen by a bank of type $j = 0, 1$ is

$$m_j(L) = \frac{1}{2\gamma_j}\left[R(L) - \gamma_j(1-p) + \sqrt{[R(L) + \gamma_j(1-p)]^2 - 4\gamma_j R_0}\right], \tag{22}$$

and the corresponding borrowing rate is

$$B_j(L) = \frac{R_0}{1 - p + m_j(L)}. \tag{23}$$

One can show that $m_0(L) > m_1(L)$,[21] which implies $B_0(L) < B_1(L)$. Thus, low monitoring cost banks choose a higher monitoring intensity, and consequently are able to borrow from investors at lower rates. Using (6) together with $\gamma_0 < \gamma_1$ one can also show that

$$\begin{aligned} \pi_0(L) &= [1 - p + m_0(L)]R(L) - R_0 - \frac{\gamma_0}{2}(m_0(L))^2 \\ &> [1 - p + m_1(L)]R(L) - R_0 - \frac{\gamma_0}{2}(m_1(L))^2 \\ &> [1 - p + m_1(L)]R(L) - R_0 - \frac{\gamma_1}{2}(m_1(L))^2 = \pi_1(L). \end{aligned} \tag{24}$$

Thus, low monitoring cost banks have higher profits per unit of loans.

A Cournot equilibrium is defined by a pair of strategies (l_0^*, l_1^*) for the two types of banks that satisfy

$$l_0^* = \arg\max_l \left[l\pi_0(l + (n_0 - 1)l_0^* + n_1 l_1^*) \right], \tag{25}$$

$$l_1^* = \arg\max_l \left[l\pi_1(l + (n_1 - 1)l_1^* + n_0 l_0^*) \right]. \tag{26}$$

From here it follows that the Cournot equilibrium will be characterized by the first-order conditions

$$L_0^* \pi_0'(L^*) + n_0 \pi_0(L^*) = 0, \tag{27}$$

$$L_1^* \pi_1'(L^*) + n_1 \pi_1(L^*) = 0, \tag{28}$$

where $L_0^* = n_0 l_0^*$, $L_1^* = n_1 l_1^*$, and $L^* = L_0^* + L_1^*$.

Figure 5 illustrates the effect of changes in the safe rate R_0 on equilibrium lending by low and high monitoring cost banks, L_0^* and L_1^*, and equilibrium total lending L^*. 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 $\lambda = L_0^*/L^*$, increases with the safe rate, reaching 100% for high values of R_0.

[21] This follows from the fact that the function in the left-hand side of (7) is increasing in γ, so the highest intersection with $R(L)$ must be decreasing in γ.

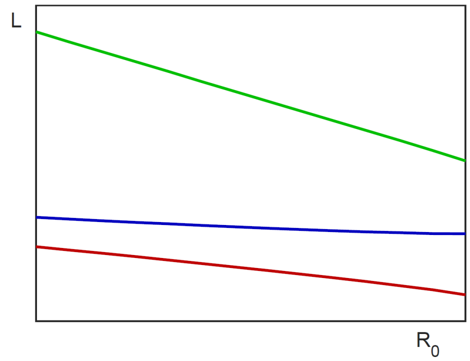

Figure 5. Effect of the safe rate on loan supply with heterogeneous monitoring costs

This figure shows the relationship between the safe rate and the aggregate supply of loans (green), and the supply of loans by banks with low (blue) and high monitoring costs (red).

Since low monitoring cost banks choose a higher monitoring intensity, their loans have a lower probability of default. Given that the market share of these banks increases with the safe rate, it follows that the average probability of loan default will get closer to that of the low monitoring cost banks. Figure 6 illustrates the effect of changes in the safe rate R_0 on the probability of loan default of low and high monitoring cost banks, $PD_0 = p - m_0^*$ and $PD_1 = p - m_1^*$, as well as on the average probability of default defined by

$$\overline{PD} = \lambda PD_0 + (1 - \lambda) PD_1. \tag{29}$$

Increases in the safe rate R_0 translate into increases in the probability of default of the loans granted by high monitoring cost banks, and decreases in the probability of default of the loans granted by low monitoring cost banks. These banks become safer because higher safe rates increase their comparative advantage relative to the high monitoring cost banks, since their borrowing rate $B_0(L)$ increases by less than the borrowing rate $B_1(L)$ of the high monitoring cost banks; see equation (23). Hence, when heterogeneity in monitoring costs is high enough (as in the case in our numerical example), the intermediation margin

$R(L) - B_0(L)$ of the low monitoring cost banks goes up, while the intermediation margin $R(L) - B_1(L)$ of the high monitoring cost banks goes down, which explains the differential effects on monitoring incentives.[22] Moreover, Figure 6 also shows that, due to the increase in the market share λ of low monitoring cost banks, the average probability of loan default $\overline{PD}$ in (29) goes down, approaching PD_0 for large values of R_0.

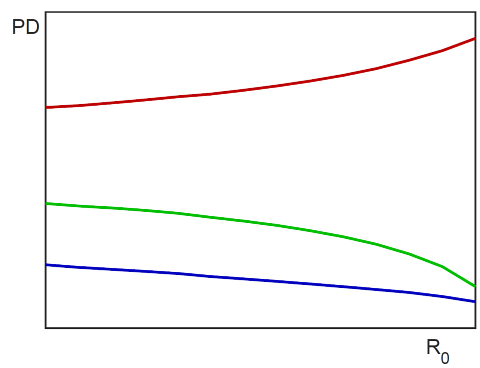

Figure 6. Effect of the safe rate on the probability of loan default with heterogeneous monitoring costs

This figure shows the relationship between the safe rate and the average probability of default (green), and the probability of default of loans by banks with low (blue) and high monitoring costs (red).

A conclusion that can be drawn from this analysis is that, when banks have different monitoring costs, the composition effect of increases in the safe rate, which leads to a greater market share of low monitoring cost banks, makes the results closer to those of the basic model with low market power (high n).

[22] For low cost heterogeneity the differential effects may not obtain, since in the limit of homogeneous costs both relationships will be either increasing or decreasing, depending on market power. However, as the safe rate increases, the intermediation margin of the low monitoring cost banks will always increase more (or decrease less) that that of the high monitoring cost banks.

3.3 Bank entry

We next consider the effects of changes in the safe rate when we allow for entry (and exit) of banks into (or out of) the loan market. In this manner, we intend to shed light on the widespread view that interest rates that are "too low for too long" are detrimental to financial stability.

In order to endogenize the number of banks, we assume that banks incur a fixed cost to operate. Banks may have different fixed costs. In particular, let f_j denote the fixed cost of bank $j = 1, 2, 3, ...$, and assume that $f_{j+1} = f_j + z$, for all j, with $z \geq 0$. We consider two possible cases: one in which all banks have the same fixed cost ($z = 0$), and another one in which the fixed cost is increasing in the number of banks ($z > 0$). The timing of the model is that first banks sequentially decide whether to enter the market by paying the fixed cost, and once n is determined they compete as in our basic setup.

Let Π_n^* denote the equilibrium bank profits (before subtracting the fixed costs) in a market in which n otherwise identical banks operate. Ignoring integer constraints, the free entry equilibrium is characterized by a number n of banks that satisfy a zero net profit condition for the marginal bank, namely $\Pi_n^* - f_n = 0$.

In what follows we analyze the effect of introducing either constant or increasing fixed costs on the relationship between the safe rate R_0 and the probability of loan default PD. The benchmark for this analysis will be the monopoly case ($n = 1$), in which, by Proposition 3, lower rates translate into higher monitoring incentives and higher profits.

Figure 7 shows the effect of introducing fixed costs on the equilibrium number of banks n for different values of the safe rate R_0. The horizontal axis represents the safe rate R_0, and the vertical axis represents the equilibrium number of banks n. The black line corresponds to the benchmark monopoly case, the blue line is the increasing fixed cost case, and the red line is the constant fixed cost case. As expected, with lower rates there will be entry which will be more pronounced for constant fixed costs.

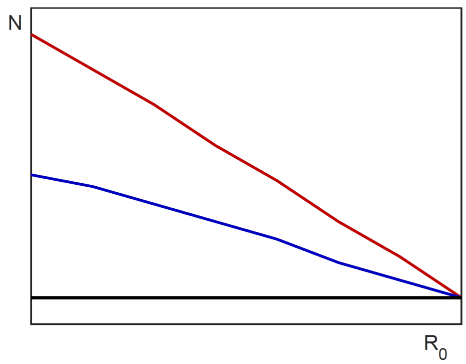

Figure 7. Effect of the safe rate on the number of banks

This figure shows the relationship between the safe rate and the equilibrium number of banks for a constant fixed cost (blue) and an increasing fixed cost of entry (red). The black line represents the fixed number of banks benchmark.

We have shown that increasing the number of banks increases equilibrium total lending, lowers the monitoring intensity of the banks, and hence increases the probability of loan default. Since there will be more entry with lower rates, we have

$$\frac{\partial PD}{\partial R_0} + \frac{\partial PD}{\partial n}\frac{dn}{\partial R_0} < \frac{\partial PD}{\partial R_0}, \tag{30}$$

where the first term in the left-hand side shows the direct effect for a fixed number of banks, and the second term the indirect effect through bank entry. The inequality follows from the result $dn/\partial R_0 < 0$ together with result $\partial PD/\partial n > 0$ obtained in Section 2. The conclusion is that bank entry will tend to strengthen the negative relationship between safe rates and bank risk-taking in competitive markets, and can possibly reverse the positive relationship between safe rates and bank risk-taking in monopolistic markets.

Figure 8 illustrates these results. The horizontal axis represents the safe rate R_0, and the vertical axis represents the probability of loan default PD. The black line corresponds to the benchmark monopoly case, the blue line is the increasing fixed cost case, and the red line is the constant fixed cost case. The effect of entry (the second term in the left-hand side of (30)) is clearly more pronounced for the constant than for the increasing fixed cost of entry.

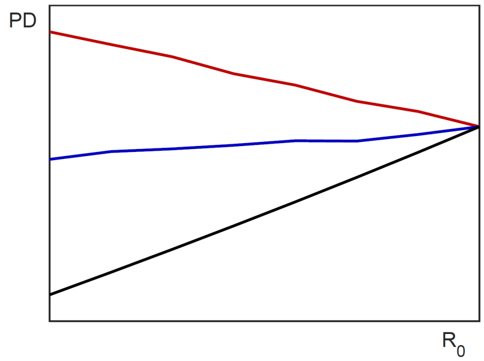

Figure 8. Effect of the safe rate on the probability of loan default with endogenous entry

This figure shows the relationship between the safe rate and the probability of default for a constant fixed cost (blue) and an increasing fixed cost of entry (red). The black line represents the fixed number of banks benchmark.

4 Alternative Funding Scenarios

This section analyzes the robustness of our previous results to incorporating three relevant aspects of banks' funding sources. First, we consider a variation of the basic model in which deposits are insured. Second, we analyze the effect of assuming that banks also compete à la Cournot in the deposit market. Finally, we introduce bank capital, and analyze whether endogenizing leverage changes the relationship between the safe rate and banks' risk-taking decisions.

4.1 Insured deposits

When deposits are insured banks can borrow from investors at the safe rate R_0, since when they fail the insurer pays them the promised return.[23] Hence, the banks' choice of monitoring is given by

$$m(L) = \arg\max_{m} \{(1 - p + m)[R(L) - R_0] - c(m)\}. \tag{31}$$

[23] To simplify the analysis, we assume that such insurance is provided at a flat rate equal to zero.

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

$$R(L) - R_0 = \gamma m(L). \tag{32}$$

This result together with (3) implies that banks' profits per unit of loans may be written as

$$\pi(L) = (1-p)[R(L) - R_0] + \frac{1}{2\gamma}[R(L) - R_0]^2. \tag{33}$$

Hence, $R'(L) = -b < 0$ implies $\pi'(L) < 0$.

Following the same steps as in Section 2, the first-order condition that characterizes a symmetric Cournot equilibrium is

$$L^* \pi'(L^*) + n\pi(L^*) = 0. \tag{34}$$

As before, we are interested in analyzing the effect on the probability of loan default PD of changes in two parameter values, namely the number of banks n and the expected return R_0 required by investors. Differentiating the first-order condition (34), and assuming that parameter values are such that $L\pi''(L)+n\pi'(L) < 0$ (which implies $L\pi''(L)+(n+1)\pi'(L) < 0$) we get

$$\frac{\partial L^*}{\partial n} = -\frac{\pi(L^*)}{L^*\pi''(L^*) + (n+1)\pi'(L^*)} > 0, \tag{35}$$

which is the same result as in the basic model.

Similarly, differentiating the first-order condition (34) and using the expression for $\pi(L)$ in (33) we get

$$\frac{\partial L^*}{\partial R_0} = -\frac{L^*\pi''(L^*) + n\pi'(L^*)}{b\left[L^*\pi''(L^*) + (n+1)\pi'(L^*)\right]} < 0. \tag{36}$$

Hence, an increase in the safe rate R_0 reduces equilibrium lending L^*. From here it follows that the effect on the intermediation margin is

$$\frac{\partial}{\partial R_0}\left[R(L^*) - R_0\right] = -b\frac{\partial L^*}{\partial R_0} - 1 = -\frac{\pi'(L^*)}{L^*\pi''(L^*) + (n+1)\pi'(L^*)} < 0. \tag{37}$$

But then by (32) we know that a decrease in the intermediation margin leads to a decrease in monitoring, so $\partial m^*/\partial R_0 < 0$.

We conclude that, when deposits are insured, an increase in the safe rate R_0 always leads to an increase in the probability of loan default PD, regardless of the number of banks n.[24] Hence, the results for the model with insured deposits on the effect of the safe rate on banks' risk-taking decisions are qualitatively similar to the results for the model with uninsured deposits when banks have significant market power (low n).

4.2 Endogenous deposit rates

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

$$R_D(D) = R_0 - c + dD, \tag{38}$$

where D is the aggregate supply of deposits, R_D is the expected return of bank deposits, and $c > 0$ 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 (38) 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 $[0, c]$.[25] An investor of type s will deposit her wealth in a bank offering a return R_D if

$$R_D + s \geq R_0. \tag{39}$$

From here it follows that if the deposit return is R_D, 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

$$D = \frac{c - (R_0 - R_D)}{d}. \tag{40}$$

[24]Note than in the limit case of perfect competition we have $R(L) - R_0 = 0$, which by (32) implies $m(L) = 0$. Thus, in this case we have $PD = p$ (a flat line) for all values of the safe rate R_0.

[25]The liquidity premium could also be interpreted as an individual-specific cost of accessing the government bond market.

Solving for R_D in this equation gives the inverse supply function (38).

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.

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 $L = \sum_{j=1}^{n} l_j$ 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 $B_j(L)$, and once the lending and the funding rates are set it chooses the monitoring intensity of its loans $m_j(L)$. As before, we will drop the subindex j and simply write $B(L)$ and $m(L)$.

To characterize the equilibrium of this model we first determine the banks' 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

$$m(L) = \arg\max_{m} \left\{(1 - p + m)[R(L) - B(L)] - c(m)\right\}. \tag{41}$$

and the depositors' participation constraint is now

$$[1 - p + m(L)]B(L) = R_D(L). \tag{42}$$

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

$$R(L) \geq \underline{R}(L) = \min_{m\in[0,p]} \left(\gamma m + \frac{R_D(L)}{1 - p + m}\right), \tag{43}$$

then we have

$$m(L) = \frac{1}{2\gamma} \left[R(L) - \gamma(1 - p) + \sqrt{[R(L) + \gamma(1 - p)]^2 - 4\gamma R_D(L)}\right] \tag{44}$$

and

$$B(L) = \frac{R_D(L)}{1 - p + m(L)} \tag{45}$$

From (44) it follows that

$$\frac{dm(L)}{dL} = -b\frac{\partial m(L)}{\partial R(L)} + d\frac{\partial m(L)}{\partial R_D(L)} < 0. \tag{46}$$

The second term in this expression is new, relative to the model with 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 $R(L)-B(L)$, due to the increase in the expected return of deposits $R_D(L)$, and hence in the deposit rate $B(L)$.

A Cournot equilibrium is defined as in the basic model, with $m(L)$ and $B(L)$ in (44) and (45) replacing the previous expressions in (11). Solving the first-order condition (13) gives the equilibrium amount of lending L^* (and deposit taking $D^* = L^*$). As before, the equilibrium loan rate is $R^* = R(L^*)$, the deposit rate is $B^* = B(L^*)$, and the probability of loan default is given by $PD = p - m(L^*)$.

Figure 9 shows that the qualitative effects of changes in the safe rate R_0 on the probability of default PD for different values of n are similar to the ones in Figure 1. Increasing 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 equilibrium probability of loan default PD (in the vertical axis). For sufficiently high n the the slope changes sign from positive to negative. The conclusion is that adding Cournot competition in the deposit market does not change our initial 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 market power is high.

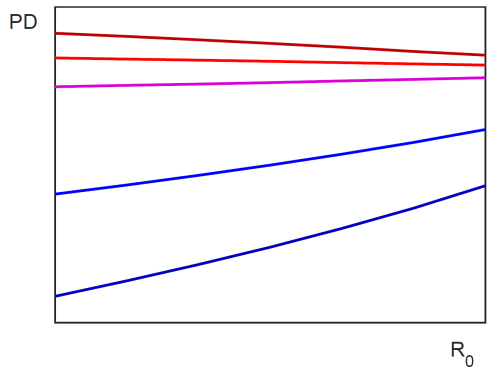

Figure 9. Effect of the safe rate on the probability of loan default with Cournot competition for deposits and loans

This figure shows the relationship between the safe rate and the probability of default for markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks that compete à la Cournot for both deposits and loans.

The introduction of imperfect competition in the deposit market relates our results to those of Drechsler et al. (2018). In particular, we construct a model in which the supply of deposits D is a decreasing function of the spread $s = R_0 - R_D$, and we show that an increase in the safe rate R_0 leads to an increase in the spread s and a reduction in both deposits D and loans $L = D$. However, in contrast with their results (and as illustrated in Figure 10), our model predicts that the contractionary effect of an increase in the safe rate R_0 is more significant in competitive markets (high n) that in monopolistic markets (low n), that is $\partial^2 L/\partial R_0 \partial n < 0$.[26] The reason for the difference is that in our model the direction of causality does not go from deposits to loans, since banks are also assumed to have market power in lending and simultaneously determine both D and L, for any given level of the safe rate R_0.

[26] This is in line with the prediction of simple microeconomic models, in which quantities are more sensitive to prices in competitive settings. For example, in a model without default where the demand for loans is $R(L) = a - bL$ and the borrowing rate is R_0, equilibrium lending would be $(a - R_0)/2b$ under monopoly and $(a - R_0)/b$ under competition.

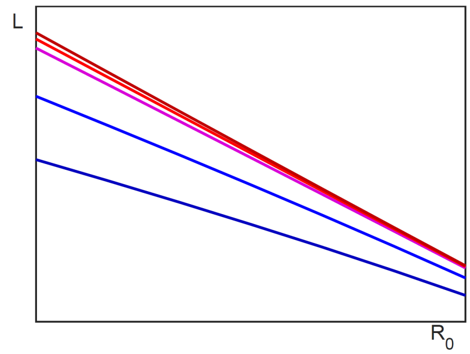

Figure 10. Effect of the safe rate on aggregate loan supply with Cournot competition for deposits and loans

This figure shows the relationship between the safe rate and the aggregate loan supply for markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks that compete à la Cournot for both deposits and loans.

4.3 Endogenous leverage

Finally, we analyze the effect of changes in the safe rate when banks can adjust their leverage. As highlighted by Dell'Ariccia et al. (2014), leverage decisions are an important driver of the risk-taking effects of monetary policy.[27]

In what follows we consider two models with endogenous leverage: one in which the aggregate supply of bank capital is fixed at K (in which case each bank will have K/n capital), and one in which, as in Dell'Ariccia et al. (2014), there is an infinitely elastic supply of capital at the rate $R_0 + \delta$, where $\delta > 0$ is an exogenous equity premium.

In the former case, the sequence of moves is as in the basic model, except for the fact that the supply of loans l_j by each bank $j = 1, ..., n$ determines not only the total supply of loans $L = \sum_{j=1}^{n} l_j$ and the loan rate $R(L)$, but also its capital per unit of loans $k_j = K/nl_j$. In the latter case, each bank $j = 1, ..., n$ first 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 $R(L)$, and then chooses its capital

[27] It is important to note that in our model, as in Dell'Ariccia et al. (2014), bank equity is taken to be inside equity, that is funds provided by agents that either make the unobservable risk-taking decisions or are aligned with those that take them.

per unit of loans k_j.

In both cases, after $R(L)$ is determined, bank j offers an interest rate $B_j(L)$ to the debt investors, and once the lending and the funding rates are set it chooses the monitoring intensity of its loans $m_j(L)$. Notice that each bank j only has to raise $(1-k_j)l_j$ funds from investors, since the rest is funded with equity. As before, we will drop the subindex j and simply write $B(L)$, $m(L)$, and $k(L)$.

Given a loan rate $R = R(L)$, a safe rate R_0, and a capital per unit of loans $k = k(L)$, a bank's choice of borrowing rate B^* and monitoring intensity m^* is a solution to the problem

$$m^* = \arg\max_m \left[(1-p+m)[R-(1-k)B^*] - c(m)\right], \tag{47}$$

subject to the investors' participation constraint

$$(1-p+m^*)B^* = R_0. \tag{48}$$

By the convexity of the monitoring cost function (3), the solution to (47) is characterized by the first-order condition

$$R-(1-k)B^* = \gamma m^*. \tag{49}$$

Solving for B^* in the participation constraint (48) and substituting it into the first-order condition (49) gives the key equation that characterizes the banks' monitoring intensity

$$\gamma m^* + \frac{(1-k)R_0}{1-p+m^*} = R. \tag{50}$$

The left-hand side of (50) is convex in m^*, so in general there will be two solutions for m^*. By the same arguments as in Proposition 1, we can show that the banks prefer the highest one, which is

$$m(R,k) = \frac{1}{2\gamma}\left[R-\gamma(1-p)+\sqrt{[R+\gamma(1-p)]^2 - 4\gamma(1-k)R_0}\right]. \tag{51}$$

It follows from this expression that a higher loan rate R and a higher a capital per unit of loans k increase the bank's monitoring intensity m^*, that is $\partial m^*/\partial R > 0$ and $\partial m^*/\partial k > 0$.

For the model with a *fixed aggregate supply of bank capital*, banks' profits per unit of loans are

$$\pi(R,k) = [1-p+m(R,k)]R - (1-k)R_0 - c(m(R,k)). \tag{52}$$

Given that $R = R(L)$ and $k = K/nl$, with a slight abuse of notation we can write

$$\pi(L, l) = \pi(R(L), K/nl) = [1 - p + m(L, l)]R(L) - (1 - K/nl)R_0 - c(m(L, l)). \tag{53}$$

A symmetric Cournot equilibrium is then defined by

$$l^* = \arg\max_l [l\pi(l + (n-1)l^*, l)]. \tag{54}$$

For the model with an *infinitely elastic supply of bank capital*, banks' profits per unit of loans are

$$\pi(R, k) = [1 - p + m(R, k)]R - (1 - k)R_0 - k(R_0 + \delta) - c(m(R, k)). \tag{55}$$

Given that $R = R(L)$, let us define

$$\pi(L) = \max_k \pi(R(L), k). \tag{56}$$

A symmetric Cournot equilibrium is then defined by

$$l^* = \arg\max_l [l\pi(l + (n-1)l^*)]. \tag{57}$$

Figure 11 illustrates the effects of changes in the safe rate R_0 for the model with a fixed aggregate supply of bank capital on capital per unit of loans k (Panel A) and the probability of default PD (Panel B) for different values of n. Panel A shows that an increase in the number of banks n leads to a reduction in k, due to the higher equilibrium supply of loans (recall that $k = K/L$). It also shows that an increase in the safe rate R_0 leads to an increase in k, due to the lower equilibrium supply of loans. Panel B shows that the results for this model of endogenous leverage are similar to those of the basic model. For sufficiently high n the the slope of the relationship between the safe rate R_0 and the equilibrium probability of default PD changes sign from positive to negative. Thus, low interest rates are detrimental to financial stability when banks' market power is low, but not when their market power is high. A comparison between Panels A and B shows that while lower rates always lead to an increase in leverage, this does not necessarily increase the probability of default. In particular, when banks have significant market power (low n) the increase in leverage is more than compensated by the higher intermediation margin.

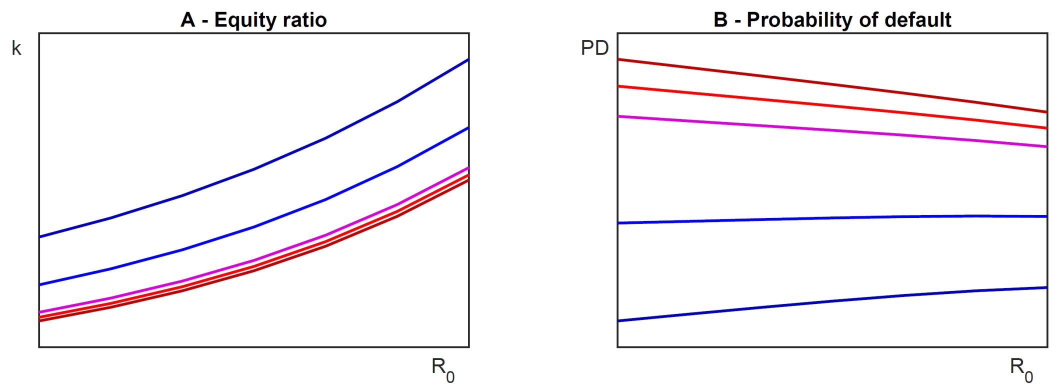

Figure 11. Effect of the safe rate on the equity ratio and the probability of loan default with a fixed aggregate supply of capital

This figure shows the relationship between the safe rate and the capital per unit of loans (Panel A) and the probability of default (Panel B) for loan markets with 1 (dark blue), 2, 5, 7, and 10 (dark red) banks with a fixed aggregate supply of equity capital.

Figure 12 illustrates the effects of changes in the safe rate R_0 for the model with an infinitely elastic supply of capital on capital per unit of loans k (Panel A) and the probability of default PD (Panel B) for different values of n. Panel A shows that the effects of an increase in the number of banks n and in the safe rate R_0 on banks' capital per unit of loans are qualitatively the same as those for the model with a fixed aggregate supply of bank capital. However, the results in Panel B are different: although an increase in the number of banks n also leads to an increase in the probability of default PD, now the relationship between the safe rate R_0 and the probability of default PD is always decreasing. Thus, as previously shown by Dell'Ariccia et al. (2014), when banks can raise capital at a fixed equity premium δ low interest rates are always detrimental to financial stability. The intuition for this result is as follows: low safe rates increase the cost of equity finance, $R_0 + \delta$, relative to the cost of debt finance, R_0, so banks react by increasing their leverage, as shown in Panel A. This, in turn, leads to higher risk-taking, as shown in Panel B. In the case of high market power (low

n), this means that the effect of a higher intermediation margin is more than compensated by the increase in leverage.

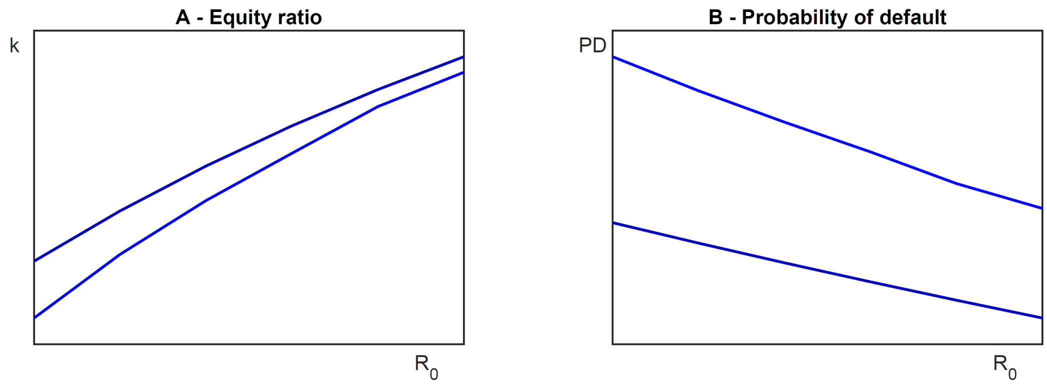

Figure 12. Effect of the safe rate on the equity ratio and the probability probability of loan default with an infinitely elastic supply of capital

This figure shows the relationship between the safe rate and the capital per unit of loans (Panel A) and the probability of default (Panel B) for loan markets with 1 (dark blue) and 2 (light blue) banks with an infinitely elastic supply of equity capital.

More generally, we can consider intermediate cases between the fixed and the infinitely elastic aggregate supply of bank capital. For example, we could assume that the differential cost of equity finance is an increasing and convex function $\delta(K)$ of the aggregate supply of bank capital. When $\delta(K) = \delta$ we have the case of an infinitely elastic supply, while when $\delta(K) = 0$ for $K \leq \overline{K}$ and $\delta(K) = \infty$ for $K > \overline{K}$ we have the case of a fixed supply of bank capital. By changing the shape of the function $\delta(K)$ we can obtain results that are close to one of the two limit cases examined above. However, in models in which bank equity is taken to be inside equity, it may be reasonable to assume that it is in limited supply. For this reason, we may conclude that adding leverage does not essentially change our initial results on the effect of safe rates on banks' risk-taking: low interest rates are expected to have a negative impact on financial stability when banks' market power is low, and a positive impact when their market power is high.

5 Conclusion

Are low interest rates driven by lax monetary conditions conducive or detrimental to financial stability? This question has recently received ample attention both from academic and policy circles and generated a large, mostly empirical literature. This paper sheds light on this question from a theoretical perspective. We present a model that highlights the relevance of the market structure of the financial sector to assess the effect of safe rates on financial intermediaries' risk-taking decisions.

Our basic model features a fixed number of intermediaries that raise uninsured funding from risk-neutral investors and compete à la Cournot in providing loans to penniless entrepreneurs. Intermediaries choose the monitoring intensity of their loans, which reduces the probability of default, but monitoring is unobservable, so there is a moral hazard problem between intermediaries and investors. Under our simple parameterization, in equilibrium monitoring will be proportional to the intermediation margin. Thus, the higher the margin, the lower the probability of default. It follows from here that to assess the effect of low rates on risk-taking decisions it suffices to understand their effect on the intermediation margin.

The expected return required by investors is assumed to be equal to an exogenous safe rate, which can be interpreted as a proxy for the stance of monetary policy. We show that in monopolistic loan markets the pass-through from funding costs to loan rates is weak, so lower rates result in higher intermediation margins and hence lower risk-taking by intermediaries. In contrast, in competitive markets the pass-through is strong, so lower rates result in lower intermediation margins and hence higher risk-taking by intermediaries. This implies that the slope of the relationship between the safe rate R_0 and probability of default PD changes from positive to negative as we increase the number of banks n, so that $\partial^2 PD/\partial R_0 \partial n < 0$.

Our analysis provides other novel testable implications regarding the relevance of market structure for the effects of lower safe rates on risk-taking incentives. In particular, when intermediaries' market power is limited by the possibility of firms borrowing directly and without monitoring from investors we predict a U-shaped relationship between the safe rate R_0 and probability of default PD. We also predict that, when banks are heterogeneous in their monitoring technologies, lower safe rates increases the market share of intermediaries with high monitoring costs, a composition effect that moves the overall results in the direction of the competitive benchmark.

Our results also highlight the relevance of certain characteristics in the liability side of the financial intermediaries' balance sheet. In particular, we predict that a higher proportion of insured liabilities (which can be proxied by insured deposits, but due to implicit government guarantees might exceed them) makes it more likely that low safe rates translate into higher intermediation margins and hence lower risk-taking. We also predict that easier access to equity capital (proxied by stock market listing) makes it more likely that low safe rates translate into higher leverage and hence higher risk-taking.

Thus, our theoretical model provides a rich set of novel testable predictions regarding how different market and financial intermediaries' characteristics can affect the relationship between interest rates and risk-taking in the financial sector. However, it should be noted that although we relate the safe rate to the stance of monetary policy, our setup abstracts from other possible relevant effects of monetary policy on aggregate credit demand or deposit supply, which can introduce further relevant interactions left for future research.

Appendix

Proof of Proposition 1 To simplify the notation, let R denote $R(L)$. If $R < \underline{R}$, for any $m \in (0, p]$ we have

$$R - \frac{R_0}{1 - p + m} - \gamma m < 0,$$

which implies that the bank has an incentive to reduce m. But for $m = 0$ we have

$$R - \frac{R_0}{1 - p} < 0,$$

which violates the banks' participation constraint $R \geq B = R_0/(1 - p)$.

If $R \geq \underline{R}$, by the convexity of the function in the right-hand side of (8) there exist an interval $[m^-, m^*] \subset [0, p]$ such that

$$R - \frac{R_0}{1 - p + m} - \gamma m \geq 0 \quad \text{if and only if} \quad m \in [m^-, m^*].$$

By our previous argument, for any $m \in (0, p]$ for which

$$R - \frac{R_0}{1 - p + m} - \gamma m < 0,$$

the bank has an incentive to reduce m. Similarly, for any $m \in [0, p)$ for which

$$R - \frac{R_0}{1 - p + m} - \gamma m > 0,$$

the bank has an incentive to increase m. Hence, there are three possible values of monitoring in the optimal contract: $m = m^*$, $m = m^-$, and $m = 0$ (when $m^- > 0$).

To prove that the bank prefers $m = m^*$, notice that our assumptions on the monitoring cost function together with the definition of m^* imply

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

for $m < m^*$. Hence, we have

$$(1 - p + m^*)R - R_0 - c(m^*) > (1 - p + m)R - R_0 - c(m),$$

for either $m = m^-$ (when $m^* > m^-$) or $m = 0$ (when $m^- > 0$), which proves the result. □

Proof of Proposition 2 The effect of changes in the safe rate R_0 on equilibrium lending L^* is obtained by differentiating the first-order condition (13), which gives

$$\frac{\partial L^*}{\partial R_0} = -\frac{\frac{\partial}{\partial R_0}[L^*\pi'(L^*) + n\pi(L^*)]}{L^*\pi''(L^*) + (n+1)\pi'(L^*)}.$$

Since we have assumed that $L\pi''(L) + (n+1)\pi'(L) < 0$, we need to show that

$$\frac{\partial}{\partial R_0}[L^*\pi'(L^*) + n\pi(L^*)] = L^*\frac{\partial \pi'(L^*)}{\partial R_0} + n\frac{\partial \pi(L^*)}{\partial R_0} < 0.$$

Starting with the second term, using the expressions for $\pi(L)$ and $m(L)$ in (14) and (10) we have

$$\frac{\partial \pi(L^*)}{\partial R_0} = \gamma[1-p+m(L)]\frac{\partial m(L^*)}{\partial R_0} = -\frac{\gamma[1-p+m(L)]}{\sqrt{[R(L)+\gamma(1-p)]^2 - 4\gamma R_0}} < 0.$$

With regard to the first term, we need to sign

$$\frac{\partial \pi'(L^*)}{\partial R_0} = \gamma[1-p+m(L)]\frac{\partial m'(L^*)}{\partial R_0} + \gamma m'(L)\frac{\partial m(L^*)}{\partial R_0}.$$

For this, we first note that using (10) we can write

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

Hence, using (2) and (10) we have

$$\begin{aligned}
&\gamma[1-p+m(L)]\frac{\partial m'(L^*)}{\partial R_0} \\
&= \gamma[1-p+m(L)]\frac{\partial}{\partial R_0}\left[-\frac{b}{2\gamma}\left(1+\frac{R(L)+\gamma(1-p)}{\sqrt{[R(L)+\gamma(1-p)]^2-4\gamma R_0}}\right)\right] \\
&= -\frac{b}{2}[1-p+m(L)]\frac{2\gamma[R(L)+\gamma(1-p)]}{[[R(L)+\gamma(1-p)]^2-4\gamma R_0]^{3/2}} \\
&= -\frac{b}{2}\left[\frac{[R(L)+\gamma(1-p)]^2}{[[R(L)+\gamma(1-p)]^2-4\gamma R_0]^{3/2}} + \frac{R(L)+\gamma(1-p)}{[R(L)+\gamma(1-p)]^2-4\gamma R_0}\right] < 0.
\end{aligned}$$

Next, we have

$$\begin{aligned}
&\gamma m'(L)\frac{\partial m(L^*)}{\partial R_0} \\
&= \frac{b}{2}\left[1+\frac{R(L)+\gamma(1-p)}{\sqrt{[R(L)+\gamma(1-p)]^2-4\gamma R_0}}\right]\frac{1}{\sqrt{[R(L)+\gamma(1-p)]^2-4\gamma R_0}} \\
&= \frac{b}{2}\left[\frac{1}{\sqrt{[R(L)+\gamma(1-p)]^2-4\gamma R_0}} + \frac{R(L)+\gamma(1-p)}{[R(L)+\gamma(1-p)]^2-4\gamma R_0}\right] > 0.
\end{aligned}$$

Putting together the two previous expressions we conclude

$$\begin{aligned}\frac{\partial \pi'(L^*)}{\partial R_0} &= -\frac{b}{2}\left[\frac{[R(L)+\gamma(1-p)]^2}{[[R(L)+\gamma(1-p)]^2-4\gamma R_0]^{3/2}} - \frac{1}{\sqrt{[R(L)+\gamma(1-p)]^2-4\gamma R_0}}\right] \\ &= -\frac{2\gamma R_0 b}{[[R(L)+\gamma(1-p)]^2-4\gamma R_0]^{3/2}} < 0,\end{aligned}$$

as required. □

Proof of Proposition 3 Starting with the monopoly case, we first note that (14) implies that $\pi(L)$ is monotonic in $m(L)$. Now let R_0 and R_1 denote two safe rates with $R_0 < R_1$, and let π_0^* and π_1^* denote the corresponding equilibrium profits per unit of loans for the monopoly bank. Assuming that the monopolist's profits per unit of loans are decreasing in its funding costs, that is $\pi_0^* > \pi_1^*$,[28] we conclude that $m_0^* > m_1^*$. In other words, higher safe rates reduce the monitoring intensity of the monopoly bank and consequently increase the probability of default of its loans.

The proof of perfect competition case is essentially identical to the one in Martinez-Miera and Repullo (2017). As shown in (16), increasing the number of banks n increases equilibrium lending L^* and reduces the equilibrium loan rate R^*. There will be a point in which the constraint $R(L) \geq \underline{R}$ becomes binding,[29] in which case by Proposition 1 the equilibrium monitoring intensity m^* equals the value $\underline{m}$ defined in (9). When $\underline{m}$ is not at the corner with zero monitoring, solving the minimum condition

$$\frac{d}{dm}\left(\gamma m + \frac{R_0}{1-p+m}\right) = 0, \tag{58}$$

gives

$$\underline{m} = \sqrt{\frac{R_0}{\gamma}} - (1-p) > 0, \tag{59}$$

so increases in the safe rate R_0 increase $\underline{m}$. Hence, higher rates increase the monitoring intensity of the competitive banks and consequently reduce the probability of default of their loans. □

[28] This condition is also satisfied in all of our numerical results.

[29] In fact, the constraint will be binding for a finite number of banks $\underline{n}$, where $\underline{n}$ satisfies the first-order condition $L^*\pi'(L^*) + \underline{n}\pi(L^*) = 0$ for $L^* = \underline{L}$ such that $R(\underline{L}) = \underline{R}$. Thus, the equilibrium loan rates and risk-taking decisions for all $n > \underline{n}$ will be the same as those for $n = \underline{n}$.

References

Adrian, T., and N. Liang (2018), "Monetary Policy, Financial Conditions, and Financial Stability," *International Journal of Central Banking*, 14, 73-131.

Adrian, T., and H. S. Shin (2010), "Financial Intermediaries and Monetary Ecoomics," in B. Friedman and M. Woodford (eds.), *Handbook of Monetary Econmics*, New York: Elsevier, 601-650.

Allen, F., and D. Gale (2000), *Comparing Financial Systems*, Cambridge, MA: MIT Press.

Beck, T, Demirgüç-Kunt, A., and R. Levine (2006), "Bank Concentration, Competition, and Crises: First Results," *Journal of Banking and Finance*, 30, 1581-1603.

Bernanke, B., and A. Blinder (1988), "Credit, Money, and Aggregate Demand," *American Economic Review P&P*, 78, 435-439.

Bernanke, B., and M. Gertler (1989), "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* 79, 14-31.

Boissay, F., Collard, F., and F. Smets (2016), "Booms and Banking Crises," *Journal of Political Economy*, 124, 489-538.

Borio, C., and H. Zhu (2012), "Capital Regulation, Risk-taking and Monetary Policy: A Missing Link in the Transmission Mechanism?," *Journal of Financial Stability*, 8, 236-251.

Boyd, J., and G. De Nicolo (2005), "The Theory of Bank Risk Taking and Competiton Revisited," *Journal of Finance*, 60, 1329-1343.

Brunermeier, M., and Y. Koby (2019), "The Reversal Interest Rate," mimeo.

Chodorow-Reich, G. (2014), "Effects of Unconventional Monetary Policy on Financial Institutions," *Brookings Papers on Economic Activity*, 155-204.

Coimbra, N., and H. Rey (2017), "Financial Cycles with Heterogeneous Intermediaries," NBER Working Paper No. 23245.

Corbae, D., and R. Levine (2020), "Competition, Stability, and Efficiency in Financial Markets," mimeo.

Dell'Ariccia, G., L. Laeven, and R. Marquez (2014), "Real Interest Rates, Leverage, and Bank Risk-Taking," *Journal of Economic Theory*, 149, 65-99.

Dell'Ariccia, G., L. Laeven, and G. Suarez (2017), "Bank Leverage and Monetary Policy's Risk-Taking Channel: Evidence from the United States," *Journal of Finance*, 72, 613-654.

Drechsler, I., A. Savov, and P. Schnabl (2017), "The Deposits Channel of Monetary Policy," *Quarterly Journal of Economics*, 132, 1819-1876.

Heider, F., F. Saidi, and G. Schepens (2019), "Life below Zero: Bank Lending under Negative Policy Rates," *Review of Financial Studies*,32, 3728–3761,

Hellmann, T. , K. Murdock, and J. Stiglitz (2000), "Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?," *American Economic Review*, 90, 147-165.

Holmström, B., and J. Tirole (1997), "Financial Intermediation, Loanable Funds, and the Real Sector," *Quarterly Journal of Economics*, 112, 663-691.

Ioannidou, V., S. Ongena, and J.-L. Peydro (2015), "Monetary Policy, Risk-taking, and Pricing: Evidence from a Quasi-natural Experiment," *Review of Finance*, 19, 95-144.

Jiang, L., Levine, R., and C. Lin (2018), "Does Competition Affect Bank Risk?," mimeo

Jimenez, G., S. Ongena, J.-L. Peydro, and J. Saurina (2014), "Hazardous Times for Monetary Policy: What Do Twenty-Three Million Bank Loans Say About the Effects of Monetary Policy on Credit Risk-Taking?," *Econometrica*, 82, 463–505.

Kashyap, A., and J. Stein (1995), "The Impact of Monetary Policy on Bank Balance Sheets," *Carnegie Rochester Conference Series on Public Policy*, 42, 151-195.

Keeley, M. (1990), "Deposit Insurance, Risk, and Market Power in Banking," *American Economic Review*, 80, 1183-1200.

Kiyotaki, N., and J. Moore. (1997), "Credit Cycles," *Journal of Political Economy,* 105, 211-248.

Maddaloni, A., and J-L Peydró (2011), "Bank Risk-taking, Securitization, Supervision, and Low Interest Rates: Evidence from the Euro-area and the U.S. Lending Standards," *Review of Financial Studies,* 24, 2121-2165.

Martinez-Miera, D., and R. Repullo (2010), "Does Competition Reduce the Risk of Bank Failure?," *Review of Financial Studies*, 23, 3638-3664.

Martinez-Miera, D., and R. Repullo (2017), "Search for Yield," *Econometrica*, 85, 351-378.

Repullo, R. (2004), "Capital Requirements, Market Power, and Risk-Taking in Banking," *Journal of Financial Intermediation*, 13, 156-182.

Stiglitz, J., and A. Weiss (1981), "Credit Rationing in Markets with Imperfect Information," *American Economic Review*, 71, 393-410.