The Risk-Taking Channel of Banks' Debt and Monetary Policy*

Stephan Imhof
Swiss National Bank

Cyril Monnet
BIS
University of Bern
Study Center Gerzensee

Shengxing Zhang
London School of Economics

December 2019

Abstract

We study the implications of liquidity regulations and monetary policy on deposit-making and risk-taking. Banks give risky loans by creating deposits that firms use to pay suppliers. Firms and banks can take more or less risk. In equilibrium, higher liquidity requirements always lower risk at the cost of lowering investment. Nevertheless, a positive liquidity requirement is always optimal. Monetary conditions affect the optimal size of liquidity requirements, and the optimal size is countercyclical. It is optimal to impose a 100% liquidity requirement when inflation is sufficiently low and a positive but less than 100% requirement when inflation is high.

*For comments and suggestions, we thank seminar and conference participants at the BIS, SMU, NUS, University of Bath, Bundesbank, 2017 Chilean S&M workshop, European Central Bank, 2018 Konstanz Conference on Monetary Theory and Policy, 2017 Money and Liquidity conference at the Bank of Canada, 2017 Swiss National Bank research conference, the Reserve Bank of New Zealand, 2018 Shanghai International Conference, and the University of Zurich, as well as Juerg Blum, Regis Breton, Michael Kumhof (discussant), Alessandro Gioffre (discussant), Steven Ongena, Guillaume Plantin, Jean-Charles Rochet, Lukas Voellmy, Stephen Williamson (discussant), Randall Wright, Cathy Zhang, and especially Jonathan Chiu and Todd Keister. The views, opinions, findings, and conclusion or recommendations expressed in this paper are strictly those of the authors. They do not necessarily reflect the views of the Bank for International Settlements (BIS) or the Swiss National Bank (SNB). The BIS and the SNB take no responsibility for any errors or omissions in, or for the correctness of, the information contained in this paper.

1 Introduction

Typically, financial crises build up from risk-taking in the financial sector and culminate in liquidity crises. Lax monetary policy is one of the factors contributing to the buildup of financial risk. When interest rates are low, banks lend more, thus increasing their liquidity risk, and they lend to riskier borrowers.[1] Following the recent crisis, the Basel Committee on Banking Supervision was quick to recognize that some banks mismanaged their liquidity risk, and it adopted new regulations with two objectives in mind. The first objective is to promote short-term resilience of a bank's liquidity risk profile by ensuring that a bank always has enough liquid assets to sustain operations during a stress scenario lasting one month. In Basel III, this objective is achieved with the liquidity coverage ratio. The second objective is to promote resilience over a longer time horizon by incentivizing banks to fund their activities with more stable sources of funding. In Basel III, this second objective is achieved with the net stable funding ratio.

While these liquidity regulations make sure there is sufficient liquidity in crisis periods and may reduce risk-taking incentives, they also limit the creation of liquidity by banks. Much like maturity transformation, liquidity creation (or transformation) is a fundamental aspect of banking. Generations of students have been taught that banks fund illiquid assets using liquid, and even money-like, liabilities and that it is socially optimal that they do so although it may induce financial fragility (e.g., Diamond and Rajan, 2001).

Hence, at the heart of liquidity requirements is the issue of limiting money creation by banks. Banks that cannot create money because of 100% liquidity requirements, e.g., narrow banks, would always be resilient to any liquidity stress scenario. This resilience brings us to a fundamental question in monetary economics and banking: Is an economy that allows banks to freely create (inside) money, such as tradable deposits, more or less stable, more or less productive, and more or less efficient than the same economy constrained by higher liquidity requirements? The famous Chicago plan called for 100% reserve requirements and narrow

[1] There is growing empirical evidence that banks' loan portfolios tend to be riskier when interest rates are low. For example, see Jimenez, et. al (2014) or Dell'Ariccia, et. al. (2017). Also Drehmann et al. (2018) investigate the link between the cost of servicing debt and financial stability.

banking at a time when the Great Depression gave ammunition to those arguing for limiting the creation of deposits. Under this plan, banks would hold \$1 in reserve for each \$1 of deposits on their balance sheet. The Great Recession revived the academic debate (see for instance Chari and Phelan, 2014 or Cochrane, 2014), and policy makers imposed new liquidity regulations on banks, although small compared with 100% reserves.[2] However, by imposing stricter liquidity requirements, regulations limit the modus operandi of banks, increase the costs of funds, and in the end penalize the real economy. Since monetary policy also affects the cost of funds, this paper studies the tension between liquidity creation and risk-taking of the banking sector under different monetary policy conditions. We analyze the effects of imposing liquidity requirements – including reserve requirements on deposits – and we solve for the optimal level of liquidity requirements as a function of monetary policy.

The theoretical and empirical literature is large. Below, we review only its most recent developments, but first, let us mention two recurrent themes. A system relying on the free creation of deposits is arguably more efficient because banks have more flexibility to respond to loan demand (e.g., Williamson, 1999). However, this system is inherently unstable because it may, for instance, allow multiple equilibria, which opens the door to exotic dynamics, cycles, and crashes (e.g., Sanches, 2015). One puzzling aspect of the literature is that risk is missing from the analysis: banks and their borrowers do not engage in risk-taking activities. Rather, as in the seminal paper by Diamond and Dybvig (1983), it is the source of funding that is fragile. Here, instead, we analyze the effect of the risk-taking decision of borrowers on financial stability.

More precisely, we introduce moral hazard in an otherwise standard monetary model with banks. By monitoring its borrower, a bank effectively chooses the borrowers' success rate. But it is costly to monitor. We associate lower monitoring intensity with more risk taking. While it is socially optimal that banks take no risk at all, moral hazard and limited liability implies that banks will not guarantee the success of their loans. As is standard, the more deposit they issue, the more indebted they are, the less they monitor their loans, the more

[2] In countries with less developed financial markets, reserve requirement is an even more frequently used monetary policy instrument (see for instance Chang et al, 2018 on reserve requirement and stabilization policy in China).

risk they take. When monetary policy is lax, borrowers face a relatively lower loan rate and they tend to borrow more, increasing deposit issuance and so lowering the bank's incentives to monitoring. In this context, we study if and how liquidity requirements can help achieve the (constrained) optimal level of debt and monitoring intensity. A bank's reserves are remunerated, but maybe at a rate lower than the prevailing market rate. We say that monetary conditions are tighter when the spread between the interest rate paid on reserves and market rates is larger.

We show that liquidity requirements combined with tighter monetary policy exploit a trade-off between risk-taking and the level of investment. As banks can fail, requiring liquidity in the form of central bank reserves or money can be useful to control the riskiness of inside money (deposits and loans). Monetary policy will determine the cost of holding reserves for banks, and therefore the loan rate. Increasing the reserve requirements or reducing the rate of return on central bank reserves makes private loans more expensive. While the loan rate is higher, firms take smaller loans, thus reducing their leverage. As a result, banks issue less deposits and monitor more intensively. Similarly, we show that when the funding cost is low, firms take on higher leverage and banks take more risk because they issue more deposits. Since monetary policy balances the tradeoff between asset safeness and the leverage of banks, the Friedman rule, or the zero-liquidity requirement, is not necessarily optimal, as it would induce too high leverage and too much risk-taking. In spite of being the safest system, fully backed deposits may not be optimal as it can reduce leverage too much.

Our paper sheds light on the effects of the current policy trend to increase liquidity requirements for banks. Bech and Keister (2017) have shown the effects of such an increase on the functioning of the interbank market. We look at the macroeconomic effects of liquidity requirements. Liquidity policies such as the Basel III Liquidity Coverage Ratio require banks to hold enough liquidity to be able to meet their liquidity needs for thirty days in a stress scenario. While we do not model such disruption, for instance, due to a bank run, our results support the view that liquidity requirements will make the overall financial system safer. The different components of the liquidity requirement however cannot be set independently, and most importantly they cannot be set independently of prevailing monetary conditions. High liquidity requirements can be optimal when interest rates are low. However, they should be set lower when interest rates are higher: liquidity requirements force banks to hold low (real) yield assets, which are costly when policy rates are high. In that case, the requirements become costly, and banks would reduce their loans too much. Finally, we compare and contrast the effects of liquidity requirements and leverage ratio requirements.

The rest of the paper is organized as follows. We present the model in Section 2 and we derive the equilibrium in Section 3. Section 4 contains several extensions, such as the effect of bail-out policies and deposit insurance, and the consequence of capital requirements. We place our results in the recent literature in Section 5. The last section summarizes the findings and concludes.

2 Backbone toy model

Before delving further in the model we present a simple partial equilibrium set-up that captures the main risk taking channel.[3] Suppose a bank operates a technology that can transform k units of capital into $F(k)$ units of the consumption good with probability q and gives nothing with probability $1-q$. We refer to q as the quality of the bank. Of course q is also related to the risk that the project fails to return any output. So q is inversely related to risk taking.

In this partial equilibrium set-up, we posit that the bank funds its investment level k by incurring debt $D(k,i)$ when it faces interest rate i (which is one to one related to the central bank policy rate). A large part of the paper consists in endogenizing this function that we now take as given. For the moment, it suffices to say that this function is increasing in k and i and has positive cross derivatives. An example is simply $D(k,i) = \tau(1+i)k$ for some $\tau > 0$. Therefore, ceteris paribus, a higher policy rate increases the bank's debt. The bank can monitor the firm to increase q by incurring a utility cost $q^2F(k)/2$. As is natural, we

[3] This model bears some resemblance with models with a moral hazard problem at their heart. For example Cordella and Levy Yeyati (2003) who study the moral hazard effect of bail-outs in a dynamic setting, Allen, Carletti, and Marquez (2009) who analyze capital investment as a commitment device for banks to monitor their loans.

assume this cost is increasing and convex in q and increasing in the scale of the firm.[4]

Given its technology, the bank chooses its monitoring effort q and its investment k to maximize its expected payoff given limited liability. That is, the bank solves

$$\max_{q,k} q\left[F(k) - D(k,i)\right] - \frac{1}{2}q^2 F(k)$$

The first order conditions with respect to q and k are respectively,

$$q = 1 - \frac{D(k,i)}{F(k)}, \tag{1}$$

$$q\left(1 - \frac{q}{2}\right) F'(k) = \frac{\partial D(k,i)}{\partial k}. \tag{2}$$

Several points are worth making. First, (1) implies that the bank's monitoring choice is decreasing in its debt relative to potential output $D(k,i)/F(k)$. So, everything else constant a higher level of debt will decrease the bank's monitoring effort and increase risk taking. Second, as the central bank increases its rate i, the bank's debt increases ceteris paribus, so its monitoring effort tends to drop. However, the marginal cost of investment $\partial D(k,i)/\partial k$ also increases, so (2) implies investment k falls. Therefore, and this is the final point, $D(k,i)/F(k)$ may rise or fall following an increase in the policy rate, depending on the relative sensitivity of debt and potential output to i. As a consequence, the overall effect of the policy rate on monitoring depends crucially on the form of $D(k,i)$. It is therefore necessary to endogenize the function $D(k,i)$ in order to learn which of the investment or policy rate effects dominates.

In the sequel, we endogenize $D(k,i)$ by having the bank issuing short term deposits to a firm to pay the firm's capital suppliers. In this case, we find that the investment effect always dominates so that q will always rise with i.

[4] The model is simple enough that one can easily track the effect of this assumption throughout.

3 The Model

The model is a version of Rocheteau, Wright, and Zhang (2018). Time $t = 1, 2, ...$ is discrete and continues forever. There are two goods, a capital good, which fully depreciates at the end of each period, and a perishable consumption good. There are three types of risk-neutral agents, each with measure one: two period-lived firms and bankers, and long-lived suppliers. All agents use the same discount factor $\beta \in (0, 1)$. Each period is divided in two sub-periods. New firms and new bankers are born at each date t at the start of the second subperiod and live through to the second sub-period of date $t+1$. In the first subperiod, a centralized market for capital goods (KM) opens. In a second subperiod once the KM closes, the centralized market for consumption goods (CM) and the decentralized loan market (LM) open.

Suppliers produce capital using a technology that transforms hours worked one-for-one into capital in the KM.[5] Their utility function in each period is $u(c, h) = c - h$ where $c \geq 0$ is consumption and $h \geq 0$ is hours worked.

New firms have no resources but they are endowed with a production technology. For any k units of capital invested in KM, their technology returns $F(k)$ units of consumption in the CM with probability q and nothing otherwise. The output realization is idiosyncratic across firms. $F(k)$ is a neoclassical production function homogeneous of degree $\sigma < 1$. Firms like to consume the CM good from which they derive utility $u(c) = c$.

New bankers (and only new bankers) can transform hours worked one-for-one into consumption in the CM.[6] All bankers can produce tradable deposits that cannot be counterfeited. Deposits are similar to bearer notes: a bank issuing one unit of deposit promises to its bearer one unit of the consumption good in the next CM. Bankers can commit to redeem their banknotes if they have the resources to do so. Bankers have a capacity constraint and they can only lend to one firm but they benefit from limited liability.[7] Bankers have a monitoring

[5] Conveniently, this assumption implies that we can also interpret capital as labor.

[6] In section 5.4, we show how new bankers can raise equity by selling shares of the bank instead of producing and selling the consumption good.

[7] It is not necessary that banks are short lived. It would suffice to assume that they can have difficulty raising equity, so that default is a possible event. We could introduce some scope for risk diversification in the following way: suppose there is a continuum of aggregate states, $s \sim U[0, 1]$. The bank has to choose from a continuum of projects of type q. With k investment, a risky project of type q yields $F(k)$ whenever

technology. They can choose the probability of success of a firm q by bearing a cost of effort $q^2F(k)/2$ which is proportional to the firm's size as captured by its potential output $F(k)$. Old bankers like to consume the CM good and the preferences of a new banker is represented by the utility function $U(c, h) = \beta c - h$ where $c \geq 0$ is consumption in the CM market when they are old and $h \geq 0$ is hours worked when they are born.

To make things interesting, we assume suppliers do not trust firms to repay any debt. As a result firms need to find means to pay suppliers. There are two possible means of payments: banks deposit is one, and new firms can borrow bank deposits from new bankers in the LM. There is also money.

Finally, we denote the stock of money at date t as M_t. A central bank controls the stock of money, which evolves according to $M_{t+1} = (1 + \pi)M_t$, by making lump-sum transfers in the CM to young bankers.[8] The price of money in terms of consumption at date t is ϕ_t. In stationary equilibrium $\phi_{t+1}M_{t+1} = \phi_t M_t$, so $\phi_t = (1 + \pi)\phi_{t+1}$. So the rate of inflation is $1 + \pi$. The nominal rate of interest is $i = (1 + \pi)/\beta - 1$. It is the rate on a nominal bond that cannot be used as a means of payment.

The central bank can also impose reserve requirements on deposits. This requires banks to keep a fraction $\tilde{\tau} \in [0, 1]$ of the deposits they create in money. The central bank pays an interest rate $r \geq 0$ on required and excess reserves (IOR for short).[9] Formally, banks lending ℓ deposits must hold enough reserves R to satisfy the constraint[10]

$$\tilde{\tau}\ell \leq (1 + r)R. \tag{3}$$

Below and for simplicity we use the normalization $\tau \equiv \tilde{\tau}/(1+r)$. Reserves differ from capital

the aggregate state $s \leq q$. But the cost of monitoring to reach a success probability q is $q^2k/2$. In this environment, risks across projects cannot be diversified because they are perfectly correlated with aggregate state. Our model is isomorphic to this one.

[8]The central bank could also make transfers to old banks as long as these transfers are not contingent on the old bank's success.

[9]For brevity we do not present the case where $r < 0$, although it is also feasible. In a previous version of the model banks could also borrow reserves on an interbank market.

[10]One could make the case that the reserve constraint should not account for the interest rate on reserves, in which case we should write $\tilde{\tau}d \leq M$. Under this scenario, banks with a binding reserve requirement may still be able to pay their liabilities in case the firm defaults whenever r is large enough. This outcome complicates the analysis without adding substantive value, and so we opted for (3).

requirements insofar as reserves are not invested and a bankrupt bank can use required reserves to (partially) pay holders of deposits. In an extension, we analyze how capital requirements affect the results.

Timing and markets The timing is as follows. In each LM, new bankers are randomly matched pairwise with a new firm. Once matched, a new banker and a new firm bargain over the terms of a loan to be reimbursed in the next CM, in a way we describe below. Then new bankers have access to the CM where they can produce to acquire reserves (**'start'** in Figure 1) and they effectively issue deposits to the firm ('**loan market**' in Figure 1).[11] In the KM, firms who managed to obtain a bank loan can purchase capital from suppliers ('**capital market**' in Figure 1). Then, they invest capital and the banker monitors the firm to achieve a probability of success q. At the beginning of the following CM, the now old firms sell their production and reimburse their loans if they can.[12] Old bankers redeem their banknotes or default, suppliers readjust their portfolio, and consumption takes place ('**loan repay & redemption of deposits**' in Figure 1). We now describe in detail the actions of agents in each market and in chronological order.

3.1 Loan market (LM)

When a new bank is matched with a new firm, they bargain over the term of the loan. A bank loan consists of a quantity of deposits that the firm can use to buy capital in the KM. Let p denote the price of capital in terms of deposits in the KM. Firms need pk units of deposits to buy k units of capital.[13] The banker charges interest rate i_b on this loan so that the firm's debt is $d = (1 + i_b)pk$. Also, the banker may hold nominal reserves R. We assume that the banker's monitoring effort – or q – is contractible.[14] So there is no moral hazard

[11] Stephen Williamson refers to this form of equity as "sweat equity."

[12] While it would be natural (and feasible) to assume that firms sell their output for deposits/cash and then repay their loans, it is equivalent and simpler to assume that firms repay their (now old) banker by transferring some of their output. See Rocheteau, Wright, and Zhang (2017) for details.

[13] $p > 1$ is possible here because we do not assume deposit insurance and banks may default on their deposits. We consider an extension with deposit insurance in Section 5.3.

[14] We worked out a version of this model where monitoring is not contractible. The results are qualitatively identical.

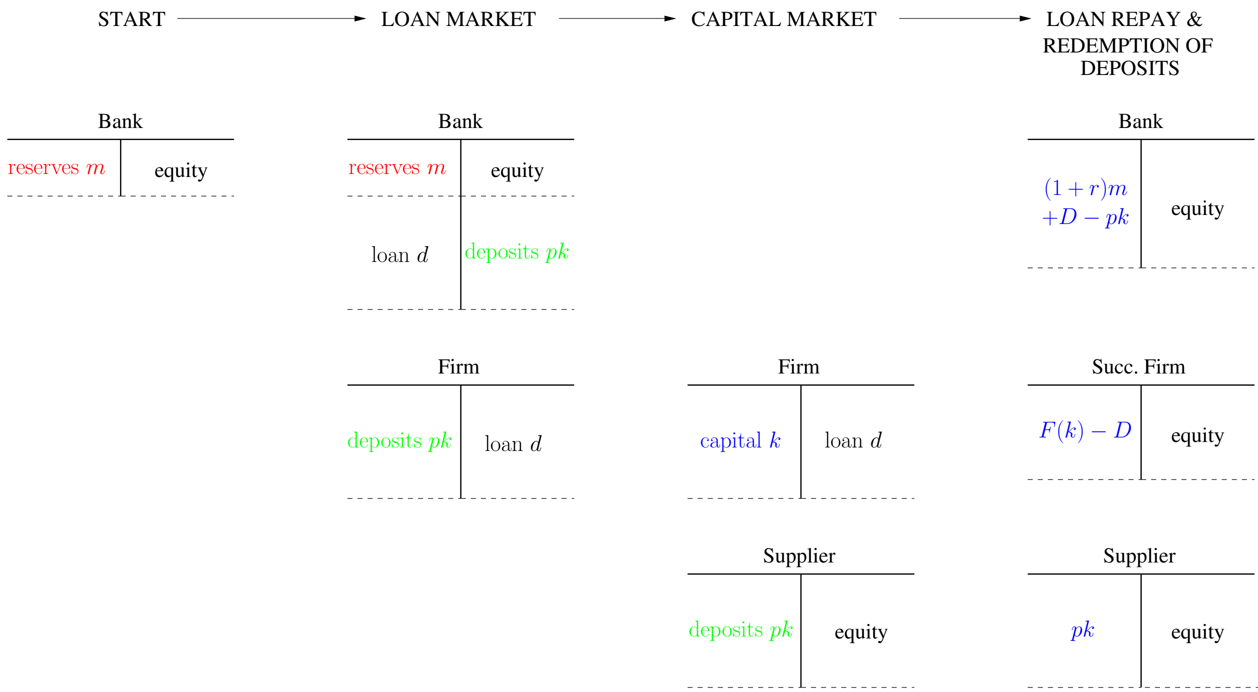


Figure 1: Balance sheets, circulation of deposits and consumption goods. D is the firm's debt including interests.

between the firm and the banker in this version of our model.

A loan contract is the list (pk, R, q, d) that maximizes the total surplus of the firm-banker pair, and the interest payment d distributes the surplus according to some sharing rule (e.g. Kalai). Let T_{t-1} be the lump-sum transfer by the central bank at date $t-1$. Then we can represent the bargaining taking place at date $t-1$ to implement the contract $(p_t k_t, R_t, q_t, d_t)$ at date t, by the following problem

$$\max_{k_t, q_t, y_{t-1}, M_t} \quad -y_{t-1} + \beta \left\{ q_t [F(k_t) + (1+r_t)\phi_t R_t - p_t k_t] - \frac{1}{2} q_t^2 F(k_t) \right\},$$

$$s.t.$$

$$\tau pk \leq \phi_t R_t, \tag{4}$$

$$\phi_{t-1} R_t \leq y_{t-1} + \phi_{t-1} T_{t-1}. \tag{5}$$

where y_{t-1} is the young bank's hours worked in the CM at date $t-1$ in order to accumulate reserves R_t for the next date, and (4) is the reserve requirement condition (3) in real terms. The bargaining takes into account the cost of accumulating reserves to satisfy reserve requirement, and the discounted expected utility of funding the firm through deposits. The firm succeeds with probability q_t in which case the return on the investment is $F(k_t)$ plus the IOR but minus the payment to depositors $p_t k_t$. The pair gets nothing when the project fails because reserves are used to pay depositors. Of course, the bargaining problem also takes into account the (discounted) monitoring cost. We assume that the rate on the illiquid nominal bond is strictly greater than the interest rate on reserves, $i_t > r_t$ for all t. In this case it is standard to show that (5) binds. Then we can simplify the problem by using $\phi_t = (1+\pi)\phi_{t+1}$, $1+i = (1+\pi)/\beta$, as well as $\phi_t R_t = m_t$,

$$\max_{k,q} -(1+i)m + q[F(k) + (1+r)m - pk] - \frac{1}{2}q^2 F(k),$$
$$\text{subject to } \tau pk \leq m.$$

where we dropped the time index as we will concentrate on the steady state equilibrium. We refer to the spread $i-r$ as the cost of holding reserves. Since we rule out a possible signaling game below, it is straightforward to show that the reserve constraint binds whenever $i > r$,

$$m = \tau pk \tag{6}$$

So bankers will default on depositors whenever their loan does not pay off. The first order conditions for k and q are, respectively,[15]

$$k \quad : \quad qF'(k) = qp + [(1+i) - q(1+r)]\,\tau p + \frac{1}{2}q^2 F'(k) \tag{7}$$
$$q \quad : \quad q = 1 - \frac{(1-(1+r)\tau)pk}{F(k)} \tag{8}$$

The firm's marginal benefit of investment is on the LHS of (7). The firm's marginal funding costs consists of the expected cost of redeeming deposits qp, as well as the expected opportunity cost of required reserves $[q(1+r) - (1+i)]\,\tau p$ – where the pair obtains the IOR only when the firms is successful. Finally, the last term in (7) captures that additional investment

[15]It is straightforward to verify that the second order conditions are satisfied whenever q is large enough. To be precise, for $F(k) = k^\alpha$, there is a function $q(\alpha) < 1$ such that for all $q \geq q(\alpha)$ the second order conditions are verified.

makes monitoring more difficult. Turning to the monitoring choice q, (8) clearly shows that q is decreasing with the banker's level of indebtedness as measured by $(1-(1+r)\tau)pk$ – the banker owes pk to depositors, but already holds $(1+r)\tau pk$ in reserves – and increasing with the interest rate on reserves. Notice that the ratio $(1-(1+r)\tau)pk/F(k)$ is related to the leverage of the bank/firm pair. So the banker monitors the firm less whenever the leverage is higher. Finally, when the banker's surplus equals a fraction φ of the total surplus, the interest payment d is

$$d \;=\; \varphi F(k) - \frac{(1-\varphi)}{q}\left[-(1+i)\tau pk + q[(1+r)\tau pk - pk] - \frac{1}{2}q^2 F(k)\right], \tag{9}$$

Since q is contractible, the way total surplus is shared between the firm and the banker will play no fundamental role in what follows.

Given i, r, p, ϕ, and φ, and using $m = \phi R$, the equilibrium loan contract is a list (k, m, q, d) that satisfies (6)-(9). Once firms and bankers agree on a loan, bankers issues the agreed amount of deposits to firms, and bankers acquire required reserves in the CM.

3.2 Capital market (KM)

Suppliers of capital are aware of the banker's monitoring problem, and they expect each firm (and their bank) to fail with probability $1-Q$. When the bank fails, suppliers expect to get the required reserves held by the bank. The capital market being Walrasian, suppliers can perfectly diversify the risk by selling capital to every productive firm.[16] Also, since they are selling k units of capital through the auctioneer, they do not observe how much capital a particular firm is buying, so they cannot make their expectation about their failure rate conditional on the amount of capital the firm is buying. However, suppliers correctly anticipate that whenever they sell an additional unit of capital to a firm against deposits, the bank has to set aside reserves τp that suppliers get if the bank fails. Hence, the problem

[16] The ability to diversify plays no role in this model where suppliers are risk neutral.

of a supplier entering the capital market with m^s real units of money is

$$V^s(m^s) = \max_{k\geq 0} m^s - k + (1-Q)(1+r)\tau pk + Qpk, \tag{10}$$

where k is the capital sold for deposits at (real) price p. The first order condition gives

$$p = \frac{1}{Q + (1-Q)(1+r)\tau}. \tag{11}$$

Clearly, deposits carry a risk premium unless bankers hold 100% reserves, that is $\tau(1+r) = 1$.[17]

3.3 Consumption market (CM)

In the CM, successful firms settle their debt and bankers redeem their deposits. They consume whatever is left. Suppliers consume their real net worth. It is standard to show that when $i > 0$, suppliers choose to hold no real balances, as their reserves are not remunerated and they have no liquidity needs, so that $m^s = 0$. New bankers will choose real balances m according to the negotiated loan contract so that $m = \tau pk$.

3.4 Moral hazard

There is one source of moral hazard in our model, related to the terms of trade when a firm trades its deposits for capital. The real value p assigned to the deposit depends on the average default probability of a bank rather than the default probability of that specific firm's bank. In other words, suppliers form their own beliefs about a bank's default. If the banker were to monitor the firm more intensively, the increased probability of success implies that the bank deposit it holds is less likely to default. If suppliers recognized that fact, capital would be cheaper when bought with that deposit and the price p would decrease. If it did, it is straightforward to show that the efficient levels of effort and investment are

[17] If we allowed for $\tilde{\tau} > 1$, we would need to require $p(Q; \tau, r) \geq 1$ as banks would always be able to make depositors whole. This requirement complicates the analysis without adding much value.

achieved in equilibrium and there is no need for reserve requirements. However, a bank takes p as given when monitoring the firm. As a result, the equilibrium level of monitoring will be inefficiently low, as will be the level of investment, output and welfare.

3.5 Equilibrium

We can now define a symmetric stationary equilibrium.

Definition. Given the policy variables i, r, and τ a symmetric stationary equilibrium is a list consisting of a loan contract (k, m, q, d), project quality Q, prices p, so that given p and the policy variables, the loan contract maximizes the surplus of the firms and bankers, and suppliers behave optimally, i.e. (6), (7), (8), and (11) all hold, the market for balances clears $m = \phi M$, and aggregate quality is consistent with the bankers' monitoring choice $Q = q$.

4 Equilibrium characterization

In this section, we characterize the equilibrium when $i > r$ so that the regulator remunerates reserves, but not enough to compensate banks for the cost of holding them. Replacing the equilibrium value for the interbank rate, the price of deposits, as well as m, and arranging we obtain how the (optimal) contract responds to changes in policy variables, i and τ but also in the market perception of risk Q.

$$q\left(1-\frac{1}{2}q\right)F'(k) = \frac{1}{Q+(1-Q)(1+r)\tau}\left[q(1-(1+r)\tau)+(1+i)\tau\right] \tag{12}$$

$$(1-q)\frac{F(k)}{k} = \frac{1-(1+r)\tau}{Q+(1-Q)(1+r)\tau} \tag{13}$$

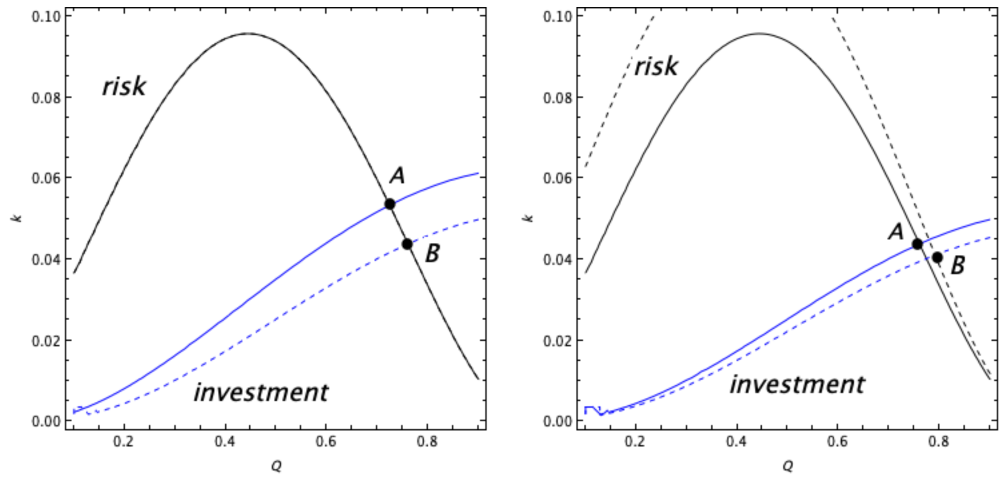
Equations (12) says that, given q, investment will increase with market perception Q, but will decrease with inflation and reserve requirement τ, while given k, (13) says that the banker's monitoring choice q is increasing with Q and τ. Thus, we have the following partial equilibrium result:

Lemma 1. *The firm's investment level k and the banker's monitoring choice q are both increasing with market perception Q.*

The intuition is simple: an improvement in the market perception of quality reduces the risk premium on deposits. This makes investing cheaper, and given q, investment increases. Similarly, given k, leverage declines when the risk premium on deposits decline, so the banker has more incentive to monitor the firm. However, the reader should note the feedback loop playing through leverage: As k increases, leverage can increase, in which case the banker would choose to monitor the firm less rather than more. This outcome is a key mechanism of our paper: by reducing the risk premium, the market perception makes funding cheaper, which induces the firm to invest more and the banker to take more risk. Of course in equilibrium $q = Q$.

Proposition 1. *If $i > r$, there exists a unique symmetric stationary equilibrium where the reserve requirement always binds. The equilibrium quality Q and investment k solve (12) and (13) with $q = Q$. The equilibrium satisfies $Q'(i), Q'(\tau) > 0$, as well as $k'(i) < 0$ for all i. Also $k'(\tau) > 0$ when i is close enough to r.*

Setting $q = Q$, Figure (2a) shows the investment curve (12) and the risk curve (13) and how they shift following a rise in inflation. The equilibrium with no inflation is at point A. As the spread $i - r$ increases from zero, the marginal cost of holding reserves increases, everything else constant. Hence, given Q, investment will decline, and the investment-curve shifts down. However, the risk curve does not depend on i, and so the new equilibrium merely moves along the risk curve from A to B: As leverage declines, monitoring increases and risk drops. The adjustment mechanism following a rise in reserve requirement is slightly different however, because both curves are affected by τ. So given k, raising τ always decreases leverage and thus plays to increase monitoring. As a result, the risk-curve shifts up as τ increases. The effect of τ on the investment is less obvious as the effect of τ on the RHS of the investment-curve (12) is at first sight indeterminate. However, it is straightforward to check that the derivative of the RHS of (12) with respect to τ is proportional to the cost of holding reserves $i - r$. If there is no cost of holding reserves, then the investment curve does not change with τ. Otherwise



(a) Equilibrium Q, k (increase in i) (b) Equilibrium Q, k (increase in τ)

the investment curve shifts down with τ and holding everything else constant investment will fall with τ since investing becomes more expensive. So the equilibrium moves from point A down the solid-black risk curve to the intersection of the blue-dashed new investment curve. However, the effects on investment of a rise in τ are somewhat counteracted by the direct effect of a rise in τ on the risk-curve. The banker is now monitoring more, and this plays to increase slightly investment. So the new equilibrium is now at point B, where monitoring increased but investment is lower.

In addition, there are several remarks worth making on Proposition 1.

- When $i > r \geq 0$ and $\tau > 0$, reserve requirements and inflation are substitutes, albeit imperfect, in affecting monitoring and risk. However, it must be that $\tau > 0$ for inflation to impact risk. Indeed, the bank only lends deposits to the firm and keeps just enough reserves to satisfy its requirements. Setting $\tau = 0$, it is obvious that Q is independent of inflation or the interest rate on reserves.

- When $\tau > 0$, the comparative statics of Q with respect to its arguments are

$$\frac{\partial Q}{\partial i} \geq 0, \ \frac{\partial Q}{\partial \tau} \geq 0, \ \text{and} \ \frac{\partial Q}{\partial r} \geq 0.$$

  So, a higher cost of holding reserves, and higher reserve requirement or a higher IOR all increase monitoring and reduce risk-taking. The intuition for the last result is simple:

When the IOR is higher, the bank has more to lose by lending to the firm (e.g., if the firm fails, the bank loses the interest on the reserves it holds) and so it monitors it more. However, suppliers are now reducing their risk-premium because they expect the bank to have more resources in case the firm fails. This effect encourages the bank to issue more credit, which somewhat reduces the original increase in monitoring. Our result shows that the overall effect of the IOR on monitoring is positive.

- From (13), we can write $q = 1 - (\text{effective rate} \times k)/F(k)$,[18]. Therefore, the sensitivity of monitoring with respect to investment is related to the curvature of the production function since
$$\frac{\partial q}{\partial k} = -\frac{(\text{effective rate})}{F(k)}\left(1 - \frac{F'(k)}{F(k)}k\right).$$
When $F(k) = k^{\sigma}$, $F'(k)k/F(k) = \sigma$. If σ increases towards 1, monitoring becomes less (negatively) sensitive to investment. In the limit, q is totally insensitive to the investment level.

- As Figure 2a shows, the equilibrium level of investment always drops with the cost of holding reserves. For example, take a rise in the rate of inflation, or i. This induces a large drop in investment. When this drop is large enough, debt declines and bankers choose to monitor the firm more. This (aggregate) increase in monitoring induces cheaper funding conditions for firms, which may in turn invest a little more, but not enough to induce investment to raise above its initial level. However, as Figure 2b shows, investment can be increasing in liquidity requirements τ, if the cost of reserves is small, but it will be decreasing if τ becomes too large. Indeed, we already pointed out that the shift in the investment-curve following a change in τ is proportional to $i - r$. If this is small, the cost of increasing τ is tiny. The value of deposits however can increase by an order of magnitude more due to the effect on the risk-curve. Since the investment curve does not shift by much, the new equilibrium then moves from A to the north-east of A, and firms invest more. This, however, does not induce less monitoring because the cost of funds drops more than the increase in investment.

[18]Where the effective rate is $\frac{1}{Q}\left\{1 + \left[(i - r) - \lambda(1 + i)\right]\tau p(Q)\right\}$.

For the sake of illustration, assume $F(k) = k^{\sigma}$ where $\sigma \in (0,1]$, then the equilibrium investment and risk curves are

$$Q\left(1-\frac{1}{2}Q\right)F'(k) = 1+\frac{(i-r)\tau}{Q+(1-Q)(1+r)\tau} \tag{14}$$

$$(1-Q)\,F'(k) = \sigma\frac{1-(1+r)\tau}{Q+(1-Q)(1+r)\tau} \tag{15}$$

and dividing (14) by (15) and rearranging, we obtain a quadratic equation in Q. The solution can only be the positive root as the negative root would give a negative level for monitoring. Hence

$$Q = \frac{1-\sigma-\frac{(1+i)\tau}{(1-(1+r)\tau)}+\sqrt{\left(1-\sigma+\frac{(1+i)\tau}{(1-(1+r)\tau)}\right)^2+2\sigma\frac{(1+i)\tau}{(1-(1+r)\tau)}}}{2-\sigma} \tag{16}$$

which is clearly increasing in i and τ.

4.1 Welfare

In this section, we study the welfare consequences of the risk-investment trade-off. As all agents are risk neutral, welfare is given by aggregate output net of the cost of producing the investment good and the banker's monitoring cost

$$\mathcal{W} = Q\left(1-\frac{1}{2}Q\right)F(k)-k.$$

A planner seeking to maximize welfare will choose investment k^* and monitoring level Q^* to maximize $\mathcal{W}$. The first order conditions are

$$Q^*\left(1-\frac{1}{2}Q^*\right)F'(k^*) = 1, \tag{17}$$

$$\text{and} \qquad Q^* = 1,$$

so that $F'(k^*) = 2$. This implies there is room for policy actions, if only because leverage implies monitoring is less than perfect in equilibrium, $Q < 1$. To make this clear, suppose there is no reserve requirement. Then the equilibrium with $\tau = 0$ is characterized by

$$Q\left(1 - \frac{1}{2}Q\right)F'(k) = 1 \tag{18}$$

$$Q(1-Q)\frac{F(k)}{k} = 1 \tag{19}$$

So from (19), $Q = 1$ cannot be an equilibrium but Q must be less than one. Then (18) implies $F'(k) > 2$. So we have

Corollary 1. *In an unregulated equilibrium ($\tau = 0$), there is too little monitoring $Q < Q^*$, and too little investment $k < k^*$.*

We want to know how welfare moves with τ, i.e., we want to compute $\partial\mathcal{W}/\partial\tau$ when the planner is constrained by the behavior of agents in the economy, summarized by the equilibrium equation (14) and (15). The planner considers the following problem

$$\max_{\tau} \mathcal{W} \text{ subject to (14) and (15).}$$

The first order condition is

$$\frac{\partial\mathcal{W}}{\partial\tau} = (1-Q)F(k)Q'(\tau) + \left[Q\left(1-\frac{1}{2}Q\right)F'(k) - 1\right]k'(\tau),$$

where $Q'(\tau)$ and $k'(\tau)$ are given by the two equilibrium curves. Using the investment curve (14), we obtain

$$\frac{\partial\mathcal{W}}{\partial\tau} = (1-Q)F(k)Q'(\tau) + \frac{(i-r)}{Q+(1-Q)(1+r)\tau}\tau k'(\tau).$$

As $Q'(\tau) > 0$ for all $(1+r)\tau = \tilde{\tau} \in [0,1]$, we obtain that $\frac{\partial\mathcal{W}}{\partial\tau}|_{\tilde{\tau}=1} > 0$ whenever $i \approx r$, so that in this case 100% reserve requirement, $\tilde{\tau} = 1$, is constrained optimal. However, if the spread $i - r$ is large enough, then the (negative) second term in the welfare derivative dominates and $0 < \tilde{\tau} < 1$ is optimal. We should stress that the optimal reserve requirement is always strictly positive. We summarize this discussion in the following proposition.

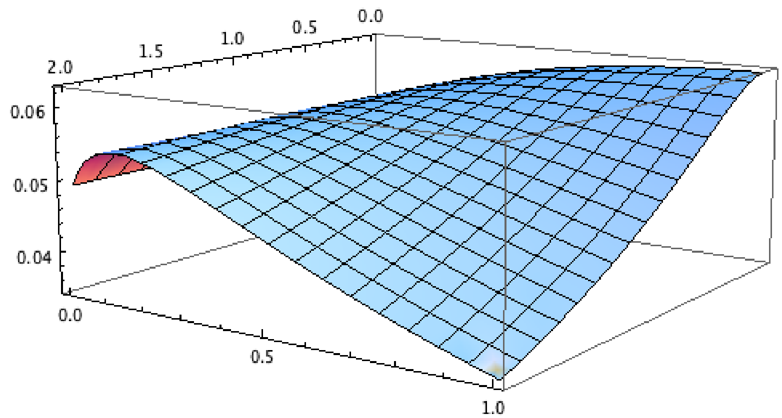


Figure 2: Welfare, $\sigma = 0.5$ and $r = 0$.

Proposition 2. *$\tilde{\tau} > 0$ is always (constrained) optimal for all $i > r$. There is $\bar{i} > r$ such that $\tilde{\tau} = 1$ is (constrained) optimal for all $i \in (r, \bar{i}]$.*

Proposition 2 shows the trade-off between monitoring/quality and output: When the cost of holding reserves is high, investment is already low and increasing reserve requirements, while improving monitoring would also make investment more costly. Thus, it is optimal to reduce reserve requirements. Alternatively, when holding reserves is not so costly increasing reserve requirement is optimal as the increase in monitoring dominates the possible decline in investment. Figure 2 illustrates the optimal level of reserve requirement $\tilde{\tau}$ as a function of the spread $i - r$. For small spread levels, the optimal reserve requirements is 100% or close to 100%. However, as the spread increases the optimal level of reserve requirements falls, but always remains positive.

In words, if money is relatively cheap for banks to hold ($i \approx r$), it is optimal to raise the level of reserve requirements. This raise is intuitive: With low cost of holding reserves, raising reserve requirements does not hurt banks much. However, higher reserves imply that deposits are safer. Hence, the lower risk premium on deposits dampens the increase in the firms' funding cost due to higher reserve requirements. The effect on investment of higher reserve requirements then is small (if negative) or positive, and for welfare, the higher level of monitoring dominates the possibly lower investment.

5 Extensions

5.1 Operating banks α

Most, if not all, regulators will agree that it is socially costly for any bank to fail. One such cost is the disruption of the payment system, and some even argue that there is also a loss of expertise. In this section, we get to the idea that bank failure is costly by assuming it takes time to unwind a failing bank. As a result, a bank that fails is replaced by a new bank, but with a one-period lag. Bankers being short-lived will not fully internalize the cost of their default. Of course, our qualitative results that reserve requirements can be welfare improving do not depend on this assumption, although it may affect the quantitative predictions of the model.

We now compute the number of operating banks in period t. Since banks that financed a failing firm lose their license for one period, the number of operating banks in period t is α_t:

$$\alpha_t = Q\alpha_{t-1} + (1 - \alpha_{t-1}).$$

Therefore, in steady state $\alpha \equiv \alpha_t = \alpha_{t-1}$, and

$$\alpha = \frac{1}{1 + (1 - Q)}. \tag{20}$$

Naturally, if $Q = 1$, all banks are operating, while less banks are operating otherwise. Then, all of our equilibrium analysis goes through. Welfare is given by the aggregate output net of the cost of producing the investment good and the firm's cost of effort,

$$\mathcal{W} = \alpha \left[Q(1 - \frac{1}{2}Q)F(k) - k \right],$$

where α is now given by (20). Therefore, optimal investment k^* and quality Q^* solve

$$Q^* \left(1 - \frac{1}{2}Q^* \right) F'(k^*) = 1, \tag{21}$$

and $Q^{*}=1$.[19] The unit upper bound on quality binds because the planner would require a higher quality since she internalizes the cost of bank failure. If anything, the cost of failure would reinforce the need for reserve requirement.

5.2 (Anticipated) bail-outs

In this section, we consider the case where the government decides to bail-out failing banks. This bailout means that the government will pay off all of the failing bank's liabilities by taxing suppliers in a lump-sum way. When banks are bailed out, all of their liabilities are always repaid so none of their liabilities carries a risk premium. Hence, the market does not perceive or price any risk. More precisely, the real price of deposits becomes $p=1$. The rest of the model is as before. In particular, and in addition to using (6), the first order conditions (7) and (8) become

$$k: \qquad q\left(1-\frac{1}{2}q\right)F'(k) = q+\left[(1+i)-q(1+r)\right]\tau, \tag{22}$$

$$q: \qquad (1-q)\,F(k) = (1-(1+r)\tau)k. \tag{23}$$

An equilibrium with bail-out is a list (p,k,q,Q,m) such that given the bail-out policy, and policies i, τ, price p and aggregate risk $1-Q$, banks optimally choose m^{b}, firms choose k and q to maximize their surplus, $p=1$, and $q=Q$. Combining (22) and (23), we obtain a solution for q that is exactly the same as with no bail-out (16). Therefore adding a bail-out does not change the intensity of monitoring and risk taking behavior, and Q^{b} is

$$Q^{b} = \frac{1-\sigma-\frac{(1+i)\tau}{(1-(1+r)\tau)}+\sqrt{\left(1-\sigma+\frac{(1+i)\tau}{(1-(1+r)\tau)}\right)^{2}+2\sigma\frac{(1+i)\tau}{(1-(1+r)\tau)}}}{2-\sigma} \tag{24}$$

[19] The first order condition with respect to Q is

$$\frac{1}{\left[1+(1-Q)\right]^{2}}\left[Q(1-\frac{1}{2}Q)F(k)-k\right]+\frac{(1-Q)}{1+(1-Q)}F(k)\geq 0,$$

with equality if $Q\in(0,1)$ and inequality if $Q=1$. At $Q=1$, the first order condition above simplifies to $F(k)/k\geq 2$, while the first order condition with respect to k simplifies to $F'(k)=2$. Since $F'(k)\leq F(k)/k$, we obtain $Q^{*}=1$.

To provide some intuition, notice that an anticipated bailout will eliminate the risk premium on bank deposits. Everything else constant, this reduces bank leverage and so incentivizes banks to monitor their investment more. However, this also reduces the cost of funds and encourages banks to invest more, thus increasing leverage and reducing monitoring. Therefore while investment increases, the effect on monitoring is ambiguous. However assuming $F(k) = k^{\sigma}$, (24) shows that monitoring will not change relative to the economy with no bailout. Formally, a change in p shifts both the investment and risk curves in the same proportion, so the choice of monitoring is not affected by a change in p. However, as the right hand side of (7) is always greater than the right hand side of (22), we obtain that the (anticipated) bailout is implying more investment as it reduces the cost of debt.

Proposition 3. *In an equilibrium with bail-out, the investment level is k^b given by (22) and the quality of projects is Q^b given by (23). k^b always declines with inflation or reserve requirements. Q^b increases with i and τ. For any $i \geq r$ and $\tau > 0$, an anticipated bail-out policy increases equilibrium investment relative to no-bail out but does not modify the level of monitoring.*

To complete the proof of Proposition 3, we now compare welfare under bail-out and no bail-out given policy variables τ, r and i. Since the level of monitoring does not change, but investment is higher, welfare with an anticipated bailout is larger than without. Of course, this result hinges on the fact that a bail-out does not involve any distortion (such as the use of distortionary taxes).

5.3 Deposit insurance

In this section, we analyze whether a well designed insurance scheme for deposits can do better than reserve requirements, or the bail-out policies we analyzed in the previous section. We now assume that banks have to work in the CM when they are born and pledge resources to the deposit insurance fund, as a fraction δ of their deposits pk. In this sense, the insurance scheme is similar to a lending tax. However, it is more than a tax, as the deposit insurance company would then tap into the fund to guarantee deposits. Sustainability of the deposit insurance mechanism requires that it has enough resources to cover the shortfall, i.e., $\delta pk = (1-Q)pk(1-\tau(1+r))$ – where we still assume that all banks will hold reserves τpk. Since in an equilibrium with deposit insurance deposits are as safe as money, $p=1$ and we obtain $\delta = (1-Q)(1-(1+r)\tau)$. Notice that we allow cross-subsidization and all banks always lose their contributions to the deposit insurance fund. With such an insurance scheme in place, the bank's problem becomes

$$\max_{k,q} -(1+i)\tau k - \delta k + q[F(k) + (1+r)\tau k - k] - \frac{1}{2}q^2 F(k),$$

with first order conditions

$$\begin{aligned} q\left(1-\frac{1}{2}q\right)F'(k) &= \delta + (1+i)\tau + q\left[1-(1+r)\tau\right], & (25)\\ (1-q)F(k) &= (1-(1+r)\tau)k. & (26)\end{aligned}$$

An equilibrium with deposit insurance is a list (p,k,q,Q,m) such that given the deposit insurance policy δ, and policies π, τ, prices p, and aggregate risk $1-Q$, banks optimally choose m, the contract k and q maximize the bank/firm's surplus, $p=1$, and $q=Q$. To solve for the equilibrium quality choice Q, we use $q=Q$, $\delta=(1-Q)(1-(1+r)\tau)$ in the first order conditions to obtain

$$Q\left(1-\frac{1}{2}Q\right)F'(k) = (1-(1+r)\tau) + (1+i)\tau, \tag{27}$$

$$(1-Q)F(k) = (1-(1+r)\tau)k. \tag{28}$$

We can now compare the investment and risk curves with bail-out with the one with deposit insurance. The two risk curves are identical, while the investment curve with deposit insurance defined by (27) lies above the one with bailout defined by (22) in the (Q,k)-space. Therefore, the equilibrium with deposit insurance (Q^d, k^d) will feature more monitoring but a lower level of investment than the equilibrium with anticipated bail-out.We summarize this discussion in the following proposition.

Proposition 4. *In an equilibrium with deposit insurance, the investment level is k^d given* *by (27) and the quality of projects is Q^d given by (28). k^d always declines with inflation or reserve requirements. Q^d increases with i and τ. For any $i \geq r$ and $\tau > 0$, deposit insurance increases the equilibrium level of monitoring and reduces risk-taking and investment.*

Welfare can be increasing with deposit insurance relative to a bail out policy when the effect on monitoring dominates the investment effect. Also, the deposit insurance can achieve the efficient allocation whenever $i = r$ and $(1 + r)\tau = 1$.

To summarize the economy with an anticipated bailout policy will feature more investment but lower monitoring than the economy with deposit insurance. The intuition is simple: both policies can be seen as two fiscal policies with different timing and different tax-base. The bailout policy levies resources by taxing suppliers ex-post which has on an indirect incidence on bank's investment behavior ex-ante through the price of deposits. To the contrary, deposit insurance is a direct tax on banks' investment ex-ante. As a result, although the price of deposits is the same across both economies, investment with deposit insurance is smaller than with a bailout. As a consequence, banks ' leverage decrease and banks monitor their investment more.

5.4 Capital requirements

In this section, we compare and contrast the effects of capital and liquidity requirements. We replace the liquidity requirement constraint by an equity constraint. More precisely, we assume that for any loan size k, the bank has to have at least a fraction $\varepsilon \in [0, 1]$ of its investment in own equity. Therefore, the bank can finance a fraction $(1 - \varepsilon)$ of its loan with deposits and the remaining fraction with equity. We assume that young banks raise equity by selling shares to suppliers instead of working in the CM. A share is a claim to the bank's future profit and promises to pay a dividend ρ when the bank succeeds. We assume the bank pays just enough dividends to compensate shareholders, and we assume that shareholders understand the bank's monitoring choice is q.[20] Therefore the problem of suppliers is

$$\max_s -(1+\pi)s + \beta q \rho s$$

so in equilibrium, the bank must pay dividend

$$\rho = \frac{1+i}{q}.$$

When there is inflation, it is costly to hold (unused) capital and so the equity requirement will bind. Then, when a bank invests k, it raises εk equity from suppliers and issues deposits for the remaining $(1-\varepsilon)k$. Then the bank maximizes its expected profit net of the monitoring cost,

$$\max_{k,q} q\left[F(k) - p(1-\varepsilon)k - \rho\varepsilon k\right] - \frac{1}{2}q^2 F(k),$$

and using the dividend policy this is

$$\max_{k,q} q\left[F(k) - p(1-\varepsilon)k\right] - (1+i)\varepsilon k - \frac{1}{2}q^2 F(k).$$

In the KM, suppliers no longer expect banks to hold reserves, so that the price of deposits fully reflects the risk of bank's failure,

$$p = \frac{1}{Q}. \tag{29}$$

This is one difference with reserves requirement: where liquidity requirement helps reduce the risk premium of deposits, capital requirement does not. Then, the first order conditions of the problem are

$$\begin{aligned} q\left(1 - \frac{1}{2}q\right)F'(k) &= qp(1-\varepsilon) + (1+i)\varepsilon, \\ (1-q)\,F(k) &= p(1-\varepsilon)k. \end{aligned}$$

[20] We assume shareholders fully internalize the bank's monitoring choice. It is straightforward to redo the calculations assuming that shareholders believe the bank succeeds with probability Q.

It is easy to see that full equity requirement $\varepsilon = 1$ achieves the first best allocation whenever $i = 0$. The reason is that suppliers do not require a risk premium when they are paid with cash and there is no distortion of the allocation aside from inflation coming from this margin. Also, when $i = 0$, we assume it is costless to build equity because shareholders internalize the monitoring choice of the bank. Therefore, there is no distortion out of this margin either. In equilibrium

$$\begin{aligned} Q\left(1 - \frac{1}{2}Q\right) F'(k) &= (1-\varepsilon) + (1+i)\varepsilon, \\ Q\,(1-Q)\,\frac{F(k)}{k} &= (1-\varepsilon). \end{aligned}$$

Comparing these two equations with (12) and (13), it is straightforward to see that setting $\varepsilon = \frac{(1+r)\tau}{Q^\tau + (1-Q^\tau)(1+r)\tau}$ gives us the same equilibrium condition for (13) as in the case with reserve requirements, where Q^τ is the equilibrium quality choice with reserve requirement τ. However such equity requirement gives us

$$Q\left(1 - \frac{1}{2}Q\right) F'(k) = 1 + \frac{i(1+r)\tau}{Q + (1-Q)(1+r)\tau}$$

and the RHS is higher than the one of (12). Therefore, in this model, if the capital and liquidity requirements are set such that the risk curve is the same under both requirement, the investment curve will be lower in the case with capital requirement, corresponding to a higher quality choice and lower investment level in equilibrium. This is intuitive: suppliers holding equity of a bank know the monitoring this bank will conduct, and the bank takes it into account when choosing its level of monitoring. This reduces the moral hazard problem coming with deposits described in Section 3.4. Therefore, the more equity the bank issues, the closer the bank will be to the first best investment and monitoring levels. As a consequence, investment is lower and monitoring higher with equity requirements than in the economy with reserve requirements.

6 Literature review

The idea that interest rate policy affects risk-taking by intermediaries also referred to as the risk-taking channel of monetary policy, a term coined by Borio and Zhu (2012) prompted a recent empirical literature. One main finding of this literature is a negative relationship between the level of interest rates and bank risk-taking. In light of this observation, it has been argued that central banks could have prevented the buildup of risk in the run-up to the recent financial crisis and the ensuing negative consequences for the macroeconomy by raising interest rates. Dell'Ariccia, Laeven, and Marquez (2014) and De Nicolò, Dell'Ariccia, Laeven, and Valencia (2010) document a negative relationship between the *real* fed funds rate and the riskiness of U.S. banks assets. Others use *nominal* interest rate data to establish a negative relationship to bank risk-taking in different countries.[21]

On the theoretical side, Williamson (1999) argues that the creation of tradable deposit allows productive intermediation and is thus desirable. Using a similar angle of attack, Chari and Phelan (2014) argue that the creation of deposits has the (private) benefits of insuring against liquidity shocks, while at the same time imposing a pecuniary externality by raising the price level. This outcome implies that the social benefits of deposit creation can even be negative. As a result, 100% reserve requirement can be desirable. Our mechanism also plays through a pecuniary externality, but while Chari and Phelan study the effect of consumption loans, we study the effect of corporate credit lines on the production process. Then, we can show that deposits possibly increase leverage beyond its optimal level and increasing risk (in addition to the price level). Monnet and Sanches (2015) also show that a competitive banking sector is unstable and may require regulation. Their results play through the charter value of banks, like in Hellmann, Murdoch, and Stiglitz (2000) or Repullo (2004) among many others. Instead, our results are driven by limited liability. Still, with limited commitment but with moral hazard for banks decision, Hu and Li (2017) analyze the effect of capital regulation. Instead, we concentrate on the effects of monetary policy on banks' balance sheet risk. Sanches (2015) argues that a purely private monetary regime is inconsistent with

[21] For example, Gambacorta (2009), Ioannidou, Ongena, and Peydró (2015), Jiménez, Ongena, Peydró, and Saurina (2014), Delis and Kouretas (2011) and Altunbas, Gambacorta, and Marques-Ibanes (2014) and Cociuba, Shukayev and Ueberfeldt (2016).

macroeconomic stability. The result hinges on endogenously determined limits on private money creation and the presence of self-fulfilling equilibrium characterized by monetary collapse. The papers perhaps closest to ours are Stein (2010) and Kashyap and Stein (2012), who study the effect of reserve requirements on banks' issuance of short term debt which exposes them to some asset shocks. We differ by explicitly modeling the risk taking channel on the asset side of banks' balance sheet, while they take it as given.

Jakab and Kumhof (2015) remark that, with a few exceptions, the academic literature has focused on a debatable model of banks, namely, the "intermediation of loanable funds" model. In this model, banks intermediate funds from savers to borrowers. A prime example of such a model is Diamond and Dybvig (1983), or Berentsen, Camera, and Waller (2007). Calomiris, Heider, and Hoerova (2015) is also using the "intermediation" model but is more related to our question, as they analyze the need for liquidity requirements for banks. In their model, liquidity requirements act as collateral a disciplining device for bankers who otherwise would engage in moral hazard. Instead, we investigate another channel: liquidity requirement reduces leverage and thus risk taking, by increasing the cost of firm's funding. Also we provide a general equilibrium model where banks can create deposits that circulate as the means of payments, and we can analyze the effect of monetary policy on bank risk-taking. Jakab and Kumhof argue that banks' main activity is to finance firms through the creation of money (or deposits). Among many other results, they show that the "financing" model of banking explains why leverage is pro-cyclical. Our model belongs to the financing view of banking and we concentrate on risk-taking, the optimal reserve requirement policy and its interaction with monetary policy when banks issue tradable deposits.[22] Our paper is also related to Williamson (2016) that features the moral hazard problem of creating low quality collateral when the interest rate is low.

[22] We refer the reader to Bigio and Weill (2016) for a recent theory of banks balance sheet and why banks are useful in providing liquid assets.

7 Conclusion

We presented a model to study the implications of deposit-making on risk-taking. We believe our arguably simple model captures several important features of bank lending activities: Firms need funding and they obtain it from banks. Banks finance firms by creating deposits. Deposits are used as a means of payments. Deposits carry a risk premium as long as they are not insured or only partially backed by liquid assets. We find that banks' monitoring effort is an increasing function of inflation: The increased cost of liquid asset induces banks to charge higher rates to borrowers. As a consequence, banks lend less and they issue less deposits so that their debt level falls. As a consequence they have more incentive to monitor their borrowers.

The model is simple, and we chose to abstract from many relevant aspects. Let us mention the most obvious ones: First, banks do not take deposits from depositors and they finance their liquidity requirements using only (sweat) equity. Hence, we cannot study issues such as bank runs in the current version of the model. Still let us stress that the risk premium on deposits is getting to the idea of a run on banks: If the risk premium increases to infinity, firms cannot trade deposits. We think it would be interesting to extend the model in this direction. The second aspect that is missing from the model is the cost of raising equity. Here, we modeled equity as an effort level that banks have to exert in order to get started. Finally, analyzing growth should yield interesting insights in particular regarding the debate on growth versus stability of the financial system. Overall, we expect the mechanism we highlighted to be robust to these three and other extensions.

8 Bibliography

Allen, F., E. Carletti, and R. Marquez (2009) "Credit Market Competition and Capital Regulation", *Review of Financial Studies* 24(4), 983-1018.

Bech, M., and T. Keister (2017) "Liquidity regulation and the implementation of monetary policy", *Journal of Monetary Economics* 92(C), 64-77.

Berentsen, A., G. Camera, and C. Waller (2007) “Money, Credit, and Banking”, *Journal of Economic Theory* 135 (1), 171-195.

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(4), pp.236-251.

Calomiris, W. C., F. Heider, and M. Hoerova (2015) “A theory of bank liquidity requirements”, Working paper, ECB.

Chang, C., Z. Liu, M.M. Spiegel, and J. Zhang (2018) “Reserve requirements and optimal Chinese stabilization policy”, Federal Reserve Bank of San Francisco.

Chari, V. V., and C. Phelan (2014) “On the social usefulness of fractional reserve banking”, *Journal of Monetary Economics*, 65, 1-13.

Cochrane, J. (2014) “Toward a run-free financial system”, in M. N. Bailey and J.B Taylor eds. Across the Great Divide: New Perspectives on the Financial Crisis, Hoover Press.

Cordella, T. and E. Levy Yeyati (2003) “Bank Bailouts: Moral Hazard vs. Value Effect”, *Journal of Financial Intermediation* 12(4), 300-330.

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(2), 613-654.

De Nicolò, G., Dell’Ariccia, G., Laeven, L., and F. Valencia (2010) “Monetary policy and bank risk taking”, IMF Working Paper.

Diamond, D.W., and P.H. Dybvig (1983) “Bank runs, deposit insurance, and liquidity”, *Journal of Political Economy*, 91(3), pp.401-419.

Diamond, D. W., and R. G. Rajan (2001) “Liquidity risk, liquidity creation, and financial fragility: A theory of banking”, *Journal of Political Economy*, 109(2), 287-327.

Drehmann, M., M. Juselius, and A. Korinek (2018) “Going With the Flows, New Borrowing, Debt Service and the Transmission of Credit Booms,” mimeo, BIS.

Jakab, Z., and M. Kumhof (2015) “Banks are not intermediaries of loanable funds – and why this matters,” Bank of England Working Paper No. 529. May 2015.

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?”, *Econometrica*, 82(2), 463-505.

Kashyap, A. and J. Stein (2012) “The Optimal Conduct of Monetary Policy with Interest on Reserves,” *American Economic Journal: Macroeconomics*, 4(1): 266-282.

Hellmann, T.F., K. C. Murdoch, and J. E. Stiglitz (2000) “Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?” *American Economic Review* 90(1), 147-165.

Hu, T.-W., and Y. Li (2017) “Optimal Banking Regulation with Endogenous Liquidity Provision”, mimeo.

Monnet, C., and D. Sanches (2015) “Private money and banking regulation”, *Journal of Money, Credit, and Banking* 47 (6), 1031-1062.

Repullo, S. (2004) “Capital Requirements, Market Power and Risk-Taking in Banking”, *Journal of Financial Intermediation* 13(2), 156-182.

Rocheteau, G., R. Wright, and C. Zhang (2018) “Corporate finance and monetary policy”, *American Economic Review* 108(4-5), 1147-86.

Sanches, D. (2015) “On the inherent instability of private money”, *Review of Economic Dynamics* 20, 198-214.

Stein, J. (2012) “Monetary Policy as Financial Stability Regulation,” *Quarterly Journal of Economics,* 127 (1): 57-95.

Williamson, S. (1999) “Private Money”, *Journal of Money, Credit, and Banking* 31(3), 469-491.

Williamson, S. (2016) “Low Real Interest Rates, Collateral Misrepresentation, and Monetary Policy”, Federal Reserve Bank of St Louis, Working Paper 2014-026B.

A Proof of Lemma 1

Proof. To show Lemma 1, it is convenient to use $X = Q + (1-Q)(1+r)\tau$ and rewrite (12) and (13) as

$$\begin{aligned}\left(1-\frac{1}{2}q\right)F'(k)X - \frac{1}{q}(1+i)\tau &= 1-(1+r)\tau \\ (1-q)\frac{F(k)}{k}X &= 1-(1+r)\tau\end{aligned}$$

Since $(1+r)\tau < 1$, X is increasing in Q. When X increases, both the first and second equations imply that q and/or k have to increase, since their RHS is constant and their LHS is decreasing in both q and k.

□

B Proof of Proposition 1:

Proof. To show Proposition 1, rewrite (12) and (13) as

$$F'(k) = \frac{1-(1+r)\tau+\frac{1}{Q}(1+i)\tau}{\left(1-\frac{1}{2}Q\right)[Q+(1-Q)(1+r)\tau]} \tag{30}$$

$$\frac{F(k)}{k} = \frac{1-(1+r)\tau}{(1-Q)[Q+(1-Q)(1+r)\tau]} \tag{31}$$

Given Q, the first equations gives $k_1(Q)$ and the second equation gives $k_2(Q)$. There is $0 < \bar{Q} < 1$ such that the RHS of (30) is greater than the RHS of (31) whenever $Q < \bar{Q}$. Since $F(k)/k \geq F'(k)$ for all k and using concavity of the production function, $k_2(Q) > k_1(Q)$ for all $Q < \bar{Q}$. Also, the RHS of (31) tends to infinity as $Q \to 1$, so that $k_2(Q) \to 0$, while $k_1(Q) > 0$. This shows there is a $Q^* \in (0,1)$ such that $k_2(Q^*) = k_1(Q^*)$. To show that Q^* is unique, we show that the level of quality Q_1 that maximizes $k_1(Q)$ is above 1. In this case, $k_1(Q)$ is an always increasing function of $Q \in [0,1]$. To show that $Q_1 \geq 1$, we want to minimize the RHS of (30). It is straightforward albeit cumbersome to check that the RHS of (30) is convex and its derivative evaluated at $Q = 1$ is negative whenever $i \geq r$. This guarantees that $Q_1 \geq 1$ and shows the result.

□

C Comparative statics.

We first show that $Q'(i) > 0$ and $k'(i) < 0$. Let $k_1(Q)$ and $k_2(Q)$ be defined as in the proof of Proposition 1. The locus $k_2(Q)$ is not affected by i, while the locus $k_1(Q)$ must rotate down when i increases (in the (Q, k)-plane). Since $k_1(Q)$ is increasing and crosses $k_2(Q)$ in its decreasing part, we obtain that Q has to increase with i while k has to decrease with i.

Then we show that $Q'(\tau) > 0$ and $k'(\tau) < 0$. We use

$$\begin{aligned} F'(k) - \frac{1-(1+r)\tau + \frac{1}{Q}(1+i)\tau}{\left(1-\frac{1}{2}Q\right)[Q+(1-Q)(1+r)\tau]} &= 0 \\ \frac{F(k)}{k} - \frac{1-(1+r)\tau}{(1-Q)[Q+(1-Q)(1+r)\tau]} &= 0 \end{aligned}$$

By the implicit function theorem,

$$\begin{bmatrix} Q'(\tau) \\ k'(\tau) \end{bmatrix} = - \begin{bmatrix} H_{1Q} & H_{1k} \\ H_{2Q} & H_{2k} \end{bmatrix}^{-1} \begin{bmatrix} H_{1\tau} \\ H_{2\tau} \end{bmatrix}$$

so

$$\begin{bmatrix} H_{1Q} & H_{1k} \\ H_{2Q} & H_{2k} \end{bmatrix} = \begin{bmatrix} -\frac{\partial X}{\partial Q} & F''(k) \\ -\frac{\partial Y}{\partial Q} & \frac{\partial F(k)/k}{\partial k} \end{bmatrix}$$

where

$$\begin{aligned} X &= \frac{1-(1+r)\tau + \frac{1}{Q}(1+i)\tau}{\left(1-\frac{1}{2}Q\right)[Q+(1-Q)(1+r)\tau]} \rightarrow \frac{\partial X}{\partial Q} < 0 \\ Y &= \frac{1-(1+r)\tau}{(1-Q)[Q+(1-Q)(1+r)\tau]} \rightarrow \frac{\partial Y}{\partial Q} > 0 \end{aligned}$$

we have used the fact that in equilibrium $k_2(Q) = k_1(Q)$, and both curves cross in the region where $k_2(Q)$ is decreasing so that $\frac{\partial Y}{\partial Q} > 0$. Then the determinant is

$$Det = -\frac{\partial X}{\partial Q}\frac{\partial F(k)/k}{\partial k} + F''(k)\frac{\partial Y}{\partial Q} < 0$$

and

$$-\begin{bmatrix} H_{1Q} & H_{1k} \\ H_{2Q} & H_{2k} \end{bmatrix}^{-1} = -\frac{1}{Det}\begin{bmatrix} \frac{\partial F(k)/k}{\partial k} & -F''(k) \\ \frac{\partial Y}{\partial Q} & -\frac{\partial X}{\partial Q} \end{bmatrix}$$

Finally,

$$H_{1\tau} = -\left[\frac{-(1+r)+\frac{1}{Q}(1+i)}{\left(1-\frac{1}{2}Q\right)\left[Q+(1-Q)(1+r)\tau\right]} - \frac{\left[1-(1+r)\tau+\frac{1}{Q}(1+i)\tau\right]\left(1-\frac{1}{2}Q\right)(1-Q)(1+r)}{\left\{\left(1-\frac{1}{2}Q\right)\left[Q+(1-Q)(1+r)\tau\right]\right\}^2}\right]$$

$$\begin{bmatrix} H_{1\tau} \\ H_{2\tau} \end{bmatrix} = \begin{bmatrix} \frac{-2(i-r)}{(2-q)[q+(1-q)(1+r)\tau]^2} \\ \frac{1+r}{(1-q)[q+(1-q)(1+r)\tau]^2} \end{bmatrix} \begin{matrix} <0 \\ >0 \end{matrix}$$

Therefore,

$$\begin{bmatrix} Q'(\tau) \\ k'(\tau) \end{bmatrix} = -\frac{1}{Det}\begin{bmatrix} \frac{\partial F(k)/k}{\partial k} & -F''(k) \\ \frac{\partial Y}{\partial Q} & -\frac{\partial X}{\partial Q} \end{bmatrix}\begin{bmatrix} H_{1\tau} \\ H_{2\tau} \end{bmatrix}$$

$$\begin{bmatrix} Q'(\tau) \\ k'(\tau) \end{bmatrix} = \underbrace{-\frac{1}{Det}}_{>0}\begin{bmatrix} \underbrace{\frac{\partial F(k)/k}{\partial k}H_{1\tau}}_{>0} - \underbrace{F''(k)H_{2\tau}}_{<0} \\ \underbrace{\frac{\partial Y}{\partial Q}H_{1\tau}}_{<0} - \underbrace{\frac{\partial X}{\partial Q}H_{2\tau}}_{<0} \end{bmatrix} \begin{matrix} >0 \\ ? \end{matrix}$$

Hence, Q is always increasing with τ, while the effect on investment is indeterminate. However, if $i \approx r$, $H_{1r} \approx 0$, so that $k'(\tau) > 0$.