Endogenous bank risks and the lending channel of monetary policy[*]

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Abstract

This paper develops a general equilibrium banking model where lending and payment flows endogenously link credit, liquidity, and solvency risks. Banks issue deposits at loan origination. As deposits circulate, reserve settlement creates liquidity exposure and repayment shortfalls generate credit and solvency risk. These risks are jointly determined by credit provision and bound balance sheet expansion at an internally determined profitability threshold rather than an external funding or capital limit. We present an application of the theory that provides a new look to the bank lending channel where monetary policy operates through the endogenous generation of bank risks. Our quantitative results align with empirical observations, including declines in deposit growth after monetary policy tightening and its different impact on lending depending on the balance sheet strength of banks as well as the relation of funding costs in interbank markets with liquidity and solvency ratios.

Keywords: Monetary policy; banks; payments; liquidity risk; credit risk; solvency risk; risk premium; interbank market.

JEL classification codes: E10, E44, E52, G21.

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1 Introduction

A clear understanding of the risk exposures of banks when providing credit is essential for addressing both the transmission of monetary policy as well as the determinants of bank failures. Episodes such as the Global Financial Crisis of 2007 or the 2023 US regional bank failures suggest that liquidity strains, credit losses, and solvency concerns are interconnected and rarely arrive alone.

In fact, the empirical literature has provided evidence about the linkages between credit, liquidity and solvency risks and their connections with certain items of banks' balance sheets. For example, Schularick and Taylor [2012], Jorda et al. [2013], or Mian et al. [2017] connect the expansion of credit and bank leverage with the probability of a banking crisis and the size of economic downturns. Similarly, Correia et al. [2025] show how bank failures are preceded by losses that gradually weaken solvency and increase reliance on expensive noncore funding. These results are in line with empirical work showing the rise in wholesale funding costs for banks perceived as riskier [Arnould et al., 2022, Aymanns et al., 2016, Carvalho et al., 2022, Schmitz et al., 2017]. Furthermore, Correia et al. [2025] document that runs on healthy banks are rare historically. On the contrary, weak bank fundamentals are a necessary condition for failure where this deterioration of fundamentals is often anticipated by rapid lending growth and caused by the realization of credit risk. Consequently, these authors show, bank failures are highly predictable using public bank balance sheet data.

These empirical findings have important implications for theories of bank failures. In particular, this evidence could undermine the relevance of theories based on self-fulfilling runs in the tradition of Diamond and Dybvig [1983] or on asymmetric information (e.g. Gertler and Karadi [2011]). Moreover, these results also question the way we model loan provision and its funding, that is, the dynamics of deposit creation and destruction. In macroeconomic models incorporating a banking sector (such as Gertler and Kiyotaki [2010], or Gertler and Karadi [2011]), depository institutions first need to collect deposits in order to extend credit. The consequence of this assumption is that the expansion of credit is bounded by the amount of the existing stock of assets saved in the economy not already used to fund lending. In other words, to expand credit in one sector, funding of investments should be reduced in another place in the economy. This idea of a resource constraint for the financing of investment also applies to bank credit. If, as a response to an exogenous increase in interest rates, depositors decide to move their savings to some other use with a higher remuneration, say, public securities, aggregate deposits are consequently reduced and, therefore, credit should shrink if banks do not have access to other sources of funding or if these other sources are more expensive. This, in a nutshell, is the basic mechanism of the bank lending channel of monetary policy.

In contrast with this representation of the financial intermediation performed by banks, descriptions of the way deposits are created and destroyed tell a different story. On the one hand, work by McLeay et al. [2014], Bundesbank [2017], Jordan [2018], Bailey [2020] or Brainard [2021], among others, emphasize the process by which commercial banks create deposits at the time of loan origination. In fact, evidence by Thakor and Yu [2023] shows that 92 percent of total bank deposits created between 2001 and 2010 were due to lending activities of U.S. banks. On the other hand, as pointed out by Bindseil and Senner [2024], in general, "bank deposits, a claim of the depositor on a specific bank, do not simply disappear". Transactions such as buying a security from, or investing in, non-banks, just reallocate deposits across banks. These type of transactions may have distributional effects but should not affect the aggregate amount of deposits potentially able to fund existing aggregate lending. According to Bindseil and Senner [2024], the only instances in which deposits are destroyed in the aggregate arise whenever they are converted into central bank money or, else, absorbed through bank operations such as depositors repaying a loan, or buying bank debt, bank equity or a security already existing in the bank portfolio. In this sense, deposit reduction through bank operations does not necessarily decrease the funding available for banks. In fact, they may enhance it in the case of equity expansion. Finally, cash withdrawals may affect funding for loans only to the extent that central banks are not willing to provide that extra liquidity.

In this paper, we propose a tractable general equilibrium model of banking that is consistent with all these findings. As a first building block, the model is in line with the dynamics of creation and destruction of deposits. In the model, private IOUs issued by non-banks cannot circulate as means of payment due to a resaleability friction (Kiyotaki and Moore [2002]). As a consequence, firms do not have any resource accepted by workers to compensate them for their labor. Banks arise to solve this problem. When a firm demands labor but does not have the means of payment to pay for it, a bank produces transferable deposits that are loaned to that firm. This is how deposits are created. Credit provision expands the bank's balance sheet by crediting the firm's deposit account. These deposits are then transferred to workers in exchange for labor. Workers in turn spend these resources buying goods from some firms in the economy. These expenditures allow firms to get back the means of payment they need to pay for the loans they asked for previously. This is how deposits are destroyed.[1]

A novel feature of our analysis is the ability of banks to autonomously expand or contract their balance sheet at will through the provision of credit. This capacity to create their own liabilities in the form of deposits endogenously connects bank risk exposures to credit

[1]We could incorporate other forms of deposit destruction such as currency withdrawal, or conversion in other bank asset or liability. These other ways to eliminate deposits complicate the model without adding other insights to our mechanism.

provision through the payment system. As demand deposits circulate between buyers and sellers, payment flows between banks expose them to liquidity risk, that is, the need to obtain reserves in the interbank market to settle net outflows. These payment flows also generate credit risk, since borrowers must receive sufficient revenues in the form of existing liquidity to repay their loans. Furthermore, if the payment flows in the economy are such that enough borrowers cannot pay back their loans, banks could fail. Therefore, payment flows are also behind solvency risks faced by banks.

In the model there are no exogenous restrictions to bank's balance sheet growth in the form of capital requirements. Instead, there exist endogenous limits associated with how expanding the balance sheet of a bank impacts risk exposures and profitability. As a result, there is an optimal level of credit provision for a bank which maximizes expected profits. Bank capital is relevant in this process of credit production as it affects this connection between loan provision and bank risks. Of course, with this modeling choice we do not claim that capital requirements are not important. But we want to study how bank capital affects the nexus of loan provision with liquidity, credit, and solvency risks, as these are the main concerns banks have to face regarding their decisions to expand or contract their balance sheets.

We present an application of the theory that provides a new look to the bank lending channel where monetary policy affects credit supply through its impact on the cost of bank liabilities and the expected returns to intermediation. This channel has two dimensions. In the long run, monetary policy in the form of permanent changes in the policy rate has persistent effects on the real side of the economy.[2] In particular, a permanent reduction of the policy rate moves the economy to a new steady state characterized by a higher price level, a larger amount of labor and, consequently, more output. The reverse would follow from a permanent monetary policy contraction. The mechanism is as follows. Lower official rates ease credit conditions increasing the supply of loans and allowing firms to borrow more to hire more labor and produce more output. Because this new lending expands the means of payments in the economy, prices also rise. The drawback of this expansion is an increase in credit and solvency risks in the form of larger NPL ratios and the fraction of insolvent banks.

The second dimension is the transition. A temporary decrease in the policy rate generates qualitatively similar responses in terms of transitory lower market rates, as well as larger labor, output and prices. In the short-term, NPL and bank failures also increase. Thus, in the model, an expansionary monetary policy produces data that could be interpreted as risk seeking behavior of banks although the underlying distribution of risk has not changed.[3]

[2] Jorda et al. [2024] shows that the real effects of monetary policy are long lasting.

[3] The term risk-taking channel of monetary policy was first coined in Borio and Zhu [2012] and has received empirical support in, among others, Maddaloni and Peydro [2011], Buch et al. [2014], Jiménez et al. [2014],

Furthermore, associated with the increase in credit there is also an increase in deposits. This comovement could be interpreted as the deposit channel of monetary policy although the causality goes in the opposite direction to the one proposed in that literature.[4]

Quantitatively, we calibrate the model to aggregate data and show that it can reproduce several empirical regularities within a unified and internally consistent framework. Apart from the negative response of loans and deposits to a monetary tightening mentioned above (as in Drechsler et al. [2017]), the model also produces (1) heterogeneous lending responses to monetary shocks depending on banks' capital and liquidity positions [Altunbaş et al., 2002, Ehrmann et al., 2001, Gambacorta, 2005, Gambacorta and Mistrulli, 2004, Kashyap and Stein, 1995, Kishan and Opiela, 2000, 2006, van den Heuvel, 2002], and (2) rising wholesale funding costs for banks perceived as riskier [Arnould et al., 2022, Aymanns et al., 2016, Carvalho et al., 2022, Schmitz et al., 2017]. These results are untargeted and emerge from the mechanism considered here. Capturing these patterns simultaneously within one parsimonious model underscores the explanatory strength and coherence of the proposed mechanism. It is important to notice we assume a perfectly competitive environment with symmetric information and flexible prices. Thus, our results arise from the internal interactions of bank risks rather than market power, agency frictions, or nominal rigidities.

The remainder of the paper proceeds as follows. Section 2 discusses related literature. Section 3 presents the model and equilibrium. Section 4 reports results. Finally, section 5 concludes.

2 Related literature

Our paper is related to the literature analyzing risk exposures through the asset and liability structure of bank balance sheets. He and Xiong [2012] identify the dependence on short-term debt structures as the element connecting liquidity and credit risk. Imbierowicz and Rauch [2014] point out the relationship between liquidity and credit risk as the fundamental cause that aggravates defaults for US commercial banks. Morris and Shin [2016] use global game methods to decompose credit risk into solvency and liquidity risk and show how both are jointly determined as a function of the balance sheet. We contribute to this literature by showing how credit provision and deposit flows endogenously connect liquidity, credit and solvency risks altogether. We show how payment shocks might produce a deterioration of economic conditions, provoking credit risk realizations when deposits do not flow back to

Ioannidou et al. [2015], or Bubeck et al. [2020]. A theoretical model reproducing this channel is developed in Dell'Ariccia et al. [2014].

[4] The term deposit channel of monetary policy was first proposed by Drechsler et al. [2017].

borrowers, and leading to solvency risks that boosts the cost for wholesale funding in the interbank market. This endogenous connection among bank risks allows us to characterize the deterioration of bank fundamentals empirically identified in Correia et al. [2025].

Our paper also relates to the literature on endogenous risk and financial amplification in banking. Models such as Brunnermeier and Sannikov [2014] and He and Krishnamurthy [2013] highlight how feedback between asset prices, leverage, and balance sheet strength can amplify shocks. We share their emphasis on endogenous risk creation but differ in focus and in the type of frictions that generates it. In our model, risk arises not from agency problems or market power but from the interaction of payment flows and balance sheet composition.

Our work is connected to the macroeconomic literature on money as a medium of exchange. Descriptions of the process of inside money creation by banks such as McLeay et al. [2014], Bundesbank [2017], Jordan [2018], Bailey [2020] or Brainard [2021], are used by Disyatat [2011] or Jakab and Kumhof [2018] to break with the idea that deposits are needed to provide credit but that the direction of causality is exactly the opposite. We contribute to this literature by introducing a tractable approach that embeds payment flows and deposit creation and destruction into a general equilibrium setting with endogenous bank balance sheets. This allows us to study how payment flows affect bank lending and the monetary transmission. Our model jointly accounts for observed relationships between policy rates, spreads, funding costs, and heterogeneous lending responses. To our knowledge, existing macro models examine these channels separately. General equilibrium approaches such as Bianchi and Bigio [2022] and Di Tella and Kurlat [2021] analyze individual bank risks but do not integrate the credit-liquidity-solvency triad in a single structure as we do. Furthermore, dynamic banking models like Bolton et al. [2025] also underscore the value of deposit flows as a constraint to lending.

Furthermore, our paper relates to the strand of the literature emphasizing the lending channel of monetary policy. Early contributions, such as Bernanke and Blinder [1988] and Kashyap and Stein [2000], modeled the bank lending channel through balance sheet constraints or reserve requirements that limit credit creation. More recent research has incorporated modern funding structures, including the role of wholesale markets, market-based intermediation, liquidity regulation and studies the dynamic implications for bank balance sheets and lending [e.g. Adrian and Shin, 2010, Bianchi and Bigio, 2022, Bolton et al., 2025, Diamond and Kashyap, 2016, Heider et al., 2015, Van den Heuvel, 2008]. In contrast, the key mechanism in our framework arises from the joint exposure of banks to credit, liquidity, and solvency risks that stem from payment flows and balance sheet composition. Unlike models in which credit supply is constrained by external limits on deposits, capital, or funding, banks in our model face an endogenous bound to expanding credit associated with expected profitability. Monetary policy therefore operates by influencing the cost of intermediation and the maximum level of profits, rather than by relaxing or tightening exogenous constraints.

Another strand of the literature studies banks' liquidity management and the role of reserves and interbank markets in transmitting monetary policy. Recent work, such as Afonso et al. [2019] and Di Tella and Kurlat [2021], models the functioning of the interbank market and shows how the distribution of reserves influences interbank rates and the effectiveness of monetary policy. Our paper contributes to this literature by incorporating the interaction between interbank borrowing and the endogenous determination of liquidity and solvency risks affecting banks' funding costs.

Finally, our results connect to the deposit channel of monetary policy described by Drechsler et al. [2017]. These authors empirically observe that, when the fed fund rate rises, banks widen the spread they charge on deposits and cut lending as deposits flow out to other more productive alternative investments. They construct a model with monopolistically competitive banks in the deposit market to reproduce these empirical findings. Our framework replicates the same facts but in a perfectly competitive environment. Contrary to Drechsler et al. [2017], in our mechanism, changes in deposits are not the driving force for the reduction in lending but rather a by-product of the adjustments of banks and the real sector to policy changes. Because banks create deposits in the lending process, aggregate deposits drop jointly with lending but as a consequence of the contraction in intermediation, not as a cause. Of course, there are other modeling differences across both frameworks. Banks in Drechsler et al. [2017] do not fail and there is no bank capital. Accordingly, they cannot account for cross-sectional differences of the responses of banks to monetary policy shocks according to their levels of capitalization and liquidity.

Taken together, our paper bridges these strands of the literature by offering a unified framework in which the provision of credit, payment flows, and bank risks are jointly determined.

3 The model

The economy is organized in a continuum of nodes, with measure one, indexed by $j \in [0, 1]$. On each of these nodes, there is a continuum of banks, a continuum of firms, and a continuum of workers each with measure one also. Banks supply means of payment. Firms demand labor and produce goods. Workers supply labor and consume. Outside these nodes there is a measure one of investors who save and invest in firms and banks. Finally, there is a government composed of a central bank and a fiscal authority.

We assume there is specialization in production, consumption and lending. With this assumption, workers and firms on each node are involved in the production of only one good. However, workers on that node consume a different one produced in a different node. This specialization in production and consumption prevents private IOUs issued by firms to circulate as a mean of payment. So, instead, workers and firms rely on private banks, which use their balance sheets to intermediate payments among them. The process works as follows. Whenever a firm demands labor from a worker but does not have enough means of payment to acquire it, a bank creates these means of payment in the form of deposits and lends them to that firm. For that, we assume the firm can only get the loan from a bank in its node. We impose these extreme specialization assumptions to simplify the exposition of the model. Below we show it would be possible to relax them as long as there is no complete diversification of firms across different goods and of banks across different nodes.

Once created, these deposits are transferred to workers in exchange for labor and circulate in the economy as workers use them to buy goods from other firms. For the original borrower (firm) to pay back the loan she asked for in the first place, the so-created deposits need to get back to her, as this firm sells whatever product she is specialized in to other workers in the economy. Regarding this payment process, we assume that workers' consumption expenditures are randomly distributed across firms. This generates two key effects. First, because workers and firms are distributed across banks, deposits flow unevenly across intermediary institutions. These interbank imbalances are settled using reserves and expose banks to liquidity risk. Second, since some firms receive more revenue than others, there is heterogeneity in loan repayment. Some firms repay in full, while others default. These defaults expose banks to credit risk. When loan losses are sufficiently large, bank capital is eroded, and solvency risk arises. In this way, liquidity, credit, and solvency risks emerge endogenously from banks' lending decisions.

Finally, there is a public sector composed of a central bank and a fiscal authority. The central bank is in charge of backing up this private monetary system through the production of outside money, i.e., cash and reserves. For that, we impose three institutional arrangements we observe in reality. First, the central bank provides commercial banks with reserves which are used to settle accounts between them derived from the asymmetric nature of payments. To manage these reserves, the central bank offers two facilities, a lending facility to provide reserves and a deposit facility to absorb excess reserves. Both facilities imply the same official rate, i^o. Second, we assume deposits to be convertible, on a one-to-one basis, into cash, i.e. the second form of outside money issued by the central bank. Finally, we impose cash to be legal tender, that is, a form of money that courts of law recognize as satisfactory payment for any monetary debt. Thus, in this model, deposits are liquid because, at any time, either can be used directly to make payments or, else, are convertible to an asset that can be used to make payments. Because of this convertibility, deposits earn the same nominal net return of cash, namely, zero. Furthermore, the fiscal authority transfers resources to workers. These transfers are financed by the central bank through reserves.

3.1 Workers

Workers are hand-to-mouth agents. At the beginning of the period, each worker supplies labor h^s to a centralized labor market within the node she lives in and is hired by one of the firms in exchange for a wage payment. Later in the period, after labor is supplied and output has been produced, the worker decides how much to consume. However, she consumes only one of the varieties produced in one of the nodes of the economy. Which variety the worker consumes is random and not known at the time labor is exerted, earlier in the period. Because there is a continuum of goods potentially demanded by workers, private IOUs issued by any single firm redeemable for output of the firm cannot be used to pay the wage bill of its workers. This is because these workers are not consuming that good, nor the firms they buy goods from assign any value to those promises.[5]

Commercial banks represent an arrangement to fill this gap. For that, these banks lend to firms enough funds in the form of nominal units of account called deposits to pay their nominal wage bill $W \times h^s$. These funds are then transferred to workers who use them to consume. As they consume, these deposits are transferred to the account of one other firm in another node in the economy. The receiving firm is willing to accept these deposits because, as deposits are convertible with cash, a legal tender, they are the means to cancel the debts they incurred with its respective bank at the beginning of the period. In fact, they are willing to store additional deposits over the amount needed to cancel their debts as these funds will allow them not to borrow as much the following period. As these payments are made, trade determines nominal prices of each variety of the good.

As mentioned above, at the time of consumption, each worker buys goods from a random firm in the economy. Because each firm borrows from one bank only, selecting a firm is equivalent to selecting the bank the firm has asked the loan for before consumption takes place. For that, let $c(j)$ be the consumption by a worker of goods produced by a firm who has asked a loan from a bank in node j. Preferences over consumption and labor after the

[5] In words of Kiyotaki and Moore [2002] resaleability of firms' paper is zero in this economy.

taste shock is realized are described by the quasi-linear function

$$log[c(j)] - h^s, \tag{1}$$

as in Rogerson [1988] or Williamson [2008]. Let $P(j)$ be the price of the good the worker is buying. The problem of the worker is, given the wage W as well as the price $P(j)$ to choose consumption, $c(j)$, and labor h^s to maximize utility (1) subject to the budget constraint

$$P(j)c(j) = Wh^s + B. \tag{2}$$

In this expression, B is a transfer from the government which also has the form of a deposit at the same bank the worker has her wage deposited in.[6] The solution to this problem is summarized by the consumption sharing rules

$$c(j) = \frac{W}{P(j)}, \tag{3}$$

and the labor supply schedule

$$h^s = 1 - \frac{B}{W}. \tag{4}$$

An important assumption of the model has to do with the distribution of worker's taste shocks over the universe of firms and banks. For that, assume these shocks are not evenly distributed in the economy but rather clustered around firms located in particular nodes and serviced by banks also located there. The result of this clustering is that banks in node $j \in [0, 1]$ will see its firm clients receive a fraction γ of all expenditures in the economy where γ is a random variable with distribution function $\Phi_\gamma(\gamma)$, mean $E(\gamma) = 1$ and support $[0, \gamma_{max}]$.

The idea we want to capture with the shock γ is as follows. Banks in reality are not fully diversified. This lack of diversification arises because each bank provides loans to a different pool of borrowers regarding their geographical location, production sector, or some other characteristic. Because of these differences, revenues from selling their respective goods vary across each pool of borrowers. This variation in revenues affects the ability of those borrowers to pay back the loans they received from their respective banks. This is what generates the credit risk banks face and is what the idiosyncratic bank shock γ is trying to summarize. However, apart from the characterization of γ as a credit shock, we also want to highlight that this shock has a liquidity component as it is associated with payments done with deposits. Because these payments are uneven across banks, they have to be settled with reserves.

[6] This transfer is needed for the labor supply to respond to changes in the wage rate.

3.2 Investors

There is a mass one of investors outside the nodes in this economy. They do not consume and only save investing in the net worth of both banks and firms. Each of them starts the period with assets $\mathcal{A}$ split between net worth of firms, $\mathcal{N}$, and net worth of banks, $\mathcal{K}$ for all the nodes in the economy, that is,

$$\mathcal{A} = \mathcal{N} + \mathcal{K}$$

with

$$\mathcal{N} = \int_0^1 N(j)dj,$$

and

$$\mathcal{K} = \int_0^1 K(j)dj.$$

In these expressions, $N(j)$ and $K(j)$ are the initial net worth of each firm and bank in node $j \in [0, 1]$, respectively. Because all firms and banks start identical, they distribute equally these investments across nodes so that $N(j) = N = \mathcal{N}$, and $K(j) = K = \mathcal{K}$.

Denote next period values with a prime. Then, next period wealth of investors is

$$\mathcal{A}' = \mathcal{N}' + \mathcal{K}' - \mathcal{T}$$

where $\mathcal{T}$ are lump sum taxes levied by the fiscal authority. As investors do not consume, they decide how much to invest in firms and banks so that the return on each investment is equalized. That is,

$$\frac{\mathcal{N}'}{\mathcal{N}} = \frac{\mathcal{K}'}{\mathcal{K}}. \tag{5}$$

These returns are computed below.

Because each investor is small relative to the whole pool of investors, they take decisions of firms and banks as given. Next, we describe these decisions.

3.3 Firms

Each firm produces a perishable consumption good of one variety in node $j \in [0, 1]$. The firm starts the period with internal funds, N, decided by investors at the beginning of the period. As it will be clear below, these funds are in the form of deposits at a particular bank. The only input needed to produce is labor. This firm decides then how much labor, h^d, to hire to maximize expected net worth next period. However, as it was described in the problem of workers, the wage has to be paid for in advance before production takes place. Thus, in the event that initial funds N are not enough to cover for the wage bill, $W \times h^d$, the firm needs to borrow the necessary funds from the bank the firm has its initial funds deposited. This credit costs the interest i^L to be paid for at the beginning of the following period. Thus, the demand for credit by a firm is

$$L^d = max\{0, Wh^d - N\}. \tag{6}$$

After obtaining the credit and pay for the wage of its workers, the firm produces $y = (h^d)^\alpha$, where $0 < \alpha < 1$. The parameter α can be thought of as the span of control of the producer. Output is sold in the market under perfect competition at the price $P(j)$ to other workers in the economy. These revenues are obtained at the end of the period in the form of deposits in the local bank. As mentioned above, because of full convertibility into cash, deposits earn a zero net nominal rate. Firms are assumed to be risk neutral. They just accumulate wealth through producing goods and selling them.

Under limited liability, the net worth of a borrowing firm at the beginning of the following period is, then

$$N(j)' = max\{0, P(j)(h^d)^\alpha - (1 + i^L)L^d\}. \tag{7}$$

Notice next period's net worth is in the form of deposits at the local bank. Given the choice of labor demand, next period's net worth is uncertain because the price of the good $P(j)$ is stochastic at the time when production takes place. Let P_L be the break even price. This is the price of the good produced for which profits are zero, that is,

$$P_L = \frac{(1 + i^L)L^d}{(h^d)^\alpha}. \tag{8}$$

Any price below this number will make the firm default on the loan, while prices above P_L induce the firm to pay for the loan and obtain profits. As it will be clear below, the price level depends linearly and positively on the realization of the taste shock γ of the pool of firms producing on the same node. Thus, the break even price level P_L is associated with a break even level of the taste shock, call it, γ_L. Realizations of the shock below this level will generate revenues that will induce loan defaults while realizations above that level will make the firm to repay the loan and have profits. Using the definition for P_L in (8) we can write the expected profits of the firm as

$$E[N(j)'] = (h^d)^\alpha \left[\int_{\gamma_L}^{\gamma_{max}} P(\gamma)\Phi_\gamma(d\gamma) - P_L[1 - \Phi_\gamma(\gamma_L)] \right]. \tag{9}$$

In this expression, we have used the fact that price determination depends upon the realization of the shock, $P(\gamma)$.

At the time of the hiring and borrowing decisions, firms do not know yet the demand for their goods and, therefore, the revenue they will obtain when selling it. This is to say, the taste shocks γ have not realized yet. Given the initial funds, N, the wage rate, W, the bank rate, i^L, and the distribution of taste shocks which will translate into possible prices of the good $P(j)$, the firm decides labor demand, h^d, and therefore, production, y, and borrowing, L^d, to maximize expected profits (9). Notice hiring more labor will generate higher output which produces more expected revenues increasing expected profits. However, at the same time, hiring more workers implies a larger demand for credit, L^d. Thus, the threshold price for which the firm starts making profits, P_L, also increases. This effect reduces expected profits. The first order condition associated with the choice of labor demand is

$$\frac{\alpha}{1-\Phi_\gamma(\gamma_L)}\int_{\gamma_L}^{\gamma_{max}} P(\gamma)\Phi_\gamma(d\gamma) = (1+i^L)W(h^d)^{1-\alpha}. \tag{10}$$

Given the market wage, W and initial funds, N, labor demand implies a demand for credit as in (6).

3.4 Banks

3.4.1 Initial state and choices

Banks are assumed not to be fully diversified and service a pool of firms producing in the same node. Banks start the period with a balance sheet derived from decisions taken by investors. On the asset side, banks hold liquid assets, A, in the form of reserves. The liability side is composed of bank capital, K, and deposits representing internal funds of all the firms serviced by the bank, N. Thus, the initial balance sheet of the bank reads

$$A = N + K. \tag{11}$$

Banks take this initial balance sheet as given. As it will be clear below, the items in the balance sheet of the bank are the only ones transiting from one period to the next.[7]

Right at the beginning of the period, the government channels transfers to workers, B, in the form of deposits. These expenditures are paid for with reserves, held at a checking account at the central bank.[8] Banks take these transfers as exogenous. After these transfers

[7] To simplify notation, we eliminate the reference to the particular node the bank is in, $j \in [0,1]$ and write problems for a generic bank.

[8] The public sector could also use these deposits to buy goods from the economy directly. The impact of such fiscal policy is similar to the one of direct transfers and is not pursued here.

are done, banks make two decisions. First, each bank has access to the deposit and lending facilities of the central bank. With those facilities, the bank borrows, $O > 0$, or deposits $-A \leq O < 0$, units of reserves at an interest rate i^O.[9] Second, banks decide how much credit, L, to provide to the firms in their location. For that, we adhere to the idea that banks do not need existing funds to supply loans. In fact, the defining characteristics of depository institutions is precisely the ability to produce deposits when providing loans to their customers.

Thus, the balance sheet after lending is provided is

$$(O + B + A) + L = O + (N + L + B) + K = O + D + K \tag{12}$$

where $D = N + L + B$ are total deposits at the bank. All these deposits are now in the hands of workers, paid by firms as wages in exchange of labor services, $L + N$, or as direct transfers from the government, B. With all this, the bank has now two types of assets, namely, reserves, $O + B + A$, and loans provided to firms, L. On the other hand, the bank now holds three types of liabilities. The borrowing from the central bank, O, deposits owned by workers, D, and capital, K.

As mentioned above, workers spend all their deposits D to pay for their consumption. But, since expenditure by workers cover all firms in the economy and because this bank is a point in a continuum of banks, these payments imply an outflow of funds for the bank. Let $\mathbb{D} = \mathbb{N}+\mathbb{L}+\mathbb{B}$ be the aggregate flow of payments by workers for consumption goods in the whole economy. We have assumed that a random fraction of these payments are channeled to the pool of firms serviced by each bank on each node in the economy. This fraction corresponds to the realization of the shock γ of that particular node with this random variable being identically and independently distributed across nodes. Thus, firms serviced by a bank in node j receive total payments $\gamma\mathbb{D}$ for selling the good they produce. This represents an inflow of deposits by banks in that node. Then, the net inflow of funds by a particular banks j is,

$$F_\gamma = \gamma\mathbb{D} - D = \gamma(\mathbb{N} + \mathbb{L} + \mathbb{B}) - (N + L + B),$$

in the form of both, deposits and reserves. After these payments from workers, firms have $\gamma\mathbb{D}$ in deposits at their banks. Assume these funds are re-shuffled further by introducing a pure

[9] In this economy, although borrowing from the central bank is senior to all other liabilities of the bank, it is nevertheless assumed unsecured.

liquidity shock ϵ such that the amount

$$F_\epsilon = (\epsilon - 1)\gamma\mathbb{D}$$

is also moved across banks. As with the shock γ, the shock ϵ is identically and independently distributed across nodes with distribution $\Phi_\epsilon(\epsilon)$, mean $E(\epsilon) = 1$, and support $\epsilon \in [0, \epsilon_{max}]$. In summary, each firm ends up the period with $\gamma\mathbb{D}$ in deposits but only $\epsilon\gamma\mathbb{D}$ in the bank who obtained the loan from. The rest of deposits is scattered in accounts in other banks doing business in other nodes.[10]

The total flow of funds for a single bank after these two shocks are realized is then

$$F = F_\gamma + F_\epsilon = \gamma\epsilon\mathbb{D} - D.$$

This flow of funds represents a net transfer of both reserves and deposits between one bank and the rest of banks. Then, bank deposits at the end of the period are

$$D + F = \gamma\epsilon\mathbb{D}.$$

The reserve position of the bank in node j at the end of the period, R, is then equal to the initial reserve, $O + B + A$, plus the net flow of funds, F,

$$R = O + B + A + F = O + B + A + \gamma\epsilon\mathbb{D} - D. \tag{13}$$

Because the realizations of both shocks are specific to each node, the balance sheet of the bank in the same node is as follows

$$R + L = O + \gamma\epsilon\mathbb{D} + K.$$

At this point, it is important to discuss the role reserves play in this economy. At the time banks have to make payments, F, they have to transfer an asset together with the deposits. Absent reserves, these banks only have loans, L. We assume this class of assets is not acceptable as general means to settle debts between banks.[11] Thus, to fulfill these payment flows, banks need a generally accepted means of payments. Central banks offer such service by providing units of account in the form of reserves, the same way private banks offer

[10]We could interpret the shock ϵ in a variety of ways. On the one hand, this shock could reflect payment delays or trade credit between firms. On the other hand, firms could have temporary deposit accounts in other banks to manage payments, although they only deal with one bank when they asked for a loan at the beginning of the period.

[11]We could think of frictions such as costs to transfer ownership of information sensitive assets such as loans.

that service to the nonfinancial sector, i.e., firms and workers.

3.4.2 Interbank market

Banks cannot end up the period with a negative reserve position. To this end, an interbank market opens where banks with reserve deficits ($R < 0$) borrow funds from banks with positive reserve holdings. The interest rate received in this interbank market is i^R. Because there is possibility of default, borrowing banks pay a risk premium of $s(R)$. Notice this risk premium can depend, and, in fact, will depend, on the reserve position of the bank. Using (13), a bank will borrow funds in the interbank market when $R < 0$, or, in other words, when

$$\gamma\epsilon < \frac{D - O - B - A}{\mathbb{D}} = \frac{L + N - O - A}{\mathbb{D}} \equiv \gamma_R. \tag{14}$$

That is, producing more deposits through the provision of loans, has a liquidity cost as it increases the probability of borrowing from the interbank market. This is because it increases the threshold level γ_R. On the other hand, accumulating reserves by borrowing from the central bank, O, reduces that possibility.[12]

3.4.3 Settlement of financial positions

At the beginning of the following period, all financial positions are settled and interest is paid on them. First, interests on the central bank facilities, i^O, are paid if the bank used the lending facility, or received if the deposit facility was used instead. These payments are done in reserves. Then, the balance sheet of the bank at this point is

$$R - (1 + i^O)O + L = \gamma\epsilon\mathbb{D} + (K - i^O O).$$

Next, deposits and loans are settled. For that, the temporary liquidity shock ϵ is reversed as firms collect their deposits to pay back their loans. That is,

$$R - F_\epsilon - (1 + i^O)O + L = \gamma\mathbb{D} + (K - i^O O).$$

Then, each firm starts with deposits $\gamma\mathbb{D}$ and faces the payment of $(1+i^L)L$. Thus, the firms in this location will be able to pay the loan to the bank whenever the realization of the demand shock satisfies

$$\gamma \geq (1 + i^L)\frac{L}{\mathbb{D}} \equiv \gamma_L. \tag{15}$$

[12]Here, we assume by the time the bank realizes it has a reserve deficiency the only margin banks have is to borrow in the interbank market and cannot access the lending facility of the central bank.

Other things equal, higher realizations of the demand shock γ induce larger revenues for firms in the same location which makes it easier for them to repay the loan. The value γ_L provides the threshold value for the demand shock γ that separates banks where firms repay their loans from banks where firms default on their loans. In this sense, assuming a symmetric equilibrium where all agents make similar choices, the non performing loan (NPL) rate for the economy as a whole would be $\Phi_\gamma(\gamma_L)$.[13]

Thus, in the event that firms are able to pay back the loan, so that they receive a realization for γ such that $\gamma \geq \gamma_L$, the beginning of period balance sheet of the bank where these firms are operating would be

$$R - F_\epsilon - (1 + i^O)O = [\gamma\mathbb{D} - (1 + i^L)L] + [K - i^O O + i^L L - \gamma\mathbb{D}].$$

That is, the bank maintains its interbank position, R, yet to be settled, while pays (receives if negative) the cost of borrowing (revenue of depositing) reserves from (at) the central bank, $(1 + i^O)O$. On the liability side, firms keep the remaining deposits after loans are paid off, $\gamma\mathbb{D} - (1 + i^L)L$. To the initial capital, K, the bank then adds the remuneration of loans and subtract the costs of borrowing from the central bank and its deposits.

On the contrary, if firms' revenues are not enough to cover for the repayment of their loans, so that $\gamma < \gamma_L$, those loans are written off from the balance sheet and represent a loss for the bank. In the context of the current model, this means the beginning of period balance sheet of the bank would now be

$$R - F_\epsilon - (1 + i^O)O = K - i^O O + \gamma\mathbb{D} - L. \tag{16}$$

That is, the bank still pays the cost of reserves from the central bank, $(1 + i^O)O$. However, on the liability side, existing deposits are written off together with the loans of the firms. Whatever loans cannot be recovered with existing firms' deposits is a loss for the bank.

Clearly, firms defaulting on their loans can erase bank's capital. In fact, if banks make enough losses in their loan portfolio they could become insolvent. In other words, a bank will be solvent as long as its capital, as measured by the right hand side of expression (16), is positive. This implies a threshold value for the demand shock γ, call it, γ_K, separating solvent from insolvent banks. That is, the bank will remain solvent as long as

$$\gamma \geq \frac{L - K + i^O O}{\mathbb{D}} \equiv \gamma_K. \tag{17}$$

[13] Notice that, for an individual bank, either all loans are repaid or, else, all of them are defaulted upon.

Notice we evaluate the possibility of insolvency only in the event that firms default on their loans, that is, whenever $\gamma < \gamma_L$. Insolvency in general will not happen otherwise.[14]

We can now understand the role of the liquidity shock ϵ. The shock γ affects the liquidity position of the bank. This is because it determines how much funds enter the bank relative to those funds leaving it. At the same time, it also determines whether the bank is solvent or not as it tells the fraction of loans that are repaid, as summarized by the threshold γ_K. If this was the only shock banks face, their demand for funds in the interbank market would be enough for lenders to know if the borrowing bank is insolvent or not. Thus, the role of ϵ is to detach liquidity positions from solvency issues at the time of trading in the interbank market.

Finally, there is the settlement of interbank positions, the junior asset in this economy. If the bank was borrowing in the interbank market (so that $R < 0$ because $\epsilon\gamma < \gamma_R$) the bank will pay (if solvent) the amount $[i^R + s(R)]R$. On the other hand, if the bank had an excess of reserves (so that $R > 0$ because $\epsilon\gamma > \gamma_R$) and lends in the interbank market, its revenues will be $i^R R$. The balance sheet of a solvent bank at the end of settlement would then be, if firms pay back their loans ($\gamma \geq \gamma_L$),

$$\begin{aligned} R - F_\epsilon - (1+i^O)O + min[i^R R; (i^R + s(R))R] &= [\gamma\mathbb{D} - (1+i^L)L] \\ + K - i^O O + i^L L - \gamma\mathbb{D} + min[i^R R; (i^R + s(R))R]. \end{aligned} \tag{18}$$

while if firms default but the bank is still solvent ($\gamma_K \leq \gamma < \gamma_L$),

$$\begin{aligned} R - F_\epsilon - (1+i^O)O + min[i^R R; (i^R + s(R))R] \\ = K - i^O O + \gamma\mathbb{D} - L + min[i^R R; (i^R + s(R))R]. \end{aligned} \tag{19}$$

3.4.4 Choices by banks

For a particular value of γ, call it $\underline{\gamma}$, define the function

$$G(\underline{\gamma}) = \int_{\underline{\gamma}}^{\gamma_{max}} \gamma\Phi_\gamma(d\gamma) - \underline{\gamma}[1 - \Phi(\underline{\gamma})]. \tag{20}$$

Then, as shown in the Appendix, the expected net worth of an individual bank next period equals

$$E(K') = \mathbb{D}\left[G(\gamma_K) - G(\gamma_L)\right] + \Pi(O, L) \tag{21}$$

[14] Another possibility for banks to be insolvent could be that they borrow large amounts in the interbank market they will not be able to repay later. However, this will never be an optimal choice for banks and we do not consider it.

where

$$\Pi(O,L) = i^R \int_{\gamma_K}^{\gamma_{max}} \int_0^{\epsilon_{max}} R\Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma) + \int_{\gamma_K}^{\gamma_{max}} \int_0^{\frac{\gamma_R}{\gamma}} s(R)R\Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma) \tag{22}$$

is the net profit of trading in the interbank market. The bank then chooses borrowing from, depositing to, the central bank, O, and the supply of credit, L, to maximize expected net worth next period (21). Notice, choosing these two variables, together with the idiosyncratic realization of the shocks γ and ϵ, determine the reserve position of the bank, R, as defined in (13). The first order conditions with respect to O, and L are, respectively,

$$i^O = i^R + \frac{1}{1-\Phi_\gamma(\gamma_K)} \int_{\gamma_K}^{\gamma_{max}} s(R)\Phi_\epsilon\left(\frac{\gamma_R}{\gamma}\right)\Phi_\gamma(d\gamma), \tag{23}$$

and

$$(1+i^L)[1-\Phi_\gamma(\gamma_L)] = (1+i^O)[1-\Phi_\gamma(\gamma_K)]. \tag{24}$$

Expression (23) relates the pricing of funds in the interbank market, as summarized by the rate i^R and the premium $s(R)$, with the cost of reserves as determined by the central bank, i^O. Although the revenue interbank lenders get is below the official rate, $i^R < i^O$, it can be easily shown that the rate borrowers pay is larger, namely, $i^O < i^R + s(R)$, for all $R < 0$. Below we show how the spread of borrowing banks, $s(R)$ responds to individual bank characteristics. On the other hand, expression (24) defines a loan supply curve. It expresses the amount of loans provided by a bank, L, as a function of the loan rate, i^L, given the policy rate, i^O, and its initial capital, K, as well as aggregate quantities like aggregate deposits, $\mathbb{D}$. The supply of loans equate the expected marginal revenue of lending, expressed by the lending rate, to the marginal expected cost. Since deposits created when lending leave the bank, the relevant cost is associated with the rate to be paid to fund this outflow of funds, i^O. Because of limited liability, both these revenues and costs are multiplied by the probability that firms repay the loan and the probability that the bank remains solvent, respectively.

3.4.5 Liquidity risk, credit risk, solvency risk and lending

At this point we see the model has produced three thresholds for the demand shock γ. These are the value separating liquid and illiquid banks, γ_R,[15] the value determining whether firms pay back their loans or not, γ_L, and the value below which banks become insolvent, γ_K. Larger values for these thresholds increase the liquidity risk, γ_R, the credit risk, γ_L, and the solvency risk, γ_K, of banks. By looking at expressions (14), (15), and (17), we can see that,

[15] Conditioned on the pure liquidity shock ϵ to be equal to its mean, $E(\epsilon) = 1$.

given initial conditions of the bank as measured by initial assets, A, and liabilities, K and N, as well as the population value of deposits, $\mathbb{D}$, and prices, i^L, and i^O, larger loan production, L, jointly increases all of these risks for a single bank. Because these risks affect the expected profits of the bank, as summarized in (21), they are the endogenous limits to the expansion of the bank's balance sheet through the choice of loans and deposits provision. Furthermore, in general, it will be the case that $\gamma_K < \gamma_L < \gamma_R$. That is, relatively bad realizations of the demand shock first make the bank being illiquid. Worse realizations produce firms to default on their loans and only with very bad draws will the bank become insolvent.

To understand how these risks affect the lending decision by banks, it is useful to plot the thresholds γ_R, γ_L and γ_K from expressions (14), (15) and (17) in the (γ, ϵ) plane as done in figure 1. First, expression (14) separates liquid from illiquid banks. It is represented by the decreasing green curve in figure 1. Banks placed below that schedule will have relatively low realizations of payment shocks γ and ϵ so that they will be iliquid and will be borrowing funds in the interbank market. Banks placed above that schedule will be liquid and lending in that market. Second, expression (15) separates banks with defaulting loans from banks with conforming loans. It is represented by the blue vertical line. Banks whose realization for γ are placed to the left of the line have firms defaulting on their loans while those to the right have firms paying those loans back in full. Finally, expression (17) determines, given the initial situation of the bank and its choices, the level of the shock γ separating solvent and insolvent banks. It is represented as the vertical red line in figure 1. Banks whose realization for γ are placed to the left of the line are insolvent and those to the right are solvent. In this manner, expressions (14), (15) and (17) divide the population of banks in six groups regarding their liquid/illiquid, performing/non-performing loans and solvency/insolvency situation.

Each of these six areas in figure 1 contribute differently towards expected profits of the bank. To concentrate on some examples, the area to the left of the threshold γ_K contributes $-K$ since there the bank is insolvent and losses all capital. The area to the right of threshold γ_L and above the locus for γ_R contributes with profits from lending to firms that pay back their loans combined with revenues from lending in the interbank market. Furthermore, to the right of γ_L but below the locus γ_R the bank earns rents from lending to firms but pays the cost of borrowing from other banks. Notice, other things equal, a larger provision of credit, L, pushes expressions (14), (15) and (17) to the right increasing the areas of insolvency, firm defaults and illiquidity. Thus, given market rates, in deciding the optimal amount of lending, the bank compares the change in revenues and costs associated with this decision.

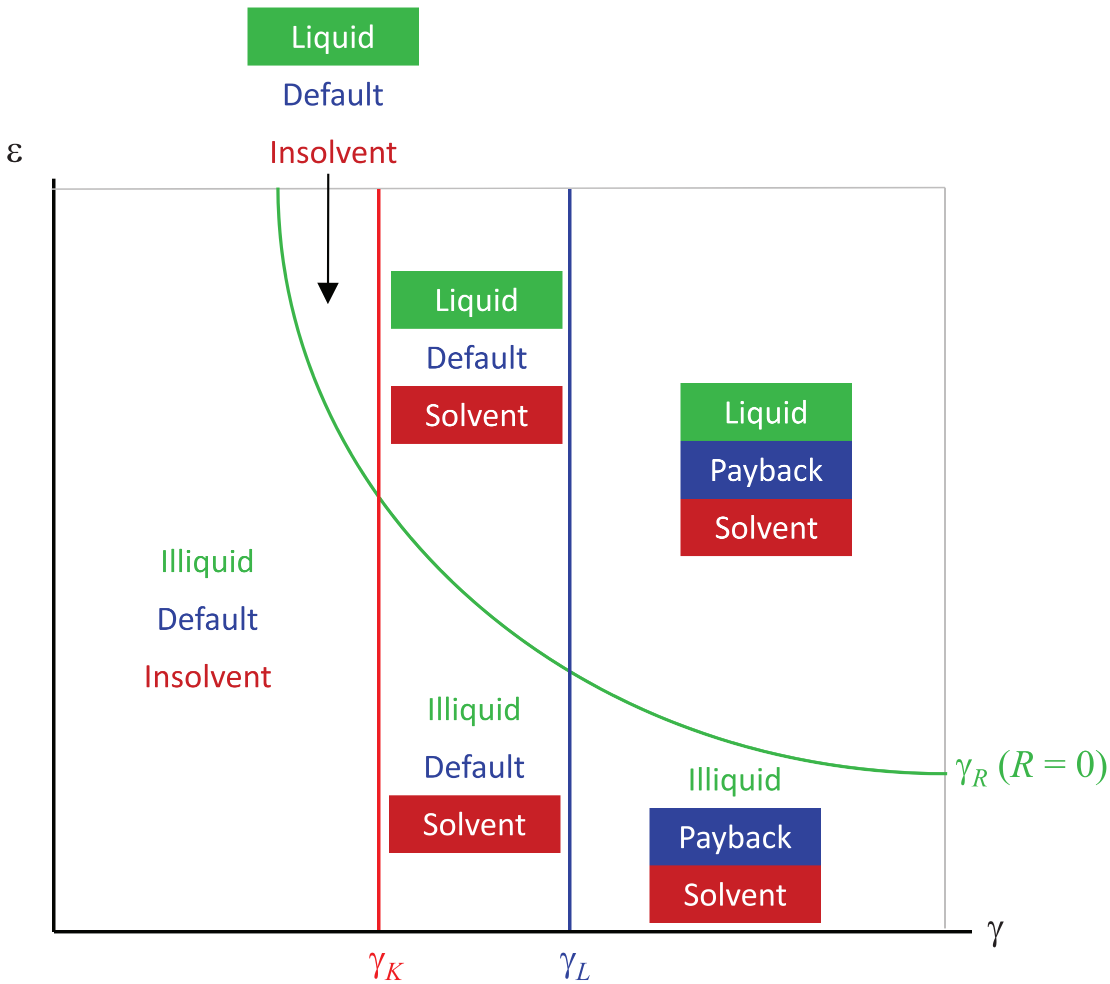

Figure 1: Solvency, credit, and liquidity risks

3.5 Consolidation of accounts

The settlement of individual bank and firm positions results in a distribution of net worth of banks, $K(j)'$, and firms, $N(j)'$, across all nodes in the economy. At the beginning of each period, after settling individual positions, investors pool the net worth of the distribution of banks and firms. For the conglomerate of firms, assuming all of them have taken the same decisions through the previous period, consolidating their net worth would imply an aggregate net worth for each investor of

$$\mathcal{N}' = \mathbb{D}G(\gamma_L), \tag{25}$$

where the function $G(\gamma)$ was defined in (20). Notice the resulting net worth of the conglomerate of firms is in the form of deposits in all the banks.

Regarding the conglomerate across all banks, the next period consolidated balance sheet would be

$$\mathcal{A}' = \mathcal{N}' + \mathcal{K}' - \mathcal{T}. \tag{26}$$

In this expression

$$\mathcal{A}' = \mathcal{A} + B - i^O O - \mathcal{T}, \tag{27}$$

is the resulting accumulated level of reserves the conglomerate ends up with while

$$\mathcal{K}' = \mathbb{D}\left[G(\gamma_K) - G(\gamma_L)\right], \tag{28}$$

is the resulting accumulated bank capital next period. In these expressions we are using the fact that all firms and banks make the same decisions. Furthermore, $\mathcal{T}$ is lump sum taxes levied on investors' net worth and paid in reserves. Then, expressions (25) and (28) are used to compute the returns to firm funds and bank capital in (5).

The following period, once net worth from banks and firms are accumulated, investors allocate initial assets to each individual firm and bank. Because, exante, all firms and banks are identical, these funds are equally distributed across firms and banks so that firms start next period with $N' = \mathcal{N}'$ and banks start with $K' = \mathcal{K}'$ and the process reproduces itself.

3.6 The government

The government is composed of a central bank and a fiscal authority. The central bank provides or drains reserves, $\mathbb{O}$, in the aggregate, with its two facilities at the rate i^O and monetizes the transfers to workers, $\mathbb{B}$, introduced by the fiscal authority. This fiscal authority also levies lump sum taxes on investors. Assuming a balanced budget, the government budget constraint is then simply

$$\mathbb{A}' = \mathbb{A} + \mathbb{B} - i^O \mathbb{O} - \mathbb{T}. \tag{29}$$

The left hand side represents next period liabilities in the form of reserves. The right hand side includes the initial aggregate liabilities plus aggregate transfers, $\mathbb{B}$, minus the aggregate net revenues arising from banks using the central bank facilities, $\mathbb{O}$, and the aggregate lump sum taxes imposed on the net worth of investors, $\mathbb{T}$. We assume the government treats all investors, workers, and banks equally so $\mathbb{B} = B$ and $\mathbb{T} = \mathcal{T}$. Furthermore, in a symmetric equilibrium, all banks make the same decisions so $\mathbb{O} = O$.

3.7 Discussion

In this economy, each worker contributes to the production of one good but consumes from a different firm in a different node randomly assigned to her. Once all decisions are taken, consumption expenditures by workers are unevenly distributed across nodes. This crucial assumption incorporates the idea that banks are not fully diversified in their credit risks. Because production is predetermined, a larger flow of payments generates larger revenues for the corresponding firms which, in turn, will be able to pay back the loans they asked for before. On top of these payment shocks, labeled γ in the model, we incorporate other, pure liquidity shock, ϵ, to detach the liquidity position of banks from their solvency situation.

In this model, there are five important frictions we assume. First, because of the nature of production and preferences, private IOUs issued by any firm have no market value for other firms in different nodes. This is because the good is perishable and because of the continuum of workers and firms, finding the right person to trade these IOUs with would be impossible. In other words, there is no double coincidence of wants. Banks can represent a cheap and implementable alternative to these markets in firms' IOUs. In this way, banks are in charge of producing the units of account, i.e. deposits, used to keep track of trades among workers and firms. Similarly, the second friction has to do with banks not having assets generally acceptable by other banks at the time payment flows occur. For that problem, the central bank acts as a bank of banks and issue reserves tracking down the net payment flows between banks. What this model exploits is the connection between the production of inside money when producing loans and the risks associated with providing credit to the economy. Furthermore, monetary policy affects this connection by fixing the cost of the outside money needed to settle the corresponding payment flows. The third friction assumes that banks cannot infer credit risks from deposit flows. In other words, they observe the product $\epsilon\gamma$ and not each component separately.

The fourth friction has to do with restricting firms to borrow from only a bank (or a collection of banks) in its very same node. Finally, the fifth friction imposes that neither workers, firms or banks can insure against the idiosyncratic payment shocks occurring at the node level. In this sense, we could generalize the model by allowing firms to borrow from a subset of banks in different nodes or include the possibility of some insurance. We could also complicate the model by adding the possibility that firms and bankers consume too. Or by allowing workers to borrow or save. However, as long as there is no full insurance against payment shocks, agents will need financial liquidity to settle trade positions, there would be payment flows with liquidity, credit, and solvency risks involved, and the results found in this paper would still apply,

Ultimately, the risk firms face in this economy is the inability to attract enough revenue to pay back the loan they asked for. If severe enough, this credit risk can generate insolvency in the banks that created those means of payments in the first place. Notice this is not an issue of asymmetric information between borrowers and lenders but the inability of the existing financial intermediaries to fully insure against the payment risks in the economy. This is the crucial friction behind the results produced with this model.

3.8 Equilibrium

Market clearing conditions are as follows. Market clearing for labor means that

$$h^s = h^d = h \tag{30}$$

for all workers and firms where labor supply is given by (4) and labor demand by (10). Thus, output for every firm is $y = h^\alpha$ and market clearing for goods imply

$$\gamma c(j) = h^\alpha \tag{31}$$

for all $j \in [0, 1]$, where γ is the realization of taste shocks for that particular node. Furthermore, given clearing in the labor market, for the loan market to clear it has to be the case that

$$L^d = Wh - N = L, \tag{32}$$

for all banks. Finally, clearing in the interbank market implies

$$\int_0^1 R(j)dj = 0. \tag{33}$$

We define a symmetric equilibrium as follows. The appendix shows how to compute it.

Definition (Symmetric competitive equilibrium). *Given a monetary policy as defined by the official rate, i^o, and a fiscal policy as defined by equal taxes to all investors, $\mathcal{T} = \mathbb{T}$, and equal transfers to all workers, $B = \mathbb{B}$, a symmetric competitive equilibrium is a set of prices $\{P(j)\}$, for all $j \in [0,1]$, interest rates, i^L and i^R, risk premia, $s(R)$, aggregate allocations, $\mathbb{O}$, $\mathbb{N}$ and $\mathbb{K}$, as well as individual allocations $\{c(j), h, y, K, N, O, L, R(j)\}$, for all $j \in [0,1]$ such that, (i) given prices and risk premia, individual allocations solve the problems of all workers, investors, firms and banks, (ii) markets for goods, labor, loans and reserves clear, (iii) individual choices coincide with aggregate ones, and (iv) the government budget constraint is satisfied.*

4 Results

4.1 Calibration

The solution is neutral with respect to the value of the initial liquid bank assets $\mathbb{A}$. For this reason, we normalize this variable to be $\mathbb{A} = 1$. Then, the model contains only one parameter, two distributions, and two policy variables to calibrate. These are the span of control, α, the distributions of shocks, $\Phi_\gamma(\gamma)$ and $\Phi_\epsilon(\epsilon)$, as well as the policy rate i^O and the transfers from the government, B.

Among the parameters of the model, we set the value of the span of control to $\alpha = 0.85$ as in Atkeson and Kehoe [2005]. The rest of parameters are calibrated using quarterly data for the US between the first quarter of 1986 until the fourth quarter of 2021. This is the period for which we could retrieve data for most of the variables considered. In the baseline, we fix the value for the policy rate, i^O, to be 3 percent which corresponds to the average of the federal funds rate (FFR) over that time period. Furthermore, we assume normal distribution functions for γ and ϵ. We truncate these distributions at 0 but given the means and standard deviations used below, the errors from imposing the truncation as compared with the untruncated densities are insignificant. We fix the means of these distributions to be $\mu_\gamma = \mu_\epsilon = 1$ so that, on average, no funds enter or leave the banks. The standard deviations, σ_γ and σ_ϵ, and the transfer from the government, B, are calibrated to match three targets. One of the targets is the average risk premium in the interbank market as measured by the TED spread, that is, the difference between the 3-month LIBOR and the 3-month T-Bill. In the model this number is approximated by the weighted average risk premia, $s(R)$, where the weights are the fraction of total borrowing by each borrowing bank, which we denote by ρ.

We also use quarterly data from the Flow of funds accounts of the US to match two ratios the balance sheet of banks. These two ratios are leverage, L/K, and deposits to loans, D/L.[16]

Table 1 presents the calibration exercise. As the table shows, the calibrated value for the parameters are $\sigma_\gamma = 0.22$, $\sigma_\epsilon = 0.204$, and $B = 0.5$. With these values we closely match the data targets on the TED spread, bank leverage and the ratio of the ratio of deposits to loans. Below these targets we also include comparisons of other variables we have data for. First, the model gets close to the NPL ratio although it falls a little bit short of approximating the fraction of insolvent banks. In the model, these two ratios are measured by the distribution $\Phi_\gamma(\gamma)$ evaluated at the firm default threshold, γ_L, and the bank insolvency threshold, γ_K, respectively. Finally, the model also closely matches the size of the nonfinancial sector as measured by the endogenous variable N.

External parameters					
Param.	Value	Source			
α	0.85	Taken from Atkeson and Kehoe [2005]			
Targeted moments					
Param.	Value	Variable	Meaning	Data	Model
i^O	0.03	i^O	Federal funds rate	0.03	0.03
σ_γ	0.22	L/K	Bank leverage	7.3	7.2
σ_ϵ	0.204	$\int_0^1 \rho \times s(R)dj$	TED spread	0.55	0.55
B	0.5	D/L	Deposits to loans	1.2	1.7
Untargeted moments					
		Variable	Meaning	Data	Model
		$\Phi_\gamma(\gamma_L)$	NPL ratio	0.021	0.023
		$\Phi_\gamma(\gamma_K)$	Insolvent banks	0.013	0.006
		N	Size of nonfinancial sector	0.828	0.792

Table 1: Calibration and model fit

Figure 2 shows loan supply (denoted Ls in the figure) and demand (denoted Ld) for the calibrated values of parameters and the equilibrium values for other variables such as the net worth of firms, N, or bank capital, K.[17] We can see how supply is inelastic at the level of the official rate i^O which in this case equals 0.03 (or 3 percent). Also, loan supply is backward bending. Given the capital of the bank, increases in the lending rate i^L raise marginal revenues inducing the bank to lend more. However, more credit provision also increases risks for the bank, as measured by thresholds γ_R, γ_L and γ_K. As this process continues, there is a point where these risks have grown so much that it is not worth it for the bank to increase lending

[16]The appendix includes information of the data used in the calibration and in the model fit below.
[17]Please notice lending rates are in the horizontal axis while loan quantities are in the vertical axis.

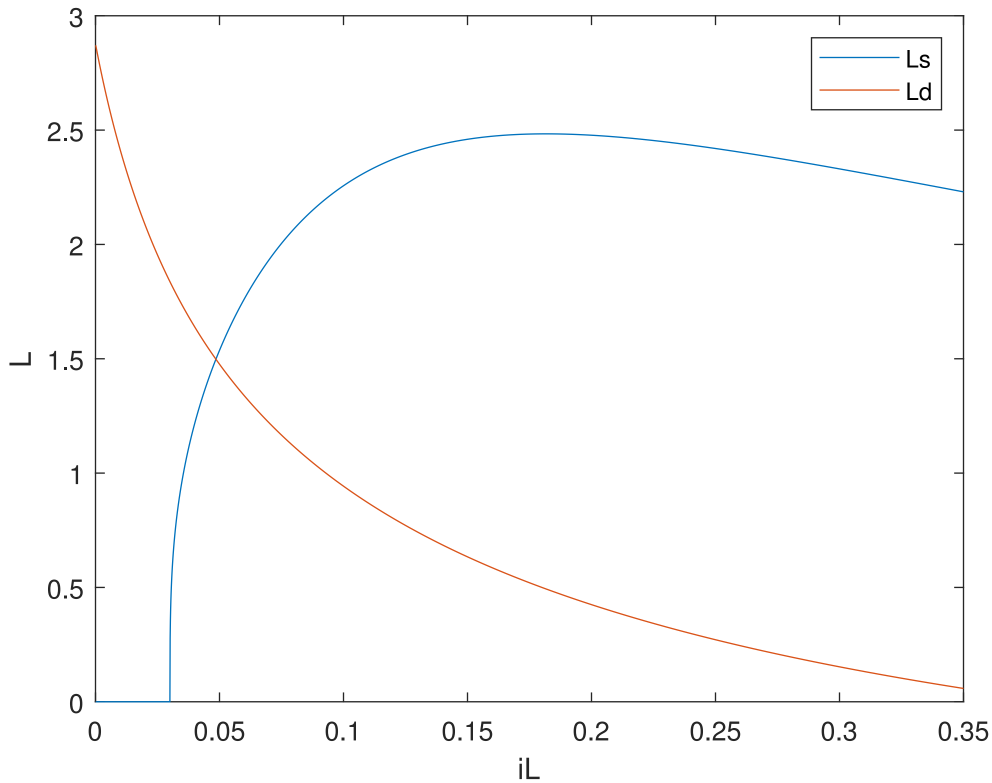

Figure 2: Loan supply and demand

further as a response to larger lending rates. In fact, beyond that point the bank reduces its credit provision for further increases in lending rates. This is the tipping point of the loan supply curve depicted in figure 2. Notice, unlike models with agency problems, the supply schedule is backward bending despite information being symmetric between borrowers and lenders.

4.2 The lending channel redux

In our model, changes in the policy rate i^O engineered by the central bank have effects in the economy. The transmission mechanism works as follows. As the central bank raises the policy rate, commercial banks find that liquidity is costlier. In terms of figure 1, the cost associated with the area below the threshold γ_R has increased while revenues stay the same. Thus, profits decrease. Banks respond by cutting on lending. Thus, as the policy rate increases, loan demand stays the same, but loan supply moves to the right (with curves depicted as in figure 2 where lending rates are in the horizontal axis and quantities in the vertical axis). This

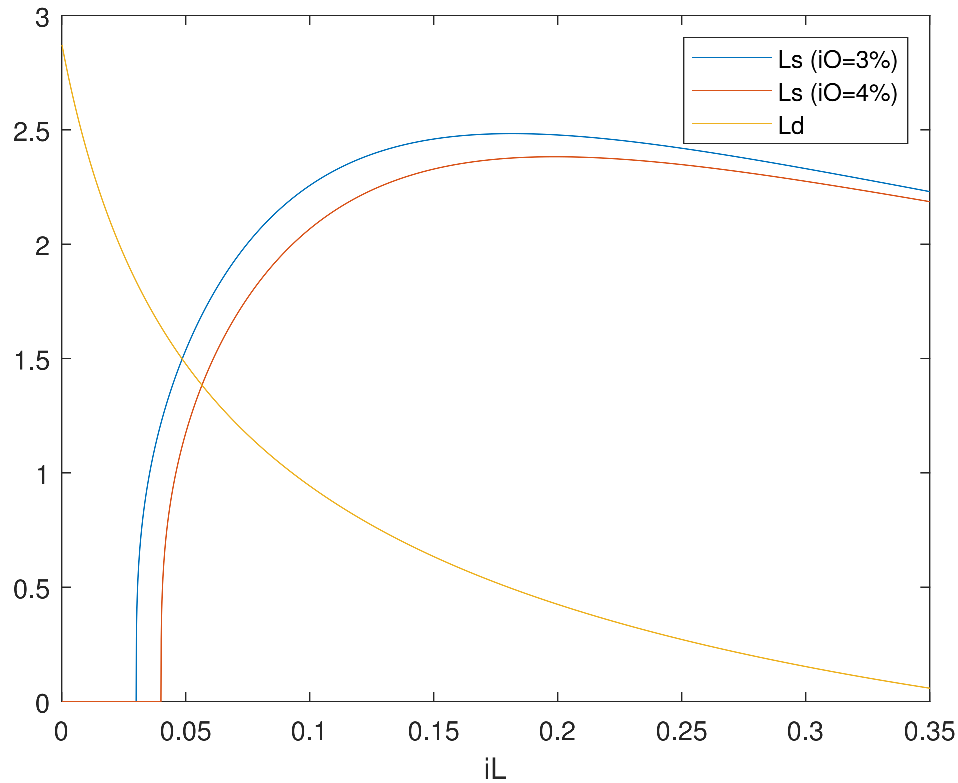

Figure 3: Effect of an increase in the policy rate on the loan market

is shown in figure 3 for a change of the policy rate from 3 percent to 4 percent. This increase in lending rates generates a reduction in the amount of lending along the loan demand curve. Because deposit rates are kept constant at zero, the increase in the lending rate caused by the raise in policy rates automatically widens the net interest margin of banks as well as the deposit spread with respect to the official rate.

Figure 4 shows the effect of permanently keeping the official rate at different values between 1 percent and 10 percent. The top left figure shows the spread between the lending rate, i^L, and the policy rate, i^O. We see the lending rate increases with the policy rate, making borrowing costlier for firms. Consequently, if we move to the right and from top to bottom in figure 4, lending, L, decreases. Deposits, D, also fall. The reason is twofold. On the one hand, the creation of new deposits is smaller because lending has dropped. On the other hand, net worth of firms, N, which are maintained as deposits, also falls. The cut on lending also reduces bank leverage, L/K. The increase in the cost of borrowing together with the financial repression generated by the hikes in official rates, make hiring more expensive which lowers the demand for labor depressing the economy with lower levels of output, y, and prices, W. This downturn is more pronounced the more contractionary monetary policy is. Furthermore, the last panel presents the NPL ratio of banks, $\Phi(\gamma_L)$ (denoted as PhiL), as well as the fraction of insolvent banks, $\Phi(\gamma_K)$ (denoted as PhiK). Interestingly, looser monetary policy, generated with lower policy rates, induces an increase in risk associated with these two margins. This is what the literature has labeled the risk-taking channel of monetary policy. Importantly, in our economy, ex ante, all borrowers have the same risk. Thus, the larger exposure of banks as a response to monetary policy loosening is not due to banks reaching a pool of riskier borrowers. Instead, this increase in risk is just a consequence of the expansion of credit by banks as the cost of funds decrease. The easing of monetary policy induces banks to expand credit compensating the reduction in costs with larger values for the thresholds γ_K and γ_L.

As figure 4 shows, in our model, monetary policy has long run effects. That is, the economy sits on a different real equilibrium for each particular level of the official rate. Furthermore, in this economy, there are no transitions as we are assuming investors can reallocate funds between firms and banks instantly to equate the return on these investments. This was shown in the fourth panel of figure 4. As the policy rate increases, the return on investing in bank capital rises above that of initial firm funds. Investors respond to this change by channeling less funds to firms and more to banks.

One way to generate transitions in our model is to shut down the possibility of investors to reallocate funds every period. Instead assume, investors start period 1 with the corresponding split of funds, $1 = N + K$ associated with the baseline policy rate $i_1^O = 0.03$. On period $t = 2$ the official rate is increased to $i_2^O = 0.04$. After that, the official interest rate slowly returns to its initial value of 3 percent assuming a smoothing parameter of $\delta = 0.75$. That is to say, the official rate follows the expression

$$i_t^O = \delta i_{t-1}^O + (1-\delta) i_1^O,$$

for all $t \geq 3$. As official rates are moving, we do not allow investors to transfer funds between banks and firms but, instead, they just accumulate funds in each investment from profits separately.

Figure 5 shows the transition. The top left panel shows the exogenous path followed by the official rate, i_t^O. Going left and down in the figure, the second panel presents the equilibrium lending rate, i_t^L. This rate follows the path of the official rate. The two panels on the second row include the evolution of firm funds, N_t and bank capital, K_t, respectively, as proportions of the steady state associated with the initial official rate, $i_1^O = 0.03$. As mentioned above, raising interest rates is profitable for banks and costly for firms. Accordingly, net worth of firms decrease and that of banks increase. As interest rates return to their original levels, so

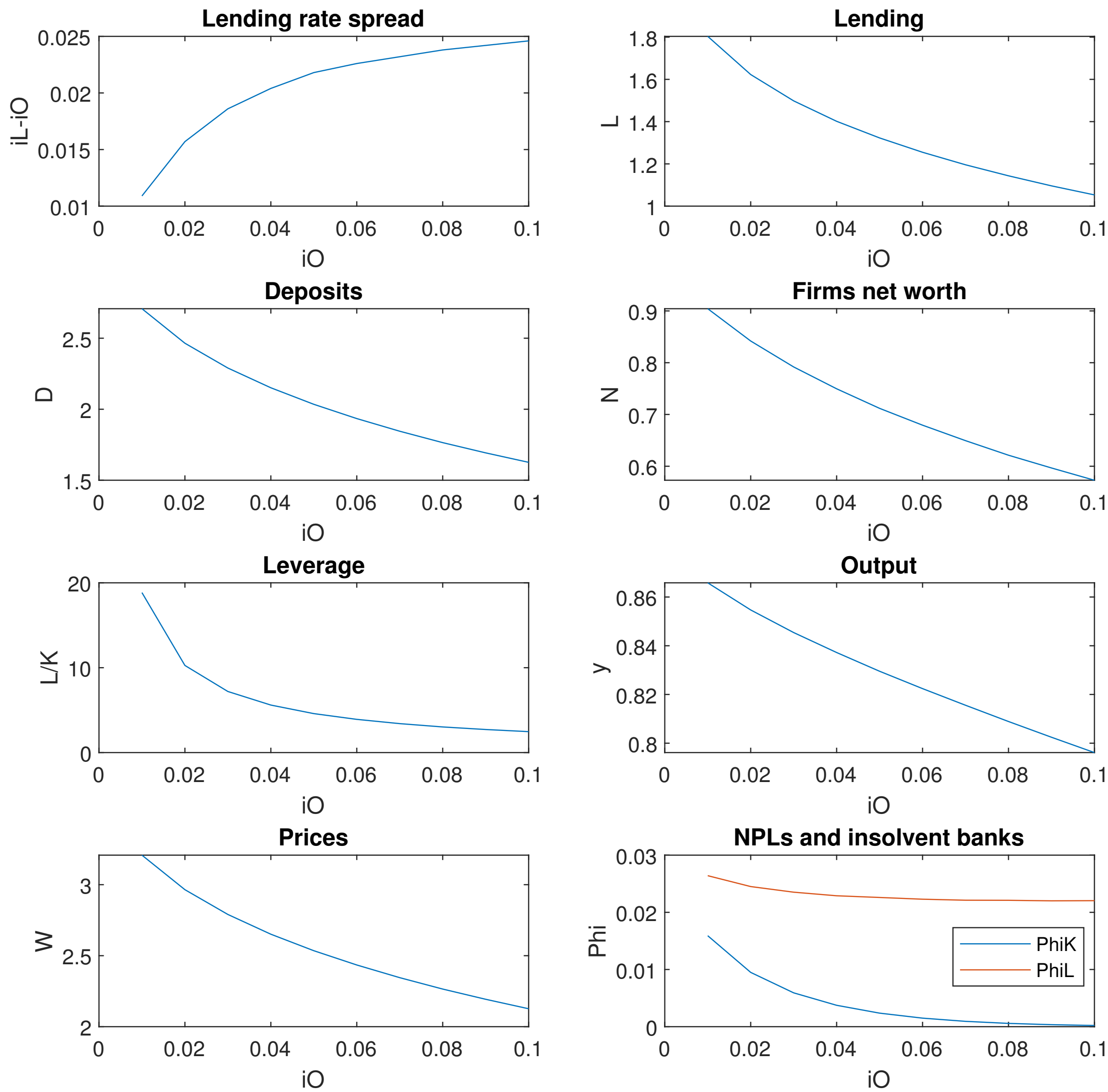

Figure 4: Equilibrium for different policy rates

does net worth. The rising interest rates generates a reduction in lending causing a recession with a temporary drop in output and prices. The reduction in both lending, L and finrms net worth, N produce a reduction in deposits, $D = L+N$, not shown here. Notice the combination of a drop in deposits together with a widening of deposit spreads is what Drechsler et al. [2017] identify as the deposit channel of monetary policy. However, our results show that the same correlation can be obtained with reverse causation where it is changes in loan supply by banks what is driving the drop in deposits. Finally, the rise in bank capital and the drop in lending reduces bank leverage.

4.3 Risk premium in the interbank market

Carvalho et al. [2022], Aymanns et al. [2016], Schmitz et al. [2017] and Arnould et al. [2022] present evidence on how solvency ratios are negatively related to bank funding costs. These authors notice that this negative relationship is stronger for funding sources more sensitive to market pressure, such as interbank lending. For example, Aymanns et al. [2016] estimated that a 1 percent reduction in the level of solvency is associated with a significant increase of 4 basis points in wholesale funding costs. Interestingly, they also note that bank's liquidity position negatively affects funding costs, a result also found in Ashcraft and Bleakley [2006].

To understand the determination of the risk premium borrowing banks have to pay in the interbank market, $s(R)$, it is useful to plot the combination of realizations for the shocks γ and ϵ generating a particular reserve position. Using expression (13), a bank with a given initial state and decisions on endogenous variables would end up with a specific reserve position, call it $\bar{R}$, if the realizations of the shocks fulfill the expression

$$\gamma\epsilon = \frac{\bar{R} + D - O - A - B}{\mathbb{D}} = \frac{\bar{R}}{\mathbb{D}} + \gamma_R. \tag{34}$$

Figure 6 includes two of such schedules for two different negative levels for the reserve position of a bank, $\bar{R}_{low}$ and $\bar{R}_{high}$, such that $\left|\bar{R}_{low}\right| < \left|\bar{R}_{high}\right|$. Notice the schedule with the largest borrowing, $\bar{R}_{high}$, is below the one with banks borrowing less, $\bar{R}_{low}$. Furthermore, the section of these schedules in the region to the left of the vertical line associated with the value for γ_K, represent realizations of the shocks inducing the bank to be insolvent and, therefore, will imply a default on the interbank loan.

Then, the question for an interbank lender is: given the balance sheet of a borrowing bank (which is public information), what would be the likelihood that an interbank loan of size $\bar{R}$ will get repaid. This will happen whenever the realization of the γ shock is above the solvency

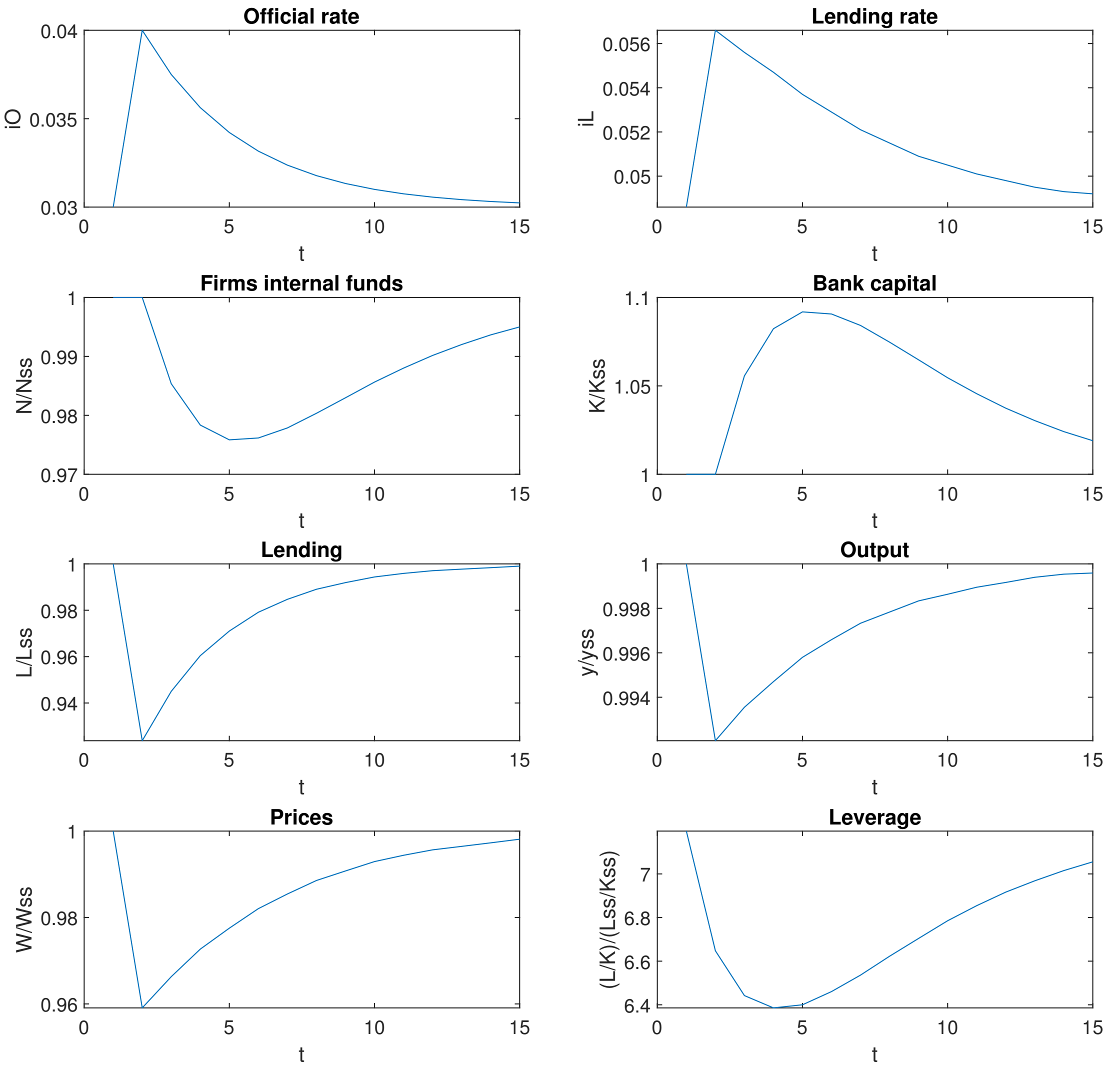

Figure 5: Transition from a temporary increase in the official rate

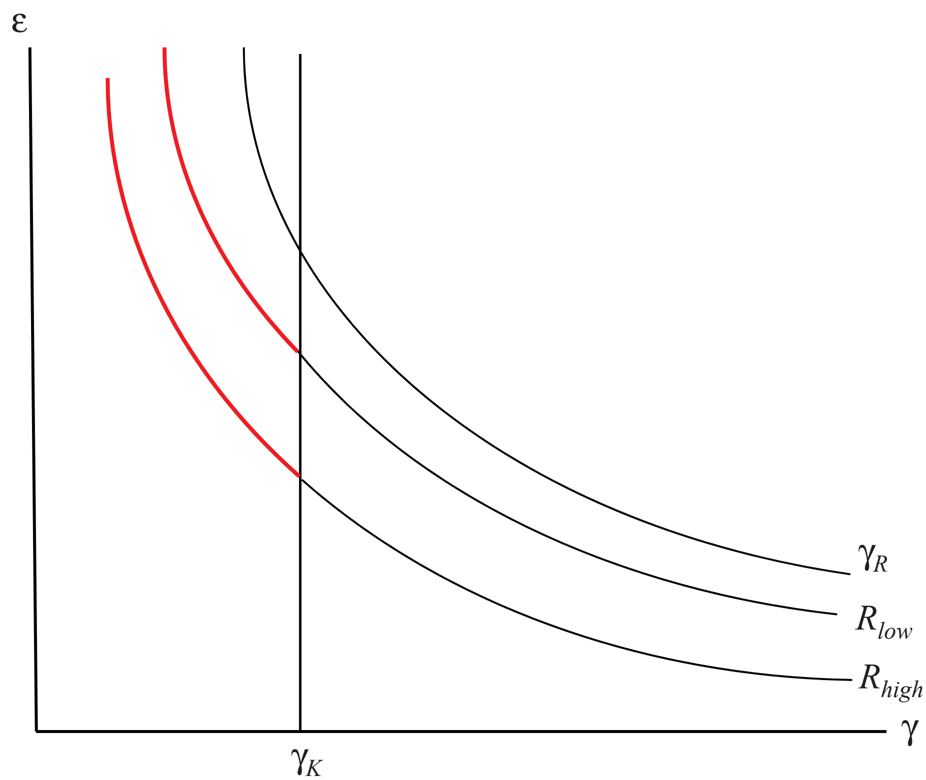

Figure 6: Different reserve positions

threshold, γ_K, namely

$$prob\left(\gamma \geq \gamma_K | \bar{R}\right) = prob\left[\epsilon \leq \frac{1}{\gamma_K}\left(\frac{\bar{R}}{\mathbb{D}} + \gamma_R\right)\Big| \bar{R}\right] = \Phi_\epsilon\left[\frac{1}{\gamma_K}\left(\frac{\bar{R}}{\mathbb{D}} + \gamma_R\right)\right], \tag{35}$$

where this expression uses (34). Because the lending bank wants to receive the rate i^R in all its lending, it must be the case that, for banks borrowing a particular amount $\bar{R}$, the risk premium charged must satisfy

$$1 + i^R = \left[1 + i^R + s(\bar{R})\right] \times \Phi_\epsilon\left[\frac{1}{\gamma_K}\left(\frac{\bar{R}}{\mathbb{D}} + \gamma_R\right)\right]$$

or

$$s(\bar{R}) = (1 + i^R)\frac{1 - \Phi_\epsilon\left[\frac{1}{\gamma_K}\left(\frac{\bar{R}}{\mathbb{D}} + \gamma_R\right)\right]}{\Phi_\epsilon\left[\frac{1}{\gamma_K}\left(\frac{\bar{R}}{\mathbb{D}} + \gamma_R\right)\right]}. \tag{36}$$

Grafically, the risk premium is proportional to the density associated with the segment of schedule (34) inside the insolvency area, that is, to the left of the level γ_K. That segment is marked in red in figure 6. As the amount borrowed gets larger, the schedule moves down and the segment representing insolvency gets larger increasing the risk premium the bank needs to pay. In other words, because banks in the market cannot differentiate between pure liquidity (ϵ) and liquidity/solvency (γ) shocks at the time they reach the interbank market, they assign a higher probability of default to those banks borrowing more wholesale funds and, therefore, a larger risk premium. Similarly, other things equal, a bank with lower capital levels will face a higher threshold for solvency, γ_K. As a consequence, there is pressure for the risk premium, $s(R)$, to be larger too.[18]

Figure 7 presents the spread over the interbank rate borrowing banks have to pay as a function of the amount they borrow. In particular, it shows the term

$$\frac{1 - \Phi_\epsilon\left[\frac{1}{\gamma_K}\left(\gamma_R + \frac{R}{\mathbb{D}}\right)\right]}{\Phi_\epsilon\left[\frac{1}{\gamma_K}\left(\gamma_R + \frac{R}{\mathbb{D}}\right)\right]}$$

in (36) for different negative values of the reserve position R. These are the positions forcing banks to borrow in the interbank market. All computations are done assuming a policy rate of 3 percent. As banks borrow more, the spread they have to pay over the interbank rate increases going from a few basis points to a maximum of 1.6 percent for very large demands of reserves. We also observe how this relation is nonlinear with spreads being proportionally

[18]Of course, endogenous variables will not be equal for two banks with different initial capital levels so the overall effect on the spread will depend on endogenous choices of banks.

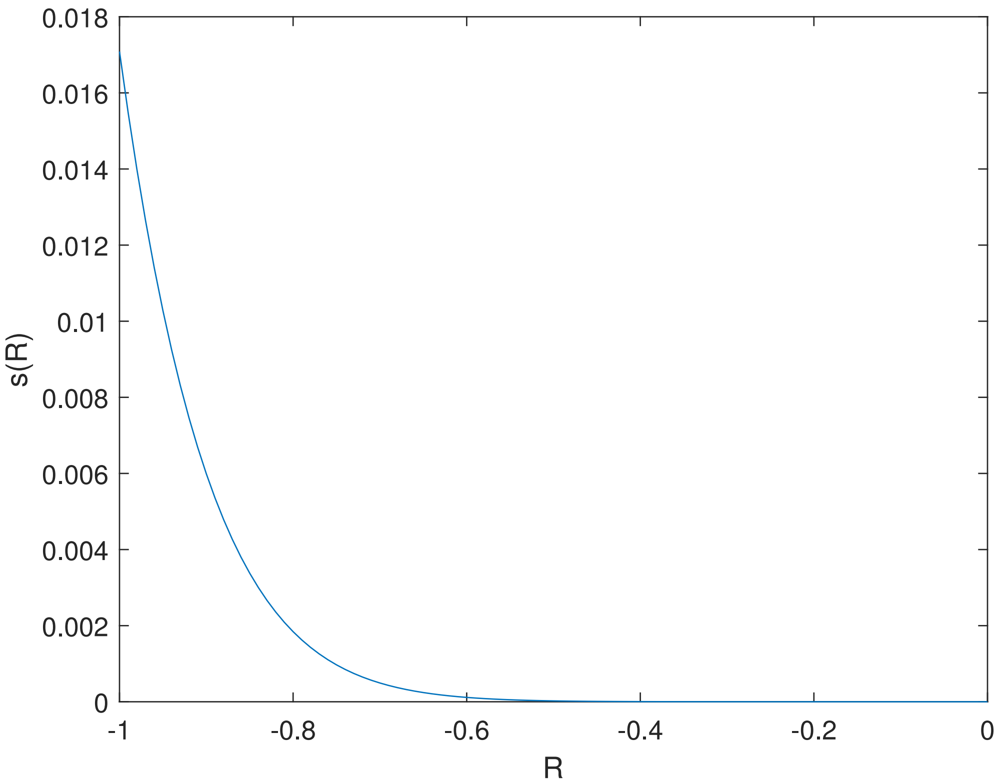

Figure 7: Risk spread in the interbank market

larger the more the bank borrows as this is a signal of higher probability of insolvency.

4.3.1 Balance sheet strength and the effects of monetary policy

Finally, Altunbaş et al. [2002], Ehrmann et al. [2001], Gambacorta and Mistrulli [2004], Gambacorta [2005], Kashyap and Stein [1995], Kishan and Opiela [2000, 2006], or van den Heuvel [2002]) study how the response of banks to changes in monetary policy depends on cross-sectional differences in their balance sheets. In particular, these papers suggest that banks cut back more on their lending in response to a contractionary monetary policy shock when they are less capitalized and/or more illiquid. For example, Gambacorta [2005] uses data for Italian banks and estimates a statistically significant drop in lending of 0.825 percent in response to a 1 percent increase in the policy rate. This drop in lending varies across the capitalization level of the bank. The average decrease is 0.622 percent for well capitalized banks while it is 0.976 percent for poorly capitalized banks. These effects remain statistically significant after the introduction of further controls and changes in the sample.

Figure 8 shows the percentage change drop in lending of an individual bank in response to

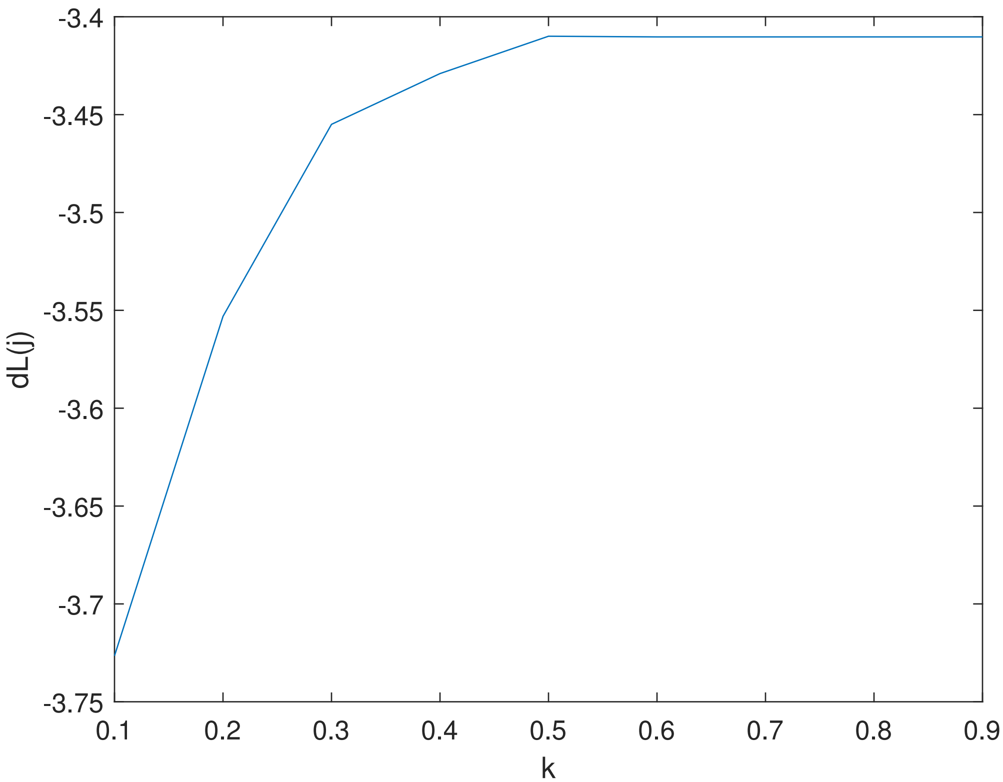

Figure 8: Changes in lending for different capital levels

an increase in the official rate i^O from 3 percent to 4 percent as a function of its capital. To produce that figure we keep aggregate variables at the equilibrium levels and solve individual problems of banks imposing different capital levels ranging from 0.1 until 0.9. We see how the drop in lending in response to the increase in official rates is monotonically larger as banks maintain lower capital levels.

To understand this effect, notice that, other things equal, schedules γ_R and γ_L are the same for both banks, but the locus γ_K is to the left for the bank with more capital. Because the area to the left of γ_K is larger for the least capitalized bank, its supply of lending is more sensitive to increases in the cost of liquidity as summarized by the risk premium this less capitalized bank has to pay for borrowing in the interbank market. Thus, increases in the cost of liquidity generated exogenously by a contractionary monetary policy will have a larger effect on lending for banks with a smaller capital position.

5 Conclusions

We have constructed a model where banks endogenously decide the size of their balance sheet by providing loans to firms. In the process of providing these loans, banks also create the means of payments (deposits) that the economy uses for transactions. This process of autonomous deposit and credit creation exposes banks to liquidity, credit and solvency risks that, in turn, endogenously limit their willingness to expand their balance sheets, as these risks affect profitability. First, deposits created when loans are issued typically leave the originating bank, generating liquidity risk as reserves must be transferred to other banks to settle the transaction. Second, for borrowers to repay their loan, they must attract enough deposits by selling their output. Thus, as a bank individually increases lending, borrowers' repayment burden rises, thereby increasing credit risk. Finally, as non-performing loans rises, banks face solvency risks since loan losses leads to a reduction in bank capital.

We have shown how changes in the monetary policy stance transmit to the real economy by altering the relationship between bank risk exposures and credit provision. As monetary policy gets tighter, the cost of liquidity increases, raising the potential costs banks face when liquidity risks materialize. In response, banks increase lending rates and reduce the supply of credit and consequently the production of deposits generating a contraction in the economy. This process generates data similar to the so-called deposit channel of monetary policy but with the causality going in the opposite direction, namely, from lending to deposits.

This mechanism linking bank risks to credit provision also delivers two other empirical facts that, to the best of our knowledge, had not previously been jointly addressed in the literature. These are: (1) heterogeneous lending responses to monetary policy shocks depending on banks' capital and liquidity positions, and (2) higher wholesale funding costs for banks perceived to have weaker solvency positions. Our model provides a unified explanation for these empirical observations.

Although we do not introduce regulation explicitly, the model could also offer new insights for the design of prudential and supervisory frameworks. Currently, these frameworks design liquidity and solvency regulations in isolation. Our model demonstrates an endogenous link between liquidity and solvency risk, both of which stem from banks' lending decisions. Thus, larger liquidity needs would signal solvency distress. The interaction between these two risks and their implications for financial stability have been empirically examined by, among others, Imbierowicz and Rauch [2014], Pierret [2015], and Schmitz et al. [2019]. This situation would suggest that designing prudential tools that target solvency and liquidity separately could reduce their effectiveness. As Tarullo [2013] pointed out a "more interesting approach would be to tie liquidity and capital standards together by requiring higher levels of capital for large firms unless their liquidity position is substantially stronger than minimum requirements. [...] While there is decidedly a need for solid minimum requirements for both capital and liquidity, the relationship between the two also matters. Where a firm has little need of short-term funding to maintain its ongoing business, it is less susceptible to runs. Where, on the other hand, a firm is significantly dependent on such funding, it may need considerable common equity capital to convince market actors that it is indeed solvent." These connections between solvency and liquidity risk have also induced a discussion to design joint stress tests (see, among others, Gauthier et al. [2014], for International Settlements [2015], Cont et al. [2020]). We leave the design and evaluation of such integrated regulatory frameworks for future research.

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A Derivation of (21) and (22)

According to expressions (18) and (19), we can express the expected value of next period's bank net worth as

$$
\begin{aligned}
E(K') &= \int_{\gamma_K}^{\gamma_{\max}} \int_0^{\epsilon_{\max}} K' \Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma) \\
&= \int_{\gamma_K}^{\gamma_L} \int_0^{\gamma_R/\gamma} \left[K - i^O O + \gamma\mathbb{D} - L + (i^R + s(R))R\right] \Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma) \\
&+ \int_{\gamma_K}^{\gamma_L} \int_{\gamma_R/\gamma}^{\epsilon_{\max}} \left[K - i^O O + \gamma\mathbb{D} - L + i^R R\right] \Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma) \\
&+ \int_{\gamma_L}^{\gamma_{\max}} \int_0^{\gamma_R/\gamma} \left[K - i^O O + i^L L - i^D \gamma\mathbb{D} + (i^R + s(R))R\right] \Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma) \\
&+ \int_{\gamma_L}^{\gamma_{\max}} \int_{\gamma_R/\gamma}^{\epsilon_{\max}} \left[K - i^O O + i^L L - i^D \gamma\mathbb{D} + i^R R\right] \Phi_\epsilon(d\epsilon)\Phi_\gamma(d\gamma),
\end{aligned}
$$

where the interbank rate charged or received depends on whether reserves are positive, so that $\epsilon < \gamma_R/\gamma$ or negative, so that $\epsilon > \gamma_R/\gamma$. Applying the definition of γ_K and γ_L yields (21) and (22).

B Computation of equilibrium

Using the market clearing condition for the interbank market (33) together with the expression for reserves (13)

$$\int_0^1 R(j)dj = \int_0^1 (O(j) + A + B + \gamma\epsilon\mathbb{D} - D(j))dj = 0$$

implies

$$O(j) = -(A + B). \tag{A.1}$$

Because the interbank market involves the continuum of banks $j \in [0, 1]$, it spans the whole distribution of shocks γ and ϵ. As payment shocks are symmetric and banks expect a zero net reserve position at the end of the period, banks do not need to accumulate reserves and, in fact, at the initial OMO, the central bank drains the reserves previously injected with the transfer, B. Then, the threshold γ_R equals,

$$\gamma_R = \frac{D}{\mathbb{D}} = 1, \tag{A.2}$$

which assumes a symmetric equilibrium where all banks make the same decision $D(j) = D = \mathbb{D}$, given that they start from the same situation.

From the market clearing condition for goods (31) together with the market clearing in the labor market (30), and the choice of consumption by the worker, prices are

$$P(\gamma) = \gamma \frac{Wh + B}{h^\alpha}. \tag{A.3}$$

Then, plugging this expression in the definition for the break even price P_L, (8) produces the threshold value γ_L^d for firms

$$\gamma_L^d = (1 + i^L) \frac{Wh - N}{Wh + B}. \tag{A.4}$$

This threshold together with the demand for labor (10) determine the wage rate as

$$\frac{\alpha}{1 - \Phi_\gamma(\gamma_L^d)} \int_{\gamma_L^d}^{\gamma_{max}} \gamma \Phi_\gamma(d\gamma) = (1 + i^L) \frac{Wh}{Wh + B} \tag{A.5}$$

which implies a demand for credit of

$$L^d = Wh - N. \tag{A.6}$$

On the other hand, the loan supply of banks is

$$(1 + i^L)[1 - \Phi(\gamma_L^s)] = (1 + i^O)[1 - \Phi(\gamma_K)] \tag{A.7}$$

where the thresholds for banks are

$$\gamma_L^s = (1 + i^L) \frac{L}{\mathbb{D}}, \tag{A.8}$$

and

$$\gamma_K = \frac{L - K + i^O(A + B)}{\mathbb{D}}. \tag{A.9}$$

Of course in equilibrium it must be the case that $\gamma_L^d = \gamma_L^s = \gamma_L$ for all banks and firms in the economy.

One additional item has to do with default in the interbank market. In this model, banks have three types of liabilities, borrowing from the central bank, deposits, and borrowing from the interbank market, for those banks with negative reserve positions at the end of the period. Banks solvency issues potentially affect depositors and interbank lenders. However, a bank defaults because its firm clients (the ultimate depositors at the time solvency risks materialize) default themselves on the loans. Thus, depositors cannot be the residual claimants of the assets of the banks and there is no need for a deposit insurance scheme. Then, the ultimate residual claimants on banks are interbank lenders which impute a risk premium to lending as interbank loans are unsecured.

Finally, using the government budget constraint, (29), and the equilibrium in the interbank market, (A.1), lump sum taxes to compensate for the accumulation of reserves by investors should satisfy

$$\mathbb{T} = i^O \mathbb{A} + (1 + i^O)\mathbb{B}. \tag{A.10}$$

Because of the design of taxes and the symmetry of the solution, the equilibrium of this economy implies that, for a given level of the policy rate, i^O and fiscal transfers, B, aggregate assets $\mathbb{A}$ are constant over time, namely, $\mathbb{A} = \mathbb{A}'$. This also means that the split between funds going to firms, N, and banks, K, is also constant but could differ for each monetary policy stance or fiscal transfer.

C Data sources

Computations for the calibration in table 1 are as follows. We compute averages with quarterly data from the first quarter of 1986 until the fourth quarter of 2021. This is the period we have data for most of the following variables. For variables with a higher frequency we produce quarterly data by averaging over the corresponding quarter.

1. The TED rate approximates the risk premium in the interbank market and is obtained from the FRED database of the Federal Reserve Bank of St.Louis (with acronym TEDRATE). This is a series starts on January 1986 and was discontinued in January 2022.

2. Data for the federal funds rate is taken from the Effective federal funds rate series from the FRED database of the Federal Reserve Bank of St.Louis (FEDFUNDS).

3. Data on loans, deposits and capital to compute bank leverage and the deposits to loans ratio use table L111 of the Financial accounts of the United States (Z.1). Loans (L) are

measured as Loans in that table (FL764023005). Deposits (D) is the sum of Checkable deposits (FL763127005) and Time and savings deposits (FL763130005). Capital (K) is represented by Total equity (FL763181105).

4. For the NPL ratio, we use Nonperforming Loans (past due 90+ days plus nonaccrual) to Total Loans for all U.S. Banks from the FRED database (acronym USNPTL). This series was discontinued on July 2020. In table 1 we include the average from January 1986 until that date.

5. For the fraction of insolvent banks, we looked at the Bank Failures and Assitant Data section of the BankFind Suite data application of the FDIC. For each year between 1986 and 2021 we manually downloaded data on the balance sheet of failed banks. The number in table 1 corresponds to the ratio of the deposits of these failed banks over total deposits of depository institutions obtained from table L111 of the Financial accounts of the United States (Z.1).

6. Finally, the size of the real sector is approximated as the ratio of equity of Nonfinancial business to the sum of equity of Nonfinancial business plus equity of the Financial sector. For Nonfinacial business we use table L102 of Financial accounts of the United States (Z.1), column FL143181105. For the Financial sector we use equity of the Domestic financial sector (table L108 column FL793181105) minus equity of the Monetary authority (table L109, column FL713164005).