Bank regulation, monetary policy and banks' supply of liquidity services

Josef Schroth*

Bank of Canada

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Are banks necessarily safer when they hold more safe assets or when monetary policy leans against economic downturns? This paper builds a model in which banks supply liquidity services through uninsured deposits. Banks consider equity costly and supply more deposits when holding more safe assets. Expansive monetary policy can reduce banks' losses on loans but also provides liquidity which shifts demand for bank deposits downward. The main result is that during normal times banks should hold fewer safe assets and more equity. Further, during crisis times the monetary-policy stance should be relatively tighter while banks rebuild their equity.

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*Bank of Canada, 234 Wellington St W, Ottawa, ON K1A 0G9, Canada, jschroth@bankofcanada.ca
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1 Introduction

Following the 2007–2008 Global Financial Crisis there have been profound changes in the scope and conduct of bank regulation and monetary policy. Banks are now subject to comprehensive liquidity regulations and monetary-policy accommodations are more forceful. This paper identifies banks' role as providers of liquidity services as a novel economic channel through which both of these policy changes decrease financial and economic stability.

Banks derive significant revenue from providing liquidity services to the economy.[1] Specifically, banks can provide liquidity services by issuing demandable deposits and investing the proceeds in safe assets. Adapting the Friedman rule to banks' liquidity provision, it could then be argued that bank regulation should enable or even encourage banks to increase holdings of safe assets, to provide more liquidity services.[2] The difference in the returns between safe assets and deposits, the "liquidity premium on deposits," would then be reduced and depositor welfare, at least in a narrow sense, increased. Liquidity regulation, which pushes banks to hold more safe assets, could then be seen as having the positive side effect of lowering liquidity premiums. Similar, when aggressive monetary policy accommodation during economic downturns not only reduces distortions due to wage rigidities ("labor gaps") but also reduces liquidity premiums, then the latter could be seen as a positive side effect.

[1]For example, depositors in the United States enjoyed liquidity services corresponding to $42bn in forgone interest earnings in the third quarter of 2022, even exceeding banks' net profits (*The Wall Street Journal*, 2022). Berger and Bouwman (2009) show how to construct comprehensive measures of the volume of liquidity created by banks.

[2]On the one hand, tighter liquidity regulation can increase banks' supply of liquidity services as banks tend to respond to regulatory pressure to increase their "liquidity coverage ratio" by increasing the amount of safe financial assets they hold (Sundaresan and Xiao, 2024). On the other hand, some jurisdictions impose leverage ratio requirements on banks that can curb their provision of liquidity services. For example, in the United States large banks must maintain a "supplementary leverage ratio" of tier 1 capital to total assets of at least 3%, and the largest banks (G-SIBs) must maintain 5%. Such a leverage ratio constrains banks' holdings of, in particular, safe assets subject to low risk weights.

However, these views are too narrow because banks not only provide liquidity services, but also supply risky loans. To smooth banks' loan supply over financial cycles, recently implemented frameworks for macroprudential capital regulation require banks to hold more equity capital (*Basel Committee on Banking Supervision*, 2010), which is costly for banks to do. These frameworks tend to ignore how profits from liquidity premiums can help to compensate banks for the cost of holding more equity capital. Moreover, these frameworks typically do not feature coordination with monetary policy to take into account the effect of monetary policy on the liquidity premium enjoyed by banks.

There are two key policy implications from banks' role as liquidity providers for bank regulation and its coordination with monetary policy. First, a policy that smooths out banks' supply of liquidity over the financial cycle also maximises banks' own liquidity. Such a policy requires banks to hold fewer, not more, safe assets during normal times. Second, when monetary policy accommodation is used to close the labor gap during financial crises, then this widens the output gap.

The core ingredients of the dynamic stochastic general equilibrium model used in this paper are standard. The model economy is populated by households, firms and banks. Banks fund loans to firms and holdings of safe bonds with retained earnings (equity) and by supplying liquidity services in the form of deposits to households. Banks consider equity capital costly and face elastic demand for deposits. An extension of the model introduces nominal rigidities to study the effects of monetary policy during financial crises.

In the model banks' capital structures affect the liquidity premium of bank deposits through their effect on the supply of deposits. This channel gives rise to an unintended side effect. Specifically, when bank regulation induces banks to hold more safe assets, then this increases the equilibrium interest rate enjoyed by depositors. But a decrease in revenue from liquidity premiums lowers the ability of banks to hold costly capital to support a stable supply of loans and deposits. This implies that tighter liquidity regulation during normal times can make liquidity crunches more likely by reducing banks' ability to intermediate in the bond market during times of financial stress.[3]

Over time exogenous shocks to firms' loan repayments may deplete equity and thereby occasionally cause banks' funding constraints to bind. The motivation for market-imposed equity constraints is that bank shareholder value should be high enough to ensure that banks have sound risk management and do not engage in moral hazard (as in Gertler and Kiyotaki, 2010).[4] While these constraints ensure banks' solvency at all times, they can create severe liquidity problems for banks because depositors refuse to roll over deposits when banks' shareholder value is too low. When banks' funding is sufficiently constrained, then banks' supplies of both loans and liquidity services (deposits) decrease significantly and the economy experiences a financial crisis.

The cost of bank funding decreases in the liquidity premium on deposits in the model. This premium reflects the value of deposits to households who use them to meet sudden idiosyncratic consumption needs, or liquidity shocks. While households can also use safe bonds to pay for consumption goods, they must first sell them which incurs a deadweight transaction cost. In the model this transaction cost is a decreasing function of the share of aggregate household savings held in form of deposits. This feature captures the intuition that when households can meet more of their liquidity shocks with deposits, then there are fewer sellers in the secondary market for bonds at a given point in time so that it is easier for each seller to find a buyer. When households

[3]During the covid-19 pandemic, credit-line draw-downs caused capital encumbrance at banks and thus constrained their ability to supply deposits (Li, Strahan, and Zhang, 2020; Eisenbach and Phelan, 2023; Acharya, Engle, Jager, and Steffen, 2024) or intermediate bonds (Kargar et al., 2021).

[4]For example, when lending margins were low during the covid pandemic, some smaller banks in the United States may have ceased to manage interest rate risk appropriately (*Financial Times*, 2023), possibly searching for yield in a "gamble for resurrection" (Freixas, Rochet, and Parigi, 2004).

allocate their savings optimally, then the liquidity premium of deposits is equal to the transaction cost that households face when selling bonds at the times of their respective consumption needs. It follows that liquidity premiums on deposits are decreasing in the aggregate amount of deposits in the model.

The paper characterizes optimal policy by studying the constrained-efficient allocation, or second best, of the model. Policy implications are derived by comparing the second best and the competitive equilibrium. The focus on constrained-efficiency is motivated by the discretion that financial regulators have in practice. In particular, the tool kit of regulators is expanding and and no clear rules regarding its usage have been formulated (there is no "Taylor rule" for macroprudential bank regulation).[5] While it is difficult to predict new policy tools or kinds of regulatory forbearance during times of financial stress, we can identify regulators' objectives (to maximize some measure of welfare) and the important constraints they are facing (funding and capital market pressure for banks). Useful policy implications can therefore be derived by comparing constrained-efficient and competitive-equilibrium allocations.

The main result of the paper is that banks hold fewer safe bonds during normal times in the second best compared with competitive equilibrium. The resulting reduced need for deposit funding allows banks to offer lower deposit rates in second best. This way the liquidity premium is increased which enables banks to hold more costly capital during normal times. Moreover, while banks' second-best bond holdings are smaller during normal times, compared with the competitive equilibrium, they are larger during financial crises. During normal times, the liquidity premium is higher in second best,

[5]Changes in time-varying capital buffer requirements, equity payout restrictions and reporting 'forbearance' were among the ad-hoc measures taken by regulators during the COVID pandemic in jurisdictions such as United States, the European Union and Canada. The analysis in the paper follows a "non-parametric" approach to optimal regulation to account for the observed ad hocness in practice (simple rules that could implement the constrained-efficient allocation may still exist).

compared with the competitive equilibrium, but it is much more stable during financial crises.

The main policy implication in this paper is that existing regulatory tools should be coordinated to avoid undermining the effectiveness of recently introduced macroprudential capital buffer frameworks. The analysis implies that banks should reduce their overall size by reducing safe asset holdings, and should adopt a higher capital ratio. In other words, banks should become smaller and focus on funding riskier assets with more stable funding. While a higher supplementary leverage ratio (SLR) would work in support of this implication, a higher liquidity coverage ratio (LCR) would work in the opposite direction and would undermine banks' abilities to rely on more stable equity funding. Therefore, there is a complementarity, during normal times, between tightening the SLR, relaxing the LCR, and requiring banks to build up larger capital buffers.

The paper identifies a negative side effect of liquidity regulation in the form of a "paradox of thrift" wherein each bank's accumulation of safe assets ends up making other banks' liabilities less stable. In the model, bank funding market participants are wary of the potential for bank moral hazard. Specifically, deposit "run-off rates" adjust endogenously *ex ante* to mitigate *ex-post* banks' incentives to engage in moral hazard. Banks with more equity capital are able to roll over more of their deposit funding each period (Holmstrom and Tirole, 1997; Gertler and Kiyotaki, 2010), consistent with empirical evidence that deteriorations in banks' funding access are driven by fundamentals (Correia, Luck, and Verner, 2024). Liquidity regulation undermines banks' ability to maintain high levels of costly equity capital by creating upward pressure on banks' funding costs. This has implications not only for the liquidity of banks themselves but also for banks' ability to provide liquidity to the economy. Any positive direct welfare effect of higher safe asset holdings of banks on their supply of liquidity during normal times may be more than offset by the general-equilibrium effect of stronger deleveraging during times of financial stress. In the model in this paper, welfare is higher over financial cycles when banks hold fewer safe financial assets, and more equity, during normal times.[6]

An extension of the model introduces nominal wage rigidity to study the coordination of monetary policy and bank regulation during financial crises. Monetary policies that narrowly focus on closing the labor gap would not be constrained-efficient in the model. The reason is that expansionary monetary policy decreases the spread between safe bonds and deposits (liquidity premium of deposits) in the model.[7] Specifically, the bond transaction cost function is shifted down (up) by more expansive (tighter) monetary policy. The intuition is that a more expansive (tighter) monetary policy operation involves bond purchases (sales); this makes it easier (harder) for sellers in the secondary bond market to find buyers at a given point in time. It follows that monetary-policy operations no only affect employment gaps, but also change the price of available liquidity in financial markets which affects the liquidity premium of bank deposits through the demand for deposits.

This channels give rise an unintended side effect of monetary policy that matters

[6]While the theoretical literature emphasizes a negative effect of liquidity regulation on the net supply of safe financial assets (Adrian and Boyarchenko, 2018; Van den Heuvel, 2022; Robatto, 2024), this paper emphasizes the positive effect of increased bank holdings of safe financial assets, or "bonds," on the supply of deposits. In the data, banks respond to regulatory pressure to increase their liquidity coverage ratios by increasing the amount of safe financial assets they hold (Sundaresan and Xiao, 2024). In the model in this paper, higher bank holdings of safe assets reduce safe-asset trading costs (Duffie, 2018; Eisenbach and Phelan, 2023). This decreases the price of liquidity and increases deposit rates.

[7]The effect of monetary policy on liquidity premiums is well documented. Nagel (2016) finds that more expansionary monetary policy lowers the liquidity premium in the treasuries market in the United States. Drechsler, Savov, and Schnabl (2017) document that more expansionary monetary policy lowers the liquidity premium of bank deposits in the United States. Heider, Saidi, and Schepens (2019) and Eggertsson, Juelsrud, Summers, and Wold (2024) find a particular importance of this relationship at the zero lower bound for the case of the Euro zone and Sweden, respectively. Investing at the lower end of the yield curve or in interest-bearing demandable deposits is a way of avoiding transaction costs associated with selling longer-term assets in case of sudden liquidity needs.

especially during financial crises. While expansive monetary policy operations may be able to avoid inefficiently low employment, they may not actually succeed in stabilizing economic output during times when banks have low equity. The reason is that a more expansive monetary policy reduces banks' lending by reducing profitability of banks at a time when they are already capital constrained. Constrained-efficient monetary policy is therefore less expansionary, relative to what would be required to close the labor gap, during financial crises. For this reason, there is a complementarity during financial crises between a less expansive monetary policy stance and releasing banks' regulatory capital buffers.

1.1 Related literature

The importance of banks' deposit spreads on credit supply has also been stressed in Wang (2025). Specifically, lower deposit spreads reduce banks' abilities to generate earnings, and this channel reduces credit supply when banks' equity capital is sufficiently low. Deposit spreads are driven by the monetary policy stance in his paper, while in this paper deposit spreads are also affected by bank regulation. The contribution of this paper is to focus on financial stability and to show that a bank regulator would like to do two things simultaneously during normal times: (i) to induce banks to hold fewer safe assets to reduce deposit supply, and (ii) to require banks to hold more equity capital. The rationale is that higher deposit spreads compensate bank shareholders for retaining more earnings, to avoid an excessive decrease in credit supply during normal times. Financial stability is increased through higher deposit spreads during normal times not by granting rents to banks but by requiring banks to hold more capital.

Begenau (2020) also studies the effect of banks' capital structures on banks' funding costs. A higher capital requirement somewhat lowers banks' deposit supply which in turn leads to greatly reduced deposit rates in her paper. In contrast, in this paper the decrease in banks' deposit supply in the constrained-efficient allocation is driven by a decrease in banks' safe bond holdings. The rationale for increasing banks' equity capital in this paper is not to decrease deposits further but to make banks more resilient. As a result, banks pay lower deposit rates not because of alternative funding sources (equity) but because they have fewer assets (safe bonds) to fund. A significant increase in equity is accompanied by a small increase in overall assets in Begenau (2020), while in this paper a significant decrease in overall assets is accompanied by a small increase in equity. The channel in Begenau (2020) operates within the liability side of banks' balance sheets, but it operates from the asset to the liability side in this paper.

Diamond and Rajan (2001) emphasize that demandable deposits are an important disciplining device in the hands of bank creditors. As in this paper, creditors are atomistic and not able to commit among themselves to renegotiating the face value of bank deposits *ex post*. They simply demand their deposits back (via a "bank run" as in Diamond and Dybvig, 1983), or refuse to roll over in the case of banks' wholesale or interbank funding sources, if they are concerned about bank moral hazard. In this paper deposits, in addition, play a role in recapitalizing banks after they experience loan losses. A decrease in deposit rates when banks are forced to reduce the size of their balance sheets allows banks to rebuild equity faster. A policy implication is that banks should rely less on demandable deposits, and more on equity, during normal times such that they are forced to reduce deposit supply less during financial crises.

Gatev and Strahan (2006) find empirical evidence for banks benefiting from procyclical funding costs, i.e., from a countercyclical liquidity premium. They argue that this effect enables banks to provide a more stable supply of loans to firms over financial cycles. This paper explores the implications of banks' role as liquidity providers for bank regulation. It finds that regulators should support banks during financial crises by lowering capital buffer requirements. During normal times regulators should require banks to hold fewer safe bonds and retain more equity. In the model such policies increase both economic output and the provision of liquidity services over financial cycles.

In the model extension, an expansive monetary policy stance lowers the liquidity premium of deposits—i.e., the spread between the return on safe bonds and the interest rate on deposits—while a contractionary stance increases it. Drechsler, Savov, and Schnabl (2017) and Wang (2025) document such relationships empirically for the case of the United States. In their models, as in the model in this paper, expansive monetary policy shifts the deposit demand curve downward and thus lowers premiums.[8] This decrease in profitability may induce banks to reduce lending in support of their capital positions. Abadi, Brunnermeier, and Koby (2023), Eggertsson, Juelsrud, Summers, and Wold (2024) and Wang (2025) highlight the importance of this channel for muting the transmission of expansionary monetary policy when the nominal rate is below a threshold (Wang, 2025, shows that this threshold can be significantly larger than zero).[9] As in this paper, and in Stein (2012), the monetary authority effectively competes with banks in the supply of liquidity services to households. This paper offers the additional insight that monetary policy should compete significantly less with banks during financial crises and during recoveries from crises. Moreover, monetary policy should also compete somewhat less with banks during normal times (as in Van der Ghote, 2021) so that banks are able to

[8] This effect does not depend on whether there is imperfect or perfect competition in deposit markets. Drechsler, Savov, and Schnabl (2017) highlight the importance of imperfect competition for the transmission of monetary policy. In their framework monopolistic deposit pricing by banks implies a lower quantity and premium when demand for deposits decreases. In the model in this paper and in Wang (2025), banks are perfectly competitive and the deposit supply curve is upward sloping in the deposit premium because banks are required to fund a fraction of assets with costly equity capital (as in Hanson, Shleifer, Stein, and Vishny, 2015).

[9] While banks can hedge against expansionary monetary policy by supplying longer-term credit (Drechsler, Savov, and Schnabl, 2021), they must do so carefully to manage the risk of sudden monetary tightening (Drechsler, Savov, Schnabl, and Wang, 2023).

bear larger capital buffers. Monetary policy has a key role in making financial crises less severe *ex post* and in supporting bank resilience *ex ante*.[10]

2 Model

This section presents a model economy in which banks lend to firms and provide liquidity services in the form of (uninsured) deposits to households.[11] The model endogenously generates occasional financial crises when banks' equity is low enough such that depositors refuse to roll over part of banks' funding. Banks do not fail during crises but face pressure to reduce the size of their balance sheets. This pressure stems from two financial frictions related to banks' funding. On the one hand, banks consider equity a relatively more costly funding source compared with (uninsured) deposits. On the other hand, market monitoring implies that banks have access to deposits only if their leverage is not too high. Banks' capital structure choices trade off these funding frictions against the risk from lending. Exogenous aggregate shocks and the aggregate amount of bank lending affect banks' returns from lending.

The economy features a consumption good and is populated by continuums of mass one of identical firms, banks, households and long-term investors, respectively. Firms are short-lived and fund their investment with loans from banks. In every period $t = 1, 2, \ldots$ households are each endowed with one unit of labor, which they supply inelastically, and with $\omega > 0$ units of the consumption good. They value the liquidity service of deposits.

[10] Jiménez, Ongena, Peydró, and Saurina (2014) provide empirical evidence that expansive monetary policy can reduce the resilience of banks *ex ante*.

[11] In the model in this paper, bank debt is used to facilitate payments (Lagos, Rocheteau, and Wright, 2017). However, there is no direct feedback channel from banks' supply of payment, or liquidity, instruments to real economic activity (as there is in Quadrini, 2017). The reason is that all risky economic activity is funded exclusively through bank loans in the model in this paper. Loans offer sufficient insurance to borrowers in the model.

Banks make loans to firms and supply deposits to households. Households and long-term investors discount future consumption using the subjective discount factor $\beta \in (0,1)$. There are aggregate productivity shocks $z \in \{z_L, z_H\}$ with $Pr(z = z_L) = \rho$ in each period. Let $z_L < z_H$ and $\rho z_L + (1-\rho)z_H = 1$. The assumption that aggregate productivity shocks are independently and identically distributed over time ensures that firms' demand for loans depends only on monetary policy and the loan interest rate.

Long-term investors trade bank shares among each other, and trade one-period non-contingent bonds with banks and households. Let $\gamma \in (0, \beta)$. At the beginning of each period, after firms have repaid loans and maturing bonds have been redeemed, a fraction $1 - \gamma/\beta > 0$ of banks exit exogenously. The equity of exiting banks is distributed among a mass $1 - \gamma/\beta$ of new banks. The shares of exiting banks become worthless and shares of new banks are distributed uniformly among long-term investors. Note that for an individual long-term investor $1 - \gamma/\beta$ is a measure of the cost of bank capital.

Markets:

There are markets for labor, bonds, bank deposits, bank loans and bank shares. Let w_t be the average price of one unit of labor in period $t = 1, 2, \ldots$. Let q and q^b be the prices of one unit of the consumption good to be delivered in the next period in the markets for deposits and bonds, respectively. Let R denote the contingent return on bank lending. Finally, let p denote the bank share price including the current dividend. The supply of bank shares is normalized to one in every period. Long-term investors are endowed with one bank share each in period $t = 0$.

Long-term investor problem:

Long-term investors choose consumption c^i, bonds b^i and bank shares ς to maximize lifetime utility

$$E_0\left[\sum_{t=0}^{\infty}\beta^t c_t^i\right],$$

subject to budget constraints

$$c_t^i + q_{t+1}^b b_{t+1}^i + p_t\left(\varsigma_{t+1} - {}^{\gamma}\!/\!_{\beta}\cdot\varsigma_t\right) \le b_t^i + p_t(1 - {}^{\gamma}\!/\!_{\beta}) + D_t\varsigma_{t+1},$$

where E denotes expectations, D_t are bank dividends, and b_0^i and $\varsigma_0 = 1$ are given. In period $t = 1, 2, \ldots$ long-term investors make net bank share purchases of $\varsigma_{t+1} - {}^{\gamma}\!/\!_{\beta}\cdot\varsigma_t$ and receive $1 - {}^{\gamma}\!/\!_{\beta}$ shares of new banks, where ${}^{\gamma}\!/\!_{\beta}$ is the fraction of banks that do not exit. The assumption that long-term investors are risk neutral and able to consume negative amounts ensures that their demands for bank bonds and shares are fully elastic when bonds and dividends are discounted at constant factors β and γ, respectively. Specifically, optimal long-term investor choices are consistent with the following bond return and bank share prices:

$$q_{t+1}^b = \beta, \tag{1}$$

$$p_t = D_t + \gamma E_t\left[p_{t+1}\right]. \tag{2}$$

Equation (2) implies that long-term investors effectively discount bank dividends using the lower discount factor $\gamma < \beta$. Long-term investors demand a higher return on bank shares than on bonds because a fraction $1 - {}^{\gamma}\!/\!_{\beta}$ of shares becomes worthless each period while bonds are always redeemed. The bank share price at date zero is as follows:

$$p_0 = E_0\left[\sum_{t=0}^{\infty}\gamma^t D_t\right]. \tag{3}$$

Household problem:

Households face hand-to-mouth and cash-in-advance constraints as follows. In periods $t = 1, 2, \ldots$ households receive liquidity shocks that require them to consume all of their income at the time they receive their labor income. This is at a later time than when they receive their endowments. Households invest their endowments in bonds and deposits, and convert them into cash at the time of consumption. Households choose consumption c^h, bonds b^h and bank deposits χ^h to maximize lifetime utility

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t c_t^h \right],$$

subject to hand-to-mouth constraints

$$\begin{aligned} &c_t^h = w_t + \chi_t^h + (1 - g_t)\, b_t^h, \quad \text{for } t = 1, 2, \ldots, \text{ and} \\ &c_0^h = \omega, \end{aligned}$$

and cash-in-advance constraints

$$q_t \chi_t^h + q_t^b b_t^h \leq \omega,$$

where g_t are transaction costs that households incur when selling bonds at the time they need to consume. There are no transaction costs for households when redeeming bank deposits, which makes them more liquid than bonds in that sense.[12] Let the transaction

[12] It is assumed that households would have to pay the same, or higher, transaction costs when selling bank shares such that there is no loss in letting only long-term investors hold bank shares. However, if bank dividends could serve households' liquidity needs, then this would be another reason for bank capital to be costly.

cost that households face be given as follows:

$$g_{t+1} = \eta \exp\left(-\chi^h_{t+1}\right), \tag{4}$$

with $\eta \in (0,1)$ and where χ^h_{t+1} denotes households' aggregate deposit holdings. Each household's bond transaction cost is lower when households in aggregate need to sell fewer bonds, i.e., when they rely more on deposits. Because households can freely allocate between deposits and bonds when they receive their endowments, the deposit price is determined as follows:

$$q_{t+1} = \frac{q^b_{t+1}}{1 - E_t\left[g_{t+1}\right]} = \frac{q^b_{t+1}}{1 - \eta \exp\left(-\chi^h_{t+1}\right)}. \tag{5}$$

Firm problem:

At the end of each period t a unit measure of firms enters. They each have access to a production technology that turns $k \geq 0$ units of the consumption good in period t and $n \geq 0$ units of labor in period $t+1$ into $z_{t+1}k^\alpha n^{1-\alpha} + (1-\delta)k$ units of the consumption good in period $t+1$, with $\alpha \in (0,1)$ and where $\delta \in (0,1)$ is the depreciation rate. Firms choose labor after aggregate firm productivity z_{t+1} has been realized. Firms choose investment before observing z_{t+1}. They cannot sell bonds and do not have any internal funds such that firms must fund any investment k with loans from banks. A firm chooses non-negative investment k to maximize expected profit

$$E_t\left[\max_{n\geq 0}\left\{z_{t+1}k^\alpha n^{1-\alpha} + (1-\delta)k - w_{t+1}n\right\} - R_{t+1}k\right]$$

subject to $\max_{n\geq 0}\left\{z_{t+1}k^\alpha n^{1-\alpha} + (1-\delta)k - w_{t+1}n\right\} - R_{t+1}k \geq 0$ for each z_{t+1}. After production has taken place firms pay wages, repay bank loans, eat any profits and exit.

Bank problem:

Banks choose dividends d, deposits χ, bonds b and loans to firms ℓ to maximize shareholder value

$$V_0 \equiv E_0 \left[\sum_{t=0}^{\infty} \gamma^t d_t \right] \tag{6}$$

subject to budget constraints

$$d_t + \ell_{t+1} + q^b_{t+1} b_{t+1} + \chi_t \leq R_t \ell_t + b_t + q_{t+1} \chi_{t+1}, \text{ for } t = 1, 2, \ldots, \tag{7}$$

$$d_0 + \ell_1 + q^b_1 b_1 \leq a_0 + q_1 \chi_1, \tag{8}$$

no-default constraints

$$E_t \left[\sum_{\tau=1}^{\infty} \gamma^\tau d_{t+\tau} \right] \geq \theta_1 \ell_{t+1} + \theta_2 q^b_{t+1} b_{t+1} \tag{9}$$

and dividend non-negativity, $d_t \geq 0$, for given initial bank equity $a_0 > 0$.

The no-default constraint (9) requires that banks value expected discounted future dividends more than the sum of fraction $\theta_1 \in (0, 1)$ of the current value of loans and fraction $\theta_2 \in (0, 1)$ of the current value of bond holding. The motivation for this constraint is that banks are able to divert fraction θ_1 of "divertable" assets $\ell + {}^{\theta_2}/_{\theta_1} q^b b$, similar as in Gertler and Kiyotaki (2010).[13] A bank that diverts assets is being shut down and defaults on its depositors who in turn seize any remaining assets. The no-default constraint (9) ensures that banks do not have an incentive to divert assets and default on depositors.

The assumption $\theta_2 > 0$ is consistent with the observation that, in practice, banks can-

[13]In practice, banks set aside some of their bonds as collateral to facilitate payment services. The model calibration in Section 5 finds ${}^{\theta_2}/_{\theta_1} < 1$. A key difference to the analysis in Gertler and Kiyotaki (2010), where banks have essentially fixed dividend-payout ratios, is that banks can choose dividends in this paper.

not absorb any amount of even safe bonds. In particular, episodes of increased spreads in (safe) bond markets such as during the 2019 US repo crisis and during the onset of the covid pandemic in March 2020 suggest that an intermediary asset pricing channel gives rise to not only risk premiums (He and Krishnamurthy, 2013; Adrian, Etula, and Muir, 2014; Du, Hébert, and Huber, 2023; Du, Hébert, and Li, 2023; Fontaine, Garcia, and Gungor, 2023) but also to liquidity premiums (Allen and Wittwer, 2023b; Eisenbach and Phelan, 2023).[14] The parameter θ_2 reflects market participants' concerns about bank moral hazard rather than regulation such as, for example, the regulatory leverage constraint featured in the model in Eisenbach and Phelan (2023). Because bonds are risk-free the no-default constraint (9) will always bind in a competitive equilibrium (see Proposition 1 below).

3 Competitive equilibrium

Definition 1. *A competitive equilibrium is characterized by (i) bank lending returns $\{R_{t+1}\}$, prices for bank deposits $\{q_{t+1}\}$ and bonds $\{q^b_{t+1}\}$, household bond transaction costs $\{g_{t+1}\}$, wages $\{w_{t+1}\}$ and bank share prices $\{p_t\}$; (ii) long-term investor choices for bonds and bank stock holdings $\{B^i_{t+1}, \varsigma_{t+1}\}$; (iii) household choices for bonds and bank deposit holdings $\{B^h_{t+1}, \chi^h_{t+1}\}$ and (iv) bank choices for dividends, deposits, bonds and loans $\{D_t, \chi_{t+1}, B_{t+1}, K_{t+1}\}$ such that given initial bank equity a_0 and household endowment ω,*

1. *long-term investor choices are optimal given $\{q^b_{t+1}\}$, $\{p_t\}$ and $\{D_t\}$;*

[14] The United States will mandate more trading in Treasuries to be centrally, rather than bilaterally, cleared (*Financial Times*, 2024). Allen and Wittwer (2023a) show that moving fixed-income trading away from over-the-counter, toward more central clearance, can increase welfare in the absence of concerns about loan supply by financial intermediaries. Such institutional changes affect the link between liquidity premiums (of cash versus safe bonds) and aggregate intermediary capitalization. In the context of the model this would imply a different calibrated value for the parameter θ_2.

2. *household choices are optimal given* $\{q^b_{t+1}\}$, $\{g_{t+1}\}$ *and* $\{\chi_{t+1}\}$;

3. *bank choices are optimal given* $\{q^b_{t+1}\}$, $\{R_{t+1}\}$ *and* $\{q_{t+1}\}$;

4. *the market for bonds clears,* $B^h_{t+1} + B^i_{t+1} + B_{t+1} = 0$, $q^b_{t+1} = \beta$;

5. *the deposit market clears,* $\chi^h_{t+1} = \chi_{t+1}$, $q_{t+1} = \frac{\beta}{1-g_{t+1}} = \frac{\beta}{1-\eta\exp(-\chi_{t+1})}$;

6. *the market for bank loans clears,* $R_{t+1} = \alpha z_{t+1} K^{\alpha-1}_{t+1} + 1 - \delta$;

7. *the market for labor clears,* $w_{t+1} = (1-\alpha) z_{t+1} K^{\alpha}_{t+1}$;

8. *the market for bank shares clears,* $\varsigma_{t+1} = 1$.

Banks' ability to provide liquidity services to households without incurring risk implies that banks' no-default constraints (9) will always bind in a competitive equilibrium (Proposition 1). Intuitively, if no-default constraints were slack, then banks could acquire some risk-free bonds that are fully funded with deposits and earn a positive spread $q_{t+1} - \beta > 0$. How much no-default constraints bind depends on banks' equity in a non-linear fashion. In the limit, as θ_2 approaches zero, banks' lending and dividends in the competitive equilibrium allocation are the same as in Schroth (2021).

Proposition 1. *In competitive equilibrium, for all* $\theta_2 > 0$, *banks' no-default constraints* (9) *always bind and* $q_{t+1} - \beta > 0$ *for all* t. *In the limit, as* $\theta_2 \searrow 0$, *banks' no-default constraints bind occasionally and* $q_{t+1} = \beta$ *for all* t.

Proof. See Appendix B. □

3.1 Welfare criterion and pecuniary externalities

Equation (5) shows that there is a pecuniary externality due to the fact that each bank's liquidity premium decreases in aggregate deposit supply.[15] This externality matters because liquidity premiums affect the shareholder value of banks which in turn enters banks' no-default conditions (9).

The welfare criterion in this paper is the discounted sum of expected long-term-investor and household consumption. Up to a constant, this equals the discounted sum of expected bank dividends and wages net of households' bond transaction costs.[16] Let $\{\chi_{t+1}, D_t, K_{t+1}\}$ be a sequence of deposits, dividends, and bank lending; then the associated welfare is as follows:

$$W_0 = D_0 + E_0 \left[\sum_{t=1}^{\infty} \beta^t \left(D_t + z_t (1-\alpha) K_t^{\alpha} - \frac{\omega}{\beta} E_{t-1}[g_t] \right) \right], \tag{10}$$

where $g_t = \eta \exp(-\chi_t)$.

4 Optimal macroprudential policies

The analysis in this paper has implications for how prudential policy should treat relatively safe assets. The reason is that the pecuniary externality highlighted in Section 3.1

[15] There is a another pecuniary externality related to banks' capital structures (Schroth, 2021). Specifically, a policy that temporarily implements higher bank dividend payout ratios following times of low equity raises the shareholder value, and thus the funding market access, of banks during times when they have low equity. The reason is that banks compete less when they retain fewer earnings, which increases bank margins. When banks rebuild costly equity capital more slowly following times of low equity capital, then the scarcity of bank lending and of bank liquidity provision can be smoothed out over time.

[16] Recall that the consumption of households in period $t+1$ is given by $w_{t+1} + \chi_{t+1} + (1 - g_{t+1}) B^h_{t+1}$. When households choose deposits and bonds optimally, then the deposit price is $q_{t+1} = \beta/(1 - E_t[g_{t+1}])$. Substituting this price in households' cash-in-advance constraint $q_{t+1}\chi_{t+1} + \beta B^h_{t+1} = \omega$ shows that $E_t \left(\chi_{t+1} + (1 - g_{t+1}) B^h_{t+1} \right) = (1 - E_t[g_{t+1}])\, \omega/\beta = constant - E_t[g_{t+1}]\omega/\beta$. For each period $t \geq 0$, the expectation for household consumption in period $t+1$ is, up to a constant, equal to $E_t \left[z_{t+1}(1-\alpha) K^{\alpha}_{t+1} \right] - E_t[g_{t+1}]\omega/\beta$.

is driven by banks' holdings of bonds—banks that hold more bonds also issue more deposits and this in turn increases the interest rate $1/q$ they must offer on deposits. Recall that bonds yield $1/\beta > 1/q$, but bank shareholders require a return on equity of at least $1/\gamma > 1/\beta$. This means banks use at least some deposits to fund bond holdings. Therefore, higher bank bond holdings decrease banks' interest rate margins. An important negative side-effect of a bank's efforts to diversify its balance sheet—by generating more safe income from bonds that, in particular, bolsters the bank's earnings at times of loan losses—is that the profitability of all banks decreases. Paradoxically, when banks hold more safe bonds in aggregate, then each bank is more likely to experience funding pressure.

Banks' access to funding depends on both their profitability and level of equity capital. On the one hand, bonds offer a return to banks that is less risky than loan repayments. On the other hand, banks' aggregate bond holdings affect their funding cost and thus their ability to earn their required return on costly capital $1/\gamma$. In practice, macroprudential bank regulators take into account the effect of higher capital requirements on banks' credit supply—however, they should also take into account how banks rely on profits from both lending *and* liquidity provision to generate the equity payouts required by shareholders.

Optimal macroprudential policies are defined as the solution to a constrained social planner problem. This approach reflects the discretion that regulators have in practice, especially during financial crises, in introducing new regulatory tools or in how they apply existing tools. What constrains regulators' discretion in the model? The social planner's, or regulator's, problem used in this paper acknowledges that banks, firms, long-term investors and households are price takers such that optimal policies are not first-best but merely constrained-efficient (see also Kehoe and Levine, 1993, 2001). In particular, it imposes the same no-default constraints that the bank funding market imposes in competitive equilibrium such that banks' limited commitment becomes an important determinant of the constrained-efficient allocation (see also Thomas and Worrall, 1988; Kocherlakota, 1996). There is no limited commitment on the part of the regulator so that the social planning problem can be expressed recursively with the help of auxiliary state variables called "promised values" (as in Kydland and Prescott, 1980). The social planner's objective, or welfare function, is a function of two state variables—aggregate bank equity A and (promised) shareholder value V.

Definition 2. *The problem of a social planner, or regulator, that can choose macroprudential policy to maximize the welfare criterion in Equation (10) can be expressed recursively as follows:*

$$\begin{aligned} W(A,V) = \max_{\{D,B,K,\chi,V_L,V_H\}} \Big\{ & D + \beta\rho \left[z_L(1-\alpha)K^\alpha - \frac{\omega}{\beta} g_L + W(A_L, V_L) \right] \\ & + \beta(1-\rho) \left[z_H(1-\alpha)K^\alpha - \frac{\omega}{\beta} g_H + W(A_H, V_H) \right] \Big\} \end{aligned}$$

subject to

$$\begin{aligned} D + K + \beta B &\leq A + \frac{\beta}{1-[\rho g_L + (1-\rho) g_H]} \chi, && \textit{(bank budget constraint)} \\ D &\geq 0, && \textit{(dividend non-negativity)} \\ \gamma\left[\rho V_L + (1-\rho) V_H\right] &\geq \theta_1 K + \theta_2 \beta B, && \textit{(no-default bank)} \\ V_j &\geq A_j,\ j = L, H, && \textit{(participation bank)} \\ D + \gamma\left[\rho V_L + (1-\rho) V_H\right] &\geq V, && \textit{(promise keeping regulator)} \end{aligned}$$

where $A_j = z_j \alpha K^\alpha + (1-\delta)K + B - \chi$ *and* $g_j = \eta \exp -\chi$ *for* $j = L, H$.

A full analysis of the problem in Definition 2 requires a numerical solution, which will be provided in Section 5. The remainder of this section provides a partial analysis of optimal liquidity supply using first-order conditions.

4.1 Marginal social benefit of liquidity services to households

An important policy question is whether banks supply the right amount of liquidity to households during normal times. Suppose households would be supplied with one additional (marginal) unit of deposits from outside the banking sector.[17] The direct liquidity benefit of the marginal exogenous increase in deposits to households would have to be traded off against the indirect effect on financial stability through a higher funding cost of banks. The resulting marginal net benefit is given by the first derivative of the Lagrangian of the social planning problem in Definition 2 with respect to household deposits but taking as given the amount of deposits in the bank budget constraint. This first-order effect is as follows:

$$\omega\eta \exp(-\chi) - \lambda\chi \frac{\beta\eta \exp(-\chi)}{(1-\eta\exp(-\chi))^2},$$

where λ denotes the social value of bank equity (i.e., the Lagrange multiplier on the bank budget constraint) in the current period.[18] When this expression is positive, then joint welfare of long-term investors and households increases when households enjoy additional liquidity services. The benefit from lower household transaction costs would then exceed the social cost of higher bank funding costs. When the expression is negative,

[17] For example, financial innovation could combine "narrow banking" deposits, fully backed by safe bonds, with a payment service. This could be provided through, for example, a privately issued stablecoin or a publicly issued central bank digital currency (CBDC).

[18] Note that the current state variables are A and V (the dependence of variables such as χ or λ on state variables is suppressed to save notation). Recall from Definition 2 that the state variables evolve over time depending on the regulator's choices and the realizations of the exogenous productivity shocks. As shown in the regulator's first-order condition for bonds, Equation (11), the regulator can use bond holdings to smooth out the social value of bank equity over time, subject to the no-default condition (9).

then joint welfare decreases because any direct improvement in liquidity services would be more than offset, going forward, by a less stable supply of credit (a lower net-present value of wages) and a less stable supply of liquidity services (a higher net-present value of bond transaction costs paid by households). To evaluate the expression, consider the first-order conditions of the regulator's problem in Definition 2 for bonds,

$$\beta\left[\rho\lambda_L + (1-\rho)\lambda_H\right] = \beta\lambda + \beta\theta_2\psi, \tag{11}$$

and deposits,

$$\omega\eta\exp\left(-\chi\right) - \lambda\chi\frac{\beta\eta\exp\left(-\chi\right)}{\left(1-\eta\exp\left(-\chi\right)\right)^2} = \beta\left[\rho\lambda_L + (1-\rho)\lambda_H\right] - \beta\lambda\frac{1}{1-\eta\exp\left(-\chi\right)},$$

where λ_j denotes the social value of bank equity in the following period for $j = L, H$ and ψ is the Lagrange multiplier on banks' no-default constraint. Substituting the former first-order condition into the latter yields the following expression for the net benefit from additional liquidity services:[19]

$$\omega\eta\exp\left(-\chi\right) - \lambda\chi\frac{\beta\eta\exp\left(-\chi\right)}{\left(1-\eta\exp\left(-\chi\right)\right)^2} = \beta\theta_2\psi - \beta\lambda\frac{\eta\exp\left(-\chi\right)}{1-\eta\exp\left(-\chi\right)}. \tag{12}$$

Suppose the regulator prefers banks to hold more equity capital than required by the no-default constraint in the current period (to increase banks' resilience against potential low loan repayments in the future). Then $\psi = 0$ and the right-hand side of Equation (12) is negative. This means that a regulator that imposes additional capital buffers on banks in the current period would also prefer that households receive fewer, rather than more, liquidity services.

[19]The effects of deposit supply and bond holdings on banks' participation constraints are suppressed because they cancel each other out exactly.

Proposition 2. *Constrained-efficient deposit supply and bank bond holdings are distorted downward whenever banks' no-default constraints are slack.*

Proof. See analysis above. □

The reason for distorting deposit supply downward in a constrained-efficient allocation is different from the reason in Hellmann, Murdock, and Stiglitz (2000). In their analysis rents from providing liquidity services are a substitute for costly capital in satisfying banks' incentive constraints; their policy implication is to increase liquidity premiums and reduce equity capital. But in this paper, as Proposition 2 shows, such rents are a complement from the viewpoint of a social planner that solves the problem stated in Definition 2. Banks get to enjoy these rents when they hold equity during normal times in excess of what the market-imposed no-default constraints require. Lower funding costs during the time when banks hold additional equity help them to earn their cost of capital and the value of banks is then no higher than their equity.[20]

5 Numerical analysis

Section 4 has shown theoretically that a constrained-efficient allocation limits banks' liquidity provision whenever banks' market-imposed equity requirements are slack (Proposition 2). From the viewpoint of a macroprudential bank regulator, higher risk weights on safe assets (or tighter leverage ratios) and additional capital buffers are complements during normal times. This section solves the model numerically to study how a regulator would want to set macroprudential policies over endogenous financial cycles. I

[20]There is no exogenous risk in Hellmann, Murdock, and Stiglitz (2000) and banks' incentive constraints always bind. In contrast, banks can experience exogenous loan losses in this paper which creates a social benefit from holding additional equity capital during normal times—it is banks' participation constraints that bind during normal times, while banks' no-default (incentive) constraints are slack in the constrained-efficient allocation.

first discuss the choices for numerical values of model parameters. Then I compare the constrained-efficient allocation to the competitive equilibrium and derive implications for optimal macroprudential policies. The computational method is discussed in Appendix C.

5.1 Calibration

Table 1 summarizes the choices of model parameter values used in the numerical analysis. The time period is one year. The choice of consumer discount factor β implies an annual interest rate on household savings of around 6 percent. This rate is between the long-run safe return of 1–3 percent and the long-run risky return of 7 percent as reported in Jordà, Knoll, Kuvshinov, Schularick, and Taylor (2019). The depreciation rate and capital income share are set to 10 percent and 40 percent, respectively. The firm productivity process is normalized to have unit mean, and the probability of the low shock realization is set to $\rho = 0.2$. Then z_H is fully determined by ρ and z_L.

The parameter values for θ_1, θ_2, η, z_L, and γ are chosen jointly such that five competitive-equilibrium model moments match their respective targets. Define "normal times" as periods during which bank equity and lending are constant as long as realized firm productivity is z_H.

The first model moment is the ratio of bank capital relative to the market-imposed capital requirement during normal times. Define this ratio as $\gamma E_t A_{t+1} / (K_{t+1} + \beta B_{t+1} \cdot \theta_2/\theta_1)$, where E_t denotes conditional expectations at time t. I set its target to 10 percent which is in line with the average ratio of equity capital to total assets of bank holding companies in the United States with assets of \$10 billion and over.[21] The second model moment is

[21] This data are collected by the Federal Reserve System and available for download at the Federal Financial Institutions Examination Council. The model feature of a fixed leverage target that banks aim to achieve during normal times is consistent with empirical evidence in Gropp and Heider (2010) and

the ratio of loans to the sum of loans and debt securities on banks' balance sheets during normal times. I set its target to $2/3$. The third model moment is banks' interest income net of interest and operating expenses relative to total assets during normal times for which I set the target to 60 basis points.

The fourth model moment is the loan-loss rate when low firm productivity is realized during normal times. I set its target to 4 percent. This target is in line with the loss rate generated by the 2018 supervisory bank stress test of the Federal Reserve Board for the case of an adverse scenario. More than one realization of low firm productivity is needed in the model to generate loan losses comparable to the stress test's severely adverse scenario.[22]

The fifth model moment is the fraction of periods during which the "lending gap," defined as the difference between bank lending during normal times and current bank lending, is at least 5 percent. I set its target to 0.05 (see Figure 1). Using data from Schularick and Taylor (2012) for the time period 1870–2008, Boissay, Collard, and Smets (2016) report that on average financial crises occur in developed countries once every 42 years and last 2.32 years. Therefore, roughly, a developed economy is expected to spend a fraction $1/42 \cdot 2.32 = 0.055$ of years in a financial crisis.

The parameter ω affects investor bond holdings B^i_{t+1} through the market clearing condition for bonds. But it does not affect any other competitive-equilibrium objects because investors have perfectly elastic bond demand at price β and can have negative consumption. However, the numerical value of ω nevertheless matters for the regulator's decision problem in Definition 2. A larger value of ω makes it more costly, in terms of reduced household liquidity services, to restrict banks' bond holdings. I set $\omega = 59/25 \cdot K^{\alpha}_{FB}$,

Begenau, Bigio, Majerovitz, and Vieyra (2020).

[22]Details on the stress test are provided by the Federal Reserve System.

Table 1: Model parameter values

parameter	value	target
β	0.94	return on savings
γ	0.91	financial crisis frequency
δ	0.10	average replacement investment
α	0.40	capital income share
θ_1	0.10	bank leverage
θ_2	0.03	bank balance sheet composition
η	0.35	banks' net interest margin
(z_L, z_H, ρ)	(0.8,1.05,0.2)	bank loss from one shock

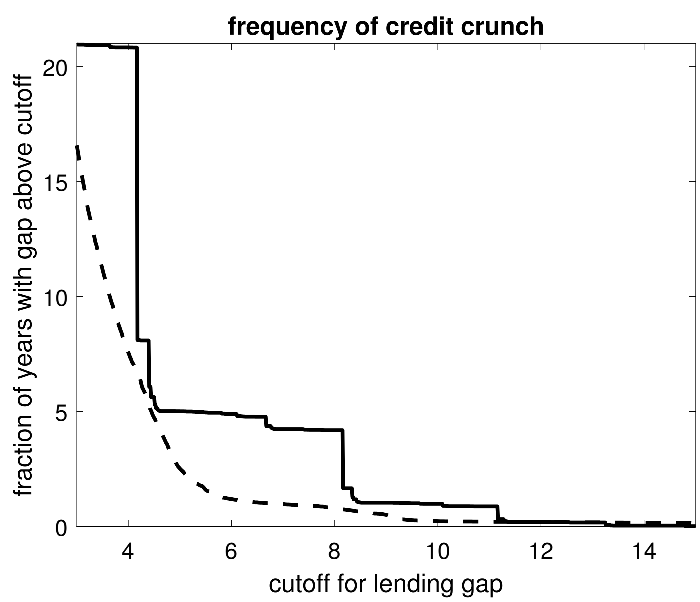


Figure 1: Frequencies of low credit in a stochastic steady state (average over 30, 000 simulated periods) in laissez-faire competitive-equilibrium allocation (CE) and the second-best allocation (SB).

Table 2: Bank balance sheets during normal times

	competitive equilibrium	second best
Assets		
loans	98.36	98.42
bonds	48.61	30.15
Liabilities		
equity	11.62	12.31
deposits	135.35	116.26
Total	146.97	128.57

Note: All quantities are in percent of first-best lending K_{FB}. Loans are K, bonds are βB, equity is post dividend, $A - D$, and deposits are $q\chi$.

where $^{59}/_{25}$ is the fraction of tradable financial assets to gross domestic product (GDP) in the United States and K_{FB}^{α} is average first-best output in the model economy.

5.2 Constrained efficient allocation

Table 2 compares bank balance sheets during normal times in competitive equilibrium and the constrained-efficient second best. There are three key differences. First, bank balance sheets are smaller in second best. Second, banks' funding is more stable in second best in the sense of more equity and fewer deposits. Third, lending is slightly higher in second best so that the smaller balance sheet is obtained by banks holding fewer bonds. Balance sheets in second best, while being smaller overall, feature liabilities that are more stable and assets that are riskier compared with competitive equilibrium. To understand the effect of these differences in bank balance sheets on financial cycles it is important to understand how balance sheets respond to exogenous shocks to loan repayments.

Figure 2 compares the second-best allocation with the competitive-equilibrium allocation for the following sequence of firm productivity shocks:

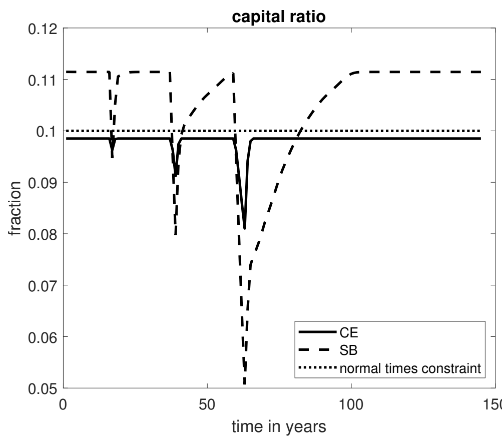
$$\{z_H, \ldots, z_H, z_L, z_H, \ldots, z_H, z_L, z_L, z_H, \ldots, z_H, z_L, z_L, z_L, z_L, z_H, \ldots, z_H\}.$$

This sequence produces three impulse responses that illustrate the non-linear effect of the shocks on bank lending and bond holdings and on banks' deposit supply. Following realizations of low firm productivity z_L, a sufficient number of realizations of high firm productivity z_H occur in the sequence for the economy to reach normal times during which bank equity and lending are constant as long as realized firm productivity is high.

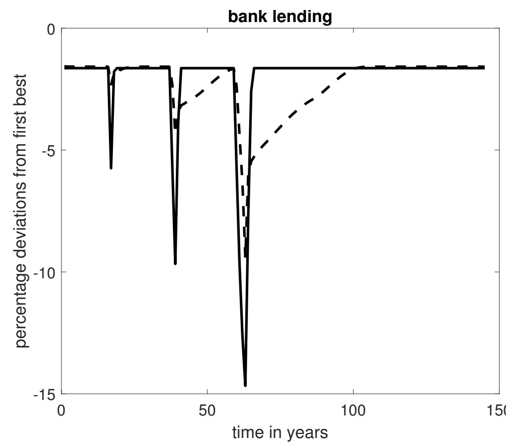
The composition of banks' assets is actually safer during normal times in competitive equilibrium compared with the second best (Figure 2 and Table 2). While both allocations feature roughly the same amount of lending to firms during normal times (Figure 2b), banks in competitive equilibrium hold far more bonds (Figure 2c). Each bank in competitive equilibrium has an incentive to increase its holding of safe bonds until its market-imposed no-default constraint Equation (9) binds.[23]

When banks holds more bonds, then the direct (partial-equilibrium) effect is that banks become safer but the indirect (general-equilibrium) effect is that banks' funding costs increase. On the one hand, the interest income from banks' safe bond holdings can be used to absorb losses from risky lending. On the other hand, such diversification with bond holdings increases the size of banks' balance sheets; and because banks consider equity capital to be costly, they fund bonds partly by supplying more deposits which reduces the equilibrium price that households are willing to pay for deposits.

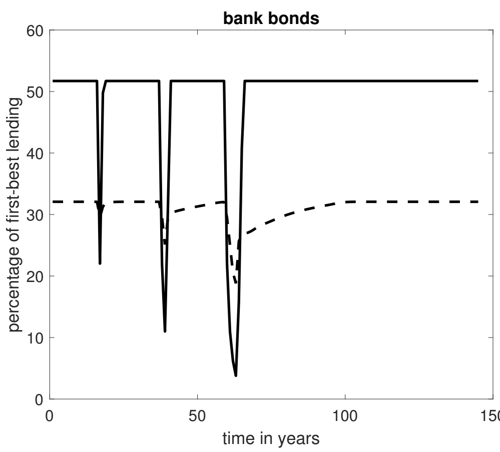
[23]Note that banks' equity capital ratio $\gamma E_t A_{t+1} / (K_{t+1} + \beta B_{t+1} \cdot \theta_2/\theta_1)$ shown in Figure 2a is slightly lower than θ_1 in competitive equilibrium during normal times, even though the no-default constraint Equation (9) holds. The reason is that banks enjoy lending spreads and liquidity premiums commensurate with their cost of capital during normal times so that banks' equity is always scarce *in expectations*. Formally, $E_t A_{t+1} < E_t V_{t+1}$ during in normal times in period t because $A_{t+1} = V_{t+1}$ if $z_{t+1} = z_H$ and $A_{t+1} < V_{t+1}$ if $z_{t+1} = z_L$.



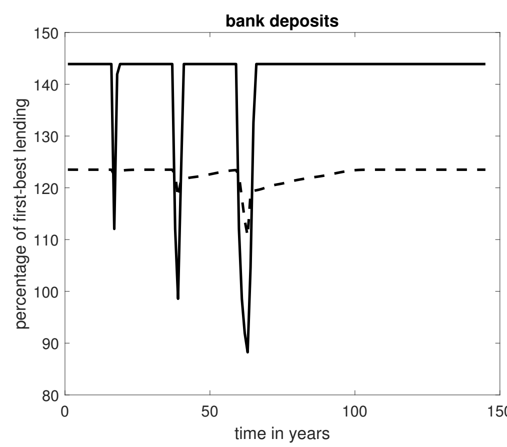
a Aggregate bank capital



b Aggregate bank lending

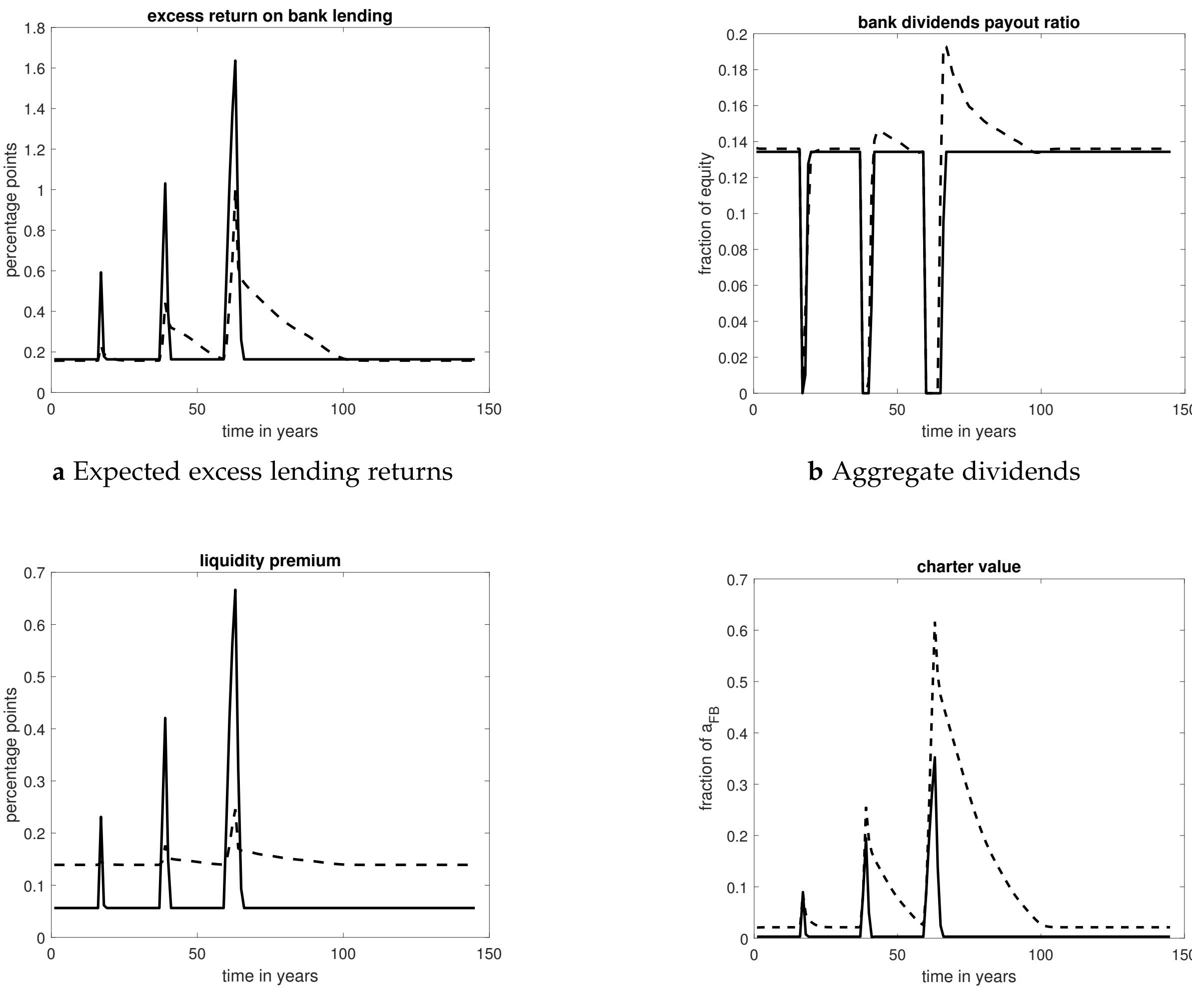


c Bank bonds



d Bank deposits

Figure 2: Panel a shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1}/(K_{t+1} + \beta B_{t+1} \cdot \theta_2/\theta_1)$, where E_t denotes conditional expectations at time t. Panel b shows bank lending relative to first-best lending, $[K_{t+1}/K_{FB} - 1] \cdot 100$. Panel c shows bank bonds, and panel d shows bank deposits.



a Expected excess lending returns

b Aggregate dividends

c Liquidity premium

d Charter value

Figure 3: Panel a shows expected lending excess returns, $[\beta E_t R_{t+1} - 1] \cdot 100$. Panel b shows the aggregate bank dividend payout ratio, D_t/A_t. Panel c shows the liquidity premium, $(q_{t+1} - \beta) \cdot 100$. Finally, panel d shows banks' charter value net of equity defined as $V_t - A_t$.

In a second best the supply of loans and deposits is much more stable compared with the competitive equilibrium. The flipside of banks avoiding sharp reductions in their balance sheets in response to loan losses in second best is that the capital ratio, shown in Figure 2a, decreases much more. In contrast, in competitive equilibrium banks' willingness to hold a larger quantity of bonds during normal times, but to also shed bonds quickly in response to loan losses, implies a capital ratio that is much more stable than in second best. A regulator would prefer that banks stabilize lending and deposit supply rather than capital ratios.

Banks in competitive equilibrium prefer to build resilience against loan losses by accumulating safe assets, rather than costly equity, during normal times. One implication of banks conducting their capital management in this way is that, in particular, their deposit supply becomes very volatile. While lending drops by almost 15% in competitive equilibrium in the most severe scenario in Figure 2b, the supply of deposits drops by 40% (Figure 2d). The liquidity premium is much more stable in second best—as the the tightness of banks' no-default constraints is alleviated due to temporarily elevated charter values (Figure 3d)—but also higher during normal times (Figure 3c). Banks' higher margins during normal times in second best compensate banks for holding more costly equity.

In the model in this paper financial stability is not determined by how safe the composition of banks' assets is (which is safer in competitive equilibrium) but by how stable the composition of banks' liabilities is (which is less stable in competitive equilibrium). Table 2 illustrates the main policy implication: banks should hold fewer safe assets. The resulting lower deposit supply increases deposit premiums and allows the banking sector to maintain higher levels of equity without reducing lending.

The supply of both loans and deposits is more stable over time when banks are discouraged from "self-insuring" with (deposit-funded) safe assets and instead are encouraged to hold more common equity. In the model, banks' efforts to reduce the risk of their incomes, by deriving more of it from holding safe assets in addition to risky loans, also reduce banks' incomes on average. This prevents banks from holding socially desirable levels of equity capital in a competitive equilibrium. A social planner would prefer to reduce risk in the banking sector with more equity capital rather than more safe assets.

The analysis in this paper cautions about potential unintended side effects of "liquidity regulation" tools such as the liquidity coverage ratio (LCR). While the LCR can be satisfied by either making liabilities more stable or assets safer, banks in practice respond to a need to increase their LCR by acquiring more safe assets (Sundaresan and Xiao, 2024). Policy prescriptions for reducing banks' holdings of safe assets during normal times include: a decrease in the LCR, an increase in the supplementary leverage ratio (SLR), and forgoing permanent exemptions for safe government bonds in the calculation of the SLR.[24]

5.3 Robustness analysis

This section studies how the main result of the paper—that banks should hold fewer safe assets in support of additional capital buffers—depends on the fraction θ_2 of safe assets that banks could potentially divert. Specifically, this robustness analysis considers the special cases of $\theta_2 = 0$ and $\theta_2 = \theta_1$.

[24] These are policy implications for normal times. The Federal Reserve temporarily exempted US Treasuries from the SLR during the covid-19 pandemic.

5.3.1 Special case $\theta_1 > \theta_2 = 0$

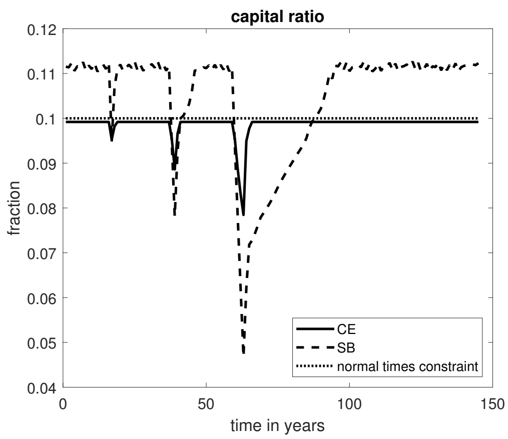
Suppose banks would not be able to divert any safe assets. When banks in competitive equilibrium do not have to hold costly equity to back up their safe asset holdings, $\theta_2 = 0$, then they will acquire more safe assets as long as the deposit premium is strictly positive. Proposition 1 shows that banks in a competitive equilibrium issue deposits until the price of deposits equals the bond price β. Banks' lending, dividends, and equity in competitive equilibrium are exactly the same as in Schroth (2021) in this case.

However, the regulator still internalizes the effect of banks' deposit supply on deposit premiums. Figure 4 shows that, instead of satiating deposit supply and holding an unbounded amount of safe assets, the regulator would prefer that banks' safe assets are around 32 percent of lending during normal times. This fraction is almost the same as in the benchmark case in Section 5.2.

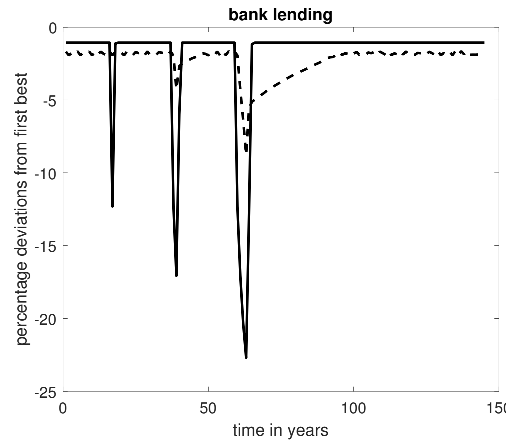
5.3.2 Special case $\theta_1 = \theta_2$

Suppose now that banks would be able to divert the same fraction of the safe assets than of loans such that $\theta_2 = \theta_1 = 0.10$. If the values of all other model parameters are unchanged, then banks in competitive equilibrium hold much less safe assets, as shown in Figure 5. Banks supply fewer deposits in this case and as a result enjoy larger liquidity premiums. In contrast, a regulator would prefer banks to hold more safe assets. Note that this does not contradict the result in Proposition 2 that the regulator prefers banks to provide less liquidity services when no-default constraints are slack. Given the high degree of capital encumbrance associated with holdings of safe assets (i.e., the same high degree as for risky loans), the regulator would not require banks to hold additional equity capital on top of what the market-imposed no-default constraints require.

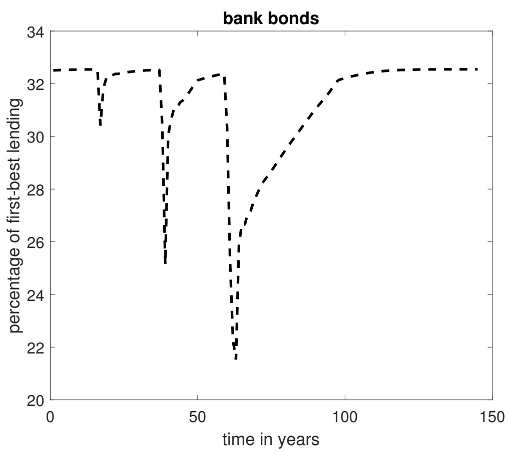
The model in the case $\theta_2 = \theta_1 = 0.10$ can be re-calibrated to target banks' safe asset



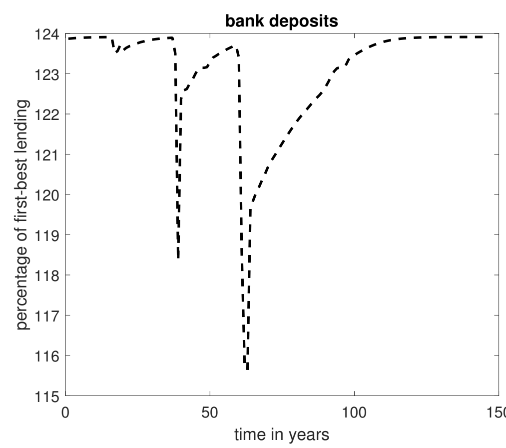
a Aggregate bank capital



b Aggregate bank lending



c Bank bonds



d Bank deposits

Figure 4: Counterfactual with $\theta_2 = 0$. Panel a shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1}/(K_{t+1}$, where E_t denotes conditional expectations at time t. Panel b shows bank lending relative to first-best lending, $[K_{t+1}/K_{FB} - 1] \cdot 100$. Panel c shows bank bonds, and panel d shows bank deposits.

holdings to be one third of total assets in competitive equilibrium (the same target as in Section 5.2). The changes in the values of model parameters are a decrease in the cost of equity (γ increases to 0.93) and an increase in loan riskiness (z_L decreases to 0.725).[25] Figure 6 shows that, during normal times, the regulator prefers market-imposed no-default constraints to be slack and banks' safe asset holdings lower, just as in Section 5.2.

6 Extension with monetary policy

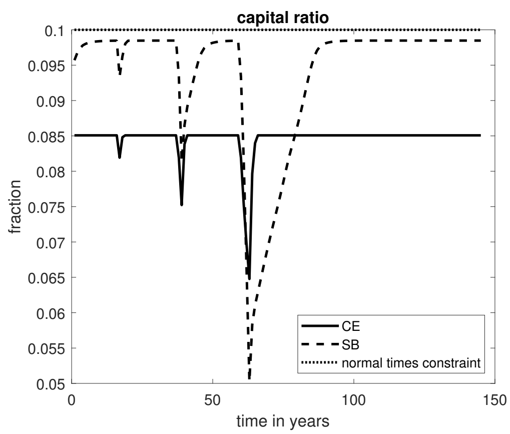
This section introduces a monetary authority to study the financial-stability implications of macroeconomic interactions between nominal and financial frictions. Suppose transactions in the labor and consumption goods markets are in nominal terms. Money is only a medium of exchange, and never a store of value, so that it is convenient to normalize the price level at the beginning of each period to $P_0 = 1$.[26] Similarly, the nominal wage at the beginning of each period t is set to $W_{t,0} = (1-\alpha)K_t^{\alpha}$, where K_t is aggregate physical capital that firms have invested in the previous period.

There is a nominal friction in the labor market. Specifically, firms are now assumed to receive idiosyncratic wage-rigidity shocks when accessing the labor market: half of them take a nominal wage of $W_{t,0}$ as given and their labor demand is fully met, while the other half take nominal wage W_t as given.[27] Let W_t denote the wage that clears the labor market, for given $W_{t,0}$, and let P_t be the price level at which consumption goods are

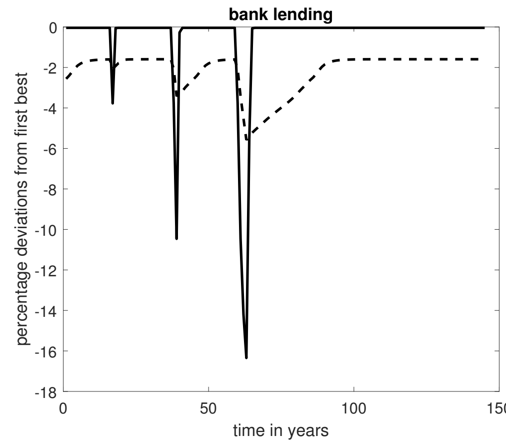
[25] Given the much lower cost of equity, despite riskier loans, credit crunches are only about half as frequent in competitive equilibrium compared to Section 5.2.

[26] The monetary authority collects no seigniorage in the model. It also does not compete with banks in issuing (public) money inter-temporally. However, through its open-market operations, the monetary authority may affect the liquidity of bonds and therefore the liquidity premium that banks can earn by issuing private money (i.e., deposits).

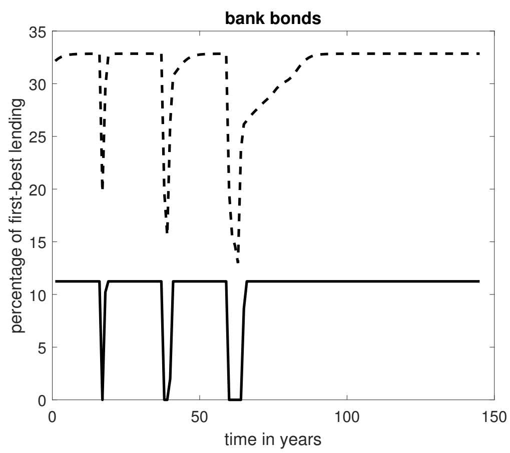
[27] Recall that workers supply labor inelastically in the model. Alternatively, in Erceg, Henderson, and Levin (2000) a fraction of households are allowed to reset their wages so that wages become "staggered" (Calvo, 1983). The labor index $\mathcal{L}$ defined in Equation (14) measures aggregate labor services demanded by firms.



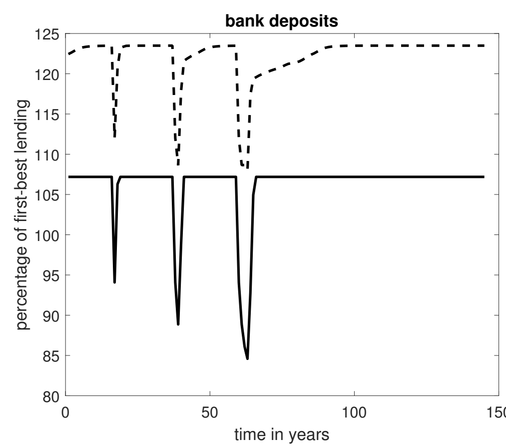
a Aggregate bank capital



b Aggregate bank lending

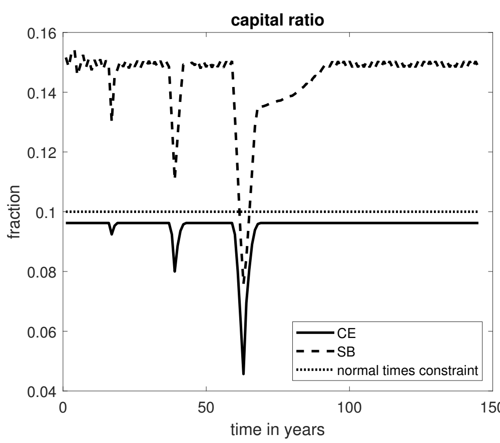


c Bank bonds

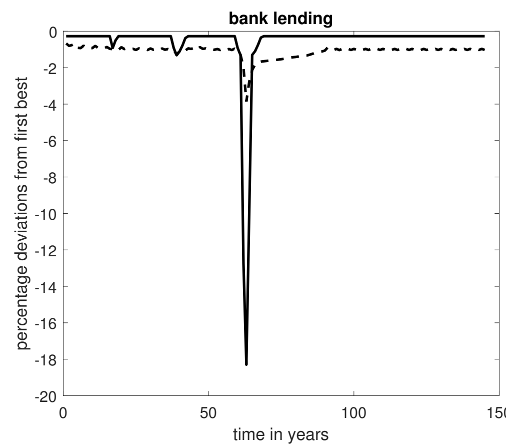


d Bank deposits

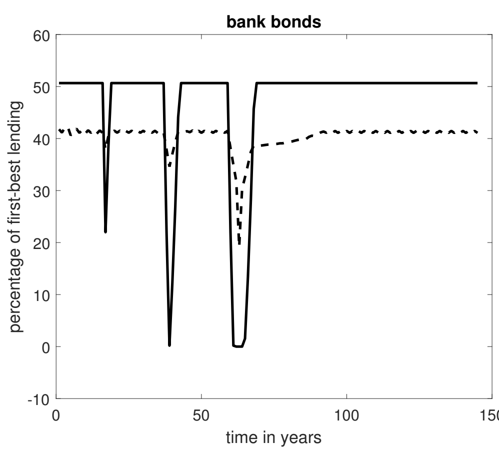
Figure 5: Counterfactual with $\theta_2 = 0.10 = \theta_1$. Panel a shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1}/(K_{t+1} + \beta B_{t+1} \cdot \theta_2/\theta_1)$, where E_t denotes conditional expectations at time t. Panel b shows bank lending relative to first-best lending, $[K_{t+1}/K_{FB} - 1] \cdot 100$. Panel c shows bank bonds, and panel d shows bank deposits.



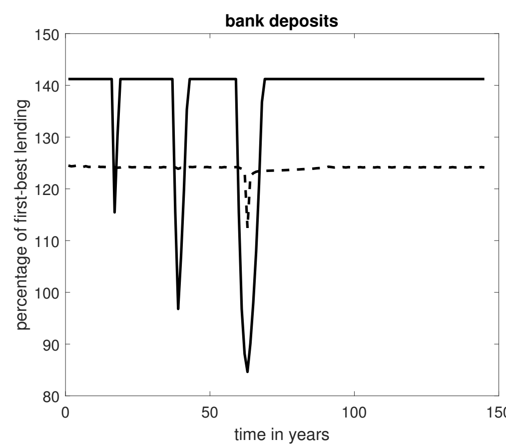
a Aggregate bank capital



b Aggregate bank lending



c Bank bonds



d Bank deposits

Figure 6: Counterfactual with $\theta_2 = 0.10 = \theta_1$, recalibrated. Panel a shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1}/(K_{t+1} + \beta B_{t+1} \cdot \theta_2/\theta_1)$, where E_t denotes conditional expectations at time t. Panel b shows bank lending relative to first-best lending, $[K_{t+1}/K_{FB} - 1] \cdot 100$. Panel c shows bank bonds, and panel d shows bank deposits.

exchanged in period t. The price level is determined by a monetary authority, which is introduced below. There are no nominal frictions in the market for consumption goods.

Firms take into account idiosyncratic wage-rigidity shocks when making their investment decision as follows:

$$
\begin{aligned}
&E_t\left[\frac{1}{2}\max\left(\max_n\left\{z_{t+1}k^\alpha n^{1-\alpha}+(1-\delta)k-\frac{W_{t+1,0}}{P_{t+1}(z_{t+1})}n-R^{sticky}_{t+1}(z_{t+1})k\right\},0\right)\right.\\
&\qquad\left.+\frac{1}{2}\max\left(\max_n\left\{z_{t+1}k^\alpha n^{1-\alpha}+(1-\delta)k-\frac{W_{t+1}(z_{t+1})}{P_{t+1}(z_{t+1})}n-R^{flexible}_{t+1}(z_{t+1})k\right\},0\right)\right]\\
&=E_t\left[\max\left(\frac{1}{2}\max_n\left\{z_{t+1}k^\alpha n^{1-\alpha}+(1-\delta)k-\frac{W_{t+1,0}}{P_{t+1}(z_{t+1})}n\right\}\right.\right.\\
&\qquad\left.\left.+\frac{1}{2}\max_n\left\{z_{t+1}k^\alpha n^{1-\alpha}+(1-\delta)k-\frac{W_{t+1}(z_{t+1})}{P_{t+1}(z_{t+1})}n\right\}-R_{t+1}(z_{t+1})k,0\right)\right],
\end{aligned}
$$

where $R_{t+1}(z_{t+1})$ denotes the average loan repayment across firms conditional on aggregate productivity being z_{t+1}.

Let $\hat{L}_t$ denote labor demand of a firm that must offer $W_{t,0}$; then the firm's optimality condition is as follows:

$$\frac{W_{t,0}}{P_t}=z_t(1-\alpha)K_t^\alpha\hat{L}_t^{-\alpha}\Rightarrow\hat{L}_t=(z_tP_t)^{\frac{1}{\alpha}}. \tag{13}$$

Firms that are not constrained to offer $W_{t,0}$ employ the remaining workers. Their labor input is $2-\hat{L}_t$ each, and they pay workers their marginal product $z_t(1-\alpha)K_t^\alpha(2-\hat{L}_t)^{-\alpha}$.

When $\hat{L}_t\neq 1$, then the marginal product of labor is not equal across all firms. Define "effective labor" employed across all firms as follows:

$$\mathcal{L}_t=\frac{1}{2}\left(\hat{L}_t^{1-\alpha}+(2-\hat{L}_t)^{1-\alpha}\right). \tag{14}$$

Equation (14) shows that there is underemployment in the form of effective labor being less than its potential of one ($\mathcal{L}_t < 1$) whenever labor is misallocated across firms as a result of the nominal friction in the labor market ($\hat{L}_t \neq 1$). Call $1 - \mathcal{L}_t$ the "labor gap" in period t.

The average household real wage, in per capita terms, and the average loan repayment that banks receive are given as follows:

$$w_t = z_t(1-\alpha)K_t^{\alpha}\mathcal{L}_t, \tag{15}$$

$$R_t = z_t\alpha K_t^{\alpha-1}\mathcal{L}_t + 1 - \delta. \tag{16}$$

The monetary policy authority targets the price level by adjusting the money supply each period. Specifically, the monetary authority trades bonds at the time when households want to sell them; this is the time when nominal transactions take place in the goods and labor markets. The remaining bond maturity is vanishing so that the price is 1. These bond trades temporarily increase the amount of money in circulation. Because money is not held intertemporally it is convenient to fix the money supply at the beginning of period t, say at $M_{t,0} = K_t^{\alpha}$. Then the bond trade that changes the money supply to M_t is given by $T_t \equiv \frac{M_t - M_{t,0}}{P_t}$. There is no seigniorage associated with T_t because the remaining maturity is zero, such that the monetary authority always maintains budget balance and there are no transfers to households.

For given T_t, transactions on the consumption good market determine the price level P_t as follows:

$$M_t = P_t Y_t = P_t z_t K_t^{\alpha}\mathcal{L}_t. \tag{17}$$

Note that the velocity of money is assumed to be constant and normalized to unity. Therefore, for given aggregate physical capital K_t and firm productivity z_t, the monetary authority can achieve a price level P_t with bond trade T_t as follows:

$$T_t = z_t K_t^{\alpha} \mathcal{L}_t(P_t) - {}^{K_t^{\alpha}}/_{P_t}, \tag{18}$$

with effective labor given by $\mathcal{L}(P_t) = \frac{1}{2}\left((z_t P_t)^{\frac{1-\alpha}{\alpha}} + \left[2 - (z_t P_t)^{\frac{1}{\alpha}}\right]^{1-\alpha} \right)$.

Monetary authority bond trades not only affect effective labor, but also the liquidity on the market for bonds at the time households need to sell bonds to consume. Specifically, assume that t households' bond transaction costs decrease in monetary authority bond purchases. Intuitively, when the monetary authority is buying bonds, then it is easier for households to find a buyer; but when the monetary authority is selling bonds (when it reduces the money supply), then households face a larger transaction cost. Households' bond transaction cost in the model extension with monetary policy is given as follows:

$$g_{t+1} = \eta \exp \cdot \left(-\chi_{t+1} - \eta_T T_{t+1} \right), \tag{19}$$

with $\eta_T > 0$. Households anticipate monetary authority bond purchases when determining how much to pay for deposits, and the deposit price is now as follows:

$$q_{t+1} = \frac{q^b_{t+1}}{1 - E_t\left[g_{t+1}\right]} = \frac{q^b_{t+1}}{1 - \eta \exp\left(-\chi_{t+1}\right) E_t\left[\exp\left(-\eta_T T_{t+1}\right)\right]}. \tag{20}$$

Equation (20) shows that if monetary policy is anticipated to be on average more expansionary, then the deposit price is lower and the implied deposit rate is higher. The liquidity premium on deposits decreases when the monetary authority creates additional liquidity.[28] Overall, the inverse demand function for deposits is downward sloping in aggregate deposits while a more (less) expansive monetary policy stance shifts it down-

[28] Greenwood, Hanson, and Stein (2015) and Drechsler, Savov, and Schnabl (2017) empirically link liquidity premiums to the expansiveness of monetary policy.

ward (upward).

Suppose that in a competitive equilibrium, the monetary authority conducts bond trades each period to fully close the labor gap. Using Equation (13), the price level that achieves $\hat{L}_t = \mathcal{L}_t = 1$ is given by $P_t = \frac{1}{z_t}$. Equation (18) shows that the monetary authority achieves full employment by not conducting any bond trades such that $T_t = 0$ for $t = 1, 2, \ldots$ in a competitive equilibrium. That is, the price level adjusts according to Equation (17) in a way that makes a constant money supply consistent with full employment. Because the associated bond trades are zero at all times deposit prices in competitive equilibrium are the same as in Section 5.2. Therefore, the competitive equilibrium in the case with nominal frictions and monetary policy is the same as in Definition 1. Recall that the values of model parameters chosen to target competitive-equilibrium moments are reported in Table 1. The only parameter value that remains to be chosen is η_T, the semi elasticity of households' bond transaction cost with respect to monetary-authority bond trades. Assume $\eta_T = 10$.

The price that households are willing to pay for bank deposits depends not only on the size of banks' balance sheets (supply of deposits) but also, through $\eta_T > 0$, on the monetary policy stance. Equation (20) shows that monetary authority bond trades affect banks' funding costs through their effect on the liquidity premium on deposits. Therefore, a policy that closes the labor gap in every period, i.e., $T_t = 0$, may not be constrained-efficient.

Note that if $\eta_T = 0$, then the regulator would see no benefit from distorting monetary policy away from a policy that always closes the labor gap and the regulator's problem would be given by Definition 2.[29] Therefore, the case in Section 5.2 can also be interpreted as the case of no coordination between macroprudential policy and monetary

[29]Households' bond transaction costs equal $g_t = \eta \exp\left(-\chi_t - \eta_T T_t\right) = \eta \exp\left(-\chi_t\right)$ whenever $\eta_T = 0$, or $T_t = 0$, or both.

Table 3: Bank balance sheets during normal times, with monetary policy

	competitive equilibrium	second best ($\eta_T = 0$)	second best ($\eta_T = 10$)
Assets			
loans	98.36	98.42	98.96
bonds	48.61	30.15	30.60
Liabilities			
equity	11.62	12.31	12.85
deposits	135.35	116.26	116.61
Total	146.97	128.57	129.56

Note: All quantities are in percent of first-best lending K_{FB} and measured at the point of dividend payment: loans are K, bonds are βB, equity is post dividend, $A - D$, and deposits are $q\chi$.

policy in the sense of the latter always targeting full employment (ignoring its effect on banks' margins, which affect output and wages through banks' loan supply).[30] Call the constrained-efficient allocation in this section the "second best with coordination."

When $\eta_T > 0$, then a regulator internalizes that the effect of monetary policy is twofold. On the one hand, it can increase aggregate employment by improving the allocative efficiency of labor across firms. On the other hand, monetary policy is conducted through open market operations that affect the transaction costs that households face when selling bonds to purchase consumption goods. When households have lower transaction costs, then their willingness to pay for deposits decreases, see Equation (20), and banks' funding cost increases. Therefore, if the regulator fully closes the labor gap, then this might lead to lower household labor income because of how banks' funding costs affect their loan supply. The regulator's constrained-efficient planning problem is stated in Definition 3 in Appendix A.

Table 3 shows that, during normal times, the main difference when monetary policy is coordinated with macroprudential policies is that banks hold more equity (around

[30]Intuitively, lack of coordination between macroprudentual and monetary policies in this way implies that while employment is always as high as possible, households' aggregate labor income may not be (unless $\eta_T = 0$).

50 basis points more in terms of lending). Figures 8 and 9 in Appendix A compare the second-best allocations for the cases with and without coordination, respectively. The shock sequence is the same as in Section 5.2. In the case of severe loan losses the decrease in banks' capital ratios is about the same (Figure 8a), while lending decreases less when when monetary policy depends on the financial cycle (Figure 8b). Banks' bond holdings and deposit supply in second best do not depend much on whether there is coordination of monetary policy with macroprudential policy (Figures 8c and 8d). Figure 9a shows that the lending margin is lower in the second best with coordination. The liquidity premium on deposits is higher with coordination (Figure 9c) because of an overall tighter monetary policy stance. In second best with coordinated monetary policy tighter monetary policy during normal times supports banks' margins and enables banks to hold more equity and to supply somewhat more loans.

Figure 7 reveals the reason, together with higher retained equity (see Table 3), for the smaller drop in second-best lending during severe financial crises when monetary and macroprudential policies are coordinated. A temporary tightening of monetary policy in response to loan losses supports banks' margins during crises and recoveries. In particular, optimally coordinated monetary policy avoids undue pressure on banks' margins during the times when banks have reduced equity. The policy implication is that the monetary policy authority should not fully close the labor gap during the times when the macroprudential authority reduces capital buffer requirements. When macroprudential policy is more accommodating, then monetary policy should be more restrictive.

Therefore, while aggressive monetary policy accommodation during financial crises (Schularick and Taylor, 2012) has been argued to either support financial markets (Adrian and Shin, 2009; Mishkin, 2009) or to sow the seeds of the next crisis (*Bank for Interna-*

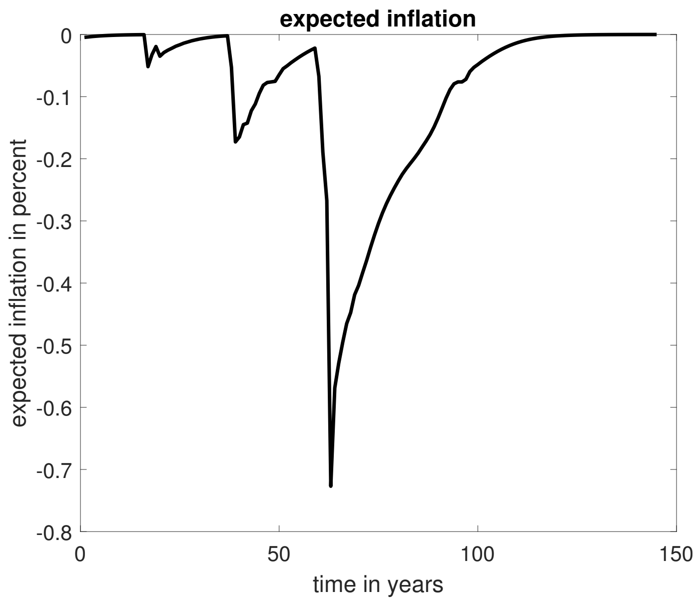


Figure 7: Difference in expected inflation, $E_t P_t - P_0$, between second-best monetary policy with coordination and a monetary policy that closes the labor gap at all times (in percentage deviations from normal times).

tial Settlements, 2014), this paper argues that it has the negative side-effect of harming financial intermediaries and prolonging the current crisis. Note that (aggressive) monetary policy accommodation in recent practice can take the form of "quantitative easing" wherein the monetary authority buys bonds and issues (excess) reserves. The model in this paper does not distinguish between quantitative easing and conventional monetary policy; it is assumed that banks use any proceeds from selling bonds to the monetary authority to facilitate payments within the same period.[31]

Figure 10 in appendix A shows that when monetary and macroprudential policies are optimally coordinated, then the frequency of financial crises is lower (the probability density shifts inward). The reason is that monetary policy will avoid excessively depressing banks' margins at a time when macroprudential policy releases capital buffers

[31] Diamond, Jiang, and Ma (2024) note the significant accumulation of banks' excess reserves since 2008 and argue that it crowds out bank lending. In contrast, the focus in this paper is on the detrimental effect of both large bank balance sheets and expansive monetary policy on the stability of the banking system rather than on bank lending during normal times.

to support bank lending. Optimal coordination (further) reduces excessive cyclicality in bank lending and deposit supply.[32]

7 Conclusion

Macroprudential regulation in practice has the objective of limiting the cyclicality of aggregate bank lending. However, another important role of banks is to provide liquidity services. During normal times, banks can easily provide more liquidity services in the form of deposits by accumulating more financial assets. But during crisis times, banks face a scarcity of capital which endogenously makes banks themselves less liquid because of moral hazard concerns. Banks are then constrained in their ability to issue deposits and forced to reduce the size of their balance sheets. Thus, banks' ability to provide liquidity services depends, just as their ability to make loans, on the capital they hold. At the same time, monetary policy affects the demand for liquidity services by affecting the transaction costs associated with selling financial assets. It is therefore important to include in an analysis of macroprudential bank regulation both its effect on banks' provision of liquidity services and its coordination with monetary policy.

A macroprudential regulator would want banks to reduce their safe asset holdings and issue fewer deposits during normal times in support of greater equity capital buffers. The idea is that banks enjoy a somewhat larger liquidity premium during normal times. This enables them to build up costly capital buffers that serve the purpose of reducing cyclicality in the supply of both loans and liquidity services. Therefore, during normal

[32] Banks in the model do not face bond transaction costs. In practice, monetary authorities sometimes conduct purchases of safe assets in the form of government debt to ensure market functioning (e.g., Duffie and Keane, 2023). Such programs limit the occurrence of undue transaction costs for the intermediaries that have access to them. The analysis in this paper cautions against expanding asset purchase programs beyond financial intermediaries.

times, imposing a capital buffer requirement is complementary to tightening the leverage ratio requirement (effectively increasing risk weights on safe assets).

During times of financial crises monetary policy should be less expansive relative to what would be needed to close the labor gap. The idea is to avoid excessive competition from monetary policy in providing liquidity services to the economy at times when banks use retained earnings to rebuild capital. A tighter monetary policy stance is thus complementary to releasing capital buffers during times of financial crises. Optimal coordination of monetary and macroprudential policies lowers the severity and frequency of financial crises.

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Appendices

A Extension with monetary policy - definitions and figures

Let $\{\chi_{t+1}, D_t, K_{t+1}, T_{t+1}\}$ be a sequence of deposits, dividends, bank lending and monetary authority bond trades; then the associated welfare is as follows:

$$W_0 = D_0 + E_0 \left[\sum_{t=1}^{\infty} \beta^t \left(D_t + z_t(1-\alpha)K_t^{\alpha} \mathcal{L}\left(P_t\right) - \frac{\omega}{\beta} E_{t-1}[g_t] \right) \right], \tag{21}$$

where P_t is determined by Equation (18) and $g_t = \eta \exp\left(-\chi_t\right) \exp\left(-\eta_T T_t\right)$.

Definition 3. *The problem of a social planner, or regulator, that can choose both macroprudential and monetary policy to maximize the welfare criterion in Equation (21) can be expressed recursively as follows:*

$$W(A,V) = \max_{\{D,B,K,\chi,T_L,T_H,V_L,V_H\}} \Big\{ D + \beta\rho \left[z_L(1-\alpha)K^\alpha \mathcal{L}(P_L) - \frac{\omega}{\beta} g_L + W(A_L,V_L) \right] \\ + \beta(1-\rho) \left[z_H(1-\alpha)K^\alpha \mathcal{L}(P_H) - \frac{\omega}{\beta} g_H + W(A_H,V_H) \right] \Big\}$$

subject to

$$D + K + \beta B \leq A + \frac{\beta}{1-[\rho g_L + (1-\rho) g_H]}\chi, \qquad \textit{(bank budget constraint)}$$

$$D \geq 0, \qquad \textit{(dividend non-negativity)}$$

$$\gamma\left[\rho V_L + (1-\rho)V_H\right] \geq \theta_1 K + \theta_2 \beta B, \qquad \textit{(no-default bank)}$$

$$V_j \geq A_j,\ j = L,H, \qquad \textit{(participation bank)}$$

$$D + \gamma\left[\rho V_L + (1-\rho)V_H\right] \geq V, \qquad \textit{(promise keeping regulator)}$$

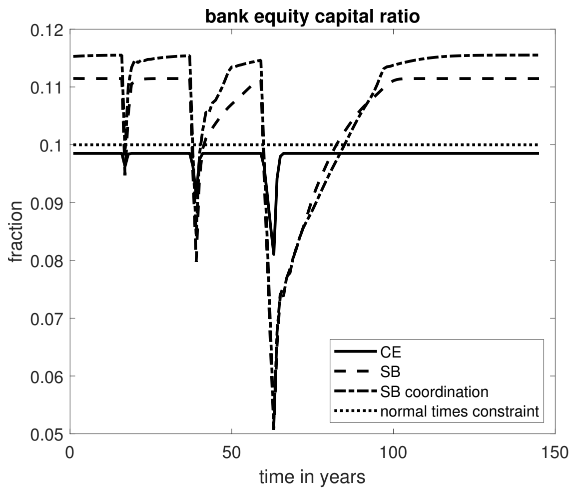
where

$$A_j = z_j \alpha K^\alpha \mathcal{L}(P_j) + (1-\delta)K + B - \chi,\ j = L,H, \qquad \textit{(next period's bank equity)}$$

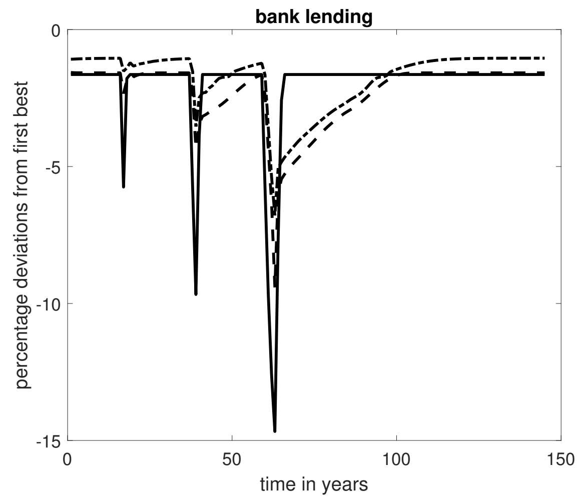
$$g_j = \eta \exp\left(-\chi - \eta_T T_j\right),\ j = L,H, \qquad \textit{(households' bond transaction costs)}$$

$$T_j = z_j K^\alpha \mathcal{L}(P_j) - \frac{K^\alpha}{P_j},\ j = L,H, \qquad \textit{(monetary authority bond trade)}$$

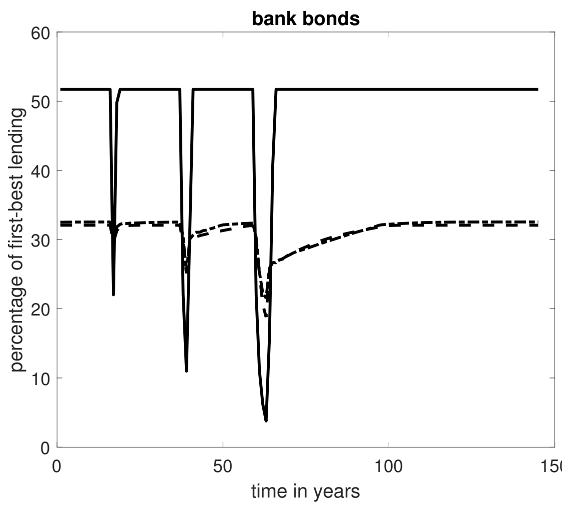
$$\mathcal{L}(P_j) = \frac{1}{2}\left[\left(z_j P_j\right)^{\frac{1-\alpha}{\alpha}} + \left(2 - (z_j P_j)^{\frac{1}{\alpha}}\right)^{1-\alpha} \right],\ j = L,H. \qquad \textit{(effective labor across firms)}$$



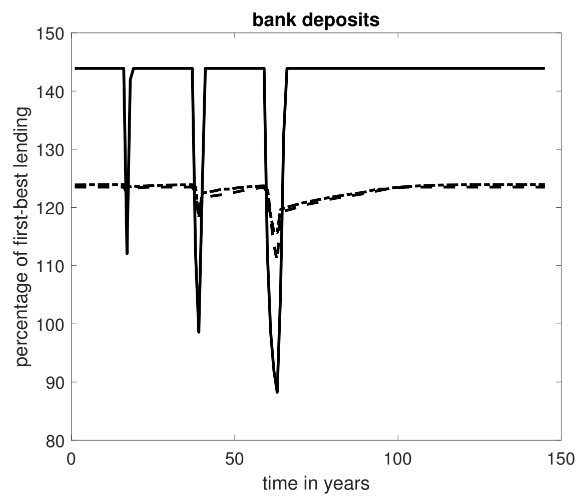
a Aggregate bank capital



b Aggregate bank lending

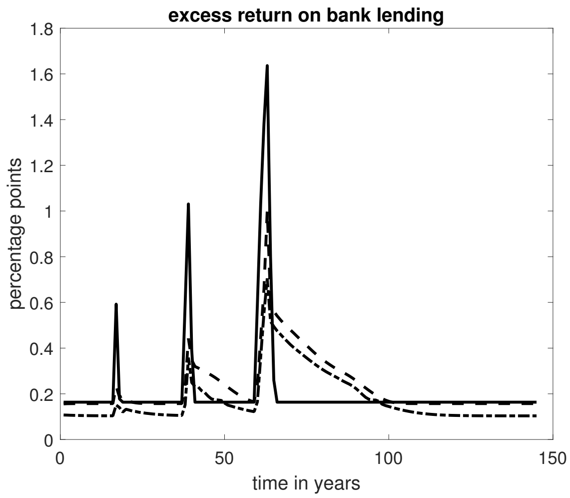


c Bank bonds

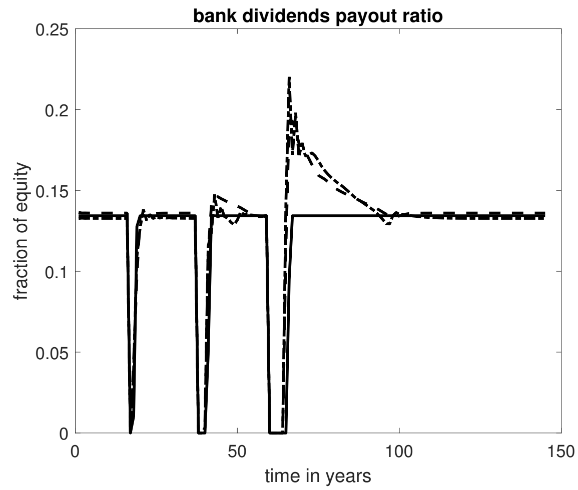


d Bank deposits

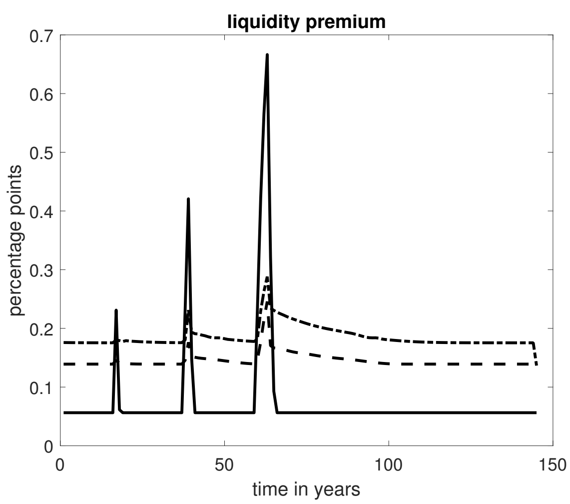
Figure 8: Panel a shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1}/(K_{t+1} + \beta B_{t+1} \cdot \theta_2/\theta_1)$, where E_t denotes conditional expectations at time t. Panel b shows bank lending relative to first-best lending, $[K_{t+1}/K_{FB} - 1] \cdot 100$. Panel c shows bank bonds, and panel d shows bank deposits.



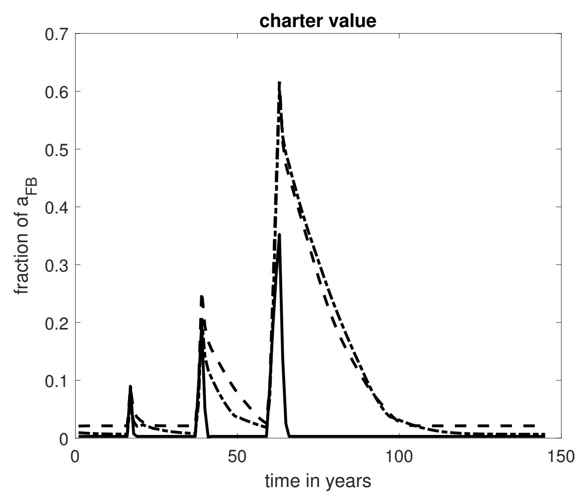
a Expected excess lending returns



b Aggregate dividends



c Liquidity premium



d Charter value

Figure 9: Panel a shows expected lending excess returns, $[\beta E_t R_{t+1} - 1] \cdot 100$. Panel b shows the aggregate bank dividend payout ratio, D_t/A_t. Panel c shows the liquidity premium, $(q_{t+1} - \beta) \cdot 100$. Finally, panel d shows banks' charter value net of equity defined as $V_t - A_t$.

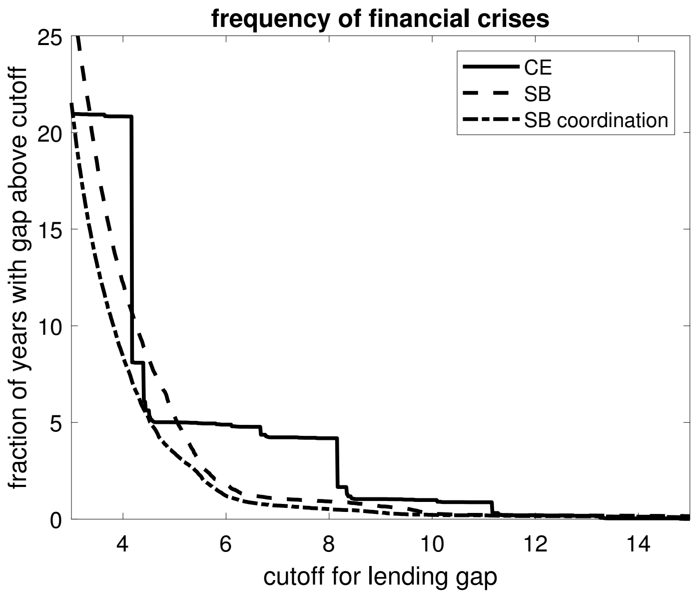


Figure 10: Frequency of low lending in a stochastic steady state (average over 30,000 simulated periods) in laissez-faire competitive-equilibrium allocation (CE), second-best allocation (SB), and second-best allocation with coordination (SB coordination).

B Proofs

Proof of Proposition 1. The problem of a bank in competitive equilibrium in recursive form is given as follows:

$$V(a,A) = \max_{\{D,B,K,\chi\}} \{D + \beta\rho\left[R(z_L,A)K + V(a_L,A_L)\right] + \beta(1-\rho)\left[R(z_H,A)K + V(a_H,A_H)\right]\}$$

subject to

$$D + K + \beta B \leq a + q(A)\chi, \qquad \text{(bank budget constraint)}$$

$$D \geq 0, \qquad \text{(dividend non-negativity)}$$

$$\gamma\left[\rho V(a_L,A_L) + (1-\rho)V(a_H,A_H)\right] \geq \theta_1 K + \theta_2 \beta B, \qquad \text{(no-default bank)}$$

where

$$a_j = R(z_j, A)K + (1-\delta)K + B - \chi,\ j = L, H, \qquad \text{(next period's bank equity)}$$

$$A_j = R(z_j, A)K(A, A) + (1-\delta)K(A, A) + B(A, A) - \chi(A, A),\ j = L, H. \qquad \text{(aggregate law of motion)}$$

Let the Lagrange multipliers on the three constraints be λ, μ and ψ, respectively. Then the envelope condition is $V_a(a, A) = \lambda(A)$. Suppress dependence on the state A and let $\lambda_j = \lambda(A_j)$. The first-order conditions are as follows:

$$\begin{aligned}
D: &\quad \lambda = 1 + \mu, \\
B: &\quad (1+\psi)\gamma\left[\rho\lambda_L + (1-\rho)\lambda_H\right] - \beta\lambda - \beta\theta_2\psi = 0, \\
K: &\quad (1+\psi)\gamma\left[\rho\lambda_L R(z_L) + (1-\rho)\lambda_H R(z_H)\right] - \lambda - \theta_1\psi = 0, \\
\chi: &\quad (1+\psi)\gamma\left[\rho\lambda_L + (1-\rho)\lambda_H\right] - q\lambda = 0.
\end{aligned}$$

Note that the focus is on parametrizations for which banks choose $B > 0$. Combining the first-order conditions for bonds B and deposits χ yields the following relationship between liquidity premium and the tightness of banks' no-default constraints:

$$q - \beta = \frac{\beta\theta_2\psi}{\lambda}. \tag{22}$$

Equation (22) shows that the no-default condition binds as long as banks can sell deposits at a higher price than they pay for bonds. Definition 1 shows that this liquidity premium will be strictly positive as long as deposit supply is bounded in competitive equilibrium. Deposit supply is bounded because banks must fund part of bonds with costly equity ($\gamma < \beta$ and $\theta_2 > 0$). Therefore, banks' no-default constraints always bind in competitive equilibrium.

In the limit case $\theta_2 \searrow 0$ banks' competitive-equilibrium choices for loans and dividends are the same as in the competitive equilibrium allocation in Schroth (2021) as banks compete away liquidity premiums fully. Because banks' no-defaults constraints only depend on banks' policies for loans and dividends, no-default constraints will bind occasionally as in Schroth (2021) (see Proposition 1 in that paper). □

C Computational method

The competitive-equilibrium allocation and the second-best allocations are obtained recursively.

C.1 Competitive-equilibrium allocation

I solve for the competitive-equilibrium allocation using policy function iteration (e.g., Rendahl, 2014) over the multiplier on the bank dividend non-negativity constraint. The endogenous state variable is bank equity. The present value of bank dividends for each level of bank equity is given by a shareholder value function. At each step in the policy function iteration I also use updated policy functions to update the shareholder value function. Only limited iterations on the shareholder value function can be performed at each step of the outer policy function iteration to achieve convergence of the latter (dampening). Policy function convergence then implies shareholder value function convergence. Monetary policy is set to close the labor gap, $P_t = 1/z_t$ and $T_t = 0$, such that employment is always maximal at $\mathcal{L}_t = 1$ (Equation (18)).

C.2 Second-best allocation

I solve for the second-best allocation of the regulator using standard value function iteration over household lifetime utility W. Specifically, this allocation solves the dynamic program presented in Definition 2 for states $(A, V) \in \mathfrak{R} \subset \mathbb{R}^2$. I also impose the transversality condition V_L, $V_H \leq M$, with $M < \infty$ large enough such that the transversality condition never binds. The set $\mathfrak{R}$ is the limit of the sequence of sets $\{\mathfrak{R}_n\}$, where $\mathfrak{R}_{n+1}$ is defined as the set of pairs $\left(A_j(A, V), V_j(A, V)\right)$ that are consistent with the Bellman equation in Definition 2 for $j = L, H$ for each $(A, V) \in \mathfrak{R}_n$. Let $\mathfrak{R}_0 = \{(K_{FB}, 0)\}$.