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Optimal Monetary and Macroprudential Policies

by Josef Schroth

Financial Stability Department
Bank of Canada, Ottawa, Ontario, Canada K1A 0G9

jschroth@bank-banque-canada.ca

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Abstract

Monetary and macroprudential policy makers trade off financial stability and economic efficiency. This paper builds a model in which banks supply liquidity services through deposits and use them to fund loans and safe bond holdings. Expansive monetary policy can increase loan repayments but also provides liquidity to non-banks, which shifts deposit demand downward and lowers the liquidity premium of deposits. Optimally coordinated policies reveal two key complementarities over financial cycles. First, during normal times additional risk-weight add-ons for bonds are complementary to additional capital buffers. Second, during crisis times relative monetary policy tightening is complementary to releasing capital buffers.

Topics: Credit and credit aggregates, Financial stability, Financial system regulation and policies, Inflation targets, Monetary policy

JEL codes: E44, E60, G21, G28

Résumé

Les autorités monétaires et macroprudentielles doivent faire des compromis entre la stabilité financière et l'efficacité économique. Dans cette étude, nous élaborons un modèle dans lequel les banques fournissent des services de liquidité au moyen de dépôts et les utilisent pour financer des prêts et des avoirs en obligations sûres. Une politique monétaire expansionniste peut faire augmenter les remboursements des prêts, mais fournit aussi de la liquidité aux institutions non bancaires, ce qui fait diminuer la demande de dépôts et la prime de liquidité des dépôts. Des politiques coordonnées de façon optimale révèlent deux complémentarités clés au cours des cycles financiers. Premièrement, en temps normal des majorations additionnelles assorties d'une pondération des risques pour les obligations sont complémentaires aux réserves de fonds propres supplémentaires. Deuxièmement, en temps de crise un certain resserrement de la politique monétaire accompagne la mobilisation de ces réserves.

Sujets : Crédit et agrégats du crédit, Stabilité financière, Réglementation et politiques relatives au système financier, Cibles en matière d'inflation, Politique monétaire

Codes JEL : E44, E60, G21, G28

1 Introduction

Banks derive significant revenue from providing liquidity services to the economy.[1] Specifically, banks provide liquidity services by issuing demandable deposits and investing the proceeds in safe short-term bonds. From a viewpoint of efficiency it could then be argued that regulatory risk weights on safe short-term bonds, and possibly also regulatory leverage ratio requirements, should be zero.[2] The liquidity premium on deposits would then be minimized and depositor welfare, at least in a narrow sense, maximized. However, this view is 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, however, tend to ignore how revenue from liquidity premiums can help to compensate banks for 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.

Capital regulation can constrain banks' capital structures and can thus affect the liquidity premium of bank deposits through its effect on the supply of deposits. Monetary-policy operations can smooth employment gaps—however, they also change the price of available liquidity in financial markets which can affect the liquidity premium of bank deposits through the demand for deposits.

[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]Some jurisdictions impose leverage ratios on banks that can curb their provision of liquidity services irrespective of risk weights on assets. For example, in the United States banks must maintain a ratio of tier 1 capital to total assets of at least 4%. Such a leverage ratio constrains banks' holdings of, in particular, assets subject to low risk weights.

For example, when capital regulation sets lower risk weights on safe bonds, for given risk weights on risky lending, then it may increase 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. Similarly, an expansive monetary policy operation can avoid inefficiently low employment, but may not actually succeed in stabilizing economic output because it may also reduce bank lending. The latter effect is due to a detrimental effect of expansive monetary policy on banks' margins through the demand for liquidity services: increasing the liquidity of safe assets *ex post*, through monetary policy authority asset purchases, decreases the liquidity premium of deposits (relative to those safe assets) *ex ante*. The contribution of this paper is to jointly study these two trade-offs between allocative efficiency and financial stability. Novel policy implications are derived for risk weights on safe bonds, for leverage ratios, and for the coordination of monetary policy with macroprudential bank regulation.

This paper studies constrained-efficient monetary policy and bank equity capital in a model economy with sticky nominal wages and occasional financial crises where banks supply both risky loans and liquidity services in the form of deposits. Banks issue uninsured deposits and use them, together with retained equity, to fund risky loans to firms and to invest in safe bonds. 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.[3] When bank funding is sufficiently constrained, then lending decreases significantly and the economy experiences a financial crisis.

[3] 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).

In the model, the cost of bank funding decreases in the liquidity premium on deposits. The latter represents the relative attractiveness of deposits compared with bonds and is inversely related to the interest rate on deposits. It depends on both banks' aggregate deposit supply and the monetary policy stance. Specifically, households' demand for deposits increases in the interest rate on deposits and decreases in bond transaction costs, which are affected by monetary policy.

When monetary policy is expected to be more expansive, and thus to on net buy more bonds, then transaction costs associated with selling bonds are lower. As a result, households choose to hold more bonds *ex ante* because they expect to be able to exchange bonds for money at lower cost in case a consumption need arises. The anticipation of more expansive monetary policy therefore reduces households' demand for deposits so that the liquidity premium on deposits decreases.

The first main result is that in a constrained-efficient second best, banks hold fewer safe bonds. The resulting decrease in deposit supply lowers deposit rates. When the liquidity premium is increased in this way, then this enables banks to hold more costly capital during normal times. Moreover, while banks' constrained-efficient bond holdings are smaller during normal times, compared with the competitive equilibrium, they are larger during financial crises. During normal times, both the liquidity premium and the net interest rate margin are higher in second best, compared with the competitive equilibrium. But they are much more stable during financial crises.

The second main result is that constrained-efficient monetary policy is on average less expansive, relative to what would be required to fully close the labor gap, during financial crises. Less expansionary policy increases the liquidity premium that banks enjoy and thereby increases their shareholder value. A higher shareholder value then helps banks access debt funding during crises. As a result, bank lending and deposit supply are both more stable during financial crises.

The policy implications from the analysis in this paper are twofold. On the one hand, the interaction of existing bank regulations with recently introduced macroprudential policy tools is highlighted. There is a complementarity, during normal times, between increasing regulatory risk weights on (safe) bonds, or tightening the leverage ratio, and requiring banks to build up larger capital buffers. On the other hand, the analysis emphasizes the importance of avoiding unintended adverse effects of monetary policy on macroprudential policy objectives during financial crises. The analysis highlights a complementarity during financial crises between a less expansive monetary policy stance and releasing banks' regulatory capital buffers in support of aggregate bank lending.

In the model, an expansive monetary policy stance lowers the liquidity, or convenience, premium associated with bank deposits, while a contractionary stance increases it. Drechsler, Savov, and Schnabl (2017) document such a relationship empirically for the case of the United States. They develop a model in which expansive monetary policy reduces the opportunity cost of holding money in the form of cash, which shifts deposit demand downward. In this paper, expansive monetary policy lowers the transaction cost associated with selling safe bonds, which makes bonds more money-like and thus also shifts deposit demand downward.[4]

Brunnermeier and Koby (2018) make the important observation that a lower liquidity premium can erode bank equity over time and eventually lead to a binding capital requirement and thus lower lending in the future.[5] In Brunnermeier and Koby (2018);

[4] Heider, Saidi, and Schepens (2019) and Eggertsson, Juelsrud, Summers, and Wold (2019) document, for the case of the Euro zone and Sweden, respectively, that banks accept a *negative* liquidity premium on deposits during a time when monetary policy is very accommodating. In my model, the liquidity premium on deposits is always non-negative.

[5] In their model expansive monetary policy may also increase current bank lending by relaxing current capital requirements through increases in prices of assets held by banks. Repullo (2020) notes that a non-monotonic effect on bank lending may not be obtained when banks' current access to outside funding also

Drechsler, Savov, and Schnabl (2017); and in this paper, as in Stein (2012), the monetary authority effectively competes with banks in the supply of liquidity services to households. The analysis in this paper suggests that monetary policy should compete less with banks during financial crises and during recoveries from crises. Moreover, monetary policy should also compete somewhat less with banks during normal times so that banks are able to 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*.

1.1 Related literature

Van der Ghote (2021) studies interaction between monetary policy and macroprudential policy focusing on optimal Markov policies rather than constrained efficiency. He finds that monetary policy should provide support to financial stability by being slightly contractionary during normal times. In his model support works through an increase in banks' margins during normal times (which increases banks' shareholder value during normal times) and, by anticipation, also during financial crises (which increases banks' access to external funding during crises). In my model it is also optimal for monetary policy to be slightly contractionary during normal times to raise bank margins. However, the intention is not to raise bank shareholder value, again by anticipation, during financial crisis states. The positive effect of higher margins is exactly offset by the negative effect of higher costly bank capital so that banks do not earn excess rents (banks' shareholder value equals their equity during normal times). In this paper, during normal times, constrained-efficient monetary policy supports bank margins somewhat to compensate them for holding more costly capital. In contrast, during recoveries from fi-

depends on future lending margins (as in this paper), i.e., when it depends on the price of bank equity and not only on the price of bank assets.

nancial crises, optimal monetary policy supports bank margins more strongly to reward banks for not defaulting on depositors during crises.

Diamond and Rajan (2001) show that one reason for why it can be socially beneficial that banks take short-term deposits is, paradoxically, the potential for bank runs. The latter can serve as a credible disciplining device in the hands of bank creditors. The analysis in this paper highlights an additional benefit of having commercial banks also provide short-term deposits. It is the role that deposit rates play in recapitalizing banks after banks 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, thus leading to a smaller increase in lending rates. Both depositors and bank borrowers contribute to recapitalizing banks.

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. They find evidence that implicit government guarantees help banks to reap the benefits of elevated liquidity premiums during financial crises. A policy implication in my paper is that regulators, and the monetary authority, should support banks during financial crises by lowering capital buffer requirements. During normal times regulators would require banks to hold fewer safe bonds so that, effectively, banks insure firms more against aggregate productivity risk at the cost of insuring households less against idiosyncratic liquidity risk.

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. The model captures macroeconomic interactions between nominal and financial frictions, and endogenously generates occasional financial crises. Section 5 uses the model to study optimal coordination between monetary and macroprudential policies over financial cycles.

Households face two frictions, one nominal and one financial, through which monetary policy affects how households supply labor and purchase goods. On the one hand, nominal wage stickiness implies that monetary policy 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. Households do not face any transaction costs when using deposits. The effect of monetary policy on banks is therefore twofold: through firms' loan repayments and through households' demand for deposits.

Banks face two financial frictions related to their 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, monetary policy actions and the aggregate amount of bank lending all affect firms' loan repayments.

The economy features a consumption good and is populated by continuums of mass one of identical firms, banks, households and long-term investors, respectively. There is also a monetary policy authority. 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. Only banks can make loans to firms and supply deposits to households.[6] Long-term investors are endowed with ω_0 units of the consumption good in period $t = 0$. 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 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 $1 - \gamma/\beta$ 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

[6] Banks have access to a monitoring technology that enables them to collect repayment from firms. It is further assumed that banks are the natural providers of liquidity services through deposits. For example, the Federal Reserve pays an interest rate on banks' reserves that is higher than the rate on overnight repurchase agreements available to a broader set of market participants (such as money market funds).

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

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

where E denotes expectations and D_t are bank dividends. Recall that $\varsigma_0 = 1$ is given. In period $t = 1, 2, \ldots$ long-term investors make net bank share purchases of $\varsigma_{t+1} - \gamma/\beta \varsigma_t$ and receive $1 - \gamma/\beta$ shares of new banks, where γ/β 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 demand for bank bonds and shares is 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 at the time they receive their labor income, which is at a later time than when they receive their endowment. For this reason, households invest their endowments in bonds and deposits, which are then redeemed 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

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

and cash-in-advance constraints

$$q_{t+1}\chi_{t+1}^h + q_{t+1}^b b_{t+1}^h \leq \omega,$$

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.[7]

Nominal friction:

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 $P_0 = 1$. 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 nomical friction in the labor market. Specifically, firms receive i.i.d. 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.[8] 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 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.

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

[7]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.

[8]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 (5) measures aggregate labor services demanded by the average firm.

good in period $t+1$, where $\alpha \in (0,1)$ and where $\delta \in (0,1)$ is the depreciation rate. Firms choose labor after aggregate firm productivity z_{t+1} has been realized. Firms cannot sell bonds and do not have any internal funds such that they must fund any investment k with loans from banks. A firm chooses non-negative investment k to maximize expected profit

$$E_t \left[\frac{1}{2} \max_n \left\{ z_{t+1} k^\alpha n^{1-\alpha} + (1-\delta)k - \frac{W_{t,0}}{P_{t+1}(z_{t+1})} n \right\} \right.$$
$$\left. + \frac{1}{2} \max_n \left\{ z_{t+1} k^\alpha n^{1-\alpha} + (1-\delta)k - \frac{W_{t+1}(z_{t+1})}{P_{t+1}(z_{t+1})} n \right\} - R_{t+1}(z_{t+1})k \right].$$

$R_{t+1}(z_{t+1})$ denotes the average loan repayment across firms conditional on aggregate productivity being z_{t+1}. After production has taken place firms pay wages, repay bank loans, eat any profits and exit.

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:

$$\frac{W_{t,0}}{P_t} = z_t(1-\alpha)K_t^\alpha \hat{L}_t^{-\alpha} \Rightarrow \hat{L}_t = (z_t P_t)^{\frac{1}{\alpha}}. \tag{4}$$

Firms that are not constrained to offer $W_{t,0}$ employ the remaining workers. Their labor demand 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:

$$\mathcal{L}_t = \frac{1}{2}\left(\hat{L}_t^{1-\alpha} + (2-\hat{L}_t)^{1-\alpha}\right). \tag{5}$$

Equation (5) 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.

I assume households supply their labor randomly across firms and banks supply loans randomly across firms (with individual firms' loan repayments conditional on aggregate productivity and on firms' i.i.d. labor-market shocks). The average household (real) wage and the average bank lending return are given as follows:

$$w_t = z_t(1-\alpha)K_t^{\alpha}\mathcal{L}_t, \tag{6}$$

$$R_t = z_t\alpha K_t^{\alpha-1}\mathcal{L}_t + 1 - \delta. \tag{7}$$

Bank problem:

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

$$V_0 = E_0\left[\sum_{t=0}^{\infty}\gamma^t d_t\right] \tag{8}$$

subject to budget constraints

$$d_t + \ell_{t+1} + q_{t+1}^b b_{t+1} + \chi_t \leq R_t\ell_t + b_t + q_{t+1}\chi_{t+1}, \text{ for } t = 1, 2, \ldots, \tag{9}$$

$$d_0 + \ell_1 + q_1^b b_1 \leq a_0 + q_1\chi_1, \tag{10}$$

no-default constraints

$$E_t\left[\sum_{\tau=1}^{\infty} d_{t+\tau}\right] \geq \theta_1\ell_{t+1} + \theta_2 b_{t+1} \tag{11}$$

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

The no-default constraint (11) requires that banks value expected discounted future dividends more than the sum of fraction $\theta_1 \in (0,1)$ of current lending and fraction $\theta_2 \in (0,1)$ of current bond holding. The motivation for this constraint is that that banks are assumed to be able to default, whereby they would lose future dividends, and threaten to hold up payments worth $\theta_1 \ell_{t+1} + \theta_2 b_{t+1}$ to bank creditors. The no-default constraint (11) ensures that banks do not have an incentive to default and extract $\theta_1 \ell_{t+1} + \theta_2 b_{t+1}$ from their creditors in exchange for not holding up payments to creditors.[9]

Monetary policy:

There is a monetary policy authority that 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. Assume that the remaining 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 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:

$$M_t = P_t Y_t = P_t z_t K_t^{\alpha} \mathcal{L}_t. \tag{12}$$

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

[9]Another possible motivation for an implicit creditor-imposed limit on bank leverage could be concerns about whether banks pay a nonverifiable monitoring cost as in Holmstrom and Tirole (1997). The assumption that bank creditors focus on the incentives of bank shareholders, rather than incentives of a bank manager (who might have a conflict of interest with shareholders) is consistent with evidence in Schaeck, Cihak, Maechler, and Stolz (2012) that shareholders rather than debt holders monitor managers.

authority can achieve a price level P_t with bond trade T_t as follows:

$$T_t = z_t K_t^{\alpha} \mathcal{L}_t(P_t) - {}^{K_t^{\alpha}}\!/_{P_t}. \tag{13}$$

But monetary policy not only affects effective labor $\mathcal{L}$. In particular, monetary authority bond trades affect the liquidity on the market for bonds at the time households need to sell bonds to consume. Let the transaction cost households face be given as follows:

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

with $\eta, \eta_T > 0$ and where χ_{t+1} denotes aggregate household deposit holdings. Households' bond transaction costs are lower when households need to sell fewer bonds, i.e., when they rely more on deposits, and also 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. Because households can freely allocate between deposits and bonds when they receive their endowments, the deposit price is determined as follows:

$$q_{t+1} = \frac{q_{t+1}^b}{1 - E_t\left[g_{t+1}\right]} = \frac{q_{t+1}^b}{1 - \eta \exp\left(-\chi_{t+1}\right) E_t\left[\exp\left(-\eta_T T_{t+1}\right)\right]}. \tag{14}$$

Equation (14) shows that if monetary policy is anticipated to be on average more expansionary, then the deposit rate is higher. The liquidity premium on deposits decreases when the monetary authority creates additional liquidity.[10]

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

3 Competitive equilibrium

This section defines the competitive equilibrium and a measure of welfare. It is assumed that the monetary authority in a competitive equilibrium targets the price level that closes the labor gap and avoids labor misallocation across firms. Using Equation (4), the price level that achieves $\hat{L}_t = \mathcal{L}_t = 1$ is given by $P_t = \frac{1}{z_t}$. Equation (13) 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 (12) in a way that makes a constant money supply consistent with full employment.

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 $\{D_t\}$;*
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. *transaction costs are consistent with a zero labor gap, $g_{t+1} = \eta \exp(-\chi_{t+1})$;*
6. *the deposit market clears, $q_{t+1} = \frac{\beta}{1-g_{t+1}}$;*
7. *the market for bank loans clears, $R_{t+1} = \alpha z_{t+1} K^{\alpha-1}_{t+1} + 1 - \delta$;*

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

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

3.1 Welfare criterion and pecuniary externality

A pecuniary externality implies that monetary policy in the competitive equilibrium is not constrained-efficient. Specifically, Equation (14) shows that monetary authority bond trades affect banks' funding costs through their effect on the liquidity premium on deposits.[11] For this reason it is useful to allow for non-zero monetary authority bond trades when formulating a welfare criterion.

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. 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:

$$W_0 = D_0 + E_0 \left[\sum_{t=1}^{\infty} \beta^t \left(D_t + z_t (1-\alpha) K_t^{\alpha} \mathcal{L}\left(P_t\right) - \frac{\omega}{\beta} g_t \right) \right], \tag{15}$$

where P_t is determined by Equation (13) and $g_t = \eta \exp\left(-\chi_t\right) \exp\left(-\eta_T T_t\right)$.

4 Optimal macroprudential and monetary policies

The pecuniary externality illustrated in Section 3.1 matters when adverse exogenous shocks reduce loan repayments enough to substantially reduce banks' equity. When

[11] There is also a pecuniary externality related to banks' capital structure (see Schroth, 2021, for a detailed discussion). In addition, as Equation (14) shows, the liquidity premium decreases in aggregate deposit supply.

equity is scare, to the extent that there is a credit crunch in the economy, then monetary policy should be mindful of its effect on banks' margins. Specifically, expansive monetary policy, $T > 0$, reduces households' bond transaction costs and increases the equilibrium interest rate on deposits. Note that the analysis in this paper not only has implications for how monetary policy should interact with macroprudential policy over financial cycles; it also has implications for how macroprudential policy should treat relatively safe assets. The reason is that when banks hold more bonds, then for given equity they issue more deposits, which increases the interest rate they must offer on deposits. Both more expansive monetary policy and higher bank bond holdings increase banks' funding cost.

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. In practice, a macroprudential bank regulator takes into account the effect of higher capital requirements on banks' credit supply—however, it should also take into account how banks rely on profits from both lending *and* liquidity provision to earn their cost of capital.

Optimally coordinated macroprudential and monetary policies can be expressed as the outcome of a dynamic game between a regulator and banks.[12] The game acknowledges that banks, firms, long-term investors and households are price takers such that optimal policies are 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;

[12]The analysis abstracts from potential conflicts of interest between monetary and macroprudential regulators and derives optimally coordinated policies by focusing on a single joint regulator for both monetary and macroprudential policies.

Kocherlakota, 1996).

Definition 2. *The problem of a regulator that can choose both macroprudential and monetary policy to maximize the welfare criterion in Equation (15) can be expressed recursively as follows:*

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

subject to

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

where

$$
\begin{aligned}
A_j &= z_j \alpha K^\alpha \mathcal{L}(P_j) + (1-\delta)K + B - \chi,\ j = L, H, && \textit{(next period's bank equity)} \\
g_j &= \eta \exp\left(-\chi - \eta_T T_j\right),\ j = L, H, && \textit{(households' bond transaction costs)} \\
T_j &= z_j K^\alpha \mathcal{L}(P_j) - \frac{K^\alpha}{P_j},\ j = L, H, && \textit{(monetary authority bond trade)} \\
\mathcal{L}(P_j) &= \frac{1}{2}\left[\left(z_j P_j\right)^{\frac{1-\alpha}{\alpha}} + \left(2 - \left(z_j P_j\right)^{\frac{1}{\alpha}}\right)^{1-\alpha} \right],\ j = L, H. && \textit{(effective labor across firms)}
\end{aligned}
$$

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.

An important policy question is whether banks, for given monetary policy actions, supply the right amount of liquidity to households during normal times. Suppose households would be supplied with one additional (marginal) unit of deposit from outside the banking sector.[13] To simplify notation suppose full employment, i.e., $T_j = 0$ such that the transaction cost $g_L = g_H = \eta \exp(-\chi)$ does not depend on the aggregate shock in this example. The liquidity benefit of the marginal exogenous increase in deposits to households would have to be traded off against the effect on financial stability through a higher funding cost of banks 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 in the current period. When this expression is positive, then joint welfare of long-term investors and households increases when households enjoy additional liquidity services. However, when the expression is negative, then joint welfare decreases because any direct improvement in liquidity services would be more than offset by a less stable supply of credit (and therefore a lower net-present value of wages). To evaluate the expression, consider the first-order conditions of the regulator's problem in Definition 2 for bonds,

$$\beta [\rho\lambda_L + (1-\rho)\lambda_H] = \beta\lambda + \theta_2\psi,$$

[13]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.

and deposits,

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

again for $T_j = 0$, 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:[14]

$$\omega\eta \exp(-\chi) - \lambda\chi \frac{\beta\eta \exp(-\chi)}{(1-\eta\exp(-\chi))^2} = \theta_2\psi - \beta\lambda \frac{\eta\exp(-\chi)}{1-\eta\exp(-\chi)}. \tag{16}$$

The right-hand side of Equation (16) is negative when banks' no-default constraint is slack (i.e., when $\psi = 0$). This means that a regulator that imposes additional capital buffers on banks would prefer that banks provide less, rather than more, liquidity services to households.

Proposition 1. *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 when no-default constraints are slack in a constrained-efficient allocation is not that rents from providing liquidity services should be a substitute for costly capital in incentivizing banks (as in Hellmann, Murdock, and Stiglitz, 2000)—in fact, Proposition 1 shows that such rents should be a complement. Banks get to enjoy these rents when they hold equity in excess of what the market-imposed no-default constraints require. Lower funding costs during the time

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

banks hold additional equity help them to earn their cost of capital and the value of banks is then no higher than their equity. Households pay higher transaction costs when selling bonds but, as the result of more stable credit supply by banks, also enjoy higher wages on average.

5 Numerical analysis

Section 4 has shown that a constrained-efficient allocation limits banks' liquidity provision whenever banks' market-imposed equity requirements are slack (Proposition 1). From the viewpoint of a macroprudential bank regulator, risk-weight add-ons for safe assets and additional capital buffers are complements. Moreover, because monetary policy interacts with banks' liquidity provision—through its effect on bond transaction costs and thus on deposit demand—there are potential benefits from coordinating it with macroprudential bank regulation.

This section solves the model numerically and shows how a regulator that sets both monetary and macroprudential policies would respond to exogenous shocks affecting bank-loan repayments. I 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 coordination of monetary and macroprudential policies. In particular, the analysis reveals complementaries between tightening monetary policy and releasing capital buffers. The computational method is discussed in Appendix A.

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 et al. (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.[15]

The first model moment is bank capital relative to risk-weighted assets in competitive equilibrium in "normal times" during which bank equity and lending are constant as long as realized firm productivity is z_H. 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.[16] The second model moment is 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' net interest margin, net of any costs, 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

[15] Note that the parameter η_T does not affect the competitive equilibrium allocation because it is assumed that $T_{t+1} = 0$ at all times in competitive equilibrium. The parameter ω only affects investor bond holdings B^i_{t+1}, which is not affecting any other equilibrium objects (investors have perfectly elastic bond demand at price β and can have negative consumption).

[16] 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 Begenau, Bigio, Majerovitz, and Vieyra (2020).

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

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.[17]

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 4 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 resulting calibration implies a market-imposed capital requirement of 10 percent in normal times, when bank future profits are zero.

Additional parameters relevant for welfare analysis:

There are two parameters that do not affect the competitive equilibrium allocation but that nevertheless matter for the regulator's decision problem in Definition 2. The first

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

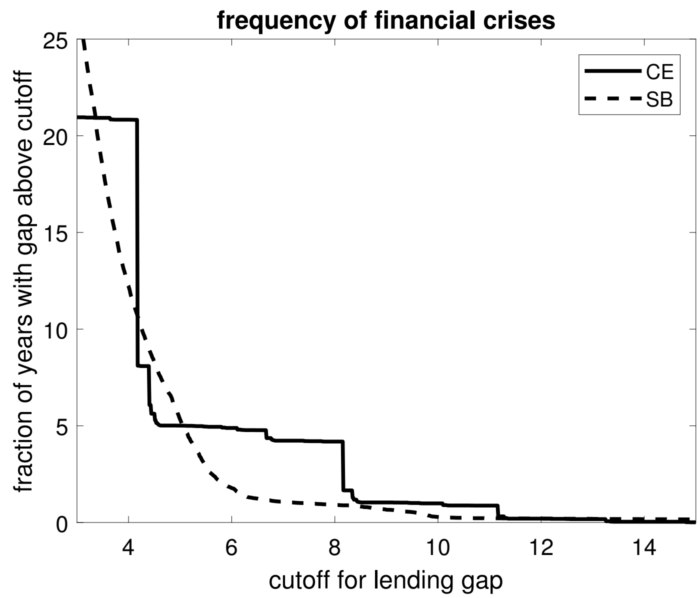


Figure 1: Frequency of low lending in a stochastic steady state (average over $30,000$ simulated periods) in laissez-faire competitive-equilibrium allocation (CE) and the second-best allocation where monetary policy does not affect banks' funding cost (SB).

is the amount of wealth that households (re)-allocate between bonds and deposits each period, ω, and the second is the effect of monetary policy bond trades on households' bond transaction cost, η_T.

A larger value of ω makes it more costly, in terms of reduced household liquidity services, to create distortions that lower banks' funding cost such as expected monetary-policy bond sales $E_t\left(T_{t+1}\right) < 0$. I set $\omega = {}^{59}/_{25} \cdot K_{FB}^{\alpha}$, 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.

For given expected monetary policy bond sales, $E_t\left(T_{t+1}\right) < 0$, a larger value of η_T implies higher household bond transaction costs and lower bank funding cost. The welfare analysis considers the two cases $\eta_T = 0$ and $\eta_T = 10$. In the first case the regulator sets monetary policy according to the same principle as in competitive equilibrium whereby monetary policy bond trades are always zero. That is, when monetary policy does not affect households' bond transaction cost g, and thus does not affect banks' funding cost, then the regulator sets it simply to maximize employment. Recall from Section 3 that a policy of no bond trades closes the labor gap. In the second case the regulator faces a trade-off between household employment, liquidity services and banks' funding cost. The remainder of this section studies the two cases sequentially.

5.2 Constrained efficiency when monetary policy does not affect the liquidity premium on deposits

In the case of $\eta_T = 0$, monetary policy affects only the allocative efficiency of labor but not the transaction costs faced by households who need to sell bonds.[18] As a result, monetary policy has no effect on the price that households are willing to pay for bank deposits. A regulator then sees no potential benefit from distorting monetary policy away from a policy that always closes the labor gap. Note that the constrained-efficient allocation for $\eta_T = 0$ is equal to the constrained-efficient allocation for any η_T when monetary policy is restricted to always close the labor gap ($T_t = 0$).[19] Therefore, the case $\eta_T = 0$ can also be interpreted as the case of no coordination between macroprudential policy and monetary 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).[20]

Table 2 compares bank balance sheets during normal times in competitive equilib-

[18] In practice this case could, for example, correspond to an extreme case of zero pass-through from primary dealers (and from the other trading counterparties of central banks conducting open market operations) to other participants in financial markets.

[19] 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.

[20] 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 $\eta_T = 0$).

Table 2: Bank balance sheets during normal times, $\eta_T = 0$

	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 $q\chi$.

rium and the 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:

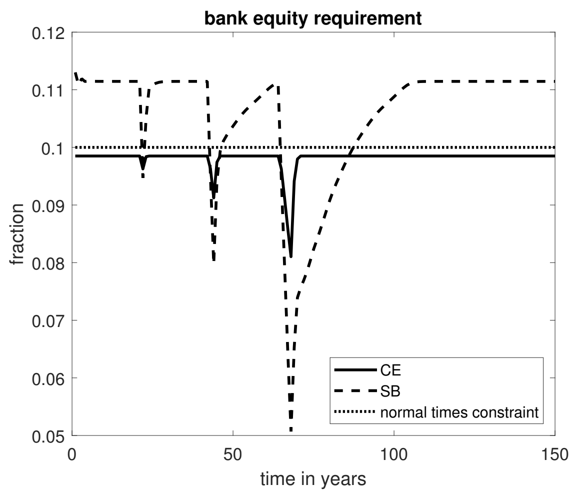
$$\{z_H, \dots, z_H, z_L, z_H, \dots, z_H, z_L, z_L, z_H, \dots, z_H, z_L, z_L, z_L, z_L, z_H, \dots, z_H\}.$$

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.

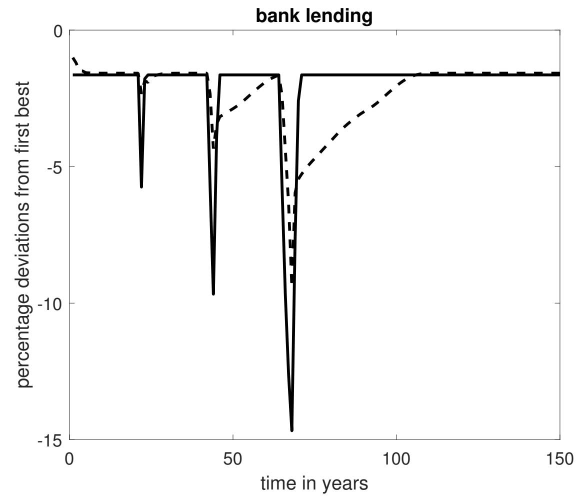
The composition of banks' assets is actually safer during normal times in competitive equilibrium compared with the second best (Figure 2 and Table 2). While both allocations feature roughly the same amount of lending to firms during normal times (Figure 2(b)), banks in competitive equilibrium hold far more bonds (Figure 2(c)). On the one hand, the 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 which increases deposit supply, for given equity, and thus reduces the price that households are willing to pay for deposits.

In a second best the supply of loans and deposits is much more stable compared with the competitive equilibrium. Therefore, following loan losses, the capital ratio in Figure 2(a) decreases much more as banks avoid sharp reductions in their balance sheets when equity is low. 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.

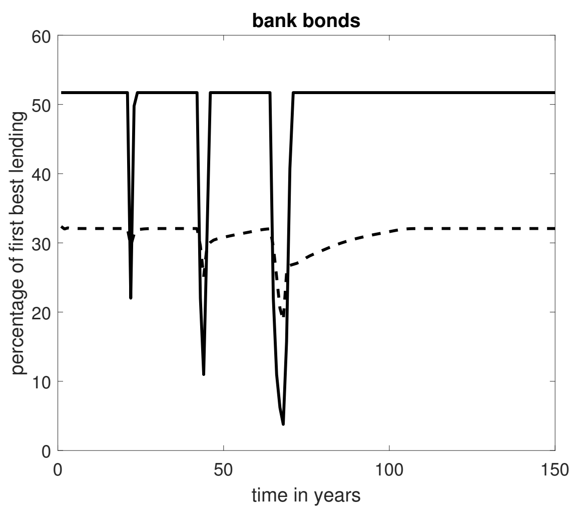
Banks in competitive equilibrium prefer to build resilience against loan losses by accumulating safe assets, rather than costly equity, during normal times. One implication of banks conducting their capital management in this way is that, in particular, their deposit supply becomes very volatile. While lending drops by almost 15% in competitive equilibrium in the most severe scenario in Figure 2(b), the supply of deposits drops by 40% (Figure 2(d)). The liquidity premium is much more stable in second best, but also higher during normal times (Figure 3(c)). Banks' higher margins during normal times



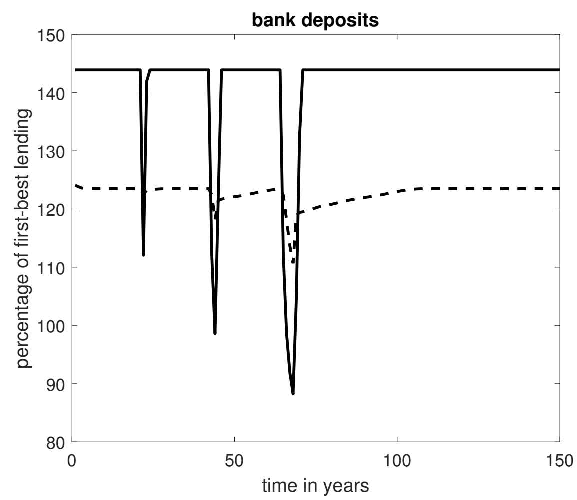
(a) Aggregate bank capital



(b) Aggregate bank lending

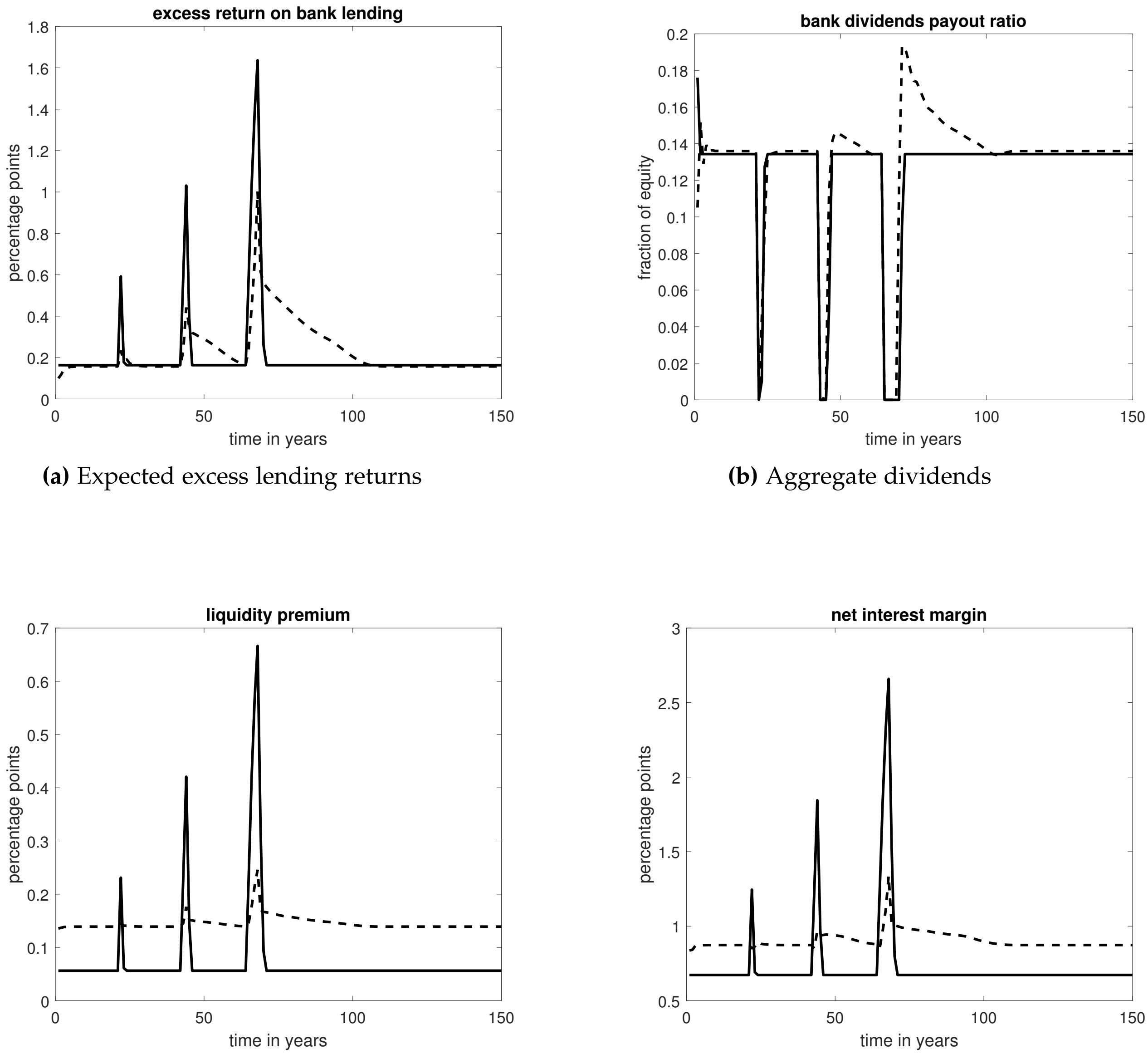


(c) Bank bonds



(d) Bank deposits

Figure 2: This is the case where monetary policy does not affect banks' funding cost. Panel (a) shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1} / (\theta_1 K_{t+1} + \theta_2 B_{t+1})$, 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.



(a) Expected excess lending returns

(b) Aggregate dividends

(c) Liquidity premium

(d) Net interest margin

Figure 3: This is the case where monetary policy does not affect banks' funding cost. 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 the (expected) net interest margin defined as $NIM_t = [\alpha K_t^\alpha - \delta K_t + (1-\beta)B_t - (1-q_t)\chi_t] / (K_t + \beta B_t)$.

in second best (Figure 3(d)) 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). A policy implication is that there should be higher riskweights on (safe) bonds during normal times (and capital requirements should be countercyclical overall as in Schroth, 2021).

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. Intuitively, in the model, banks' efforts to diversify with safe bonds during normal times are not effective because the associated interest margins are too thin. Depositors do not benefit from banks' high bond holdings in competitive equilibrium because somewhat cheaper liquidity services during normal times come at the cost of much more expensive liquidity services during financial crises. Paradoxically, the supply of liquidity services is on average higher when banks hold fewer bonds and accumulate more common equity. In other words, what matters for system-wide liquidity provision to non-banks, over the financial cycle, is not the size of banks' balance sheets during normal times but by how much banks are forced to shrink them when experiencing funding pressure.[21]

5.3 Constrained efficiency

When $\eta_T > 0$, then monetary policy affects the transaction costs faced by households who need to sell bonds. Assume $\eta_T = 10$. The price that households are willing to

[21]The net present value of bond transaction costs paid by households is about two thirds lower in second best compared with the competitive equilibrium during normal times (it is about three quarters lower during severe crises).

Table 3: Bank balance sheets during normal times, $\eta_T = 10$

	competitive equilibrium	second best
Assets		
loans	98.36	98.96
bonds	48.61	30.60
Liabilities		
equity	11.62	12.85
deposits	135.35	116.61
Total	146.97	129.56

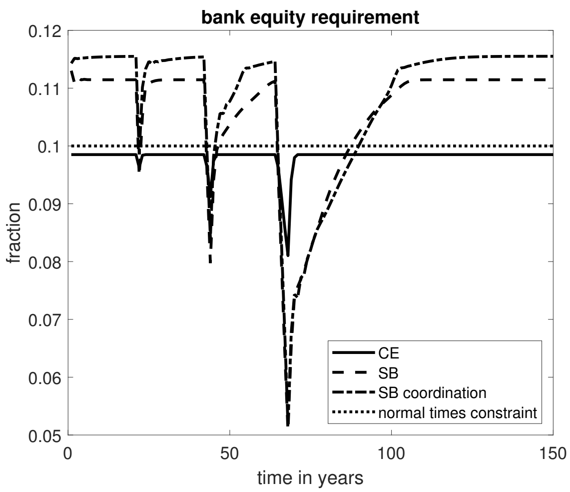
Note: All quantities are in percent of first-best lending K_{FB} and measured at the point of dividend payment: loans are K, bonds are βB, equity is post dividend, $A - D$, and deposits are $q\chi$.

pay for bank deposits now depends not only on the size of banks' balance sheets but also on the monetary policy stance. As a result, a regulator sees potential benefits from distorting monetary policy away from a policy that always closes the labor gap, in a way that favourably affects banks' cost of funding.

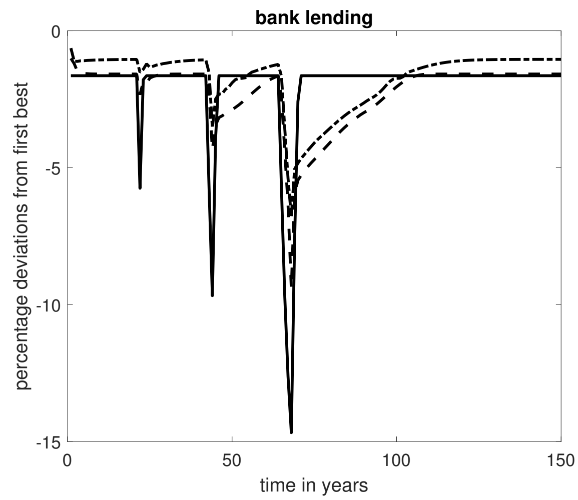
Table 3 shows that the main difference, during normal times, to the second best without optimal coordination between monetary and macroprudential policies is that banks hold more equity (around 50 basis points more in terms of lending).

Compared with the the second best without optimal coordination, banks' second-best capital ratio is higher during normal times, which means it is also somewhat higher in the case of intermediate loan losses. Figure 4(a) shows that in the case of severe loan losses the decrease in banks' capital ratios is about the same. Figure 4(b) shows that second-best lending decreases less in response to loan losses when monetary policy depends on the financial cycle. 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 4(c) and 4(d)).

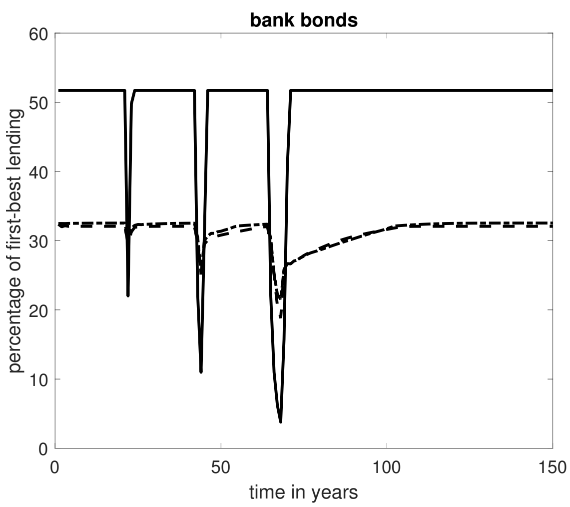
Figure 5(a) shows that the lending margin is lower in the second best with coor-



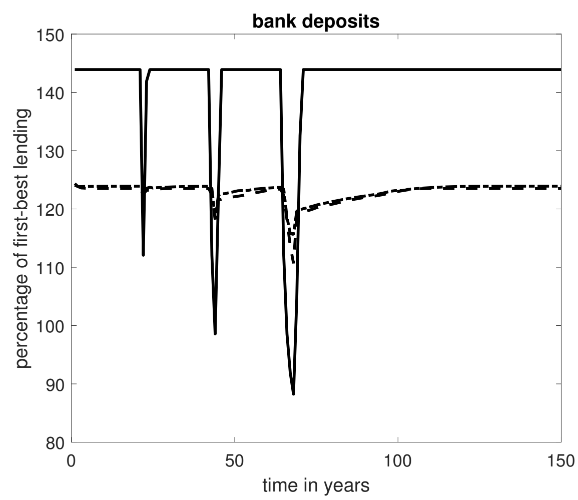
(a) Aggregate bank capital



(b) Aggregate bank lending



(c) Bank bonds



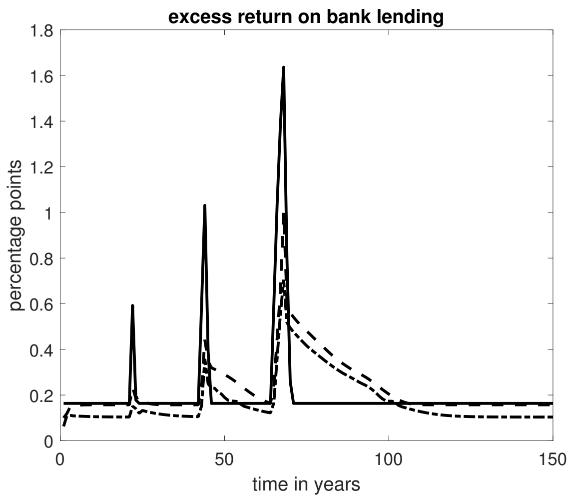
(d) Bank deposits

Figure 4: Panel (a) shows bank capital relative to the market-imposed capital requirement during normal times, $\gamma E_t A_{t+1}/(\theta_1 K_{t+1} + \theta_2 B_{t+1})$, 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.

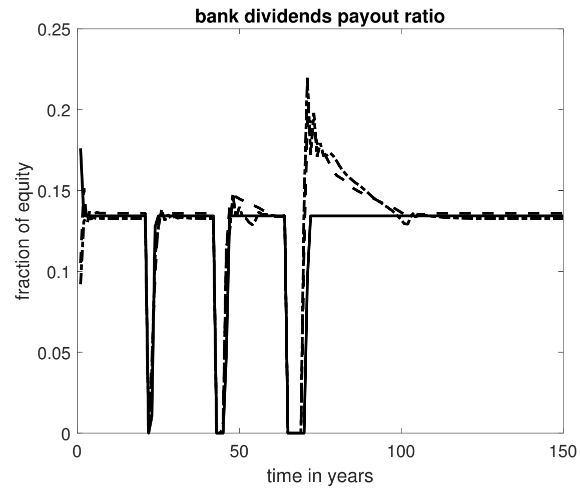
dination. The liquidity premium on deposits is higher with coordination (Figure 5(c)) because of an overall tighter monetary policy stance. As a result, the net interest rate margin does not decrease (Figure 5(d)) despite lower lending returns. Tighter monetary policy during normal times, together with smaller bank balance sheets, supports banks' margins and enables banks to hold more equity and supply more loans.

Figure 6 reveals the reason 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 crisis and recovery. 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.

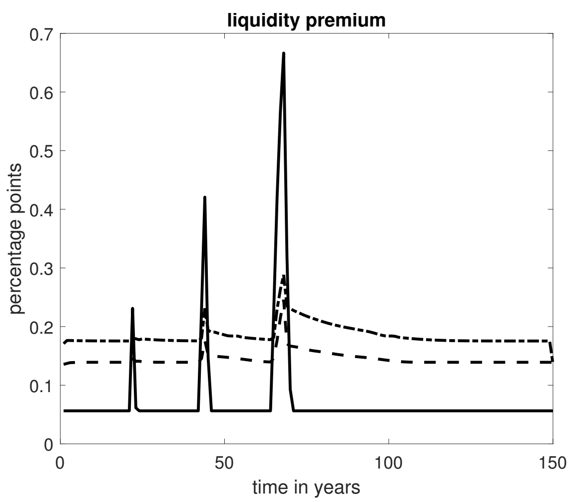
Figure 7 shows that when monetary and macroprudential policies are optimally coordinated, then the frequency of financial crises is lower (the probability density shifts inward). The reason is that monetary policy will avoid excessively depressing banks' margins at a time when macroprudential policy releases capital buffers to support bank lending. Optimal coordination reduces excessive cyclicality in bank lending and deposit supply.



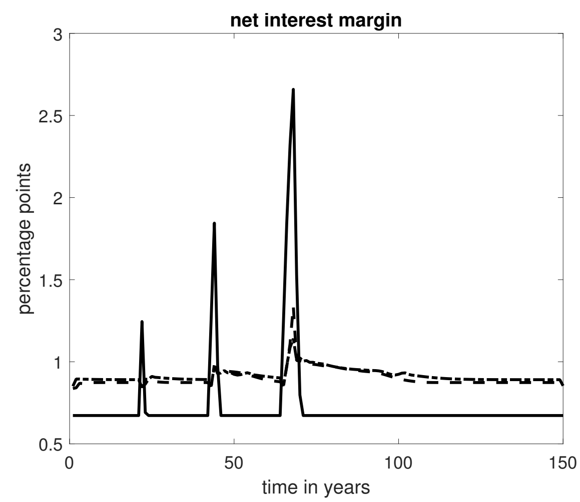
(a) Expected excess lending returns



(b) Aggregate dividends



(c) Liquidity premium



(d) Net interest margin

Figure 5: 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 the (expected) net interest margin defined as $NIM_t = [\alpha K_t^{\alpha} - \delta K_t + (1-\beta)B_t - (1-q_t)\chi_t] / (K_t + \beta B_t)$.

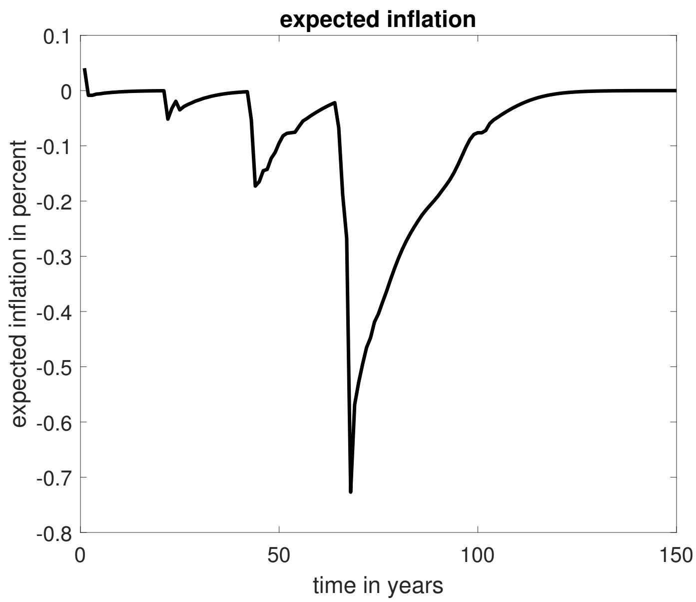


Figure 6: Difference in expected inflation, $E_t P_t - P_0$, between second-best monetary policy with coordination and a monetary policy that closes the labor gap at all times (in percentage deviations from normal times).

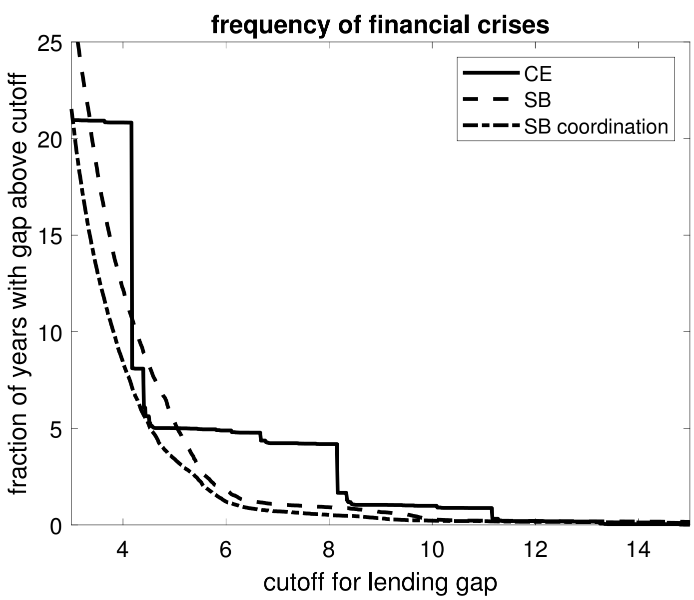


Figure 7: Frequency of low lending in a stochastic steady state (average over 30,000 simulated periods) in laissez-faire competitive-equilibrium allocation (CE), second-best allocation (SB), and second-best allocation with coordination (SB coordination).

6 Conclusion

Macroprudential capital regulation in practice has the objective of limiting the cyclicality of banks' 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 and are forced to reduce holdings of financial assets, which reduces deposit supply. 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 non-banks face when 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 hold more equity, reduce their bond holdings and issue fewer deposits during normal times. The idea is that banks enjoy a somewhat larger liquidity premium during normal times. This enables banks to build up costly capital buffers, which serves the purpose of reducing cyclicality in the supply of both loans and liquidity services. Therefore, during normal times, imposing a capital buffer requirement is complementary to a higher risk weight on (safe) bonds.

During times of financial crises monetary policy should be less expansive relative to what would be needed to achieve full employment. The idea is to avoid excessive competition in providing liquidity services to non-banks 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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A Appendix

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

A.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 (13)).

A.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 $\mathfrak{R}_0 = \{(K_{FB}, 0)\}$.