Staff Working Paper/Document de travail du personnel — 2021-31
Last updated: June 28, 2021

An Optimal Macroprudential Policy Mix for Segmented Credit Markets

by Jelena Zivanovic

Canadian Economic Analysis Department
Bank of Canada, Ottawa, Ontario, Canada K1A 0G9

JZivanovic@bankofcanada.ca

ISSN 1701-9397

Acknowledgements

For helpful comments and suggestions, I am grateful to Lutz Weinke, Jonathan Swarbrick, Matteo Cacciatore, Johanna Krenz and seminar participants at the 2018 SNDE conference, the 2018 EEA Annual Congress in Cologne and the 2019 CEA conference. The views expressed in this paper are those of the author and do not necessarily reflect the views of the Bank of Canada.

Abstract

This paper analyzes the design of simple macroprudential rules for bank and non-bank credit markets in a medium-scale dynamic stochastic general equilibrium model. In the model, mutual funds support corporate bond issuance by firms with access to capital markets; a banking sector supplies loans to the remaining producers. This model is used to study the optimal design of monetary and macroprudential rules and to address whether financial stability in the banking and bond markets is welfare improving. First, in response to aggregate productivity and financial shocks, the welfare-maximizing monetary policy rule implies near price stability, while the optimal macroprudential policy rule stabilizes bank credit and bond volumes. Second, there is no trade-off between price and financial stability. Third, if the central bank cannot correctly identify a sector-specific financial shock, responding optimally as if the shock affects both sectors, then welfare outcomes are negligibly worse than those under the optimal policy.

Topics: Business fluctuations and cycles; Credit and credit aggregates; Credit risk management; Financial stability; Financial system regulation and policies

JEL codes: E30, E44, E50

1 Introduction

Since the aftermath of the Great Recession the stability of financial markets has become a central concern for policy makers. By developing and enhancing macroprudential frameworks, regulators monitor the buildup of financial imbalances in order to preempt the risks arising from financial markets and to reduce the likelihood of a future financial crisis. Thus far, macroprudential policies have been developed primarily to improve the resilience of banking systems and the stability of housing markets (c.f., Cerutti et al., 2017). However, firms use both capital markets and bank loans to finance investment, implying that macroprudential regulation should also focus on non-bank financial institutions.[1] For example, a large fraction of firms in the US issue bond securities rather than relying on bank loans.[2] The main contribution of this paper is to determine how the design of macroprudential policy tools for segmented credit markets (the banking sector and the bond sector) can help support macroeconomic stabilization.[3]

Towards this end, I employ a New Keynesian dynamic stochastic general equilibrium (DSGE) model with a rich specification of credit markets. The model features mutual funds, which support corporate bond issuance by firms with access to capital markets, and a banking sector, which supplies loans to bank-dependent firms.[4] In order to account for the regulatory differences observed in the bank and corporate bond markets (e.g., Feve et al., 2019; Farhi and Tirole, 2017), and consistent with the previous literature, the model introduces distinct financial frictions in each financial sector.[5] In particular, banks are subject to leverage constraints, whereas mutual funds are not restricted by capital constraints. Mutual funds perform costly monitoring of firms' projects, ensuring that bond finance returns compensate for firms' default risks. Bank and bond sector-specific financial frictions are characterized by the disciplinary behavior of depositors and the costly verification of firm projects by mutual funds, respectively (Gertler and Karadi, 2011; Bernanke et al., 1999).

The model is used to address the design of macroprudential policy instruments. I consider a Taylor-type monetary policy rule[6] and two sector-specific macroprudential policy instruments that react to changes in financial conditions in their respective credit market segments. Both macroprudential policy instruments are used to stabilize a measure of financial strain in their respective sectors. I consider a range of financial indicators, such as variations in credit volumes,

[1]For example, the start of the 2007-2009 financial crisis is associated with the failures of money market funds.

[2]See Colla et al. (2013) and DeFiore and Uhlig, 2011 among others.

[3]The related work by Verona et al. (2017) studies monetary policy that "leans against the wind," where the central bank reacts to conditions in bond and bank markets by using augmented Taylor rules.

[4]The differentiation between firms in the banking and bond sectors reflects the segmentation of firms' access to bank and bond markets, which is meant to capture the empirical finding by Colla et al. (2013) on the debt specialization of large and small US firms.

[5]Two financial frictions capture differences in the operational aspects of mutual funds and banks. Mutual funds (market) monitor the performance of large firms that issue corporate bonds (publicly disclosed reports, ratings). Therefore, costly state verification is a good approximation of the relationship between mutual funds and bond-financed firms. On the other hand, since banks exist to screen borrowers, they face low monitoring costs (zero) but can be disciplined by depositors (e.g., through bank runs). Hence, the financial friction in the banking sector can be described by the limited contract enforcement between depositors and bankers.

[6]The existing literature has shown that such rules have a good empirical fit (see Taylor, 1993).

financial premia and asset prices, as possible candidates for simple macroprudential rules. By using different measures of financial conditions as targets, I can evaluate the extent to which simple, implementable macroprudential rules improve welfare outcomes. I also ask whether implementable macroprudential rules should target the same financial indicators in each sector. Finally, I assess whether the goals of monetary and macroprudential policies are aligned irrespective of the source of the business cycle fluctuations.

The economic fluctuations in the model are driven by technology and financial shocks. Financial shocks are modelled as capital quality shocks which hit each financial sector simultaneously. I also consider sector-specific financial shocks in the form of capital quality shocks that only affect one sector. These shocks persistently lower (or increase) the efficiency of installed capital, causing an effective drop (rise) in the supply of capital and a rise (fall) in its price. By changing the value of capital, the financial shocks affect balance sheet positions, causing movements in the finance premia and disrupting financial intermediation.

The key results relating to aggregate shocks can be summarized as follows. The first finding is that macroprudential policy should stabilize bank credit and bond volumes. By responding to changes in credit growth, the macroprudential tool aims to stabilize the respective sector and reduce the degree of financial distortion. The macroprudential policy instrument helps to limit the variability of both credit and leverage in each financial sector, each of which affect net worth and the return on capital. The way the macroprudential tool works can be illustrated for the case of an adverse financial shock. By relaxing the bank leverage constraints, the bank macroprudential policy reduces the degree of financial friction, which improves the credit supply conditions. The moderation of the credit cycle in the bond sector is achieved by adjusting the reserve requirements for mutual funds. Relaxing the macroprudential regulation in the bond sector in response to adverse financial shocks supports the balance sheet positions of firms, limits the increases in the financial premia and enables greater issuance of corporate bonds. The second key finding is that there is no trade-off between price and financial stability. In the presence of optimized macroprudential rules, it remains optimal for monetary policy to stabilize inflation in response to aggregate shocks. Because the economic recovery that follows both financial and technology shocks is associated with inflationary pressures, the model's aggressive monetary policy complements the easing of the financial conditions that result from the macroprudential policies. Therefore, the model predicts alignments of the monetary and macroprudential interests.

Several additional results arise from the analysis of sectoral financial shocks. First, if the policy maker wrongly identifies a sector-specific financial shock as an economy-wide financial shock, by acting *as if* it were an economy-wide shock, the policy maker's policy mix attains a negligibly worse welfare outcome than the optimal policy mix. The intuition for this result is that sectoral financial shocks trigger aggregate dynamics that are qualitatively similar to those implied by aggregate financial shocks. For this reason, in the presence of sector-specific financial shocks, the optimal policy mix yields a negligibly higher welfare gain relative to the optimal rules that abstract from sector-specific shocks. Second, the model predicts nearly identical welfare outcomes under simple macroprudential policies (reacting to alternative measures of financial conditions) when the economy is hit by sector-specific financial shocks. This result suggests that the financial indicators are substitutes, as they stabilize sectoral financial conditions through similar channels. The rationale is that macroeconomic stabilization in the credit market segment can be achieved by addressing the disrupted credit sector (i.e., by reacting to different financial indicators), whereas the policy response to the undisrupted sector plays a limited role.

This paper contributes to a growing literature on macroprudential regulation which has mainly focused on the welfare implications of macroprudential policies targeting a single financial market (see, e.g., Gelain and Ilbas, 2017; Bailliu et al., 2015; Leduc and Natal, 2017; Rubio and Carrasco-Gallego, 2014, to name a few). There are also numerous studies that address the interaction of monetary and macroprudential policies in the context of housing markets (e.g., Kannan et al., 2012; Quint and Rabanal, 2014), or in the open economy (e.g., Dedola et al., 2013; Brzoza-Brzezina et al., 2015). Most of these works conclude that the efficacy of macroprudential policy depends on the type of economic disturbance. For instance, Leduc and Natal (2017) find that monetary and macroprudential policies act as substitutes in the presence of financial shocks. Contrary to this finding, my model shows that monetary and macroprudential policy can operate together to stabilize aggregate fluctuations.

The study perhaps most closely related to this paper is one by Verona et al. (2017), who analyze the extent to which Taylor rules that are augmented with financial indicators are welfare improving in the context of a model with a banking sector and a bond sector. They find that monetary policies that react to credit growth outperform the ones that focus on finance premia. This is consistent with the results on the optimal policy mix presented in this paper. However, the study reaches different conclusions when considering shocks that affect only one sector. In this case, the optimal policy mix features a substitutability between different measures of financial conditions.

The remainder of the paper is organized as follows. Section 2 describes the model setup. Section 3 discusses the main results. Section 4 concludes.

2 The model

Similar to Zivanovic (2019), the model framework features both banks and non-banks. In particular, I consider two credit market segments: a banking sector and a bond sector. Bank-dependent firms obtain bank loans from banks, whereas firms with access to capital markets issue corporate bonds. The credit market segmentation matches the empirical finding on the debt specialization of large and small US firms (see Cantillo and Wright, 2000). Banks are modeled as depository institutions, following the setup by Gertler and Karadi (2011). Due to a moral hazard problem between depositors and banks, depositors discipline banks via a leverage constraint, which specifies the bank credit supply to bank-dependent firms. Mutual funds (or, equivalently, non-bank financial institutions such as money market funds, investment banks, etc.) are modeled as perfectly competitive financial institutions[7] along the lines of Bernanke et al. (1999). They offer underwriting services to firms with access to corporate debt markets and help them issue bond (debt) securities. The terms of the optimal bond contract specify the amounts of bonds as well as the bond finance premia.

In the model, the economy is populated by the following agents: households, intermediate firms, corporate finance firms, final goods firms, capital goods producers, lending banks and mutual funds. Households consume, supply labor and save via depositing their financial resources with financial intermediaries. Two types of corporate finance firms–bank finance firms and bond finance firms–make financing decisions regarding bank loans and corporate bonds, respectively, in order to finance their investments in physical capital. The intermediate goods sector is monopolistically competitive. Intermediate goods firms combine the physical capital acquired by corporate finance firms with labor to produce differentiated products and to set prices. Capital goods firms make investment decisions. Final goods producers combine all of the intermediate goods into final goods and make them available to households and capital producers in the form of consumption and investment goods. The central bank (or equivalently the macroprudential regulator) has at its disposal two sector-specific policy instruments with which to stabilize financial imbalances in the respective credit market. Both instruments are countercyclically related to the measure of the financial conditions. In the following, I will outline the equilibrium conditions and the definitions of the respective economic relationships.

The consumption Euler equation and the household labor supply condition take the following forms:

$$\lambda_t = E_t \left\{ \beta R_t \lambda_{t+1} \right\}, \tag{1}$$

$$w_t = \frac{\psi_L \, L_t^{\phi_L}}{\lambda_t}, \tag{2}$$

where $\lambda_t \equiv \frac{1}{(C_t - hC_{t-1})} - \frac{\beta h}{(E_t C_{t+1} - hC_t)}$ denotes the Lagrange multiplier. C_t represents real aggregate consumption, L_t is the labor hours, w_t the real wage rate, and R_t the real risk-free gross return between $t-1$ and t from holdings of real one-period government bonds. E_t is the expectational operator that is conditional on the information available at time t. Parameters $0 < \beta < 1$, $0 < h < 1$, $\psi_L, \phi_L > 0$ denote, respectively, the household's discount factor, the external habit formation parameter, the weight of the disutility of labor and the inverse of the labor supply elasticity.

Total capital is a composite of two bundles of sectoral capital; i.e., the capital of individual

[7] Wahal and Wang (2011) examine the market structure of mutual funds and find that this market is a competitive one.

bank-dependent firms and bond finance firms, K_t^S and K_t^B, respectively, and is given as follows:[8]

$$K_t = \left[\eta(K_t^S)^\rho + (1-\eta)(K_t^B)^\rho\right]^{\frac{1}{\rho}}, \tag{3}$$

where $\rho > 0$ is the degree of substitutability between the two types of capital and $0 < \eta < 1$ is the share of bank-dependent firms. The capital of firm type j has the following law of motion:

$$K_t^j = \left\{(1-\delta)\,\xi_t K_{t-1}^j + \left(1 - f\left(\frac{I_t^j}{I_{t-1}^j}\right)\right) I_t^j\right\}, \tag{4}$$

with I_t^j, K_t^j denoting the investment and capital of type j, with $j \in (S, B)$ and ξ_t denoting a capital quality shock, as suggested by Gertler and Karadi (2011). The adverse shock destroys productive capital, which can be also interpreted as the economic obsolescence resulting from the shock. This process triggers negative asset price dynamics, reflecting the characteristics of a financial crisis. Note that $f\left(\frac{I_t^j}{I_{t-1}^j}\right) = \frac{\psi^j}{2}\left(\frac{I_t^j}{I_{t-1}^j} - 1\right)^2$. Parameters $\psi^j > 0$ and $0 < \delta < 1$ measure the degree of curvature of the investment adjustment cost and the depreciation rate, respectively. The equilibrium condition for the optimal investment of type j reads as follows:

$$Q_t^j = \frac{1 - \beta E_t\left\{\Lambda_{t,t+1} f'\left(\frac{I_{t+1}^j}{I_t^j}\right)\frac{{I_{t+1}^j}^2}{{I_t^j}^2}\right\}}{1 - f\left(\frac{I_t^j}{I_{t-1}^j}\right) - f'\left(\frac{I_t^j}{I_{t-1}^j}\right)\frac{I_t^j}{I_{t-1}^j}}, \tag{5}$$

with $\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}$ denoting the real stochastic discount factor and Q_t^j the real price of capital of firm type j.

The average gross return on capital in the specific sector is given by

$$R_{k,t+1}^j = \frac{r_{k,t+1}^j + (1-\delta)\xi_{t+1} Q_{t+1}^j}{Q_t^j}. \tag{6}$$

where $r_{k,t}^j$ denotes the rental price of capital of firm type j. From the firm's cost minimization problem, the rental price of capital is determined by

$$r_{k,t}^j = \left[\alpha A_t s_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \left(K_t^j\right)^{\rho-1} K_t^{\frac{1}{\rho}-1}\right]^{\frac{1}{\alpha}}, \tag{7}$$

[8]Similar to Verona et al. (2013), in my framework, the individual members are identical within each group; i.e., $K_t^{S,a} = \eta K_t^S$ and $K_t^{B,a} = (1-\eta)K_t^B$, whereby $K_t^{S,a}$ and $K_t^{B,a}$ represent the sector-specific bundles of capital. Hence, the total capital can be also written in terms of sectoral capital bundles: $K_t = \left[\eta^{1-\rho}(K_t^{S,a})^\rho + (1-\eta)^{1-\rho}(K_t^{B,a})^\rho\right]^{\frac{1}{\rho}}$.

where s_t stands for the average real marginal cost and parameter $0 < \alpha < 1$ is the share of the total capital in the production function. The optimality condition for the choice of the particular type of capital and the labor hours results in

$$\frac{r_t^{k,B}}{r_t^{k,S}} = \left(\frac{K_t^B}{K_t^S}\right)^{\rho-1}, \tag{8}$$

$$w_t = s_t \frac{\alpha Y_t^m}{L_t}. \tag{9}$$

The intermediate goods production is determined by

$$Y_t^m = A_t(\xi_t K_t)^\alpha L_t^{1-\alpha}, \tag{10}$$

where A_t represents aggregate technology. The equilibrium conditions associated with the optimal choice of price give rise to the New Keynesian Phillips curve.

Banks are modeled along the lines of Gertler and Karadi (2011). A representative bank's net worth, N_t^S, evolves as the difference between earnings on bank loans, $Q_t^S B_t^S$, and deposits, D_t^S, $N_t^S \equiv Q_t^S B_t^S - D_t^S$. The bank lends to firms at the stochastic real interest rate, $R_{k,t}^S$, and pays the real interest rate, R_t, on household deposits:

$$N_t^S = R_{k,t}^S Q_t^S B_t^S - R_{t-1} D_t^S. \tag{11}$$

The macroprudential instrument affects the amount of bank net worth and leverage (to be shown later), which in turn eases or restricts the supply of bank loans.

Following Gertler and Karadi (2011), the equilibrium conditions associated with the banking sector specify the marginal gain from expanding bank assets, ν_t^S, the marginal gain of an additional unit of net worth, η_t^S, the growth rate of bank net worth, $z_{t,t+i}$, and the growth rate of bank capital, $\chi_{t,t+i}$:

$$\nu_t^S = E_t\left\{(1-\gamma^S)\beta\Lambda_{t,t+1}(R_{k,t+1}^S - R_t) + \beta\Lambda_{t,t+1}\gamma^S \chi_{t,t+1}\nu_{t+1}^S\right\}, \tag{12}$$

$$\eta_t^S = E_t\left\{(1-\gamma^S) + \beta\Lambda_{t,t+1}\gamma^S z_{t,t+1}\eta_{t+1}^S\right\}, \tag{13}$$

$$z_{t-1,t} = (R_{k,t}^S - R_{t-1})\phi_{t-1}^S + R_{t-1}, \tag{14}$$

$$\chi_{t-1,t} = \left\{\frac{\phi_t^S}{\phi_{t-1}^S}\right\} z_{t-1,t}, \tag{15}$$

where $R_{k,t}^S - R_{t-1}$ denotes the bank finance premium.[9] Parameter $0 < \gamma^S < 1$ is the survival probability of bankers. The term $\phi_t^S \equiv \frac{Q_t^S B_t^S}{N_t^S}$ denotes the average bank leverage ratio. The definitions of the growth rates are as follows: $\chi_{t,t+i} \equiv \frac{Q_{t+i}^S B_{t+i}^S}{Q_t^S B_t^S}$ and $z_{t,t+i} \equiv \frac{N_{t+i}^S}{N_t^S}$. Equations (12) and (13) represent the marginal value of an additional unit of bank assets and net worth,

[9] Gertler and Karadi (2011) name this term the credit spread. For convenience and comparability with the bond sector, I name the term the bank finance premium.

respectively.

The agency problem gives rise to the leverage constraint of banks:

$$\phi_t^S = \frac{\eta_t^S}{(\lambda_t^S - \nu_t^S)}, \tag{16}$$

where λ_t^S denotes the fraction of funds diverted by bankers. As λ_t^S captures the overall confidence in the banking system, the macroprudential tool, τ_t^S, can stabilize the banking sector by affecting it in the following way:

$$\lambda_t^S = \lambda^S + \tau_t^S. \tag{17}$$

In the case of positive financial market developments, the policy maker would require more resources from banks to be set aside in order to ensure that households trust banks with managing their deposits. During a financial crisis, when the perceived riskiness of the banking system (not explicitly modeled) is high, banks would be required to adjust their leverage while taking into account adverse credit market developments. Hence, the role of the macroprudential instrument would be to affect banks' balance sheet conditions (leverage and net worth) by safeguarding financial stability in the banking sector.

The evolution of bank net worth is given by

$$N_t^S = \gamma^S[(R_{k,t}^S - R_{t-1})\phi_{t-1}^S + R_{t-1}]N_{t-1}^S + \omega^S Q_{t-1}^S B_{t-1}^S. \tag{18}$$

Net worth is accumulated from revenues from bank operations (of surviving banks) and a start-up transfer from households, $\omega^S Q_{t-1}^S B_{t-1}^S$. Note that the total value of the bank loans that are extended to the representative bank-dependent firms (corporate finance firms) is used to finance their capital purchases:

$$Q_t^S K_t^S = Q_t^S B_t^S. \tag{19}$$

A representative firm that relies on bond finance uses their own net worth and bonds to finance capital purchases as follows:

$$B_t^B = Q_t^B K_t^B - N_t^B.$$

The debt contract is settled between mutual funds and large firms along the lines of Bernanke et al. (1999). The operations of mutual funds are subject to macroprudential regulation in the form of reserve requirements, τ_t^B. The reserve requirement affects the amount of resources available for funding bond issuance by altering the zero-profit condition for mutual funds:

$$E_t\left\{\left[\Gamma_t(\bar{\omega}_{t+1}^B) - \mu_{t+1}G_t(\bar{\omega}_{t+1}^B)\right] R_{k,t+1}^B Q_t^B K_t^B\right\} = \frac{R_t B_t^B}{\tau_t^B}, \tag{20}$$

where $\bar{\omega}^B$ is the threshold idiosyncratic productivity that determines the firm's ability to repay its corporate bonds. The following definitions are used: $\Gamma_t(\bar{\omega}^B_{t+1}) \equiv (1-F_t(\bar{\omega}^B_{t+1}))+\int_0^{\bar{\omega}^B_{t+1}} \omega dF_t(\omega^B)$ and $G_t(\bar{\omega}^B_{t+1}) \equiv \int_0^{\bar{\omega}^B_{t+1}} \omega^B dF_t(\omega^B)$. $\Gamma_t(\cdot)$ and $\mu G_t(\cdot)$ denote respectively the share of large firms' earnings received by the mutual fund and the monitoring costs. $F_t(\bar{\omega}^B_{t+1})$ is a cumulative distribution function (and the probability of default) of idiosyncratic productivity, ω^B. Similar to Bernanke et al. (1999), I assume that ω^B_t is log normally distributed with $E(\omega^B_t) = 1$ and $Var(\ln \omega^B_t) = {\sigma_\omega}^2$.

The bond macroprudential policy instrument, τ^B_t, is linked to a financial indicator in the bond sector. Along the lines of Leduc and Natal (2017), a change in the macroprudential regulation affects the reserve requirement, which changes the amount of corporate bonds issued since part of the funds can be held as reserves, resulting in an increase or decrease in the bond finance premium.

Solving the optimal bond contract,[10] I obtain that the relationship between the return on capital and the bond finance premium is given by

$$E_t R^B_{k,t+1} = E_t[\rho(\bar{\omega}^B_{t+1})R_t], \tag{21}$$

$$\rho(\bar{\omega}^B_{t+1}) = \frac{\Gamma'_t(\bar{\omega}^B_{t+1})}{\tau^B_t[(\Gamma_t(\bar{\omega}^B_{t+1}) - \mu_{t+1}G_t(\bar{\omega}^B_{t+1}))\Gamma'_t(\bar{\omega}^B_{t+1}) + (1-\Gamma_t(\bar{\omega}^B_{t+1}))(\Gamma'_t(\bar{\omega}^B_{t+1}) - \mu_{t+1}G'_t(\bar{\omega}^B_{t+1}))]}, \tag{22}$$

where $\rho(\bar{\omega}_{t+1})$ represents the bond finance premium. The zero profit condition of the mutual funds can be rewritten as follows:

$$E_t\left\{[\Gamma_t(\bar{\omega}_{t+1}) - \mu_{t+1}G_t(\bar{\omega}_{t+1})]\frac{Q^B_t K^B_t}{N^B_t}\frac{\tau^B_t R^B_{k,t+1}}{R_t}\right\} = \frac{Q^B_t K^B_t}{N^B_t} - 1, \tag{23}$$

which can be related to the average leverage ratio of these firms, $\phi^B_t \equiv \frac{Q^B_t B^B_t}{N^B_t}$.

The law of motion for firms' net worth is given by

$$N^B_t = \gamma^B(1-\Gamma_{t-1}(\bar{\omega}_t))R^B_{k,t}Q^B_{t-1}K^B_{t-1} + W^B, \tag{24}$$

where W^B denotes a constant lump-sum transfer of households and parameter $0 < \gamma^B < 1$ determines the fraction of these firms' earnings that is accumulated. Firms with access to bond finance default on bonds if the realization of the idiosyncratic productivity falls below the threshold productivity, which is given by

$$\bar{\omega}_{t+1} = \frac{Z_t\left(Q^B_t K^B_t - N^B_t\right)}{R^B_{k,t+1}Q^B_t K^B_t}, \tag{25}$$

[10]See, for example, Bernanke et al. (1999).

where Z_t denotes the contractual, no-default interest rate on corporate bonds.[11]

The capital rental market and the credit market clear:

$$\int_0^\infty K_{i,t}^S di = K_t^{S,a} = \eta K_t^S, \tag{26}$$

$$\int_0^\infty K_{i,t}^S di = K_t^{B,a} = (1-\eta) K_t^B, \tag{27}$$

$$B_t^{tot} = B_t^{tot,B} + B_t^{tot,S}, \tag{28}$$

where B_t^{tot} represents total credit, and $B_t^{tot,S} \equiv \eta Q_t^S B_t^S$ and $B_t^{tot,B} \equiv (1-\eta)(Q_t^B K_t^B - N_t^B)$ represent the total value of bank loans and corporate bonds, respectively. The aggregate resource constraint is given by the following:[12]

$$Y_t = C_t + I_t,$$

with $I_t = \eta I_t^S + (1-\eta) I_t^B$. The Fisher relation holds

$$R_t = \frac{R_t^n}{E_t \Pi_{t+1}}, \tag{29}$$

where R_t^n denotes the nominal interest rate.

The shocks follow autoregressive processes given by

$$\ln A_t = \rho_a \ln A_{t-1} + e_{t,A}, \tag{30}$$

$$\ln \xi_t = \rho_\xi \ln \xi_{t-1} + e_{t,\xi}, \tag{31}$$

where $\rho_A, \rho_\xi \in (0,1)$ and $e_{t,x}, \sim iid(0, \sigma_x^2)$, whereby $x = \{A, \xi\}$.

2.1 Welfare measure and policy rules

To assess the welfare implications of the policy rules, I specify the welfare measure as the unconditional lifetime household utility:

$$W_t = E \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{32}$$

with the period utility $U(C_t, L_t) \equiv \ln(C_t - hC_{t-1}) - \frac{\psi_L}{1+\phi_L} L_t^{1+\phi_L}$.

Following Lucas (1987, 2003); Faia and Monacelli (2007), I calculate the welfare costs associ-

[11] The contractual bond interest rate is associated with the threshold productivity, $\bar{\omega}$; i.e., the value of the firm's idiosyncratic productivity is such that the firm's net worth is completely eliminated and it is exactly able to pay off the corporate bond.

[12] I assume that the monitoring costs of mutual funds do not deplete the aggregate output and are transferred as a lump sum to households.

ated with each policy regime. These costs are expressed as the compensation, g, that households would require to remain indifferent between the stochastic economy and the deterministic steady-state environment. This fraction can be determined from the following equation:

$$E\sum_{t=0}^{\infty}\beta^t U(C_t, L_t) = E\sum_{t=0}^{\infty}\beta^t U((1+g)\bar{C}, \bar{L}), \tag{33}$$

where $\bar{C}$ and $\bar{L}$ denote the deterministic steady-state values of C_t and L_t. The left-hand side represents the unconditional expectation of welfare that is obtained using a second-order Taylor approximation, whereas the right-hand side is the welfare in the deterministic steady state.[13]

For the welfare comparison of the three policy rules, I consider the family of simple interest rate rules in the form of simple Taylor rules in each policy specification. In the case where the central bank employs a mix of all three instruments, I relate the sector-specific macroprudential policy instrument, τ_t^j, to a measure of financial imbalances in the respective credit market segment. Hence, the specifications of the policy rules I compare are given by the following:

1. Simple Taylor rule

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)}, \tag{34}$$

2. Optimized simple Taylor rule $\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)}$,

3. Optimized policy combination from the optimized simple Taylor rule

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)},$$

   and the optimized sector-specific macroprudential policy instrument is

$$\tau_t^j = \tau^j - \nu_j \ln\left(\frac{\Xi_t^j}{\Xi_{t-1}^j}\right), \tag{35}$$

where Ξ_t^j represents the relevant financial indicator the regulator includes in the simple macroprudential rule. The financial indicators considered include credit growth, the finance premia and the asset price growth,[14] $\Xi^j \in (B_t^{tot,j}, \frac{R_{k,t}^j}{R_{t-1}}, Q_t^j)$ for $j \in (S, B)$. I assume that the macroprudential policy instruments are not used in the steady state and, therefore, the value of each instrument, τ^j, is 0. R^n and Π denote the steady-state values for the nominal interest rate and inflation, R_t^n and Π_t, respectively. The parameter α_π is the weight on inflation, ρ_r measures the degree of interest rate smoothing. The parameter $\nu_j \geq 0$ denotes, respectively, the policy

[13] See further details in the appendix.

[14] The policy instrument is inversely related to the credit/asset price growth; however, it is positively linked to changes in the finance premia or credit spreads.

coefficient that measures the degree of responsiveness of the central bank to a financial indicator, Ξ_t^j, in the banking and the bond sectors, respectively.

Along the lines of Schmitt-Grohé and Uribe (2007), I consider constrained-optimal rules: For cases 2, and 3, I search for the value of the policy coefficient, α_π, and the joint determination of the policy coefficients, α_π, ν_S and ν_B, that yield the highest welfare, respectively.[15] In the following, I explain the modeling of each instrument in more detail.

For the conventional monetary policy, I consider implementable monetary policy rules. Following Schmitt-Grohé and Uribe (2007), these rules ensure the local uniqueness of the rational expectations equilibrium. This implies that the policy coefficient on inflation, α_π, is limited in the interval $[1.01, 3]$ in the context of my model framework. The authors argue that policy makers would have difficulties communicating policies that are associated with larger policy coefficients.

The bond macroprudential policy instrument, τ_t^B, aims to stabilize the bond sector by directly levying or relaxing the reserve requirements for mutual funds in the bond sector. I limit the policy coefficient ν_B to the interval $[0, 1]$, as suggested by Bailliu et al. (2015). They argue that the value of this policy coefficient is lower than the inflation coefficient since the prime concern of the policy maker is price stability.

The proposed banking sector policy instrument in equation (35) attempts to offset the disruption shocks cause in the banking sector. In the case of a negative development in the banking sector,[16] the macroprudential instrument can relax the leverage constraint by reacting to adverse credit conditions. For example, the macroprudential policy can aim to alleviate financial friction (i.e., households distrust banks' management) by requiring banks to communicate additional information on the state of their balance sheets (e.g., stress test). I search for the optimal value of ν_S in the interval of (0,10). The coefficient interval is larger than in the case of the bond sector for the following reason: The considered policy coefficient range reflects the fact that banks are exposed to bank (macroprudential) regulation; e.g., through Basel I, II and III, whereas non-bank institutions are mostly left unregulated. Overall, the purpose of the analysis is not to take a stance on the exact size of policy responsiveness to changes in financial conditions but rather to qualitatively evaluate which measurable financial indicators should constitute part of simple implementable macroprudential rules.

[15]For example, in the case of the joint determination of the policy coefficients, I vary policy parameters α_π, ν_S and ν_B over a grid and search for the values of the three parameters at which a welfare measure is maximized. For each parameter, I consider 10 different values.

[16]Negative financial conditions in the banking sector can be indicated by a credit crunch or heightened finance premia or an asset price plunge.

3 Results

3.1 Calibration

The time unit is one quarter. Most of the parameters are calibrated as in the model of Gertler and Karadi (2011). The parameters related to the financial sector are presented in Table 1 and elaborated in Zivanovic (2019).

Table 1: Calibration

Parameter	Value	Description	Target
η	0.263	Share of bank-dependent firms	$\frac{Loans}{Bonds} = 0.66$
γ_S	0.957	Survival probability of banker	Leverage: 4
γ_B	0.979	Survival probability of firms using bond finance	Leverage: 2
λ^S	0.609	Fraction of divertible bank capital	258bp.(annualized)
μ^B	0.079	Monitoring cost (mutual funds)	BBB spread: 209bp.(annualized)
$F(\omega^B)$	0.0134	Default probability	SG debt: 5.37% (annualized)
W^B	0.005	Transfer from households	Christiano et al. (2014)
ω^S	0.002	Transfer from households	Gertler and Karadi (2011)
ψ^j	1.72	Curvature of investment adjustment cost	Gertler and Karadi (2011)
ρ	0.6	Substitutability of capital	Verona et al. (2013)
ρ_a	0.95	Persistence of technology shock	
σ_a	0.007	Std. dev. of technology shock	
ρ_ξ	0.66	Persistence of cap. quality shock	
σ_ξ	0.013	Std. dev. of cap. quality shock	

Notes: The abbreviation bp. represents basis points, BBB spread is the spread between the BBB-rated corporate debt and the Treasury yield, SG debt refers to the US speculative-grade debt, std. dev. stands for standard deviation, cap. quality shock is the capital-quality shock.

The calibration of the key parameters is related to the characteristics of two credit market segments. The ratio of loans to bonds pins down the share of bank-dependent firms. The value of the leverage helps to determine the survival probability of banks and firms that rely on capital markets. In line with the literature, the leverage of the banking sector is higher than the leverage in the corporate sector (see, e.g., Bernanke et al., 1999; Gertler and Karadi, 2011). I use the credit spread index of Gilchrist and Zakrajšek (2012) and the BBB spread[17] as targets for the bank and bond finance premia, respectively. These spreads help with the calibration of the parameters that are related to the financial frictions in the respective credit markets. The default probability, $F(\omega^B)$, is set to match the default rate on the US speculative-grade debt

[17] I assume that a representative US corporate bond security is characterized by the BBB investment-grade debt. For example, Denis and Mihov (2003) report that the BBB is the median new corporate debt rating.

(similar to DeFiore and Uhlig, 2011).

The sources of exogenous variations are non-financial (technology) shocks and financial (capital quality) shocks. The specifications of the technology shocks follow the work of Cooley and Prescott (1995), who set the autoregressive parameter to 0.95 and the standard deviation to 0.007. For the case of the capital quality shock, I match the properties of the data on the credit market instruments, which entail the credit volumes in both credit market segments. This credit volume measure has a first-order serial correlation of 0.66 and a standard deviation of 0.0134, which are used to calibrate ρ_ξ and σ_ξ.

3.2 Welfare implications of economy-wide shocks

3.2.1 Optimal policy rules

Table 2 represents the welfare costs under the three different policy regimes specified in section 2.1 and the relative gains from the optimized rules, compared to the simple Taylor rule.[18] The welfare costs reflect a fraction of the steady-state consumption households require as compensation to live in the stochastic economy under a certain policy regime. The relative gain denotes the welfare gains from a specific policy, over the simple Taylor rule.

The main results can be summarized as follows: First, Table 2 shows that each monetary-macroprudential policy mix outperforms the simple Taylor rule under two shock scenarios. If financial shocks are the driving forces behind business cycle fluctuations, then the banking sector policy instrument should lean against changes in bank loans or in the bank finance premium, whereas the bond sector policy instrument should respond to variations in bond volumes. When a regulator is addressing financial imbalances that arise in an economy hit by technology shocks, to achieve the highest welfare they should rely on credit volumes in their macroprudential policy mix. Second, the welfare-maximizing monetary policy rule implies near price stability. The presence of optimized simple macroprudential policy rules does not alter what is prescribed by an optimized Taylor rule following both capital quality shocks and technology shocks. Third, all of the considered policies lead to an increase in the welfare measure following financial shocks, which implies that households prefer the stochastic economy with policy actions over the deterministic economy. The intuition for this result is that the recommended policies manage to substantially reduce households' perceptions of risks and their motive for precautionary savings, making agents better off under these scenarios.

In the following, I explain the mechanism behind leaning against credit growth. By responding to the decline in bank loan growth, the macroprudential tool aims to stabilize the banking sector and reduce the degree of the financial distortion: the macroprudential instrument directly affects the bank leverage ratio, which in turn changes the banks' net worth and return on capital.

[18] I do not compare the performance of the optimized rules relative to a standard Taylor rule with inflation and an output gap since the definition of an output gap is not unambiguous in the context of a New Keynesian model whose capital accumulation is endogenous (see, Woodford (2003), Chapter 5).

Table 2: Optimal policy rules and different financial indicators

	α_π	ν_S	ν_B	Welfare cost	Relative gain
Capital quality shocks only					
Simple Taylor rule	1.5	-	-	0.169	-
Optimized Taylor rule	3	-	-	0.192	0.023
Bank credit+ bond volume	3	3	1	0.440	0.271
Bank credit+ bond finance premium	3	3	1	0.389	0.221
Bank credit+ bond sector asset prices	3	1	0.2	0.232	0.051
Bank finance premium+ bond volume	3	10	1	0.440	0.271
Bank finance premium+ bond finance premium	3	10	1	0.390	0.221
Bank finance premium+ bond sector asset prices	3	10	0.2	0.230	0.061
Bank asset prices + bond volume	3	10	1	0.414	0.245
Bank asset prices + bond finance premium	3	10	1	0.366	0.197
Bank asset prices + bond sector asset prices	3	10	0.2	0.211	0.042
Technology shocks only					
Simple Taylor rule	1.5	-	-	-0.020	-
Optimized Taylor rule	3	-	-	-0.015	0.005
Bank credit+ bond volume	3	10	1	0.001	0.021
Bank credit+ bond finance premium	3	10	1	0.000	0.020
Bank credit+ bond sector asset prices	3	10	0.2	-0.006	0.014
Bank finance premium+ bond volume	3	10	1	-0.002	0.018
Bank finance premium+ bond finance premium	3	10	1	-0.002	0.018
Bank finance premium+ bond sector asset prices	3	10	0.2	-0.009	0.011
Bank asset prices + bond volume	3	10	1	-0.005	0.015
Bank asset prices + bond finance premium	3	10	1	-0.004	0.016
Bank asset prices + bond sector asset prices	3	10	0.2	-0.011	0.009

Notes: In the optimized Taylor rules, the policy parameters α_π are restricted to being within the interval $[1.01, 3]$, respectively. For the macroprudential policy rules, I restricted policy parameters ν_S and ν_B to the interval $[0, 10]$ and $[0, 1]$, respectively. All of the Taylor-type policy rules feature interest rate smoothing with $\rho_r = 0.8$. The welfare cost, $g \cdot 100$, is expressed in terms of the steady-state consumption. A negative value for welfare costs indicates that households are willing to give up a certain fraction of their steady-state consumption in order to remain in the deterministic economy relative to the stochastic environment under a certain policy regime. The relative gain is calculated as the gain of a specific policy relative to the simple Taylor rule.

In the case of adverse shocks, the bank leverage constraint that becomes less tight reduces the degree of financial friction, which improves the credit supply conditions. For the bond sector, the macroprudential policy reacts to changes in bond volumes by imposing reserve requirements for financial resources. The moderation of the credit cycle in the bond sector feeds into the sectoral leverage, which, through the finance premium, changes the conditions of the bond contract, including the issuance volumes. As the macroprudential policy mix is successful in dampening the financial accelerator mechanisms, the improved credit conditions contribute to macroeconomic stabilization.

For the scenarios that show the financial shocks, the optimal policy mix–the one that reacts to inflation, changes in bond volumes and bank credit growth (or bank finance premium)–yields the best welfare outcome. Macroprudential tools relieve financial buildups by moderating the impact of shocks on the financial conditions and by restoring the functioning of sectoral financing. In particular, the lack of household deposit depletion improves banks' balance sheets, which alleviates financial intermediation. The reduced need for precautionary savings translates to a smoother path of consumption and labor under the policy mix than under alternative policies. The moderate reaction to bank credit translates to less variation in leverage (constraint), causing more stabilization of the banking sector than in the scenario with an aggressive response to credit fluctuations. The bond instrument loosens/tightens with changes in conditions in the bond sector, so that less/more funds need to be set aside in the form of reserves, which facilitates/impedes bond issuance. The aggressive monetary policy stance is necessary to stabilize the inflationary nature of the shock. Additionally, optimized monetary policies, if implemented solely, seem to cause the shock to have moderate effects on both the bank incentive constraint and the bond contract by strengthening balance sheets (e.g., through higher net worth) and, therefore, these policies attenuate the degree of credit tightening better than the simple Taylor rule.

Following technology shocks, macroprudential instruments should vary with changes in bank credit and bond volume, respectively, to achieve the highest welfare outcome. Aggressive interest-rate reaction to inflation tries to counter inflationary pressures. Within this context, a negligibly small positive welfare gain of 0.001% in consumption equivalents under the optimal policy mix emanates from the stabilization of the bank credit market whereby agents recuperate their confidence in banks and do not fear deposit erosion. As already argued in the literature (see Bailliu et al., 2015), technology shocks are associated with the limited benefits of an optimal policy mix. This study supports this argument when it finds that the optimal policy mix's relative gain over the simple Taylor rule yields 0.021% of the steady-state consumption. If, in the case of technology shocks, the policy maker uses the macroprudential policy mix (reacting to bank and bond credit growth with comparable strength), which is optimal conditional on capital quality shocks, the relative welfare gain is decreased by 0.004% of the steady-state household consumption.[19] Impulse responses will be used to discuss the mechanisms at work following respective shocks.

3.2.2 Impulse-response functions: Financial shocks

Figure 1 shows the dynamic responses of the main variables, under the policies specified in section 2.1, in the presence of a one-standard-deviation adverse capital quality (financial) shock that causes the destruction of capital in both sectors and induces a decline in capital prices.[20] For the optimal policy mix, I use the optimized policy coefficients from Table 2 that are associated with both macroprudential policy reactions to sector-specific credit growth.[21]

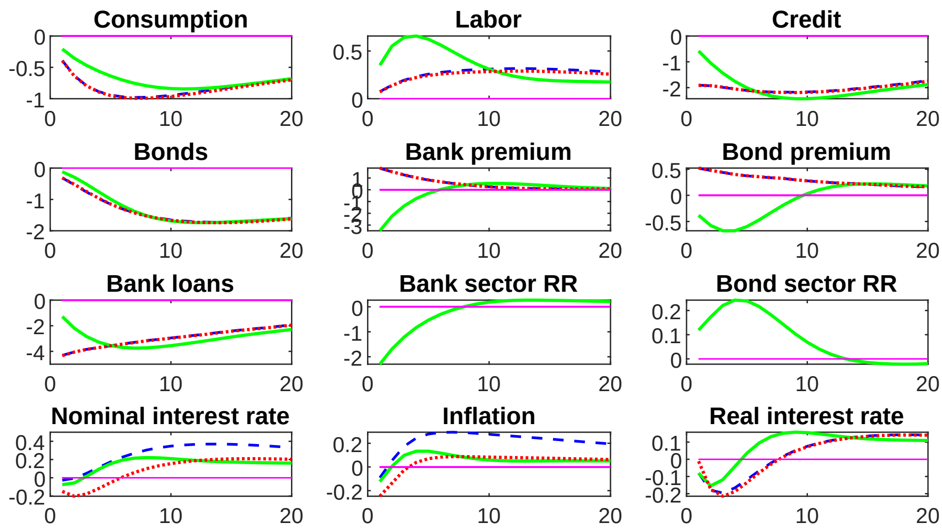
The destruction of capital stock (and therefore of firms' assets) as a result of a negative capital quality shock can be seen as missing collateral in financial relationships; this leads to the

[19] I compare the welfare under the optimal policy mix conditional on technology shocks with the welfare under the policy mix, which the regulator would optimally choose when acting upon the assumption that financial shocks have hit the economy; that is, in terms of the relative gain: $0.021\% - 0.017\% = 0.004\%$.

[20] Dedola et al. (2013) study the dynamic consequences of a capital quality shock in the context of an open economy.

[21] The impulse-response functions are very similar if the policy combination includes reactions to the bank finance premium instead of bank credit growth. For the sake of clarity, I do not plot these impulse responses.

Figure 1: Adverse capital quality shock



Note: The green lines refer to the dynamics of the model's economy with two sector-specific policy instruments, whereas the blue lines refer to the baseline economy in the model with the Taylor rule. All of the interest rates, premia, bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. The horizontal axes display quarters after the shock.

levering-up of corporate and bank balance sheets, thereby deteriorating the financial conditions. This mechanism aggravates the bank incentive constraint and bond contracts in the following way: The reduction in bank asset values increases bank leverage, which in turn reduces the ability of banks to lend by tightening their capital constraints. Similarly, in the bond sector, firms lever up as a result of their lower net worth, which leads to a rise in their bond finance premium and a contraction in bond issuance. Furthermore, the capital depletion and higher capital prices lead to substitution in production inputs away from capital goods and towards labor. The higher demand for labor pushes up real wages and this exerts upward pressure on real marginal costs, resulting in an increase in inflation.

If the central bank conducts only conventional monetary policy in the form of the Taylor-type interest rate rule, this does not prevent a rise in the finance premia and a contraction in credit. The optimized Taylor rule subdues the effects of inflation on the economy, which results in an improvement in the welfare outcome relative to the simple Taylor rule. When the conventional monetary policy cannot eliminate disruptions in credit market segments, this is associated with higher welfare costs more so than with optimal policy combinations.[22]

[22] I calculate welfare costs and analyze the model dynamics for the scenarios without interest rate smoothing. I find that the main model variables behave in a similar manner in the smoothing and non-smoothing versions of the model.

The optimal policy mix suggests that the highest welfare outcome is achieved by combining countercyclical sectoral macroprudential policies with a monetary policy stance ($\alpha_\pi = 3$) that implies perfect inflation stabilization. An aggressive monetary policy stance helps to counteract inflationary pressures, whereas the sectoral macroprudential tools reduce the disruption of credit in each credit market segment. In the banking sector, when each policy tool addresses the relevant sector of the economy, the interests of monetary and macroprudential policies are aligned. Bank macroprudential policy helps ameliorate the tightness of the bank leverage constraint. This creates an additional buffer that restores trust in banks. On impact, the strong stabilization of bank credit and leverage induces the bank finance premium to substantially decline. As market conditions improve, the bank subsidy fades out. In the bond sector, the reserve requirement reduces the bond finance premium, which leads to a small improvement in bond issuance. The reason is that when mutual funds are compensated with the reduced bond premium they are not willing to accommodate more bond issuance.

The result on the effectiveness of the policy instrument that responds to bank credit growth echoes the finding of Verona et al. (2017) in the context of the segmented credit market. The authors focus on augmented Taylor rules and find that a monetary policy that reacts to credit growth is welfare maximizing. However, my work brings macroprudential dimensions into an analysis of the bank and bond sector by explicitly studying the design of macroprudential polices. My research also emphasizes a degree of substitutability among macroprudential policy targets.

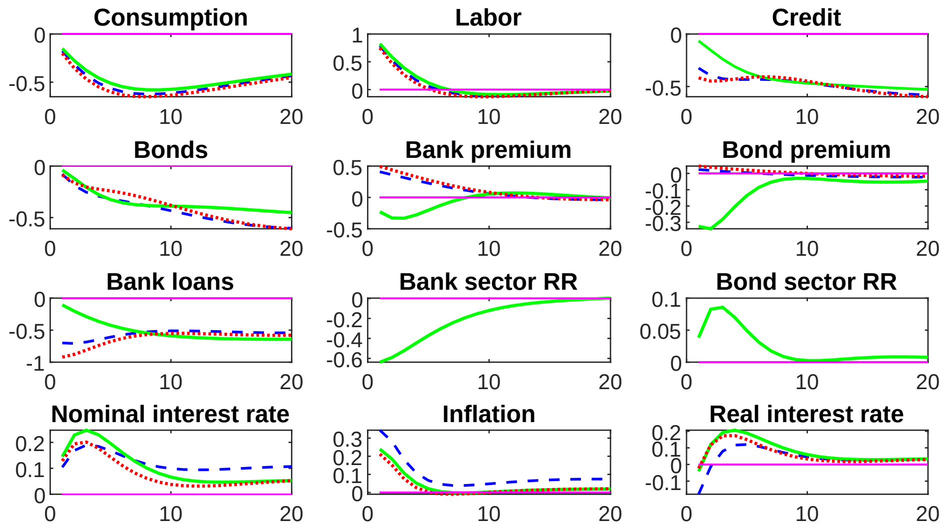
3.2.3 Impulse-response functions: Technology shocks

Figure 2 shows the dynamics of the main variables following a negative technology shock under the three policy rules. The nominal interest rate rises in response to an increase in inflation, which translates into a rise in the real interest rate. On the firm side, when facing low productivity, both sectors employ less capital in production (not reported), which induces a fall in the sectoral external financing and the total credit volume. The tightening of credit conditions together with the lower value of the net worth of banks and firms induces an increase in the respective leverage ratios and finance premia.

The qualitative behavior of the main variables is similar under the three policy regimes (as indicated by the comparable welfare costs in Table 2). The strong reaction to inflation deviations in the case of the optimized rules (i.e., $\alpha_\pi = 3$) increases the real interest rate relatively more, which in turn induces larger changes in consumption than under the simple Taylor rule. Additionally, the optimized Taylor rule reduces inflation variability but is also associated with larger deviations in the finance premia and the credit volume from their steady states than does the simple Taylor rule.[23]

[23]There is a substitution towards a cheaper form of capital, which is provided by the bond sector. Under the simple Taylor rule, bond premia become very low for mutual funds, so that mutual funds are less willing to

Figure 2: Adverse technology shock



Note: The green lines refer to the dynamics of the model whose economy consists of two sector-specific policy instruments; the blue lines refer to the baseline model with an economy with the optimized Taylor rule and the red lines are associated with the simple Taylor rule. All of the interest rates, premia, and bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. The horizontal axis displays quarters after the shock.

The results from the policy mix suggest the smooth development of credit, where most of the benefits are achieved in the short term. By responding to credit growth, policies attenuate financial frictions and contribute to restoring lending relationships. Each sectoral macroprudential policy manages to temper a rise in the finance premia in the presence of a strong anti-inflationary monetary stance, offsetting the effects of a monetary policy that tightens the finance premia. This leads to positive welfare gains associated with the policy mix (e.g., 0.001% of steady-state consumption), resulting in a smoother profile of consumption and labor, as documented in Figure 2. Notably, the presence of bank macroprudential policy acts *as if* a strong bank subsidy effectively reduces the financial friction (by eliminating the risks of household deposit depletion).

In my model framework, monetary and macroprudential policy interests do not conflict following technology shocks.[24] This is because the strong anti-inflationary stance is optimal not only under the optimized Taylor rule but also under the optimal policy mix. Interestingly, the

provide bond financing compared to the case with the optimized Taylor rule (associated with a positive absolute deviation of bond premia from their steady state). This explains the differences in bond finance between two model economies that use only the monetary policy rule.

[24]An opposite mechanism can be found if the targets in the macroprudential rules are based on the nominal variables in the context of the model with the optimal debt contract á la Bernanke et al. (1999). For example, Bailliu et al. (2015) show that the macroprudential policy that aims to stabilize nominal credit growth counteracts the effects of the monetary policy.

optimal choice of targets in the simple macroprudential rules is associated with positive welfare gains. Households benefit from living in the stochastic economy with the optimal policy mix because simple macroprudential rules can eliminate their need for additional precautionary savings.

3.3 Sectoral financial shocks

3.3.1 Welfare analysis

In this section I look at the scenarios that are generated under the assumption of sector-specific financial shocks; i.e., only one credit market is affected by a capital quality shock. Table 3 presents the policy coefficients that are associated with the optimized and non-optimized policies. I assume that the central bank chooses an optimal policy combination according to equations (34) and (35), knowing exactly which credit market segment is affected by the shock. Non-optimized policies refer to policy mixes that are not optimal from the point of view of an economy that is only hit by the considered sectoral shock. Relative gain (1) denotes the welfare gains of a specific policy over the simple Taylor rule, whereas relative gain (2) denotes the welfare gains of a policy relative to the policy mix chosen by a policy maker who is acting upon the assumption that the capital quality shocks have hit both sectors.

In the case of banking sector shocks, it is desirable to react moderately to the bank macroprudential rule ($\nu_S = 3$) by affecting bank credit and to respond strongly to the bond finance premium ($\nu_B = 1$) in order to neutralize the adverse effects of these shocks. The simple Taylor rule is associated with a positive welfare outcome, whereas the policy mix that is conditional on the shock originating in both sectors results in a welfare outcome that is comparable to the optimal policy mix. The welfare results suggest that the size of the inflation coefficient and the bond policy coefficient play a minor role (c.f., the relative gain of the optimal policy mix over the non-optimized policies is 0.003% of the steady-state household consumption. Similarly, this result implies that the variation of the bond policy tool with the bond finance premium or the bond volume plays a minor role in the welfare outcome.[25]

How large are the mistakes if the central bank does not respond to the credit market conditions and conducts conventional monetary policy in the presence of banking sector shocks? Surprisingly, the model suggests that households gain from living in the stochastic economy under the simple Taylor rule (e.g., the welfare gain is equivalent to 0.102%). Capital quality shocks to the banking sector create inflationary pressures, which prompts the policy maker to stabilize inflation. The moderate reaction to inflation stabilization seems to adjust the real interest rate effectively in order to achieve a smooth path of consumption. The economy undergoes a process of change in the corporate debt composition towards corporate bonds in the credit market (see Zivanovic, 2019), which could be suppressed if the central bank reacts more aggressively to in-

[25] In the appendix, Table 4 reports the welfare results associated with the considered policy mixes. Strikingly, there are minor differences among the policies. The policy combinations where the bank macroprudential tool reacts to asset prices yield lower welfare compared to the respective alternatives.

flation. It should be noted that the relative gain is even higher when the economy is exposed to policy regimes that involve a combination of monetary and macroprudential policies (e.g., 0.143% of the steady-state consumption in the case of the optimal policy mix). The economic rationale for the result is the following: Households anticipate that the introduction of any policy reaction will ensure more resources with which to absorb the effects of these shocks. In particular, the presence of the bank macroprudential policy tool insures households against the risks associated with a fall in asset prices and a depletion of deposits and, thereby, eliminates their need for precautionary savings. The additional amounts of capital and deposits in these scenarios reduce the risk perceptions, yielding an increase in the mean consumption in the second-order stochastic steady state (which is established using the non-linear moving average toolkit developed by Lan and Meyer-Gohde, 2013). Overall, the additional support to the economy through the policy action induces households to prefer living in this stochastic economy over the steady-state alternative.

To what extent is it welfare improving to use the optimal policy combination conditional on banking sector shocks? The relative gain of the optimal policy mix over the policy mix chosen for the case of shocks occurring in both sectors is small and yields 0.003% of steady-state household consumption. Similarly, the welfare benefits of targeting a welfare-superior financial indicator in the simple macroprudential rules are negligible (c.f., relative gains in Table 4). The reason for the comparable welfare performance of the different optimized policy mixes is that the use of the bank macroprudential policy appears to offset the presence of financial frictions and alleviate the adverse effects of shocks. Irrespective of the financial indicators, the presence of the bank macroprudential rule is effective in restoring trust in banks and in reducing the need for household precautionary savings, which results in comparable welfare gains.

Now, I will turn to a discussion of bond sector shocks. The optimal policy response implies that the central bank pursues strict inflation stabilization ($\alpha_\pi = 3$) and reacts strongly to imbalances in the bond sector ($\nu_B = 1$) with (out) using the bank macroprudential tool.[26] Strict inflation stabilization aims to neutralize inflationary pressures, whereas the aggressive policy reaction to bond imbalances attempts to address the most disrupted credit market segment and eliminate the distortions caused by the financial frictions in this sector. The lack of (or limited) policy reaction to the banking sector is present for the following reasons: The unaffected banking sector features an increase in bank loans. This has a stabilizing effect on the economy in that it contributes to the reduced welfare cost. Hence, it is counterproductive to induce a decelerating process in bank lending activity via the macroprudential tool.

In the following, I assess the welfare implications of policy rules that are conditional on bond sector shocks. Are a central bank's mistakes large if it does not react to credit market conditions? The model predicts that the welfare benefits are non-negligible if the simple macro-

[26]In the appendix, Table 5 reports the welfare results that are associated with all of the considered policy mixes. Strikingly, there are no differences among the optimal policies conditional on shocks affecting the bond sector and both credit market segments. The policy combinations where the bond macroprudential tool reacts to changes in the bond volume yield the highest welfare irrespective of the bank policy tool.

prudential rules constitute a part of the optimal policy. For example, the relative gain of the optimal policy over the simple Taylor rule is 0.246% of steady-state consumption.

How important is it that the policy maker chooses a welfare-superior policy combination? Similar to banking sector shocks, different combinations of targets in the macroprudential rules can attain the same welfare. The results indicate that the bond macroprudential tool that varies with bond volumes (irrespectively of the bank policy instrument) outperforms the alternative policies that react to the bond finance premium or bond sector asset prices (cf., Table 5). Additionally, the model predicts that the welfare outcome under the optimal policy combination is equivalent to the one under the policies where the policy maker acts on the assumption that shocks originate in both sectors. This can be explained by the same reaction to changes in the bond volume and the same strength of this reaction. The use of the bank policy tool is not detrimental to the welfare outcomes. To gain a better understanding of the effects of the different policies, I will now turn to an analysis of impulse-response functions.

3.3.2 Impulse-response analysis

Shocks to the banking sector: Figure 3 presents the responses to an adverse shock to the capital quality in the banking sector that causes a loss of bank asset value and a disruption in bank lending. I focus on the model dynamics under the simple Taylor rule, the optimal policy mix (based on changes to bank credit and the bond finance premium) and the central bank's optimal policy combination when it assumes that the financial shocks originate in both sectors.

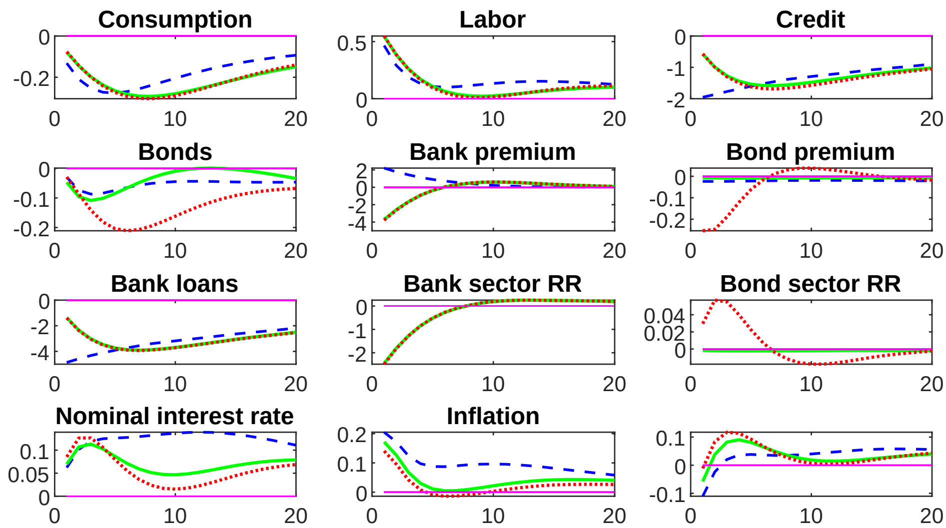
As the propagation of the capital quality shocks in the banking sector resembles the dynamics of the economy, following shocks to both sectors (in terms of large disruptions in bank lending and a substantial rise in the bank premia), the optimized policy in the economy affected by the latter shocks also performs well in the economy with banking sector shocks. These policy combinations are successful in restoring trust in banks by subsidizing their net worth and reducing bank leverage. The presence of the bank macroprudential policy manages to moderate the negative effects of the shocks by reducing any increase in the bank finance premia and relaxing the capital constraints on banks. Bank-dependent firms benefit substantially from policy actions that foster bank lending. Notably, both policy mixes provide a strong impulse to the economy, resulting in improved and smoother labor and consumption paths. The developments in the unaffected bond sector play a minor role. As a result of the tightening of the bond macroprudential tool, the low bond finance premia make mutual funds less willing to underwrite bond contracts, resulting in a decline in bond issuance. This effect is pronounced in the economy with the non-optimized policy mix; however, its contribution to credit stabilization is almost negligible.

Table 3: Optimal policy rules following sectoral shocks

	α_π	ν_S	ν_B	Welfare cost	Relative gain (1)	Relative gain (2)
Bank sector shocks only						
Optimal policy						
Policy mix	2.005	3	1	0.143	0.041	0.003
Non-optimized policy						
Simple Taylor rule	1.5	-	-	0.102	-	-0.038
Policy conditional on financial shocks to both sectors	3	3	1	0.140	0.038	-
Bond sector shocks only						
Optimal policy						
Policy mix	3	0	1	0.420	0.246	0
Non-optimized policy						
Simple Taylor rule	1.5	-	-	0.174	-	-0.246
Policy conditional financial shocks to both sectors	3	3	1	0.420	0.246	-

Notes: The optimal policy mix refers to the policy combination that is welfare maximizing in economies with respective sectoral shocks. Non-optimized policies include the simple Taylor rule and the policy mixes that the central bank would choose when incorrectly assuming the type of shock: economy-wide financial shocks or shocks originating from the non-affected sector. The welfare costs are calculated in the same way as in Table 2. Relative gain (1) is calculated as the gain of a specific policy relative to the simple Taylor rule; i.e., the difference in the welfare costs of the specific policy relative to the simple Taylor rule. Relative gain (2) is calculated as the gain from a specific policy relative to the policy mix, which is the optimal combination of the interest rate rule and the macroprudential policy instruments in the economy hit by economy-wide financial shocks.

Figure 3: Adverse banking sector specific shock

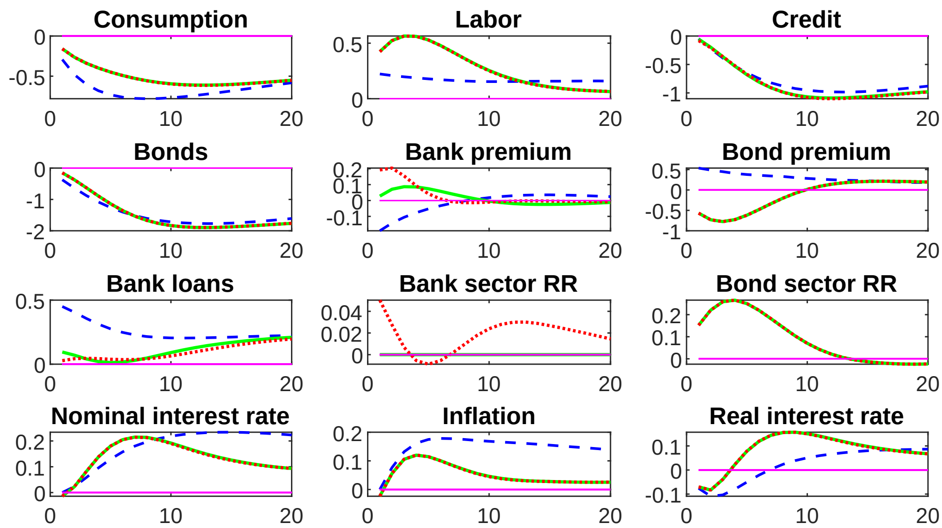


Note: The blue dashed lines refer to the dynamics of the model whose economy uses the simple Taylor rule. The green lines represent the dynamics under the optimal policy mix. The red dotted lines refer to the model dynamics where the policy maker uses a policy mix that is welfare-maximizing in an economy hit by economy-wide financial shocks. All of the interest rates, premia, and bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. The horizontal axes display quarters after the shock.

Shocks to the bond sector: A contractionary capital quality shock in the bond sector, which raises the bond finance premia and reduces the amount of corporate bonds as well as total credit, is depicted in Figure 4. The banking sector is not affected, but there is a substitution towards the capital of bank-dependent firms and bank finance. As a consequence, this sector features an investment boom whereby enhanced capital demand drives up capital prices for bank-dependent firms, thereby reducing bank premia. Even though the banking market manages to partly absorb the negative effects of shocks to the bond sector, it cannot effectively offset the disruption to the bond sector. This is because a large portion of firms relies only on bond finance; the financing and investment prospects of these firms remain dismal in the aftermath of the shock. This causes a decline in aggregate investment and real activity.

Table 3 shows that there is no difference between the two considered policy mixes as they result in the same relative gain over the simple Taylor rule of 0.246% of steady-state consumption. The optimal use of macroprudential policies leads to smoother consumption and labor responses than in the absence of these policies. The policy mix falls short of achieving credit market stabilization. Even though the bond policy instrument is exercised to the fullest extent, $\nu_B = 1$, the resulting depression of the bond premia is quantitatively small; i.e., a reduction in the bond premium by half a percentage point (on an annual basis). This exerts small effects

Figure 4: Adverse bond sector shock



Note: The blue dashed lines refer to the dynamics of the model economy with the simple Taylor rule. The green lines represent the dynamics under the optimal policy mix. The red dotted lines refer to the model dynamics where the policy maker uses a policy mix that is welfare maximizing in the economy hit by economy-wide financial shocks. All of the interest rates, premia, and bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. The horizontal axes display quarters after the shock.

on the prices of the investment goods of firms with access to bond finance (not shown). As a consequence, bond volumes change little and additional investment expenditures are negligible. The unaffected banking sector accommodates some of the effects of these shocks, whereas perfect inflation targeting stabilizes inflation. These findings show that when the considered macroprudential rules target a only a small subset of financial conditions, they can only dampen the response of the economy but they cannot eliminate the effects of sectoral shocks.

4 Conclusion

This paper analyzes the extent to which the design of simple macroprudential rules is important for welfare outcomes. In the context of a medium-scale financial DSGE model with a banking and a bond market segment, this study evaluates which measures of financial conditions should be included in sector-specific macroprudential policy rules that aim to achieve macroeconomic stabilization.

In the model with segmented credit markets, I find that macroprudential policies that react to changes in bank and bond credit lead to the highest welfare outcomes following technology and financial shocks. Credit measures are effective targets in policy rules for the banking and bond sectors since policies moderate build-ups of financial imbalances following adverse shocks by relaxing leverage constraints. The results also show that an aggressive monetary policy stance should be combined with macroprudential policies that aim to mitigate the inflationary effects of shocks.

In the context of shocks that affect only the banking sector or the bond sector, the welfare losses are small if the policy response is optimally chosen as if the economy were buffeted by shocks to both sectors. Similarly, different policy mixes yield the highest welfare, indicating that there is a high degree of substitutability among the financial indicators that can be used to alleviate sectoral disruptions.

It should be stressed that I assume that the central bank has the authority to implement all policy instruments. In cases where there are separate monetary and macroprudential authorities, one would need to consider the (non-)coordination of the two authorities.[27] Using a richer credit market framework, it would be interesting to see whether the interests of these authorities were conflicting in the presence of either aggregate or sectoral shocks.

[27]See, c.f., Gelain and Ilbas (2017); Carrillo et al. (2017).

References

Bailliu, J., Meh, C., and Zhang, Y. (2015). Macroprudential rules and monetary policy when financial frictions matter. *Economic Modelling*, 50:148 – 161.

Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of Monetary Economics*, 1(C):1341 – 1393. Edited by John B. Taylor and Michael Woodford.

Brzoza-Brzezina, M., Kolasa, M., and Makarski, K. (2015). Macroprudential policy and imbalances in the euro area. *Journal of International Money and Finance*, 51(C):137–154.

Cantillo, M. and Wright, J. (2000). How do firms choose their lenders? An empirical investigation. *Review of Financial Studies*, 13(1):155–189.

Carrillo, J. A., Mendoza, E. G., Nuguer, V., and Roldán-Peña, J. (2017). Tight money-tight credit: Coordination failure in the conduct of monetary and financial policies. Working Paper 23151, National Bureau of Economic Research.

Cerutti, E., Claessens, S., and Laeven, L. (2017). The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability*, 28(Supplement C):203 – 224.

Christiano, L. J., Motto, R., and Rostagno, M. (2014). Risk shocks. *American Economic Review*, 104(1):27–65.

Colla, P., Ippolito, F., and Li, K. (2013). Debt specialization. *Journal of Finance*, 68(5):2117–2141.

Cooley, T. and Prescott, E. (1995). *Economic growth and business cycles*. Princeton University Press, pp.138.(Chapter1).

Dedola, L., Karadi, P., and Lombardo, G. (2013). Global implications of national unconventional policies. *Journal of Monetary Economics*, 60(1):66 – 85.

DeFiore, F. and Uhlig, H. (2011). Bank finance versus bond finance. *Journal of Money, Credit and Banking*, 43(7):1399–1421.

Denis, D. J. and Mihov, V. (2003). The choice among bank debt, non-bank private debt, and public debt: evidence from new corporate borrowings. *Journal of Financial Economics*, 70(1):3–28.

Faia, E. and Monacelli, T. (2007). Optimal interest rate rules, asset prices, and credit frictions. *Journal of Economic Dynamics and Control*, 31(10):3228–3254.

Gelain, P. and Ilbas, P. (2017). Monetary and macroprudential policies in an estimated model with financial intermediation. *Journal of Economic Dynamics and Control*, 78(C):164–189.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17–34.

Gilchrist, S. and Zakrajšek, E. (2012). Credit spreads and business cycle fluctuations. *American Economic Review*, 102(4):1692–1720.

Kannan, P., Rabanal, P., and M., S. A. (2012). Monetary and macroprudential policy rules in a model with house price booms. *The B.E. Journal of Macroeconomics*, 12(1):1–44.

Lan, H. and Meyer-Gohde, A. (2013). Solving DSGE models with a nonlinear moving average. *Journal of Economic Dynamics and Control*, 37(12):2643–2667.

Leduc, S. and Natal, J.-M. (2017). Monetary and macroprudential policies in a leveraged economy. *The Economic Journal*, 49(2-3):1–30.

Lucas, R. E. (1987). *Models of business cycles: By Robert E. Lucas*. Basil Blackwell Oxford.

Lucas, R. E. (2003). Macroeconomic Priorities. *American Economic Review*, 93(1):1–14.

Quint, D. and Rabanal, P. (2014). Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. *International Journal of Central Banking*, 10(2):169–236.

Rubio, M. and Carrasco-Gallego, J. A. (2014). Macroprudential and monetary policies: Implications for financial stability and welfare. *Journal of Banking & Finance*, 49:326 – 336.

Schmitt-Grohé, S. and Uribe, M. (2007). Optimal simple and implementable monetary and fiscal rules. *Journal of Monetary Economics*, 54(6):1702 – 1725.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, 39:195 – 214.

Verona, F., Martins, M. M., and Drumond, I. (2017). Financial shocks, financial stability, and optimal Taylor rules. *Journal of Macroeconomics*, 54(Part B):187–207.

Verona, F., Martins, M. M. F., and Drumond, I. (2013). (Un)anticipated monetary policy in a DSGE model with a shadow banking system. *International Journal of Central Banking*, 9:73–118.

Wahal, S. and Wang, A. Y. (2011). Competition among mutual funds. *Journal of Financial Economics*, 99(1):40 – 59.

Woodford, M. (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press.

Zivanovic, J. (2019). Corporate debt composition and business cycles. *Bank of Canada Staff Working Paper 2019-5*. Manuscript.

Appendix

Welfare

The welfare measure is given by the lifetime household utility:

$$\text{Welfare} = \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{36}$$

with the period utility $U(C_t, L_t) \equiv \left(\ln(C_t - hC_{t-1}) - \frac{\psi_L}{1+\phi_L} L_t^{1+\phi_L}\right)$. To compute the unconditional welfare measure, I take the unconditional expectation of lifetime utility:

$$\begin{aligned} E[\text{Welfare}] &= E \sum_{t=0}^{\infty} \beta^t U((1+g)\bar{C}, \bar{L}) \\ &= \frac{1}{1-\beta} \left(\ln((1+g)(1-h)\bar{C}) - \frac{\psi_L}{1+\phi_L} \bar{L}^{1+\phi_L} \right) \end{aligned}$$

where g denotes a fraction of the steady-state consumption that makes the agents in the non-stochastic economy as well off as in the stochastic economy. The term $\frac{g \cdot 100}{C}$ represents the welfare costs reported in Tables 2 and 3. I solve for g by equating the unconditional welfare in both the deterministic steady state and the stochastic environment, as specified in equation 36 . The latter welfare measure is computed via the second order approximation of the model. A negative value of g indicates that households are willing to give up a certain fraction of permanent consumption in order to remain in the non-stochastic steady state relative to the stochastic equilibrium under a certain policy regime. Or equivalently, the negative welfare cost represents the percentage decrease in the steady-state consumption necessary to make households indifferent between the deterministic and stochastic environment.

Optimal policy rules and sectoral shocks

Tables 4 and 5 present the policy coefficients under three different policy regimes in the economies hit by sectoral shocks. There are only minor differences across different compared optimal policies. As long as the policy maker's reaction to the financial indicators is optimally chosen, the policy mix yields improvements in welfare. Three results are worth emphasizing: First, the results suggest that there is some interaction between policies: Following banking sector shocks, simple macroprudential rules require a stronger anti-inflationary monetary policy than the optimized Taylor rule. Following bond sector shocks, it is optimal to pursue strict inflation targeting together with loosening macroprudential policies. Second, different combinations of simple macroprudential rules yield the same welfare, whereby the policy mix often lacks any reaction from the undisrupted sector. Therefore, the model suggests that there is a high degree of substitutability among the policies if the economy is buffeted by sectoral shocks. Third, the type of sectoral shock matters for welfare outcomes. Welfare gains are larger conditional on bond sector shocks rather than banking sector shocks as the policy mix reduces the propagation of sectoral shocks by effectively mitigating the underlying financial distortion in the presence of the former shocks.

Table 4: Optimal policy rules and different financial indicators

	α_π	ν_S	ν_B	Welfare cost	Relative gain
Bank sector shocks only					
Simple Taylor rule	1.5	-	-	0.102	-
Optimized Taylor rule	1.607	-	-	0.102	0
Bank credit+ bond volume	2.005	3	0	0.143	0.041
Bank credit+ bond finance premium	2.005	3	1	0.144	0.042
Bank credit+ bond sector asset prices	2.005	3	0.3	0.143	0.041
Bank finance premium+ bond volume	2.005	10	0.1	0.141	0.039
Bank finance premium+ bond finance premium	2.005	10	1	0.143	0.041
Bank finance premium+ bond sector asset prices	2.005	10	0	0.141	0.039
Bank asset prices + bond volume	2.204	10	0.1	0.118	0.016
Bank asset prices + bond finance premium	2.005	10	1	0.120	0.018
Bank asset prices + bond sector asset prices	2.204	10	0.7	0.119	0.017
Bank credit+bond volume*	3	3	1	0.140	0.038

Notes: In the optimized Taylor rules, the policy parameters α_π are restricted to being within the intervals $[1.01, 3]$, respectively. For non-standard policy rules, I restricted policy parameters ν_S and ν_B to the interval $[0, 10]$ and $[0, 1]$, respectively. All Taylor-type policy rules feature interest rate smoothing with $\rho_r = 0.8$. The welfare cost, $g \cdot 100$, is expressed in terms of the steady-state consumption. A negative value for welfare costs indicates that households are willing to give up a certain fraction of their steady-state consumption in order to remain in the deterministic economy relative to the stochastic environment under a certain policy regime. The relative gain is calculated as the gain of a specific policy relative to the simple Taylor rule. The policy mix that is optimal in the case of economy-wide shocks is denoted with *.

Table 5: Optimal policy rules and different financial indicators

Bond sector shocks only					
Simple Taylor rule	1.5	-	-	0.174	-
Optimized Taylor rule	3	-	-	0.181	0.007
Bank credit+ bond volume	3	0	1	0.420	0.246
Bank credit+ bond finance premium	3	0	1	0.355	0.181
Bank credit+ bond sector asset prices	3	7	0.2	0.189	0.015
Bank finance premium+ bond volume	3	3	1	0.420	0.246
Bank finance premium+ bond finance premium	3	1	1	0.355	0.181
Bank finance premium+ bond sector asset prices	3	1	0.2	0.189	0.015
Bank asset prices + bond volume	3	1	1	0.420	0.246
Bank asset prices + bond finance premium	3	0	1	0.355	0.181
Bank asset prices + bond sector asset prices	3	1	0.2	0.189	0.015
Bank credit+ bond volume*	3	3	1	0.419	0.245

Notes: In the optimized Taylor rules, the policy parameters α_π are restricted to being within the interval $[1.01, 3]$. For non-standard policy rules, I restricted policy parameters ν_S and ν_B to the intervals $[0, 10]$ and $[0, 1]$, respectively. All Taylor-type policy rules feature interest rate smoothing with $\rho_r = 0.8$. The welfare cost, $g \cdot 100$, is expressed in terms of the steady-state consumption. A negative value for welfare costs indicates that households are willing to give up a certain fraction of their steady-state consumption in order to remain in the deterministic economy relative to the stochastic environment under a certain policy regime. The relative gain is calculated as the gain of a specific policy relative to the simple Taylor rule. The policy mix that is optimal in the case of economy-wide shocks is denoted with *.