An optimal policy mix for segmented credit markets

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Abstract

This paper analyzes welfare-improving central bank’s policy rules within the context of a medium-scale DSGE model with a banking and a bond credit market in the presence of economy-wide and sectoral shocks. A combination of a Taylor policy rule, an unconventional bank credit policy and a bond-sector macroprudential tool stabilizes the macroeconomy and attains the highest level of welfare in the economy where both credit markets are affected by financial shocks. The main reason is that non-standard policies are effective at dampening the financial cycle, improving credit conditions and, even providing an additional stimulus to the economy. The welfare gains dissipate if shocks do not originate in the financial sector. If the central bank cannot correctly identify a sector-specific financial shock, and follows the policy mix conditional on economy-wide financial shocks, the level of welfare is comparable to the one under the optimal policy. However, welfare gains of optimized policies over the simple Taylor rule depends on the source of sectoral shock.

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1 Introduction

The conduct of central banks’ monetary policy has changed substantially in the aftermath of the financial crisis starting in 2008. Central banks all around the world implemented different unconventional monetary policy measures[1] to tackle disruptions in the financial sector. To address possible future risks emanating from the financial system, central banks have established macroprudential frameworks[2] to maintain and pursue financial stability. Both sets of these measures imply that central banks extended their spectrum of policy tools. What is the optimal choice of the central bank’s policy instruments to help the economy’s response to aggregate fluctuations?

In a seminal paper by Cúrdia and Woodford (2011), the authors conclude that the use of unconventional policy instruments should be tailored to conditions specific to disrupted financial markets. Motivated by the importance of influencing conditions in financial market segments with the appropriate policy, I analyze an interaction between interest rate policy and two different credit policy instruments in a financial DSGE model. The financial sector consists of a bond market, where mutual funds make bond financing available to large firms, and a banking market, where banks supply loans to small firms[3].

This analysis of the central bank’s optimal policy setup tries to merge two strands of literature: the rich literature on optimal monetary and credit policy instruments, and the emerging literature on macroprudential frameworks[4]. In my theoretical model, two credit policy instruments are designed to respond to credit imbalances in the respective credit market segment. They are specified as follows: The unconventional bank policy instrument is inversely related to bank lending activities and, therefore, represents a form of state intervention in the banking sector, similar to the modeling of the policy in Gertler and Karadi (2011). The central bank can support private credit flows to small firms, but the public intermediation is less efficient than bank intermediation. The bond policy instrument, modeled along the lines of Kannan et al. (2012), is a countercyclical macroprudential tool that affects directly funding costs of large firms and dampens credit fluctuations in the bond sector. The standard monetary policy instrument is a Taylor-type policy rule[5] for the nominal interest rate. The sources of business cycles are

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1 See, c.f., the review of unconventional measures by Borio and Zabai (2016). All major central banks, e.g., Federal Reserve, European Central Bank, Bank of Japan adjusted their balance sheets in order to influence financial conditions. One dimension of these balance sheet policies is credit policy - operations that target private debt, banks and securities markets.

2 Macroprudential policies are aimed at closely monitoring developments in financial markets and promptly reacting to possible financial imbalances in the form of asset price bubbles or excessive credit buildups. For example, the Bank of England, unlike the Federal Reserve, in the US, has the authority to conduct macroprudential policy (c.f., Gelain and Ilbas 2017).

3 The model setup is developed in the third chapter. The reliance of large firms on the bond market and small firms on banks is meant to capture the empirical finding by Colla et al. (2013) on the debt specialization of large and small US firms.

4 In the context of DSGE models with one financial (credit) market, see the analysis of optimal credit policy in Cúrdia and Woodford (2011), Gertler and Karadi (2011) and Gertler et al. (2012) among others; for welfare implications of macroprudential policies, see Gelain and Ilbas (2017) and Bailliu et al. (2015). Note that there are numerous studies addressing the interaction of these policies in the context of housing market (e.g., Kannan et al. 2012; Quint and Rabanal 2014) or open economy (e.g., Dedola et al. 2013; Brzoza-Brzezina et al. 2015).

5 These rules have a good empirical fit (see Taylor 1993).
technology shocks and financial shocks. I differentiate between economy-wide and sectoral financial shocks. Bank sector shocks emanate from a (dis)trust in banks, whereas bond sector shocks change auditing costs by mutual funds. The economy-wide financial shock is a combination of both sectoral shocks. I perform a welfare comparison of the simple Taylor rule, the optimized Taylor rule and the policy mix of credit policy and interest rate policy instruments.

My model featuring a segmented financial market can replicate the results from the previous literature on non-standard policy measures in the context of one single financial market (see, e.g., Cúrdia and Woodford [2010] Bailliu et al. [2015] Gertler and Karadi [2011] Cúrdia and Woodford [2011]). The key results on economy-wide shocks can be summarized as follows: First, the highest welfare gain of the combined credit and interest rate policies over the simple (optimal) Taylor rule is achieved if the economy is affected by economy-wide financial shocks. By addressing a particular credit market segment, these non-standard policies are effective at dampening the financial cycle, improving credit conditions and even providing an additional stimulus to the economy. Second, if the policy maker does not implement the mix of all three policy instruments, my model predicts that welfare losses are limited in the presence of technology shocks. The reason is that non-financial shocks do not cause substantial disruptions in respective credit market segments, so that there are no large benefits from the non-standard policies. Third, of the three policy designs that are being compared, my optimized policy mix achieves an outcome closest to the Ramsey optimal policy.

I make several contributions to the literature in the context of sectoral financial shocks. First, if the policy marker wrongly identifies a sector-specific financial disturbance, acting upon economy-wide financial shocks attains virtually the same level of welfare as the optimal policy mix. The intuition for this result is the following: The propagation of bank sector shocks resembles the model economy dynamics following economy-wide shocks (in terms of large disruptions in bank lending and a substantial rise in bank premia) and, therefore, the optimized policy in the economy affected by the latter shocks performs well also in the economy with bank sector shocks. In the presence of bond sector shocks both optimal and non-optimal policies cannot accommodate the effects of these shocks, yielding comparable welfare results. Second, I find that the source of sectoral financial disturbance matters. In the context of my model, high welfare losses arise irrespectively of the policy setting if the economy is affected by shocks originating in the bond sector. In particular, the optimal combination of unconventional policy tools does not compress a rise in bond premia, and therefore, does not offset disruptions in the bond market.

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

The starting point is the model developed in chapter three. I consider two credit market sectors, a banking sector and a bond sector. Small firms rely on bank finance, whereas large firms issue
bonds to match the notion of 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, banks can supply only as much credit to small firms as allowed by their leverage constraint. Mutual funds represent a veil, as in Bernanke et al. [1999]. The terms of the optimal bond contract specify the amounts of bonds as well as bond finance premia.

The model economy is populated by the following agents: households, corporate finance firms, intermediate firms, final goods firms, capital goods producers, lending banks and mutual funds. Households consume, supply labor and save via depositing resources with financial intermediaries. Two types of corporate finance firms make financing decisions regarding bank loans and corporate bonds, respectively, in order to finance their investments in physical capital. Intermediate goods sector is monopolistically competitive. These firms combine the physical capital from two sectors with labor to produce differentiated products and set prices. Capital goods firms make investment decisions. Final goods producers combine all the intermediate goods and make it available to households and capital producers in form of consumption and investment goods. The central bank conducts monetary policy by following a Taylor policy rule. The central bank has at its disposal two sector-specific policy instruments to stabilize financial imbalances in the respective credit market. The bank policy instrument is inversely related to the bank lending activity and represents a form of state intervention in the banking sector. The bond policy instrument is a countercyclical tool that affects credit fluctuations in the bond sector. Since the details of the model have been discussed in the third chapter, I present the equilibrium conditions and definitions of respective economic relationships. I also include the changes in relevant equilibrium conditions as a result of bank credit policy or bond macroprudential tool.

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

\[ \lambda_t = E_t \{ \beta R_t \lambda_{t+1} \}, \]

\[ w_t = \psi_L L_t^{\phi_L}, \]

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, \( L_t \) labor hours, \( w_t \) 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 conditional on 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 on the disutility of labor and the inverse of the labor supply elasticity.

Total capital is the composite of two bundles of sectoral capital, i.e., capital of individual
small and large corporate finance firms, $K^S_t$ and $K^B_t$, respectively, and it is given by:

$$K_t = [\eta(K^S_t)^\rho + (1 - \eta)(K^B_t)^\rho]^{\frac{1}{\rho}},$$

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

$$K^j_t = \left\{ (1 - \delta) K^j_{t-1} + \left( 1 - f \left( \frac{I^j_t}{I^j_{t-1}} \right) \right) I^j_t \right\},$$

with $I^j_t, K^j_t$ denoting investment and capital of type $j$, with $j \in (S,B)$. Note that $f \left( \frac{I^j_t}{I^j_{t-1}} \right) = \xi^j \left( \frac{I^j_t}{I^j_{t-1}} - 1 \right)^2$. Parameter $\xi^j > 0$ and $0 < \delta < 1$ measure the degree of curvature of investment adjustment cost and the depreciation rate, respectively. The equilibrium condition for optimal investment of type $j$ reads:

$$Q^j_t = \frac{1 - \beta E_t \left\{ \Lambda^j_{t+1} \left( \frac{I^j_{t+1}}{I^j_t} \right) \right\}}{1 - f \left( \frac{I^j_t}{I^j_{t-1}} \right) - f' \left( \frac{I^j_t}{I^j_{t-1}} \right) \left( \frac{I^j_t}{I^j_{t-1}} \right)^2},$$

with $A_{t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}$ denoting the real stochastic discount factor and $Q^j_t$ the real price of capital of type $j$.

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

$$R^j_{k,t+1} = \frac{r^j_{k,t+1} + (1 - \delta)Q^j_{t+1}}{Q^j_t},$$

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

$$r^j_{k,t} = \left[ \alpha A_t s_t \left( \frac{L_t}{K_t} \right)^{1-\alpha} \left( K^j_t \right)^{\rho-1} K^j_{t-1} \right]^{\frac{1}{\rho}},$$

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

$$K^j_t = \left[ \eta^{1-\rho}(K^S_t)^\rho + (1 - \eta)^{1-\rho}(K^B_t)^\rho \right]^{\frac{1}{\rho}}.$$
capital and labor hours result in:

\[
\frac{r_{t}^{k,B}}{r_{t}^{k,S}} = \left( \frac{K_{t}^{B}}{K_{t}^{S}} \right)^{\rho-1}, \tag{8}
\]

\[
w_{t} = s_{t} \frac{Y_{m}^{n}}{L_{t}}, \tag{9}
\]

The intermediate goods production is determined by:

\[
Y_{m}^{n} = A_{t}(K_{t})^{\alpha}L_{t}^{1-\alpha}, \tag{10}
\]

where \(A_{t}\) represents aggregate technology.

Equilibrium conditions associated with the optimal choice of price give rise to the New Keynesian Phillips curve with price indexation, expressed in the recursive form using equations:

\[
\Pi_{t}^{*} = \frac{\epsilon}{\epsilon - 1} Z_{t}^{m}\Pi_{t}, \tag{11}
\]

where \(F_{t}^{m}\) and \(Z_{t}^{m}\) are defined as

\[
F_{t}^{m} \equiv Y_{m}^{n}s_{t} + \beta \theta E_{t}A_{t,t+1}\Pi_{t+1}^{\epsilon-1}F_{t+1}^{m} \text{ and } Z_{t}^{m} \equiv Y_{m}^{n} + \beta \theta E_{t}A_{t,t+1}\Pi_{t+1}^{\epsilon-1}Z_{t+1}^{m}. \tag{12}
\]

The parameter \(0 \leq \epsilon \leq 1\) measures the degree of price indexation.

Parameters \(0 < \theta < 1, \epsilon > 0\) denote, respectively, the probability that an intermediate firm cannot adjust its price and the elasticity of substitution between different intermediate goods.

Aggregate output, \(Y_{t}\), is related to the aggregate intermediate output, \(Y_{m}^{n}\), in the following way:

\[
Y_{m}^{n} = Y_{t}\Delta_{t}, \tag{13}
\]

where \(\Delta_{t}\) measures the price dispersion, which is given by:

\[
\Delta_{t} = \theta \Delta_{t-1}\Pi_{t}^{(\epsilon-1)} + (1 - \theta)^{1-\epsilon} \left( 1 - \theta \Pi_{t-1}^{(\epsilon-1)} \Pi_{t}^{\epsilon-1} \right)^{\frac{1}{\epsilon - 1}}. \tag{14}
\]

Following Gertler and Karadi (2011), the equilibrium conditions associated with the banking sector specify the marginal gain from expanding bank assets, \(\nu_{t}\), the marginal gain of an additional unit of net worth, \(\eta_{t}^{S}\), the growth rate of bank net worth, \(z_{t,t+1}\), and the growth rate of bank capital, \(\chi_{t,t+1}\):

\[
\nu_{t} = E_{t} \left\{ (1 - \gamma^{S})\beta \Lambda_{t,t+1}(R_{k,t+1}^{S} - R_{t}) + \beta \Lambda_{t,t+1}\gamma^{S}\chi_{t,t+1}^{(\epsilon-1)} \right\}, \tag{15}
\]

\[
\eta_{t}^{S} = E_{t} \left\{ (1 - \gamma^{S}) + \beta \Lambda_{t,t+1}\gamma^{S}z_{t+1,t}^{S} \right\}, \tag{16}
\]

\[
z_{t-1,t} = (R_{k,t}^{S} - R_{t-1})(1 - \tau_{t-1}^{S})(\phi_{t}^{S} - 1) + R_{t-1}, \tag{17}
\]

\[
\chi_{t,t+1} = \left\{ \frac{\phi_{t}^{S}(1 - \tau_{t}^{S})}{\phi_{t-1}^{S}(1 - \tau_{t-1}^{S})} \right\} z_{t-1,t}. \tag{18}
\]
where \(R_{sk,t} - R_{t-1}\) denotes the bank finance premium. Parameter \(0 < \gamma^S < 1\) is the survival probability of bankers. The term \((1 - \tau^S_t)\phi^S_t \equiv \frac{(1 - \tau^S_t)Q^S_t B^S_{p,t}}{N^S_t}\) denotes the average bank leverage ratio and \(N^S_t\) bank net worth. The definitions of growth rates are the following: \(\chi^S_{t,t+i} \equiv Q^S_{t,t+i} + \nu_t\) and \(\nu^S_{t,t+i} \equiv N^S_{t,t+i} \equiv N^S_t\). The total value of bank loans of a representative small firm is given by:

\[
Q^S_{t} B^S_{p,t} = Q^S_{t} B^S_{p,t} + Q^S_{t} B^S_{g,t},
\]

\[
= Q^S_{t} B^S_{p,t} + \tau^S_t Q^S_{t} B^S_{p,t}.
\]

where \(Q^S_{t} B^S_{p,t}\) is the value of loans intermediated by banks and \(Q^S_{t} B^S_{g,t}\) loans intermediated by the central bank. Similar to Gertler and Karadi (2011), the credit policy instrument, \(\tau^S_t\), determines the fraction of bank loans intermediated by the policy maker. With the state intervention in place, equations (16) and (17) are changed in comparison to the third chapter in order to account for bank loans intermediated by the central bank. Any central bank’s earnings from the state intervention are transferred to households in the form of lump-sum transfers.

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

\[
\phi^S_t = \frac{1}{(1 - \tau^S_t)} \left( \lambda^S_t - \nu_t \right).
\]

The leverage ratio is increasing for two reasons: the excess value of bank’s assets, i.e., loans, \(\nu_t\), and additional value from holding another unit of net worth, \(\eta^S_t\). The leverage ratio declines in \(\lambda^S_t\), a fraction of funds diverted by bankers. Following Dedola et al. (2013), I assume that \(\lambda^S_t\) is time varying and captures a shock to the confidence in the banking system. Hence, an increase in \(\lambda^S_t\) implies that depositors can recover less funds from banks. This action leads to the tightening of the leverage constraint and, hence, causes a disruption in bank intermediation, since banks reduce the amount of loans to small firms.

The evolution of bank net worth is given by:

\[
N^S_t = \gamma^S [(R^S_{k,t} - R_{t-1})\phi^S_{t-1} + R_{t-1}]N^S_{t-1} + \omega^S (1 - \tau^S_{t-1})Q^S_{t-1} B^S_{t-1}.
\]

Net worth gets accumulated from revenues of bank operations (of surviving bankers) and a start-up transfer from the household, \(\omega^S (1 - \tau^S_{t-1})Q^S_{t-1} B^S_{t-1}\). Note that the total value of bank loans extended to representative small firms (corporate finance firms) is used to finance their capital purchases:

\[
Q^S_{t} K^S_t = Q^S_{t} B^S_{p,t}.
\]

The representative firm that relies on bond finance uses her own net worth and bonds to finance capital purchases. Hence, the large corporate finance firm, or for convenience, large firm
issues the following amount of bonds:

\[ B_t^B = Q_t^B K_t^B - N_t^B. \]

Solving the optimal bond contract\(^7\) I obtain that the relationship between the return on capital and the bond finance premium is given by:

\[
E_t R_{k,t+1}^B = E_t[\rho(\bar{\omega}_{t+1}) R_t] \exp(\tau_t^B),
\]

\[
\rho(\bar{\omega}_{t+1}) = \frac{\Gamma_t(\bar{\omega}_{t+1})}{\left[ \Gamma_t(\bar{\omega}_{t+1}) - \mu_{t+1} G_t(\bar{\omega}_{t+1}) \Gamma_t(\bar{\omega}_{t+1}) + (1 - \Gamma_t(\bar{\omega}_{t+1})) (\Gamma_t(\bar{\omega}_{t+1}) - \mu_{t+1} G_t(\bar{\omega}_{t+1})) \right]} \]

where \( \rho(\bar{\omega}_{t+1}) \) represents the bond finance premium and \( \tau_t^B \) is the macroprudential policy instrument. The bond policy instrument is an exogenous component of the bond premium, that aims to dampen credit cycles in the bond market. \( \Gamma_t(\bar{\omega}_{t+1}) \equiv (1 - F_t(\bar{\omega}_{t+1})) + \int_{0}^{\bar{\omega}_{t+1}} \omega dF_t(\omega) \)

\( G_t(\bar{\omega}_{t+1}) \equiv \int_{0}^{\bar{\omega}_{t+1}} \omega dF_t(\omega) \). \( \Gamma_t(\cdot) \) and \( \mu_{t+1} G_t(\cdot) \) denote respectively the share of large firms’ earnings received by the mutual fund and the expected monitoring costs. \( F_t(\bar{\omega}_{t+1}) \) is a cumulative distribution function (and the probability of default) of idiosyncratic productivity, \( \omega^B \).

Similar to Bernanke et al. (1999), I assume that \( \omega^B \) is log normally distributed with \( E(\omega^B) = 1 \) and \( Var(\ln \omega^B) = \sigma^2 \). I allow for monitoring costs to be time-varying in order to model the change in the auditing ability of mutual funds. For example, an unexpected increase in monitoring costs makes the verification of the large firm’s project outcomes costlier, i.e., it increases the bond premium.

The zero profit condition of mutual funds is as follows:

\[
E_t \left\{ \left[ \Gamma_t(\bar{\omega}_{t+1}) - \mu_{t+1} G_t(\bar{\omega}_{t+1}) \right] \frac{Q_t^B K_{t+1}^B}{R_{t+1}^B} \right\} = \frac{Q_t^B K_t^B}{N_t^B} - 1,
\]

which can be related to the average leverage ratio of large firms, \( \phi_t^B \equiv \frac{Q_t^B B_t^P}{N_t^B} \).

The law of motion for large firms’ net worth is given by:

\[
N_{t+1}^B = \gamma^B (1 - \Gamma_{t-1}(\bar{\omega}_t)) R_{k,t}^B Q_{t-1}^B K_{t-1}^B + W^B,
\]

where \( W^B \) denotes a constant lump-sum transfer of households and parameter \( 0 < \gamma^B < 1 \) determines the fraction of the large firm earnings’ share that is accumulated by large firms. Large firms default on bonds if the realization of the idiosyncratic productivity falls below the threshold productivity, which is given by:

\[
\bar{\omega}_{t+1} = \frac{Z_t \left( Q_t^B K_{t+1}^B - N_t^B \right)}{R_{k,t+1}^B Q_t^B K_t^B},
\]

\(^7\)See, for example, Bernanke et al. (1999).
where \( Z_t \) denotes the contractual, no-default interest rate on corporate bonds.

The capital rental market and the credit market clear:

\[
\int_0^{\infty} K_{i,t}^S \, di = K_{i,t}^{S,a} = \eta K_t^S, \tag{26}
\]
\[
\int_0^{\infty} K_{i,t}^B \, di = K_{i,t}^{B,a} = (1 - \eta) K_t^B, \tag{27}
\]
\[
B_{t}^{\text{tot}} = B_{t}^{\text{tot,B}} + B_{t}^{\text{tot,S}}, \tag{28}
\]

where \( B_{t}^{\text{tot}} \) represents total credit, \( B_{t}^{\text{tot,S}} \equiv \eta Q_t^S B_t^S \) and \( B_{t}^{\text{tot,B}} \equiv (1 - \eta) (Q_t^B K_t^B - N_t^B) \) total values of bank loans and corporate bonds, respectively. I define the bank loan’s share, \( \Upsilon_t \), as the ratio of bank loans between corporate bonds:

\[
\Upsilon_t = \frac{B_{t}^{\text{tot,S}}}{B_{t}^{\text{tot,B}}}. \tag{29}
\]

The aggregate resource constraint is given by:

\[
Y_t = C_t + I_t + c \eta \tau_t^S Q_t^S K_t^S, \]

where the last term represents resource costs associated with the intervention in the banking sector. Note that the aggregate investment is given by \( I_t = \eta I_t^S + (1 - \eta) I_t^B \). Parameter \( c \) denotes the efficiency costs per unit of central bank’s assets, calibrated as in Gertler and Karadi (2011). Note also that the Fisher relation holds:

\[
R_t = \frac{R^n_t}{E_t \Pi_{t+1}}, \tag{30}
\]

where \( R^n_t \) denotes the nominal interest rate.

The shocks follow autoregressive processes given by:

\[
\ln A_t = \rho_A \ln A_{t-1} + e_{t,A}, \tag{31}
\]
\[
\ln \lambda_t^S = (1 - \rho_G) \ln \lambda_{t-1}^S + \rho_G \ln \lambda_{t-1}^S + e_{t,S}, \tag{32}
\]
\[
\mu_t = \frac{1}{1 + e^{\Xi_t}}, \tag{33}
\]
\[
\ln \Xi_t = (1 - \rho_G) \ln \Xi + \rho_G \ln \Xi_{t-1} + e_{t,B}, \tag{34}
\]

where \( \rho_A, \rho_G \in (0,1) \) and \( e_{t,x} \sim iid(0, \sigma_x^2) \), whereby \( x = \{A, S, B\} \). \( e_{t,S} \) and \( e_{t,B} \) denote, respectively, sectoral shocks in banking and bond sector. The specification of the bond-sector

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*The contractual bond interest rate is associated with the threshold productivity, \( \bar{\omega} \), i.e., the value of idiosyncratic productivity is such that the large firm’s net worth is completely eliminated and the firm is exactly able to pay off the corporate bond.

*I assume that the monitoring costs of mutual funds do not deplete the aggregate output and are transferred as a lump sum to households.
shock ensures that monitoring costs \( \mu_t \) falls between 0 and 1, as suggested by Fuentes-Albero (2014). Note that I also consider the economy-wide financial shock, which is a combination of two sectoral shocks. \( \lambda_t \) and \( \Xi_t \) represent the steady state values of \( \lambda_t^S \) and \( \Xi_t \).

### 2.1 Welfare measure and policy rules

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

\[
W_t = E \sum_{t=0}^{\infty} \beta^t U(C_t, L_t),
\]

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

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

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

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 which is obtained using a second-order Taylor approximation, whereas the right hand side is the welfare in the deterministic steady state environment.

For the welfare comparison of policy regimes, I consider the family of simple interest 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 two credit policy instruments, \( \tau_t^S \) and \( \tau_t^B \), to credit imbalances in the respective credit market. Hence, the specifications of policy rules I compare are given by:

1. Simple Taylor rule :

\[
\frac{R^a_t}{R^a} = \left( \frac{R^a_{t-1}}{R^a} \right)^{\rho_r} \left( \frac{\pi_t}{\pi} \right)^{\alpha(1-\rho_r)},
\]

2. Optimized simple Taylor rule:

\[
\frac{R^a_t}{\pi^a} = \left( \frac{R^a_{t-1}}{\pi^a} \right)^{\rho_r} \left( \frac{\pi_t}{\pi} \right)^{\alpha(1-\rho_r)}.
\]

3. Optimized policy combination:

Optimized simple Taylor rule:

\[
\frac{R^a_t}{R^a} = \left( \frac{R^a_{t-1}}{R^a} \right)^{\rho_r} \left( \frac{\pi_t}{\pi} \right)^{\alpha(1-\rho_r)},
\]

\[\text{See further details in appendix.}\]
Bank sector policy instrument:

\[ \tau^S_t = \tau^S - \nu^S \ln \left( \frac{B^S_t}{B^S_{t-1}} \right), \]  

(38)

Bond sector policy instrument:

\[ \tau^B_t = \tau^B + \nu^B \ln \left( \frac{B^B_t}{B^B_{t-1}} \right), \]  

(39)

where \( R^n \) and \( \Pi \) denote the steady-state values for the nominal interest rate and inflation, \( R^n_t \) and \( \Pi_t \), respectively. The parameter \( \alpha_\pi \) is the weight on inflation, \( \rho_r \) measures the degree of interest rate smoothing. Parameters \( \nu_S, \nu_B \geq 0 \) denote, respectively, policy coefficients measuring the degree of responsiveness of the central bank to credit growth in the banking and the bond sector, respectively. Similar to Gertler and Karadi (2011), I assume that the unconventional policy instruments are not used in the steady state and, therefore, the value of both instruments, \( \tau^B \) and \( \tau^S \), is 0. Along the lines of Schmitt-Groh and Uribe (2007), I consider constrained-optimal rules: For cases 2 and 3, I search for the value of policy coefficient, \( \alpha_\pi \), and the joint determination of policy coefficients, \( \alpha_\pi, \nu_S \) and \( \nu_B \), which yields the highest welfare, respectively. In the following, I will explain the modeling of each instrument in more detail.

For the conventional monetary policy, I consider implementable monetary policy rules. Following Schmitt-Groh and Uribe (2007), these rules ensure the local uniqueness of the rational expectations equilibrium. This implies that the policy coefficient on inflation, \( \alpha_\pi \), is limited in the interval [1, 0.1, 3] in the context of my model framework. The authors argue that policymakers would have difficulties in communicating the policies associated with larger policy coefficients.

The proposed bank sector policy instrument in equation (38) is in the vein of Gertler and Karadi (2011). The central bank intervenes in face of a freeze/acceleration in bank lending. In the case of a bank credit crunch, the intervention results in additional resources available to small firms relying on bank credit in the form of \( \tau^S Q^SK^S \). The amount of the intermediated loans through the central bank are financed by government bonds.

For the bank credit policy, I search for the optimal value of \( \nu^S \) in the interval of (0, 15). The chosen interval is orientated towards the specification by Gertler and Karadi (2011). The authors suggest that the value of \( \nu^S \) of 10 is a good representation of the magnitude of intervention by the Federal Reserve in the financial crisis of 2008. I do not want to take a stance on the exact number of the policy responsiveness to deviations in the bank credit growth, but rather qualitatively assign that higher values of the policy coefficient should be associated with a more

---

\[ \text{For example, in the case of the joint determination of policy coefficients, I vary policy parameters } \alpha_\pi, \nu_S \text{ and } \nu_B \text{ over a grid and search for the values of three parameters at which welfare measure is maximized. For each parameter, I consider 10 different values.} \]

\[ \text{The main difference between two specifications of the policy is the relevant financial variable in the bank policy rule. I consider bank credit growth as a relevant indicator, whereas Gertler and Karadi (2011) use credit spread in their specification. The reason for a different target is that stabilization effects from the policy related to credit volumes are larger in my framework.} \]
aggressive reaction of the central bank to credit imbalances.

The second credit policy instrument, $\tau^B_t$, aims at stabilizing the bond market by directly affecting the bond premium:

$$E_t R^B_{t,t+1} = E_t [\rho (\sigma^B_{t+1}) R^B_t] \exp (\tau^B_t)$$

in the manner specified in equation (39). In the presence of changes in bond issuance, the macroprudential instrument reacts to the growth of corporate bonds by altering the finance premium on bonds. This macroprudential tool setup follows Kannan et al. (2012) and Bailliu et al. (2015) who limit the policy coefficient $\nu_B$ to the interval of $[0,1]$. They argue that the value of this policy coefficient is lower than the inflation coefficient since the prime goal of monetary policy is price stability. Furthermore, I study one dimension of macroprudential policy frameworks without specifying the implementation of the macroprudential tool. For example, Quint and Rabanal (2014) suggest that bond premia can be increased by imposing, e.g., additional capital surcharges, whereas the direct provision of liquidity to the bond sector can decrease these premia.

3 Results

3.1 Calibration

The time unit is one quarter. Most of the parameters are calibrated as in the model by Gertler and Karadi (2011). The parameters related to the financial sector are presented in table 1 and justified in the third chapter.

The sources of exogenous variations are non-financial (technology) shocks and financial shocks. Each credit market segment features sector-specific shocks. In particular, I consider an exogenous disturbance to the monitoring ability of mutual funds and bankers’ incentive to divert assets. As explained above, the economy-wide financial shock, is a combination of sectoral shocks.

Regarding the calibration of shock processes, I specify the standard deviation of shocks so that the estimated output responses are exactly matched on impact following aggregate supply and financial shocks as in the third chapter. The persistence parameter is set so that the theoretical response of output falls within the estimated credible set. The impulse response matching leads to the following values of parameters: $\rho_A = 0.70$, $\rho_G = 0.70$, $\sigma_A = 0.012$ and $\sigma_S, \sigma_B = 0.067$. For the combined financial shock, the standard deviation is chosen to replicate a rise in both bank and bond premia, in addition to matching the response of output on impact.\(^ {14}\)

\(^{13}\) Note that Bailliu et al. (2015) specifies the macroprudential tool that reacts to the deviations of credit growth from its steady state value.

\(^{14}\) The calibrated shock generates a rise in finance premia, that corresponds to the lower bound of the credible set of the estimated financial shock, documented in the chapter three. In order to match the estimated empirical
Table 1: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>η</td>
<td>0.263</td>
<td>share of small firms</td>
<td>Leverage: 4</td>
</tr>
<tr>
<td>γₜ</td>
<td>0.957</td>
<td>survival probability of banker</td>
<td>Leverage: 2</td>
</tr>
<tr>
<td>γ₉</td>
<td>0.979</td>
<td>survival probability of large firms</td>
<td>258bp.(annualized)</td>
</tr>
<tr>
<td>λ</td>
<td>0.609</td>
<td>fraction of divertible bank capital</td>
<td>BBB-spread: 209bp.(annualized)</td>
</tr>
<tr>
<td>µ⁺</td>
<td>0.079</td>
<td>monitoring cost (mutual funds)</td>
<td>BBBS-spread: 209bp.(annualized)</td>
</tr>
<tr>
<td>F(ω⁰⁺)</td>
<td>0.0134</td>
<td>default probability</td>
<td>SG-debt: 5.37% (annualized)</td>
</tr>
<tr>
<td>W⁺</td>
<td>0.005</td>
<td>transfer from households</td>
<td>Christiano et al. (2014)</td>
</tr>
<tr>
<td>ω⁻</td>
<td>0.002</td>
<td>transfer from households</td>
<td>Gertler and Karadi (2011)</td>
</tr>
<tr>
<td>ξ</td>
<td>1.72</td>
<td>curvature of investment adjustment cost</td>
<td>Gertler and Karadi (2011)</td>
</tr>
<tr>
<td>ρ</td>
<td>0.6</td>
<td>substitutability of capital</td>
<td>Verona et al. (2013)</td>
</tr>
</tbody>
</table>

3.2 Welfare implications of economy-wide shocks

3.2.1 Optimal policy rules

Table 2 presents policy coefficients under three different policy regimes specified in section 2.1. It is important to emphasize that table 2 is only supposed to yield a qualitative indication on the combination of policy instruments which is associated with the highest welfare.

The central bank should try to achieve full inflation stabilization in each model version, i.e., απ = 3.0. The prescription for the optimal interest rate rule is the same in scenarios with and without unconventional policies, similar to the conclusions from Curdia and Woodford (2011). If additional policy measures are at the central bank’s disposal, the central bank should make use of these policy tools.

In the following, I provide some intuition for reaction coefficients of non-standard policy instruments. The use of policy measures has to be balanced against the costs of this activity. Regarding the bank credit policy, costs associated with this policy are rising in the amount of impaired bank loans. Hence, an aggressive reaction of the policy maker in the case of financial shocks is inefficient. Instead a moderate reaction of the central bank results in a sizable amount of loans to small firms. In the case of technology shocks, it is beneficial to exercise the bank policy instrument to the fullest extent, for these actions are not as costly as in the case of financial shocks. Relatively small declines in bank loans in these scenarios (to be shown) are associated with lower costs of the bank credit policy. As for the bond policy instrument, the policy maker would spread, I assume that the shock to monitoring costs is five times stronger than the shock to the banking sector.
uses this instrument with a similar intensity in different shock scenarios. If both shocks are the economy’s driving forces, optimal policy coefficients suggest that the stabilization of financial imbalances under financial shock scenarios represents a dominating feature of the policy.

Table 2 also represents welfare costs and relative gains of optimized rules compared to the simple Taylor rule. Welfare costs give a fraction of steady-state consumption that households require as a compensation to live in the stochastic economy under a certain policy regime. The relative gain denotes welfare gains of a specific policy over the simple Taylor rule. The first finding is that, the simple Taylor rule yields the highest welfare costs in every shock scenario, whereas the optimal policy mix performs best. Choosing the inflation coefficient in the interest rate policy rule optimally does not considerably improve the performance of a simple Taylor rule.

Table 2: Optimal policy rules

<table>
<thead>
<tr>
<th></th>
<th>(\alpha_\pi)</th>
<th>(\nu_S)</th>
<th>(\nu_B)</th>
<th>Welfare cost</th>
<th>Relative gain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All shocks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Taylor rule</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-0.296</td>
<td>-</td>
</tr>
<tr>
<td>Optimized Taylor rule</td>
<td>3.0</td>
<td>-</td>
<td>-</td>
<td>-0.264</td>
<td>0.032</td>
</tr>
<tr>
<td>Optimized policy combination</td>
<td>3.0</td>
<td>3</td>
<td>0.2</td>
<td>-0.037</td>
<td>0.259</td>
</tr>
<tr>
<td><strong>Technology shocks only</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Taylor rule</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-0.070</td>
<td>-</td>
</tr>
<tr>
<td>Optimized Taylor rule</td>
<td>3.0</td>
<td>-</td>
<td>-</td>
<td>-0.051</td>
<td>0.019</td>
</tr>
<tr>
<td>Optimized policy combination</td>
<td>3.0</td>
<td>15</td>
<td>0.3</td>
<td>-0.007</td>
<td>0.063</td>
</tr>
<tr>
<td><strong>Financial shocks only</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Taylor rule</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-0.315</td>
<td>-</td>
</tr>
<tr>
<td>Optimized Taylor rule</td>
<td>3.0</td>
<td>-</td>
<td>-</td>
<td>-0.310</td>
<td>0.005</td>
</tr>
<tr>
<td>Optimized policy combination</td>
<td>3.0</td>
<td>3</td>
<td>0.2</td>
<td>-0.126</td>
<td>0.189</td>
</tr>
</tbody>
</table>

Notes: In the optimized Taylor rules, the policy parameters \(\alpha_\pi\) are restricted to lie in the interval \([1.01, 3]\), respectively. For non-standard policy rules, I restricted policy parameters \(\nu_S\) and \(\nu_B\) to the interval \([0, 15]\) and \([0, 1]\), respectively. All Taylor-type policy rules feature interest rate smoothing with \(\rho_r = 0.8\). The welfare cost \(\nu \cdot 100\) is expressed in terms of the steady state consumption (see appendix). 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 stochastic environment under certain policy regime. The relative gain is calculated as the gain of a specific policy relative to the simple Taylor rule.

See appendix for details on the calculation of welfare costs.

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

15See appendix for details on the calculation of welfare costs.

16I do not compare the performance of optimized rules relative to a standard Taylor rule with inflation and output gap since the definition of an output gap is not unambiguous in the context of a New Keynesian model with the endogenous capital accumulation (see, Woodford (2003), Chapter 5).
large under extraordinary circumstances, when the process of financial intermediation is severely disrupted. On the other hand, non-financial shocks, such as technology shocks, are associated with limited benefits of the optimal policy mix, e.g., relative gain over the simple Taylor rule yields 0.063% of steady state consumption. Mechanisms at work are discussed below with the help of impulse response functions following respective shocks.

3.2.2 The Ramsey policy

In the following, I compare the performance of three policy regimes against the Ramsey optimal policy. Table 3 displays welfare losses of a particular policy compared to the Ramsey policy. The Ramsey planer maximizes household utility subject to the equilibrium conditions of the model economy setting one policy instrument, the nominal interest rate. All three policy rules are inferior to the Ramsey policy. Households are willing to sacrifice between 0.133% and 0.292% of their consumption stream to be as well off as under the Ramsey policy. Under the optimal policy mix the welfare costs are reduced twice as much as under Taylor-type rules. Hence, the suggested policy mix is closest to the Ramsey planner’s allocation.

Table 3: Welfare loss

<table>
<thead>
<tr>
<th></th>
<th>$\alpha_\pi$</th>
<th>$\nu_S$</th>
<th>$\nu_B$</th>
<th>$\lambda_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramsey policy</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Simple Taylor rule</td>
<td>1.5</td>
<td>-</td>
<td>- 0.292</td>
<td>-</td>
</tr>
<tr>
<td>Optimized Taylor rule</td>
<td>3.0</td>
<td>-</td>
<td>- 0.255</td>
<td>-</td>
</tr>
<tr>
<td>Optimized policy combination</td>
<td>3.0</td>
<td>3.0</td>
<td>0.2</td>
<td>0.133</td>
</tr>
</tbody>
</table>

Notes: Conditional welfare cost, $\lambda_c \cdot 100$, is defined as a percentage decrease in the Ramsey-optimal consumption process necessary to make the level of welfare under the Ramsey policy identical to the one under the alternative policy (see the details on the calculation of conditional welfare costs in Schmitt-Grohé and Uribe 2007). The welfare under the Ramsey policy is calculated with the social planner’s initial Lagrange multipliers set equal to their steady state values.

3.2.3 Impulse response functions: Economy-wide financial shocks

As shown in table 2 when economy-wide financial shocks are the only source of an economy’s business cycle fluctuations, it is optimal for policy makers to use a combination of policy tools. Figure 1 displays dynamic responses of main variables to an adverse combined financial shock, causing a confidence loss in banks and increased monitoring costs of mutual funds (by affecting $\lambda_t$ and $\mu_t$), respectively, under the policies specified in section 2.1.

Following the negative financial shock, the functioning of the banking market is more adversely impaired than that of the bond market, which is depicted in a deep bank credit crunch and a substantial increase in bank premia. Due to the increased incentive to divert assets, households do not "trust" banks and reduce deposits, which in turn reduces the ability of banks to

\footnote{The Ramsey plan is implemented using Dynare, which runs the package \texttt{ramsey_policy}.}
lend by tightening their capital constraints. The ensuing deleveraging process of banks induces a recessionary period. In the bond sector, an unexpected increase in monitoring costs of mutual funds raises bond premia, reduces bond volumes and, hence, investments of large firms. As shown in the third chapter, under the simple Taylor rule, there is a change in the corporate debt composition in favor of the less affected credit market segment, the bond market, which damps the effect of the shock on the real economy.

If the central bank conducts only conventional monetary policy in the form of the Taylor-type interest rate rule, it does not prevent a rise in finance premia and a contraction in credit. For the conventional monetary policy cannot eliminate disruptions in credit market segments, it is associated with high welfare costs\(^{18}\).

To understand how the optimal policy combination works, I look closer at developments in

\(^{18}\)I calculated welfare costs and analyzed 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 model versions.
sectoral credit markets. The bank credit policy stabilizes the main disruption in the financial system associated with the banking market. It helps reduce the degree of financial friction that is intensified through the misbehavior of banks. Namely, the central bank intermediates additional loans to small firms\textsuperscript{19} which enable them to finance their capital purchases. As a consequence, the prices of small firms’ capital are moderated, which in turn decreases the return on capital and, therefore, the bank premium. A second effect of the policy is that bank balance sheets improve due to the limited fall in the price of capital, which reduces tightness of bank capital constraints and banks’ leverage ratio. Therefore, banks do not reduce lending to small firms as much as in the case without the bank credit policy. The direct effect of state intervention and the indirect effect on banks’ balance sheets temper a decline in small firms’ investment and output (not shown). Similarly, the bond macroprudential tool reacts to reduced bond issuance volumes, however, it dampens a rise in bond premia negligibly\textsuperscript{20}. Nevertheless, the development in the bond market is smoothed under the bond policy tool, which also moderates capital prices in the bond sector and enhances investment spending of large firms. Overall, due to smaller disruption in the bond market, the use of the bond policy instrument improves only marginally the functioning of this market.

After understanding the economic mechanism behind the non-standard policy instruments, I will provide intuition for their superior welfare performance. The main contribution to economy’s stabilization comes from the use of the bank credit policy. This policy alleviates a credit crunch and generates a powerful stimulus to the economy in initial periods. I report a rise in the central bank’s balance sheet that corresponds to the total value of 5% of small firms’ capital purchases. Hence, the stimulus results in additional investment expenditures for bank finance-dependent firms, which translates into an increase in labor demand and labor productivity (on impact). Since wages are flexible, they will rise to establish an equilibrium in the labor market after the shock hits the economy. As the substitution effect dominates the income effect, households increase labor supply in the scenario with the credit policy. Thus, the model also generates a wealth effect of labor supply (an increase in consumption), which can be one of the reasons behind a better performance of the policy mix relative to the standard Taylor rule. Note that there is a certain degree of consumption smoothing under Taylor-type policies. In these scenarios, a shortfall in the aggregate demand induces a fall in wages and labor hours. Nevertheless, households can rely on the smooth consumption process since they reduce the amount of deposits (e.g., as a result of mistrust in banks). The credit policy restores trust in the banking system, moderating a decline in deposits. In equilibrium, the wealth effect of labor supply dominates the positive effect from the restored confidence in banks, and aggregate consumption increases

\textsuperscript{19}Initially, the central bank provides additional bank loans, however, as in the following periods bank credit growth accelerates and bank balance sheets improve, the policy tries to dampen the credit cycle. In particular, a negative bank policy instrument means that the central bank goes short in bank loans.

\textsuperscript{20}This instrument operates via balancing the growth in bond volumes. A negative value of the policy instrument indicates that it subdues the bond premium. A positive value of the bond policy instrument (following an improvement in bond issuance volumes) dampens the premium. The value of the bond instrument is low as a result of small changes in bond volumes, which results in hardly visible changes in the bond premium.
under the active bank credit policy.

The overall effect of bank and bond policy instruments is the stabilization of respective credit markets, which in turn stabilize aggregate investment and aggregate consumption. By shutting off the bank policy instrument in the counterfactual exercise, the model predicts that the recovery does not feature an overshooting effect in the labor market documented above, and welfare benefits are negligible (not reported). Hence, the stabilization of the bond market via the macroprudential instrument is not essential for welfare improvements. This result suggests that the effective policy reaction needs to address the more disrupted credit market segment.

There is a consensus in the literature that the deviation of monetary policy from the standard Taylor rule in form of an additional reaction to financial variables or the use of unconventional policy tools is effective in mitigating adverse effects of financial shocks on the real economy, if these disturbances impair the functioning of financial markets to a large extent. My model featuring a segmented financial market can replicate the results from the aforementioned literature established for one single financial market.

3.2.4 Impulse response functions: Technology shocks

Figure 2 gives a visualization of the dynamics of main variables following a negative technology shock under three policy rules, which are associated with quantitatively similar welfare costs in table 2. As documented in the New Keynesian model, consumption falls and labor hours increase in the presence of a negative technology shock. The nominal interest rate rises in response to an increase in inflation (as a result of rising marginal costs), which leads to a rise in the real interest rate (since the nominal interest rate moves more than one-to-one with inflation). On the firm side, the adverse technology shock reduces the price of capital goods and, hence, both sectors employ less capital in production (not reported), which induces a fall in sectoral external financing and the total credit volume. Tightening of credit conditions together with the lower value of net worth of banks and firms induces an increase in respective leverage ratios and finance premia.

The qualitative behavior of the main variables is similar under three policy regimes. Strong reaction to inflation deviations in the case of optimized rules (i.e., $\alpha_\pi = 3$) increases relatively more the real interest rate, which in turn induces larger changes in consumption than under the simple Taylor rule. Additionally, the optimized Taylor rule is associated with relatively larger deviations of financial premia and the credit volume from their steady states than the simple rule. However, it reduces inflation volatility, which is welfare-improving. The highest welfare
is achieved by the policy mix, which appears to be, like in the case of financial shocks, a result of stabilization of distortions in credit market segments.

Even though the technology shock generates a small propagation effect in the financial market, it is optimal for the policy maker to moderate small imbalances arising in credit market segments. Under the policy mix, bank premia are reduced for a prolonged period of time in order to eliminate a main disruption in the financial system, associated with the banking market. The state intervention reduces the costs of bank finance, fostering capital purchases of small firms and, hence, improving their investment prospects. As long as bank premia are lower than bond premia, firms substitute towards a cheaper form of finance, bank finance (see figure 5 in absolute deviation of bond premia from their steady state). This explains differences in bond finance between two model economies using only Taylor policy rule.
An additional stabilization effect of the policy mix comes from the bond sector policy instrument. It is cyclical because it counteracts movements in the corporate bond volume: An initial reduction of the bond premium via the macroprudential tool tries to prompt additional lending activity in the market, however, as the bond issuance volume rises in the following periods, the policy instrument increases the bond premium. Despite the cyclicality of the bond macroprudential instrument, it is associated with a smoother development in the bond market, which contributes to credit market stabilization. Furthermore, it affects positively capital goods prices of large firms, improving their investment outcomes. Hence, the total effect of the two non-standard tools is seen in a reduced decline of the total credit volume. The improvement of credit conditions, together with strict inflation stabilization, achieves macroeconomic stabilization, as indicated by welfare costs of 0.007% of steady state consumption in table 2.

My results suggest that the use of non-standard policy tools is beneficial in the presence of technology shocks. The literature on this point is divided. For example, Bailliu et al. (2015) show that in their model monetary and macroprudential policy tools have conflicting interests, since the latter aims to stabilize nominal credit growth and, therefore, counteracts the effects of monetary policy. Within the context of my model, both bank and bond policy tool are related to changes in real volumes of bank loans and bonds, respectively. Consequently, they do not conflict explicitly with inflation targeting interest rate rules. On the other hand, Gambacorta and Signoretti (2014) find that the Taylor rule responding to asset prices dampens the propagation of positive technology shock by reducing the expansion of bank balance sheets, their leverage and increasing lending rates. Though my optimized policy mix does not directly respond to asset prices, it tries to attain credit market and inflation stabilization, which in turn results in higher welfare. Cúrdia and Woodford (2010) also address a modified Taylor rule. They find that the rule reacting to the credit spread can be beneficial in the presence of transitory technology shocks, whereas the standard Taylor rule outperforms the augmented Taylor rule if technology shocks are highly persistent. After accounting for highly persistent technology shocks (i.e., \( \rho_A = 0.99 \) instead of \( \rho_A = 0.70 \)) within my framework, I find that it is still desirable for the central bank to use a combination of monetary, credit and macroprudential policy instruments.

Even though the optimal policy prescribes the use of non-standard policy tools in the presence of technology shocks, central bank lending programs to one credit segment may not be seen as a feasible policy option if this is too costly or not politically implementable. Especially, this argument may be relevant if shocks do not originate directly in financial markets. Furthermore, the bank credit policy alleviates the distortion associated with financial friction in the banking sector, which induces a change in the corporate debt composition towards bank finance. As already explained, this is beneficial within my framework, however, this may cause inefficient-

25Exactly the opposite mechanism happens under the (simple/optimized) Taylor rule, where bank finance is more expensive than bond finance. The enhanced reduction of credit under Taylor rules is the product of a rise in financial premia and a precipitous decline in bank loans.

26Cúrdia and Woodford (2010) show that the modified Taylor rule with credit spread is welfare improving in case of financial shocks and non-financial demand shocks. However, the standard Taylor rule suffices to stabilize the economy in the presence of preference or government shocks.
cies and moral hazard issues, when financial intermediaries anticipate state intervention and engage in more risk-taking (see, e.g., Gertler et al. [2012]). In the light of these risks, the policy maker does not make a big mistake by only conducting conventional monetary policy in response to technology shocks. My findings indicate that welfare losses are limited under these policy scenarios.

3.3 Sectoral financial shocks

3.3.1 Welfare analysis

In this section I look at the scenarios associated with sector-specific financial shocks, i.e., only one credit market is affected by a financial shock. Table 4 presents policy coefficients associated with the optimized and non-optimized policies. I assume that the central bank chooses an optimal policy combination according to equations (37), (38) and (39), knowing exactly the type of shock. Non-optimized policies refer to policy mixes that are not optimal from the point of view of an economy which is only hit by the considered sectoral shock. They are optimal, however, in economies featuring the other type of sectoral shock or combined financial shocks. The relative gain (1) denotes welfare gains of a specific policy over the simple Taylor rule, whereas the relative gain (2) denotes welfare gains of a policy relative to the policy mix, found for the economy hit only by combined financial shocks.

In the case of bank sector shocks, a welfare-maximizing policy combination implies a deviation from strict inflation stabilization ($\alpha_\pi = 1.4$), moderate reaction of the bank credit policy ($\nu_S = 3$) and no use of the bond macroprudential tool ($\nu_B = 0$). Welfare results suggest that the size of the inflation coefficient plays a minor role (c.f., the relative gains (2) of the non-optimized policies with $\alpha_\pi = 3$ and the optimal policy mix with $\alpha_\pi = 1.4$). The optimal policy mix does not feature a bond instrument for following reasons: The unaffected bond market segment features an increase in bond issuance. This has a stabilizing effect on the economy, which contributes to the reduced welfare cost. Hence, inducing a decelerating process of bond issuance, via the bond macroprudential tool, is counterproductive.

\footnote{The size of the bank sector shock is calibrated so that the response of output on impact matched the empirical counterpart, estimated in the third chapter. This results in higher standard deviation (i.e., $\sigma_S = 0.10$) than the one associated with the combined financial shock.}
Table 4: Optimal policy rules following sectoral shocks

<table>
<thead>
<tr>
<th>Bank sector shocks only</th>
<th>$\alpha_\pi$</th>
<th>$\nu_S$</th>
<th>$\nu_B$</th>
<th>Welfare cost</th>
<th>Relative gain(1)</th>
<th>Relative gain(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy mix</td>
<td>1.4</td>
<td>3</td>
<td>0</td>
<td>0.270</td>
<td>0.424</td>
<td>0.007</td>
</tr>
<tr>
<td>Non-optimized policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Taylor rule</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-0.154</td>
<td>-</td>
<td>-0.417</td>
</tr>
<tr>
<td>Policy conditional on combined fin.shocks</td>
<td>3.0</td>
<td>3</td>
<td>0.1</td>
<td>0.263</td>
<td>0.417</td>
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<td>Policy conditional on bond sector shocks</td>
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<td>4.5</td>
<td>1</td>
<td>0.257</td>
<td>0.411</td>
<td>-0.006</td>
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<tr>
<td>Policy conditional on technology shocks</td>
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<td>15</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bond sector shocks only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal policy</td>
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<td></td>
</tr>
<tr>
<td>Policy mix</td>
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<td>4.5</td>
<td>1</td>
<td>-1.033</td>
<td>0.029</td>
<td>0.005</td>
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<td></td>
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<tr>
<td>Simple Taylor rule</td>
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<td>-</td>
<td>-</td>
<td>-1.062</td>
<td>-</td>
<td>-0.024</td>
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<tr>
<td>Policy conditional on combined fin.shocks</td>
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<td>3</td>
<td>0.1</td>
<td>-1.038</td>
<td>-0.024</td>
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<td>Policy conditional on bank sector shocks</td>
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<td>-0.002</td>
<td>-0.027</td>
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<tr>
<td>Policy conditional on technology shocks</td>
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<td>15</td>
<td>0.3</td>
<td>-1.037</td>
<td>0.025</td>
<td>0.001</td>
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Notes: 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 policy mixes that the central bank would choose assuming incorrectly the type of shock - combined financial shocks or shocks originating from the non-affected sector. Welfare costs are calculated in the same way as in table 2. The relative gain(1) is calculated as the gain of a specific policy relative to the simple Taylor rule, i.e., a difference in welfare costs of the specific policy relative to the simple Taylor rule. The relative gain(2) is calculated as the gain of a specific policy relative to the policy mix, which is the optimal combination of interest rate rule and credit policy instruments in the economy hit by combined financial shock.
How large are mistakes if the central bank does not respond to credit market conditions and conducts conventional monetary policy in the presence of bank sector shocks? The simple Taylor rule results in large welfare costs, equivalent to -0.154% of steady state consumption. On the other hand, the model suggests that households gain from living in the stochastic economy with sectoral bank shocks under policy rules that feature the bank credit policy (e.g., 0.270% of steady state consumption in the case of the optimal policy mix). The economic rationale for the result is the following: Households anticipate that the state intervention will restore trust in the banking sector by providing additional loans (capital) to absorb effects of these shocks. Therefore, the presence of the bank credit policy insures households against risks of the fall in asset prices and depletion of deposits, eliminating their need for precautionary savings. The additional amount of capital and deposits in these scenarios reduce risk perceptions, yielding an increase in the mean consumption in the second order stochastic steady state (which is established using a non-linear moving average toolkit by Lan and Meyer-Gohde, 2013). Hence, the stochastic economy under unconventional policy regimes is preferred over the environment with no credit policy intervention.

Now, I will turn to the discussion of bond sector shocks. The optimal policy response implies that the central bank pursues strict inflation stabilization (\( \alpha_\pi = 3 \)), uses moderate bank credit policy (\( \nu_S = 4.5 \)), and reacts strongly to imbalances in the bond sector (\( \nu_B = 1 \)). Strict inflation stabilization aims at neutralizing inflationary pressures, whereas the purpose of bank credit policy is to dampen the financial boom in bank loans. The aggressive policy reaction to bond imbalances attempts to address the most disrupted credit market segment and eliminate distortions caused by financial frictions in this sector.

In the following, I will assess welfare implications of policy rules conditional on bond sector shocks. Are central bank’s mistakes large if she acts on the assumption that shocks originate in both sectors? The model predicts small relative gains of the optimal policy combination over the policies associated with economy-wide shocks, e.g., 0.005 % of steady state consumption. How important is it that the central bank’s policy responds to credit market conditions? The answer is that it is not important within the context of bond sector shocks, because all policy rules have a comparable welfare performance. For example, the relative gain of the optimal policy over the simple Taylor rule is 0.029% of steady state consumption. This result suggests that the optimal policy is ineffective in neutralizing the credit market distortions caused by bond sector shocks. To gain a better understanding of the effects of different policies, I will now turn to the analysis of impulse response functions.

### 3.3.2 Impulse response analysis

**Bank sector shocks:** Figure presents the responses for an adverse shock to \( \lambda_t \), causing a loss of confidence in the banking sector. I focus on the model dynamics under the simple Taylor rule,
the optimal policy mix and the policy combination, that is chosen optimally by the central bank assuming that financial shocks originate in both sectors.

Figure 3: Adverse bank sector specific shock

[Graphs showing various economic variables like Consumer, Labor, Credit, etc., with lines indicating model with bond-sector opt. policy mix, model with non-opt. policy mix, and model with simple TR.]

Note: Blue lines refer to the dynamics of model economy with optimal policy mix conditional on bank-sector shocks. Green line refers to model dynamics where the policy maker uses a policy mix, which is welfare-maximizing in the economy hit by combined financial shocks. Red line represents the dynamics under the simple Taylor rule. All 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. Horizontal axes display quarters after the shock.

As the propagation of bank sector shocks resembles the model economy dynamics following economy-wide shocks (in terms of large disruptions in bank lending and a substantial rise in bank premia), the optimized policy in the economy affected by the latter shocks performs well also in the economy with bank sector shocks. The main difference concerns an increase in bond issuance, which intensifies the change in the debt composition in favor of corporate bonds. The substitution towards bond finance, as indicated by a fall in the bank loans’ share in figure 3, happens because bond premia are lower than bank premia. Higher demand for capital of large firms increases the price of capital of these firms and investment in the bond sector. Under the simple Taylor rule, the change in the corporate debt composition is not sufficient to eliminate the
negative effects of the shock, as declines in labor hours and consumption indicate. By actively preventing a bank credit crunch, state intervention depresses bank premia, provides additional credit to small firms and stabilizes the severely disrupted bank market. The economic mechanism is described in section 3.2.3.

**Bond sector shocks:** A contractionary bond sector shock, which increases monitoring costs, rises bond premia and reduces the amount of corporate bonds as well as total credit, as depicted in figure 4. Since the banking sector is not affected, there is a substitution towards capital of small firms and bank finance, i.e., an increase in the bank loans’ share. As a consequence, this sector features an investment boom, whereby enhanced capital demand drives up capital prices of small firms, reducing bank premia. Even though the banking market manages to absorb partly negative effects of bond-sector shocks, it cannot offset the disruption in the bond market. The reason is that a large portion of firms relies only on bond finance; the financing and investment

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**Figure 4: Adverse bond sector shock**

Note: Blue lines refer to the dynamics of model economy with optimal policy mix conditional on bank-sector shocks. Green line refers to model dynamics where the policy maker use a policy mix, which is welfare-maximizing in the economy hit by combined financial shocks. Red line represents the dynamics under the simple Taylor rule. All 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. Horizontal axes display quarters after the shock.
prospects of these firms remain dismal in the aftermath of the shock. This causes a decline in aggregate investment and real activity.

It is interesting to note that bank credit policy tries to counteract a boom in bank lending activity. A negative bank policy instrument indicates that the central bank goes short in intermediating loans. Trying to restrict the bank credit supply, the credit policy induces an increase in bank premia. In my framework, banks benefit from the policy as they earn higher profits from increased premia. They face relaxed leverage constraints as a result of high net worth and the enhanced value of their assets. Therefore, they are willing to intermediate more loans, as presented in figure 4.

As indicated by table 4, there are quantitatively small differences between the policy mixes and the simple Taylor rule. The optimal use of unconventional policies leads to smoother consumption and labor responses than in the absence of these policies. The bond policy instrument is exercised to the fullest extent, \( \nu_B = 1 \), however, the resulting depression of bond premia is quantitatively small, i.e., a reduction in the bond premium by one percentage point (on annual basis). This exerts small effects on the price of investment goods of large firms. As a consequence, bond volumes change little and additional investment expenditures are negligible. These results suggest that there are financial shocks, such as bond sector shocks, where the optimal policy rule cannot eliminate disruptions in the financial system.

4 Conclusion

This paper analyzes a combination of interest rate rules and non-standard policy instruments in the context of a medium-scale financial DSGE model with a banking and a bond market segment. If business cycles are driven by financial shocks, which cause severe disruptions in the functioning of both credit market segments, the central bank should use a bank credit policy and a bond macroprudential tool, together with a nominal interest rate, to achieve macroeconomic stabilization. The benefits of these non-standard policy instruments are reduced if shocks have the non-financial nature.

In the context of shocks affecting only the bank sector, my results are promising as they indicate that the policy maker does not make a big mistake if she fails to identify this shock correctly, as long as she acts on the assumption that the shock belongs to the class of financial shocks. The welfare losses are negligible if her policy response is optimally chosen assuming that the economy was buffeted by economy-wide shocks or shocks originating in the bond market.

Conditional on shocks originating in the bond sector, welfare implications of optimal and non-optimal policies are comparable. Within the context of my model, these shocks cause a rise in bond premia, that cannot be accommodated by policy. Hence, the result indicates that some types of financial shocks amplify the distortions, resulting from financial frictions, to such

\[ \text{This can be achieved via an additional bank regulation, such as capital surcharges in Basel III (see, e.g., Repullo and Suarez, 2013; Passmore and von Hafften, 2017).} \]
a degree, that an optimal policy response brings minor benefits.

It should be stressed that I assumed that the central bank has the authority to implement all policy instruments. In case of separate monetary and macroprudential authority, one would need to consider the (non-)coordination of two authorities. Using a richer credit market framework, it would be interesting to see if the interests of these authorities are conflicting in the presence of aggregate and sectoral shocks.

\[30\] See, c.f., Gelain and Ilbas (2017); Carrillo et al. (2017).
References


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Appendix

Welfare

The welfare measure is given by the lifetime household utility:

\[ \text{Welfare} = \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \quad (40) \]

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

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

where \( g \) denotes a fraction of steady-state consumption that makes agents in the non-stochastic economy as well off as in the stochastic economy. The term \( \frac{g \cdot 100}{\bar{C}} \) represents welfare costs reported in table 2 and 3. I solve for \( g \), by equating the unconditional welfare in the deterministic steady state and in the stochastic environment, as specified in equation 40. 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 stochastic equilibrium under certain policy regime. Or equivalently, negative welfare cost represents a percentage decrease in steady state consumption necessary to make household indifferent between the deterministic and stochastic environment.
Impulse response function: Corporate debt composition

Figure 5 depicts the reaction of the bank loans’ share, i.e., the measure of corporate debt composition to aggregate shocks. Under simple Taylor rules, the composition changes in favour of corporate bonds, as bond finance is less expensive source of finance. The shift reverse in the presence of the bank credit policy. The reason is that state intervention depresses bank premia, making bank finance cheaper. Hence, the shift is reversed towards capital of small firms and bank finance is illustrated in the increase in the bank loan share.

Figure 5: Bank loan share

Note: Green lines refer to the dynamics of the model economy with two sector-specific policy instruments, whereas blue lines refer to the baseline model economy with the Taylor rule. The bank loans’ share 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. Horizontal axes display quarters after the shock.