Monetary Policy and Financial Stability *

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Abstract

How should monetary policy respond to deteriorating financial conditions? We develop and estimate a dynamic new Keynesian model with financial intermediaries and sticky long-term corporate leverage to show that active response to movements in credit conditions often helps to mitigate losses in aggregate consumption and output associated with macro fluctuations. A (credible) monetary policy rule that includes credit spreads is thus welfare-improving sometimes even obviating the need for explicit inflation targeting.

Keywords: Credit spreads, monetary policy rules, financial stability

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1 Introduction

Monetary policy during the recoveries that followed the 2008 and 2020 recessions was extremely restrained. Despite evidence of rising economic growth and inflation expectations, Central Banks increased interest rates only reluctantly and very slowly. Concerns about financial stress and the possible consequences of sharp increases in interest rate on defaults and financial stability more generally were often mentioned as as a possible justification.

As is well known, the behavior of central banks around the globe, including the US Federal Reserve, can be reasonably approximated by a Taylor rule (Taylor (1993)) linking policy rates to inflation and the output gap: when either of these is high, interest rates often will (and should) raise. As the rise in inflation in 2021-22 amply demonstrates, Central banks, however, do not follow this rule precisely. Notably, as Figure 1 shows, deviations from the Taylor rule in the US have become consistently negative since 2008. More significantly, they have also become more correlated with variables such as corporate credit spreads, suggesting that the Fed has indeed become much less willing to target inflation when financial markets are in distress.

In this paper, we investigate whether these general concerns about financial resilience should have any impact on how monetary policy might respond to inflation and output data. To do this, we develop a computable dynamic general equilibrium model that combines financial frictions with wage and price rigidities to study how monetary policy should respond to financial market conditions, and, specifically, credit spreads. Our financial frictions take the form of defaultable long term nominal corporate debt. As Gomes, Jermann, and Schmid (2016) show, introducing long-term nominal debt in general equilibrium monetary models greatly enhances the impact of a deterioration in financial market conditions on real variables by generating an endogenous overhang effect.

Our key results imply that a monetary policy rule that credibly responds to, and seeks to stabilize, fluctuations in credit spreads is generally welfare-improving.

Figure 1: Deviations from Taylor Rule and Credit Spreads

Note: This figure plots deviations from Taylor rule of the Fed and demeaned corporate credit spreads. Dark blue line corresponds to actual Federal Funds rate, light blue line – to FFR according to Taylor rule, green line – to deviations of actual FFR from its target, and red line – to Baa-Aaa corporate credit spreads. Taylor rule is estimated using iterative GMM following Clarida, Gali, and Gertler (2000). The data are downloaded from St. Louis Fed FRED database.

To perform a detailed quantitative analysis of our model we first estimate its key parameters using state-of-the-art Bayesian methods. These parameters include the average debt maturity, the cost of default and the sensitivity of credit prices to leverage, as well as persistence and volatility of shocks to productivity and firm default rates.

To build some intuition about the workings of our model economy we next illustrate how the quantitative model economy would respond to various individual shocks under alternative monetary policy rules: a standard Taylor rule that seeks to stabilize output and inflation and a *a modified Taylor rule* that also includes corporate spreads. The latter mitigates losses in many key variables such as consumption, investment, labor, output and default rates. This is true regardless of whether a recession is triggered by a negative productivity shock or a default shock.

We then conduct a detailed second-order welfare analysis across a wide range of values for the monetary policy weights on the inflation rate, the output gap, and corporate spreads. We show that, when the central bank commits to react to corporate spreads strongly enough, inflation targeting is no longer necessary or even desirable.[1] Again, this is true regardless of whether the economy is buffeted by productivity or default shocks. Although responding to credit spreads is always helpful, our results come with an important caveat in that productivity shocks are even better addressed by a monetary policy rule that places a larger weight on the output gap.

Taken together, however, our results suggest that monetary policy benefits from taking into account indicators of financial market conditions, such as corporate credit spreads, more so when the economy is hit by show to default shocks.

These findings are perhaps just about in line with Ben Bernanke's 2002 remarks that monetary policy rule should ignore asset bubbles and focus on price and output gap stability alone. After 2008, however, most economies throughout the world faced some severe financial stress, suggesting a novel approach to monetary policy was necessary.

We view our paper as primarily a contribution to a new and growing literature on the financial aspects of monetary policy. Naturally, it is also relevant for an even older literature on optimal monetary policy rules (Clarida and Gertler (1999); Woodford (2001); Giannoni and Woodford (2003); Orphanides (2001, 2003); Aoki (2003); Mertens and Williams (2021)). To the best of our knoeldge only a few papers suggest adding financial variables to these rules (Taylor and Williams (2008); Curdia and Woodford (2010)).

We model a defaultable long-term nominal bonds thus producing high credit spreads and debt overhangs that are necessary for our results. Typical models of financial frictions focus on debt and identify leverage as both a source of and an important mechanism of transmission of economic fluctuations (Kiyotaki and Moore

[1]Formally, the weight on inflation in the policy rule should be set at 1, the lowest value consistent with system stability (Taylor principle).

(1997); Carlstrom and Fuerst (1997); Bernanke, Gertler, and Gilchrist (1999); Cooley, Marimon, and Quadrini (2004); Jermann and Quadrini (2012); Gourio (2013); Elenev, Landvoigt, and Van Nieuwerburgh (2021)).[2] Such models fail to produce debt overhang which is an important source of financial distress (Reinhart and Rogoff (2011); Mian and Sufi (2014); Dobbie and Song (2020)). Our model produces a so-called *sticky leverage* – the debt burden becomes larger as a result of deflation (Gomes, Jermann, and Schmid (2016)) which allows us to produce counter-cyclical (Krishnamurthy and Muir (2017)) and high (Chen (2010)) corporate spreads.

The rest of the paper is organized as follows. Section 2 sets up a dynamic general equilibrium model. Section 3 describes the solution strategy and overview of the welfare analysis. Section 4 provides details on calibration and Bayesian estimation of the model. Section 5 shows results of the quantitative analysis and welfare implications. Section 6 concludes.

2 Model

In this section we develop a medium scale dynamic general equilibrium framework that integrates price rigidities, long term nominal debt contracts and financial intermediaries. The model has several types of agents: households, labor unions, banks, final goods and intermediate goods producing firms and a monetary policy authority. We discuss each of them in turn.

[2]Several papers that model nominal debt are Doepke and Schneider (2006); Fernández-Villaverde (2010); Bhamra, Fisher, and Kuehn (2011); Fiore, Teles, and Tristani (2011); Gomes and Schmid (2021).

2.1 Households

There are a continuum of households, indexed by $i \in [0,1]$, that choose consumption, $C_{i,t}$, hours worked, $N_{i,t}$, and bank deposits, $D_{i,t}$ to maximize their lifetime utility function:

$$U = \mathbb{E}_t \left[\sum_{s=0}^{\infty} \beta^s \left(\frac{(C_{i,t+s})^{1-\kappa} - 1}{1-\kappa} - \zeta_n \frac{(N_{i,t+s})^{1+\theta}}{1+\theta} \right) \right] \tag{1}$$

where β is the intertemporal discount factor, $1/\kappa$ is the intertemporal elasticity of substitution for consumption, $1/\theta$ is the intertemporal elasticity of substitution for labor, and ζ_n is a labor disutility parameter.

The per-period budget constraint for each agent i is given by

$$P_t C_{i,t} + D_{i,t+1} = W_t N_{i,t} + (1+R_t) D_{i,t} + T_{i,t} \tag{2}$$

where P_t is the aggregate price level, R_t the nominal interest rate and $T_{i,t}$ summarizes the total net distributions from firms and the government.

The optimal Euler equation for deposits is given by

$$1 = \mathrm{E}_t M_{t,t+1} \frac{1+R_{t+1}}{1+\pi_{t+1}} \tag{3}$$

where $M_{t,t+1} = \beta \left[\frac{C_{t+1}}{C_1} \right]^{-\kappa}$ is the real stochastic discount factor and $\pi_{t+1} = P_{t+1}/P_t - 1$ is the rate of inflation in the economy.

2.2 Labor Unions

Labor unions aggregate the labor choice of households through the Dixit-Stiglitz technology:

$$N_t = \left(\int_0^1 N_t(i)^{1-v_{w,t}} di \right)^{\frac{1}{1-v_{w,t}}} \tag{4}$$

where $v_{w,t}$ is an elasticity parameter. Each individual labor supply then obeys:

$$N_{i,t} = \left(\frac{W_{i,t}}{W_t} \right)^{-1/v_{w,t}} N_t \tag{5}$$

where $W_{i,t}$ is the wage that satisfies household i and W_t is the average wage in the economy. They are linked through the usual Dixit-Stiglitz aggregator:

$$W_t = \left(\int_0^1 W_{i,t}^{\frac{v_{w,t}-1}{v_{w,t}}} di \right)^{\frac{v_{w,t}}{v_{w,t}-1}} \tag{6}$$

We introduce nominal wage stickiness in the manner of Calvo, by assuming unions can change their wage optimally in period t with probability $1 - \gamma_w$. We assume that mark-ups, $\lambda_{w,t} = 1/(1 - v_{w,t})$, are exogenous and follow the AR(1) process:

$$\ln \lambda_{w,t} = (1 - \rho_w)\lambda_w + \rho_w \lambda_{w,t-1} + \sigma_w \epsilon_{w,t} \tag{7}$$

where $\epsilon_{w,t}$ is standard normal. The optimal wage setting process is described in detail in the Appendix.

2.3 Production and Firms

Production of final goods is organized in two separate stages to allows us to combine nominal price rigidities with financial frictions in a highly tractable way. In the first stage, a continuum of perfectly competitive firms, indexed $j \in [0, 1]$, combines capital and labor to produce a common intermediate good, Y^m. In the second stage, the intermediate good is repackaged as a continuum of differentiated goods, Y_r, each sold by a single monopolistic retailer, or final producer, indexed in $r \in [0, 1]$.

2.3.1 Retailers

Final goods are aggregated using the Dixit-Stiglitz technology

$$Y_t = \left(\int_0^1 Y_{r,t}^{1-v} dr \right)^{\frac{1}{1-v}} \tag{8}$$

where $1/v$ is an elasticity parameter.

Thus, each individual retailer $r \in [0, 1]$ faces the downward slopping demand function

$$Y_{r,t} = \left(\frac{P_{r,t}}{P_t} \right)^{-1/v} Y_t \tag{9}$$

where $P_{r,t}$ is the price for good r and P_t is the average price level in the economy, defined through the usual Dixit-Stiglitz aggregator.

$$P_t = \left(\int_0^1 P_{r,t}^{\frac{v-1}{v}} dr \right)^{\frac{v}{v-1}} \tag{10}$$

We assume each retailer can only change their price optimally in period t with probability $1-\gamma$. For brevity, we omit the (well known) details about optimal price setting behavior.

2.3.2 Intermediate goods producers

Each intermediate good j is produced by the monopolist with the following demand schedule

$$Y_{j,t} = A_t K_{j,t}^{\alpha} N_{j,t}^{1-\alpha} \tag{11}$$

where $K_{j,t}$ is the number of capital goods used, $N_{j,t}$ is the labor input, and A_t is an exogenous total productivity that evolves according to the following stationary AR(1) process

$$\ln A_t = \rho^a \ln A_{t-1} + \sigma^a \epsilon_{A,t} \tag{12}$$

where $\epsilon_{A,t}$ is standard normal.

Pre-tax, operating profits for intermediaries can be constructed from solving for optimal labor demand:

$$R_t^k K_{j,t} = \max_{N_{j,t}} A_t K_{j,t}^{\alpha} N_{j,t}^{1-\alpha} - W_t N_{j,t} \tag{13}$$

where $R_t^k = \alpha \frac{Y_t}{K_t}$ is equal across all firms j.

To generate cross-sectional variation in default rates we assume that operating profits are subject to additive idiosyncratic shocks, $z_{j,t} K_{j,t}$, where $z_{j,t}$ is distributed with c.d.f. $F_t^z(z)$ with mean μ_t^z and standard deviation σ^z. The mean of these shocks is time varying and follows the AR(1) process

$$\ln \mu_{t+1}^z = \rho^z \ln \mu_t^z + \epsilon_{t+1}^z \tag{14}$$

where ϵ_{t+1}^z is i.i.d Normal. In what follows we use $\Phi^{\mu}(\mu_t)$ to denote the c.d.f. of μ_t.

Intermediate producers accumulate capital through the usual equation:

$$K_{j,t+1} = (1-\delta) K_{j,t} + I_{j,t} \tag{15}$$

so that the gross growth rate of capital is $g_{j,t} = \frac{I_{j,t}}{K_{j,t}} + (1-\delta)$.

Financing for these firms takes place through issuance of new equity and long term, defaultable, debt with nominal face value $B_{j,t}$ Corporate debt entails payment of a fixed per-period coupon, c, until the stochastic maturity date. Every period, with probability η, the economy is hit by an aggregate liquidity shock that requires that every firms must repay the outstanding debt plus the coupon in the current period.

A firm that does not currently have the resources to repay its debt obligations enters into default. Formally, this is defined implicitly by the equation for a threshold level of firm level productivity, $z_{j,t}^{\star}$:

$$(1-\tau)\left(R_t^k - z_t^{\star}\right) K_{j,t} - (1+(1-\tau)c)\frac{B_{j,t}}{1+\pi_t} + (1-\delta(1-\tau))K_{j,t} + J(K_{j,t+1}, B_{j,t+1}, \mu_t^z) \tag{16}$$

where τ is the (effective) corporate income tax rate and $J(K_{j,t+1}, B_{j,t+1}, \mu_t^z)$ captures the continuation value of the firm which we define more precisely below. Hence, a firm will default when:

$$z_{j,t} \geq z_t^\star = R_t^k - \frac{1+(1-\tau)c}{1-\tau}\frac{b_{j,t}}{1+\pi_t} + \frac{(1-\delta(1-\tau)) + g_t j(b_{j,t+1}, \mu_t^z)}{1-\tau} \tag{17}$$

where $b_{j,t} = \frac{B_{j,t}}{K_{j,t}}$ is the leverage ratio and $j(b_{t+1}, \mu_t^z) = \frac{J(K_{j,t+1}, B_{j,t+1}, \mu_t^z)}{K_{j,t+1}}$. The probability of default is then given by $F_t^z(z_t^\star)$ and increases in the shock, μ_t^z.

Default triggers a change in ownership, whereby lenders takes over the firm and resells it to a new operator which resumes operations with unchanged capital stock and leverage. We assume that re-structuring entails a one time charge equal to a fraction, $1-\xi$, of the firm's value, paid by the creditors.

Dropping the index j, and exploiting homogeneity, the problem for each intermediate goods producer can thus be described by the pair of value functions:

$$v^1(b_t, \mu_t^z) = \max_{b_{t+1}, g_t}\Big\{(1-\tau)(R_t^k - z_{j,t}) + (1-(1-\tau)\delta) - ((1-\tau)c+1)\frac{b_t}{1+\pi_t} \tag{18}$$
$$- g_t + g_t q_t^b b_{t+1} + g_t j(b_{t+1}, \mu_t^z)\Big\}$$

and

$$v^0(b_t, \mu_t^z) = \max_{g_t}\Big\{(1-\tau)(R_t^k - z_{j,t}) + (1-(1-\tau)\delta) - (1-\tau)c\frac{b_t}{1+\pi_t} \tag{19}$$
$$- g_t + g_t j(b_{t+1}, \mu_t^z)\Big\}$$

where $v^1(b_t, \mu_t^z)$ is the value of the firm that will have to repay the debt and $v^0(b_t, \mu_t^z)$ is the value of the firm when the repayment shock is not realized and $q_t^b = q^b(b_{t+1}, \mu_t^z)$ is the (real) price of debt.

The expression for the continuation value is then

$$j(b_{t+1}, \mu_t^z) = \mathbb{E}_t M_{t,t+1} \int \left[\eta \int_{\underline{z}}^{z_{t+1}^\star} v^1(b_{t+1}, \mu_{t+1}^z) dF_t^z(z_{t+1}) + (1-\eta) v^0(b_{t+1}, \mu_{t+1}^z)\right] d\Phi^\mu(\mu_t) \tag{20}$$

where again $M_{t,t+1} = \beta \left[\frac{C_{t+1}}{C_1}\right]^{-\kappa}$ is a real stochastic discount factor.[3]

Since the optimization problem is convex and hence, the following first order conditions (FOC) characterize the solution to the firm's problem:

$$q_t^b + b_{t+1}\frac{\partial q_t^b}{\partial b_{t+1}} = \mathbb{E}_t M_{t,t+1}\eta\Big[v^1(z_{t+1}^*)f(z_{t+1}^*)\frac{\partial z_{t+1}^*}{\partial b_{t+1}} + \frac{1+(1-\tau)c}{1+\pi_{t+1}}F(z_{t+1}^*)\Big] \tag{21}$$

$$+\,\mathbb{E}_t M_{t,t+1}(1-\eta)\frac{(1-\tau)c}{1+\pi_{t+1}}$$

$$1 = j(b_{t+1},\mu_t^z) + \eta q_t^b b_{t+1} \tag{22}$$

The first term on the RHS of (21) represents the derivative of the future value of the firm if it is hit by the shock. The second term represents the derivative of the future value if the firm is not hit by the shock. The LHS shows marginal profits from issuing the bond. The conditions are derived using the envelope theorem. Equation (22) equates marginal costs and marginal benefits of investments.

The derivative of z_{t+1}^* with respect to b_{t+1} is given by[4]

$$\frac{\partial z_{t+1}^*}{\partial b_{t+1}} = \frac{1}{1+\pi_{t+1}}\left(c + \frac{1}{1-\tau}\right) \tag{23}$$

Replacing equation (22) into the value function (18) implies that

$$v^1(b_t,\mu_t^z) = (1-\tau)(R_t^k - z_t) + (1-\delta) + \tau\delta - ((1-\tau)c+1)\frac{b_t}{1+\pi_t} \tag{24}$$

Then by definition

$$j(b_{t+1},\mu_t^z) = \mathbb{E}_t M_{t,t+1}\int\Bigg[\eta\int_{\underline{z}}^{z_{t+1}^\star}(1-\tau)(R_{t+1}^k - z_{t+1}) + (1-\delta) + \tau\delta - ((1-\tau)c+1)\frac{b_{t+1}}{1+\pi_{t+1}} \tag{25}$$

$$+(1-\eta)(1-\tau)(R_{t+1}^k - z_{t+1}) + (1-\delta) + \tau\delta - ((1-\tau)c)\frac{b_{t+1}}{1+\pi_{t+1}}\Bigg]\,d\Phi^\mu(\mu_t) \tag{26}$$

[3]We calibrate the model so that there are no equity defaults, i.e., firms that are not hit by shock never default.

[4]Note that $j(b_{t+1},\mu_t^z)$ does not depends on z_t since this process is i.i.d.

2.4 Financial Intermediaries

There is a continuum of identical banks, or financial intermediaries, with unit measure. Each representative bank offers one period deposits, d_{t+1} to households at (real) price q_t^d and uses the proceeds to buy a perfectly diversified portfolio of corporate debt issues, b_{t+1}, valued at (real) price q_t^b. Deposits are perfectly insured so that $q_t^d = (1+\pi_{t+1})/(1+R_{t+1})$

At the beginning of every period, we define a bank's (real) net worth as the difference between the market value of its loan portfolio minus the value of its deposit liabilities:

$$nw_t = F_t^z(z_t^\star)[(1-\eta)(c+q_t^b)+\eta(1+c)]\frac{b_t}{(1+\pi_t)} + \eta\int_{z_t^\star}^{\bar{z}} \xi v_t^1 dF_t^z(z_t) - d_t \tag{27}$$

where the second term captures the impact of corporate defaults on the value of the banks assets (loans)

The bank's balance sheet constraint then requires that the market value of net new loan and deposits equals the retained net worth:

$$b_{t+1}q_t - d_{t+1}q_t^d = (1-\phi)nw_t \tag{28}$$

where, for simplicity, we assumed that banks always pay out a constant fraction, ϕ, of their net worth as dividends to their shareholders.

In addition, banks also face a leverage constraint which regulates the amount of risk-weighted deposits that banks can supply:

$$q_t^d d_{t+1} \leq \xi^d q_t b_{t+1} \tag{29}$$

As discussed by Elenev, Landvoigt, and Van Nieuwerburgh (2021), including market values ensures that we capture risk-weights in Basel-type leverage constraint.

Like firms, banks maximize shareholders' value, w, which obeys the Bellman equation

$$w(d_t, b_t, \epsilon_t) = \max_{d_{t+1}, b_{t+1}} \left[\phi \cdot nw_t - z_t^b + \mathbb{E}_t \int M_{t,t+1} \max\{w(d_{t+1}, b_{t+1}, \epsilon_{t+1}), 0\}\right] \tag{30}$$

where z_t^b is an exogenous shock to bank profits that with c.d.f $F_t^b(z^b)$ that has with time varying mean μ_t^b which follows a stationary AR(1) process:

$$\mu_t^b = \rho_b \mu_{t-1}^b + \sigma_b \epsilon_t^b \tag{31}$$

where ϵ_t^b is standard normal.

Equation (30) captures the fact that banks may also default strategically. In this case we assume the government seizes the bank , fully insures its depositors and resells the franchise to a new operator that resumes operations in the following period.

2.5 Monetary and Fiscal Policy Rules

In our baseline case, monetary policy is described by a standard interest rate feedback, i.e. "Taylor", rule

$$R_t = R_t^{*1-\rho_R} R_{t-1}^{\rho_R} e^{\sigma_M \epsilon_{R,t}} \tag{32}$$

where $\epsilon_{R,t}$ is a standard normal monetary policy shock and $R_t^\star$ is the target rate

$$R_t^\star = r(1+\pi^\star) \left(\frac{1+\pi_t}{1+\pi^\star} \right)^{\psi_1} \left(\frac{Y_t}{Y_t^\star} \right)^{\psi_2} \tag{33}$$

where r is the steady state real interest rate, $\pi^\star$ is the inflation target, and $Y_t^\star$ is the natural aggregate output level.

Fiscal authority consumes a fraction ζ_t of aggregate output, that is $G_t = \zeta_t Y_t$. We assume that $g_t = 1/(1-\zeta_t)$ follows a stationary AR(1) process

$$\ln g_t = (1-\rho_g) \ln g + \rho_g \ln g_{t-1} + \sigma_g \epsilon_{g,t} \tag{34}$$

where $\epsilon_{g,t}$ is standard normal.

2.6 Market clearing

The market clearing conditions are given by the following equations

$$Y_t = C_t + G_t + I_t + (1 - \xi)(1 - F(z_t^*))(\tau\delta K_t - I_t) \tag{35}$$

$$N_t = n_t \tag{36}$$

3 Model solution

We solve the model by using local perturbation methods.

The solution is significantly complicated by the recursive firm's problem. Specifically, we need to solve for j_t^*, v_t^1, v_t^0, and $\frac{\partial q_t}{\partial b_{t+1}}$. Note that q_{t+1} depends only on b_{t+1} and not b_{t+2}, because debtholders are done with firms once the debt is repaid. Hence, losses take place in the current period and are absorbed by debtholders. Therefore, we only need the expression for the price of the debt derivative to fully characterize the firm's problem.

We partly follow Gomes, Jermann, and Schmid (2016) and obtain the value of this derivative by solving the intermediates producing firms' problem (19)-(18) globally. This yields the optimal value, leverage and investment policies, as well as an expression for the default threshold and price of the debt. We define the survival c.d.f. as a cubic function of z:

$$\Phi(z) = \frac{1}{2} + \eta_1 z + \frac{1}{2}\eta_2 z^2 + \frac{1}{3}\eta_3 z^3 \tag{37}$$

where $\eta_2 = 0$ by symmetry and $\eta_1 = 0$ is chosen to ensure $\Phi(\bar{z}) = 1$.

Next we use interpolation to approximate the derivative, $\frac{\partial q_t}{\partial b_{t+1}}$ and express it as a quadratic function of leverage, b_{t+1} as well as linear function of the exogenous state variables. The R-squared from this approximation exceeds 99% and it does not increase further when we add higher order terms. Hence, we have all components of the firm problem to proceed with the local perturbations. Since the shocks in the full model occur only around the steady-state, the impact on the approximation parameters is minimal.

The tools deployed to solve the problems of other agents in the model are now well understood. Specifically, we aggregate prices and wages following the procedure described by Calvo (1983) and Christiano, Eichenbaum, and Evans (2005) and discussed in the detail in the Online Appendix.

To understand how monetary policy impacts the economy, we conduct a full welfare analysis. An important part of this has to do with the impact of the Taylor rule on volatilities. More aggressive inflation targeting can help households smooth their consumption and hence, decreases the volatility of consumption regardless of the mean. For that reason, we use a second order approximation, to express the welfare as a function of consumption, labor, and their volatilities. We then input respective impulse response functions to the second-order welfare function to compute welfare gains/losses from the shocks. This allows us to compare welfare losses for different monetary policy rules.

We compare monetary policy rules along three dimensions. First, we change the inflation sensitivity parameter, ψ_1. We consider values between 1 and 2 to satisfy the Taylor principle (Taylor (1993)). We alter the output gap parameter, ψ_2 and test values between 0.2 and 2. Finally, we propose an extended Taylor rule that includes corporate spreads following Curdia and Woodford (2010):

$$R_t^* = r(1+\pi^*)\left(\frac{1+\pi_t}{1+\pi^*}\right)^{\psi_1}\left(\frac{Y_t}{Y_t^*}\right)^{\psi_2}\left(\frac{sp_t}{sp^*}\right)^{-\psi_3} \tag{38}$$

where sp^* is a steady-state corporate spread. Spreads in the model are defined as $sp_t = 1/q_t^f - 1/q_t$ where q_t^f is a price of a risk-free bond with similar maturity (i.e. with probability η of the repayment shock and with $\Phi(\cdot) = 1$). The negative parameter implies that the central bank should tighten monetary policy when spreads are low. We test values of ϕ_3 from 0 (standard Taylor rule) and 1.

4 Calibration and estimation

We calibrate a number of parameters in the model and estimate the rest. The goal of estimation is to choose parameter values that match targeted moments well. We start by calibrating and then we use Bayesian methods to estimate the rest of the parameters given the calibrated ones. Table 1 shows values of the calibrated parameters. We calibrate the discount rate to $\beta = 0.99$ following the literature (Christiano, Eichenbaum, and Evans (2005); Smets and Wouters (2007); Gomes, Jermann, and Schmid (2016)). We pick corporate tax rate to be $\tau = 0.3$ consistent with the average post-crisis tax rate in the US.[5] Our choice of capital depreciation rate is $\delta = 2.5\%$ which is consistent with the literature (Christiano, Eichenbaum, and Evans (2005); Smets and Wouters (2007)). We follow Elenev, Landvoigt, and Van Nieuwerburgh (2021) and set $\phi_0 = 0.07$ and $\xi_d = 0.93$, i.e. banks pay 7% of their net worth to shareholders and their dividends cannot exceed 93% of risk-weighted assets. We choose Calvo price parameter $\gamma = 0.6$ to reflect that only 40% of firms can change their prices (Christiano, Eichenbaum, and Evans (2005)). We choose Calvo wage parameter $\gamma_w = 0.8$ to reflect that 20% of households can change the wage (Christiano, Eichenbaum, and Evans (2005)). Choice of $\gamma_w > \gamma$ is not random – wages should be stickier than prices to create sufficient inflation costs for households. Output aggregation parameter is equal to $\nu = 0.2$ consistent with the elasticity of substitution between goods sold by retailers equal to 5 as in Gertler and Karadi (2011) and Gomes, Jermann, and Schmid (2016). We pick the labor aggregation parameter to be equal to the output aggregation parameter. Consistent with Christiano, Eichenbaum, and Evans (2005) the choice of the parameter does not impact the model conclusions qualitatively but helps to match the moments better. We follow Clarida, Gali, and Gertler (2000) and Gomes, Jermann, and Schmid (2016) to calibrate the benchmark Taylor rule. We choose the inflation target to be $\pi^* = 0.005$, the inflation parameter to be $\psi_1 = 1.5$, and the output gap parameter to be $\psi_2 = 0.2$. We calibrate

[5]The number is bigger than 20% traditionally used in the literature (Gomes, Jermann, and Schmid (2016); Elenev, Landvoigt, and Van Nieuwerburgh (2021)) but it does better in matching key moments while not impacting qualitative results of the model.

the TFP process persistence and standard deviation by constructing Solow residuals. For that, we use data on GDP, hours, capital stock, and GDP deflator from FRED. We also calibrate the wage mark-up process persistence to be $\rho_w = 0.95$ and $\sigma_w = 0.004$. We calibrate monetary shock following Gomes, Jermann, and Schmid (2016). Finally, we set $\rho_B = 0.9$ and $\sigma_B = 0.07$ to match banking moments.

We estimate the rest of the parameters using Bayesian methods. Specifically, the set of parameters to be estimated includes capital share, risk aversion, labor disutility, labor elasticity, default distribution, costs of recovery, probability of being hit by a shock, and remaining exogenous process parameters. We propose prior distributions and initial values for all parameters. Then, we use the Blocked Metropolis-Hastings MCMC algorithm to first compute modes and tune scaling parameters and then to draw from the posterior distribution (Smets and Wouters (2003); An and Schorfheide (2007); Smets and Wouters (2007)).

We use four shocks – TFP, default, wage mark-up, and government spending. To identify the model, we can use up to four series from the data. We use output, labor share, corporate BAA spreads, and inflation from 1984 till 2008. We gather all series from FRED and detrend them. Trends are also estimated following Smets and Wouters (2007).

The analysis is complicated by the fact that we use value function iterations to approximate the derivative of the debt price. Hence, we employ the following strategy. We approximate the derivative based on initial values and obtain d_1 and d_2. Then we estimate the model and get new values for firm parameters. We use them to approximate the derivative again. We repeat the procedure until convergence on the parameter values. Then we use the obtained values as initial values and conduct the estimation again but this time also estimates d_1 and d_2. We also include the average default rate $\overline{Def}$ in the set of estimated parameters to confirm that its estimated value is close to the value obtained via VFI. We include TFP process parameters to the set of estimated parameters to later scale other processes to the TFP process since its parameters are reasonably calibrated

Table 1: Calibration of the Model

Parameter	Symbol	Value	Source
Preferences and taxes			
Discount rate	β	0.99	Smets and Wouters (2007)
Corporate tax rate	τ	0.3	Authors
Capital costs			
Depreciation rate	δ	0.025	Christiano et al. (2005)
Banks			
Dividend share	ϕ_0	0.07	Elenev et al. (2021)
Leverage constraint	ξ_d	0.93	Elenev et al. (2021)
Prices			
Calvo price parameter	γ	0.6	Christiano et al. (2005)
Output aggregation parameter	ν	0.2	Gertler and Karadi (2011)
Wages			
Calvo wage parameter	γ_w	0.8	Christiano et al. (2005)
Labor aggregation parameter	ν_w	0.2	Authors
Taylor rule			
Inflation target	π^*	0.005	Clarida et al. (2000)
Inflation parameter	ψ_1	1.5	Clarida et al. (2000)
Output gap parameter	ψ_2	0.2	Clarida et al. (2000)
Smoothing parameter	ρ_R	0.5	Clarida et al. (2000)
Exogenous processes			
TFP process persistence	ρ_a	0.95	Solow residuals
TFP process volatility	σ_a	0.007	Solow residuals
Mark-up shock persistence	ρ_w	0.95	Smets and Wouters (2007)
Mark-up shock volatility	σ_w	0.004	Smets and Wouters (2007)
Monetary shock persistence	ρ_m	0.85	Gomes et al. (2016)
Monetary shock volatility	σ_m	0.004	Gomes et al. (2016)
Bank shock persistence	ρ_a	0.9	Authors
Bank shock volatility	σ_B	0.07	Authors

Note: This table provides values of the calibrated parameters. All of them except for the labor aggregation parameter, tax rate, and productivity shock are taken from the literature. The labor aggregation parameter is chosen by the authors. As shown by Christiano, Eichenbaum, and Evans (2005) the value of that parameter does not impact the qualitative results of the model. We calibrate the TFP process parameters using Solow residuals that we construct using data on GDP, hours, capital stock, and GDP deflator. The calibration is based on quarterly data. The rest of the parameters are estimated.

in the reduced form.

Results of the estimation are shown in Table 2. We use priors that have been proposed by the literature on Bayesian estimation (Smets and Wouters (2003, 2007); An and Schorfheide (2007)). Specifically, we assume that the probability of being hit by shock, recovery cost, and persistence of the processes follow Beta distribution. Standard deviations of the processes follow inverse Gamma distribution. The rest of the parameters follow normal distribution. Modes and posterior means of the parameters are fairly close to the prior means. At the same time, posterior standard errors are small which means that parameters are identified. The average default rate is similar to the one obtained through VFI which confirms that the estimation process converged.

The risk aversion parameter is estimated to be equal to 2.31 which is slightly bigger than in the literature. The additional risk attitude might come from the deadweight losses due to firms' default. Capital share in the production function is equal to 0.31 – number consistent with New Keynesian literature. Labor elasticity and labor disutility are estimated to be 0.16 and 16.64, respectively.

We estimate that the probability of being hit by the shock that requires to repay the debt is 83% – this is close to the average maturity of the debt being between 1 and 2 years. $\xi = 0.61$ implies that debtholders keep 61% of the firm after the default – close to the reduced-form calibration of Elenev, Landvoigt, and Van Nieuwerburgh (2021). The debt price derivative constant and slope are fairly close to the values obtained through global methods.

Finally, we estimate exogenous processes. Default shock is less persistent and less volatile than TFP shock. That is because recessions happen more often than financial shocks in our sample – we consider the period before the 2008 crisis. The government spending process is slightly less persistent and as volatile as the TFP process since government spending is usually used to recover from the recession.

Table 2: Bayesian Estimation Results

		Prior distribution			Posterior distribution			
Parameter	Symbol	Distr.	Mean	St. Dev.	Mode	Mean	10%	90%
Preferences and production								
Risk aversion	κ	Normal	1.4	0.38	2.48	2.43	2.34	2.49
Labor elasticity	θ	Normal	0.1	0.02	0.057	0.06	0.056	0.066
Labor disutility	ζ_n	Normal	15	1.24	14.6	14.4	13.78	14.9
Capital share	α	Normal	0.33	0.01	0.31	0.318	0.316	0.32
Firm parameters								
Repayment rate	η	Beta	0.8	0.005	0.827	0.83	0.827	0.832
Recovery cost	ξ	Beta	0.4	0.02	0.51	0.5	0.5	0.51
Average default rate	$\overline{Def}$	Normal	0.023	0.001	0.024	0.024	0.024	0.024
Default distribution	η_1	Normal	0.47	0.002	0.476	0.473	0.472	0.474
Derivative constant	d_1	Normal	0.15	0.02	0.21	0.211	0.208	0.215
Derivative slope	d_2	Normal	-1.07	0.03	-1.052	-1.047	-1.052	-1.04
Exogenous processes								
Default persistence	ρ_{Def}	Beta	0.9	0.01	0.9	0.9	0.9	0.9
Default volatility	σ_{Def}	Gamma	0.007	0.008	0.004	0.004	0.004	0.005
Government persistence	ρ_g	Beta	0.95	0.005	0.93	0.931	0.93	0.932
Government volatility	σ_g	Gamma	0.007	0.019	0.006	0.006	0.006	0.006

Note: This table provides results of the Bayesian estimation of the model structural parameters obtained using Blocked Metropolis-Hastings MCMC algorithm. Columns 3-5 provide prior distribution, means, and standard deviations. Columns 6-9 show posterior mode, mean, and 90% confidence interval. Standard deviations and persistences of exogenous processes are estimated relative to the respective parameters of the TFP process.

5 Quantitative analysis

We solve the model using local perturbations based on the calibration and estimation discussed in Section 4. We use four stochastic processes in the benchmark analysis – TFP, inverse of government spending, wage stickiness, and default rates. We first show how the model estimation fits empirical moments. Next, we present how the model responds to the shocks. Finally, we conduct welfare analysis to understand if inclusion of financial conditions to the monetary policy rule is welfare-improving.

5.1 Aggregate moments

Table 3 compares aggregate HP-filtered moments from the model simulations to their data counterparts. We obtain macro data from St. Louis Fed FRED database, data on defaults from Moody's, and balance sheet data on leverage from Compustat. Panel A depicts first moments. The model produces the consumption-to-GDP ratio of 69% and investment-to-GDP ratio of 11%. Their data counterparts are 67% and 17%, respectively. Labor-to-GDP ratio in the model is 54% which is close to the actual number from the data – 59%. We exactly match pre-Covid inflation rate of 0.5% per quarter. Finally, the model predicts slightly higher spreads (1.59% as opposed to 1.19% in the data) and corporate market leverage (27% and opposed to 23% in the data) and slightly lower corporate default rates (1.6% as opposed to 2% in the data).

Panel B provides comparison between volatilities (relative to GDP) produced by the model and computed from the data. Generally, our model predicts lower volatilities than we see in the data, partly because we omit observations of crises – the times when volatilities are especially high. Specifically, volatilities of consumption and labor are half as large relative to volatility of output as in the data. The model poorly matches the volatility of investments because we keep the investment part of the model as simple as possible, i.e. do not include them in the household problem and do not have capital markets and adjustment costs.

Panel C shows correlations of the model variables with GDP. The model matched

Table 3: Aggregate Moments

	Description	Model	Data	Source
Panel A: First moments				
C/Y	Consumption to GDP	0.69	0.67	FRED
I/Y	Investment to GDP	0.11	0.17	FRED
N/Y	Labor to GDP	0.53	0.59	FRED
Sp	Credit spreads	1.59	1.19	FRED
π	Inflation	0.005	0.005	FRED
lev	Corporate market leverage	0.27	0.23	Compustat
Φ	Default rates	0.012	0.02	Moody's
Panel B: Second moments				
$\sigma(C)/\sigma(Y)$	Consumption to GDP	0.28	0.52	FRED
$\sigma(I)/\sigma(Y)$	Investment to GDP	5.83	4.23	FRED
$\sigma(N)/\sigma(Y)$	Labor to GDP	0.86	1.07	FRED
$\sigma(\pi)/\sigma(Y)$	Inflation to GDP	0.14	0.3	FRED
$\sigma(lev)/\sigma(Y)$	Leverage to GDP	1.33	1.03	Compustat
$\sigma(\Phi)/\sigma(Y)$	Default rates to GDP	0.15	0.42	Moody's
Panel C: Correlations				
$\rho(C,Y)$	Consumption with GDP	0.64	0.78	FRED
$\rho(I,Y)$	Investment with GDP	0.94	0.84	FRED
$\rho(N,Y)$	Labor with GDP	0.95	0.86	FRED
$\rho(\pi,Y)$	Inflation with GDP	0.77	0.53	FRED
Panel D: Auto-correlations				
Y	GDP	0.84	0.84	FRED
C	Consumption	0.81	0.83	FRED
I	Investment	0.86	0.81	FRED
N	Labor	0.85	0.89	FRED
π	Inflation	0.83	0.81	FRED

Note: This table provides aggregate moments in the model and data. The third column provides moments simulated and HP-filtered from the model. The fourth column shows moments from the pre-2019 data. Panel A contains first moments, Panel B – second moments, Panel C – correlations with GDP, and Panel D – serial auto-correlations. Data sources are mentioned in the last column.

correlations generally well. The correlation of consumption with GDP is 59% which is lower than 78% in the data. On the other hand, correlations of investments and labor with GDP are 92% and 95%,respectively – slightly larger than in the data (84% and 86%, respectively). Inflation in the model is correlated with GDP significantly more than in the data – partly because of the enforced Taylor rule without zero-lower bound. Finally, Panel D presents first-order auto-correlations. The model matches all of them very well.

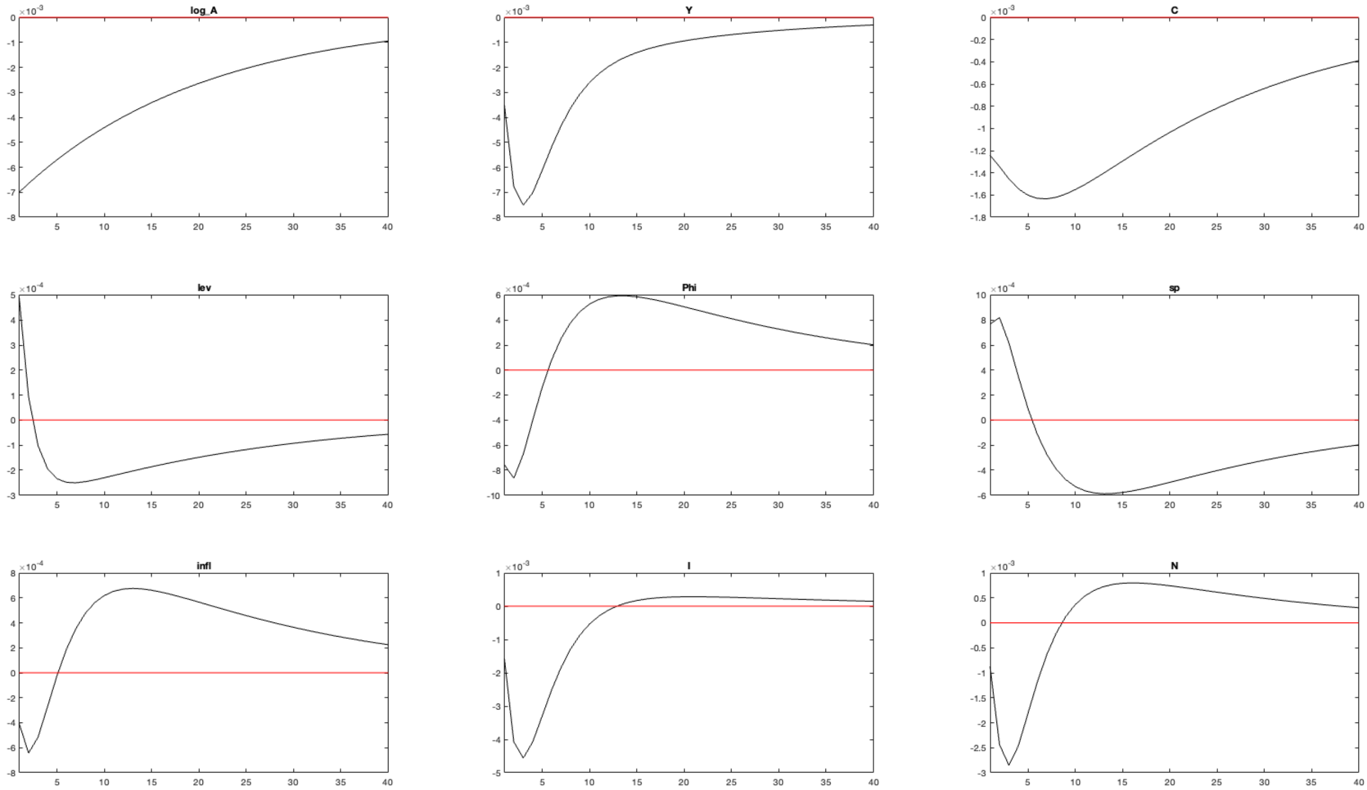
5.2 Stochastic simulations

We show the quantitative results of the model with sticky multi-period leverage and nominal rigidities. We start with the case of the standard Taylor rule given by (33). Impulse response functions to a one-standard-deviation negative productivity shock are depicted on Figure 2. Negative productivity shock leads to a drop in GDP, consumption, investments, and labor consistent with New Keynesian models. Since productivity drops, inflation also declines. Corporate leverage increases, because lower inflation and productivity make firms owe more – phenomenon that Gomes, Jermann, and Schmid (2016) call *sticky leverage*. Therefore, corporate spreads increase and default rates soar.

The effect of the productivity shock on GDP and consumption are persistent consistent with the consumption smoothing argument. The effects on investments, labor, and inflation are less persistent, potentially because corporate leverage increases. Firm variables also reverse back quickly. This is partly caused by high η – the probability of being hit by the shock. As Gomes, Jermann, and Schmid (2016) show, to get a persistently sticky leverage, one needs to model a nominal debt of a long maturity, whereas $\eta = 0.8$ is analogous to a medium-maturity bond.

Figure 3 shows IRFs to a one-standard-deviation default shock, i.e., when default rates increase unexpectedly. We find that output, consumption, investments, and labor drop significantly in response. This is caused partly by the fact that there are fewer firms to produce and partly by the dead-weight losses from firms' recoveries. Another consequence of the decreased production is a drop in inflation. Corporate leverage de-

Figure 2: Impulse Response Functions to a TFP Shock



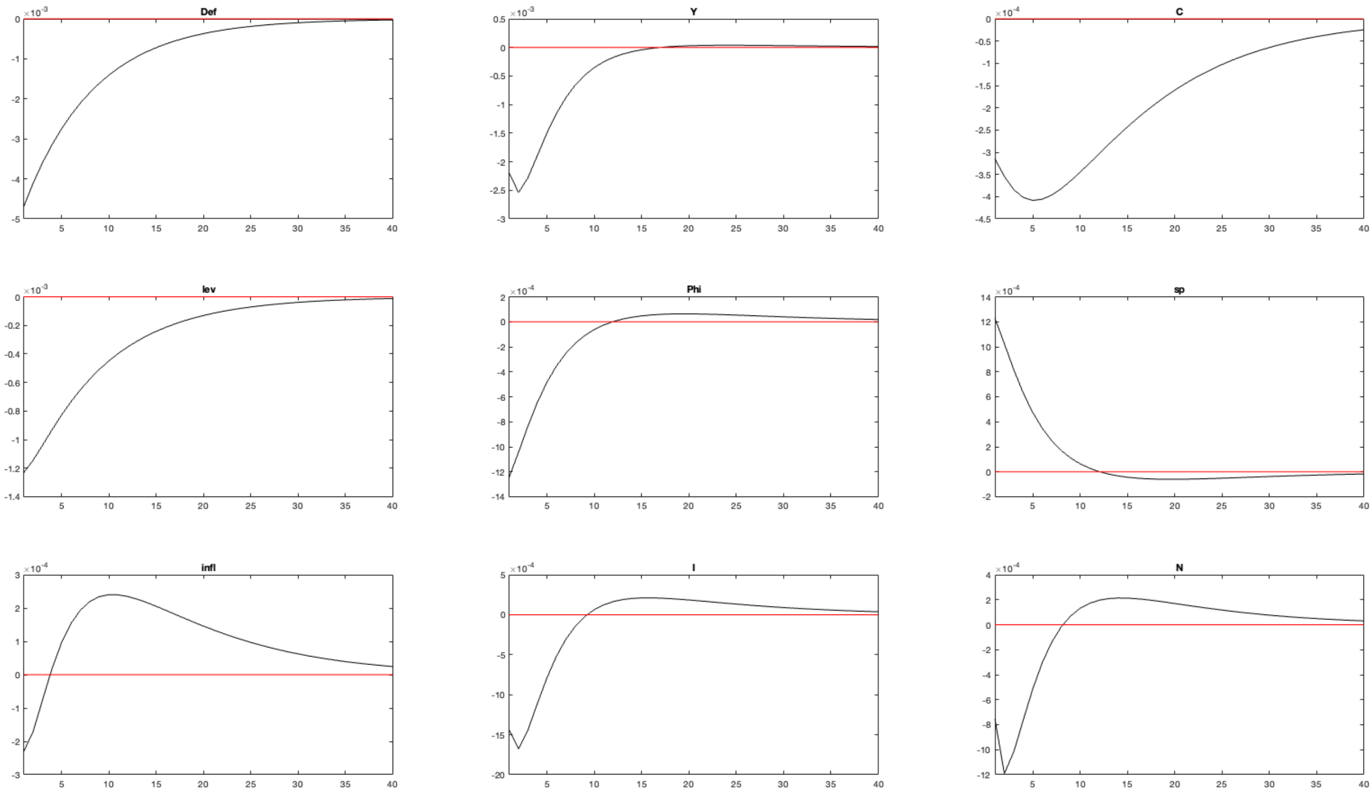
Note: This figure provides impulse response functions of the model key variables to one-standard-deviation negative productivity shock. The plots are obtained by first solving the model using first-order local perturbations around the steady-state and then by simulating the economy.

clines, because debt becomes too risky. This is clear from the IRF of the survival rate which shows that default rates increase. Finally, we see an increase in corporate spreads associated with an elevated riskiness of the debt.

Unlike in the case with TFP shock, firm variables change persistently. For example, corporate leverage reverses back only in 40 quarters. At the same time, consumption drop is as persistent as in the case of the TFP shock, indicating that the default shock is potentially as bad for households as the TFP shock.

Figure 4 shows IRFs to a wage stickiness shock, i.e., decrease in the share of labor unions that can change the wage each period. Sticky wages are costly for consumers since they keep them poor even when inflation rises. Hence, when wages become stickier,

Figure 3: Impulse Response Functions to a Default Shock

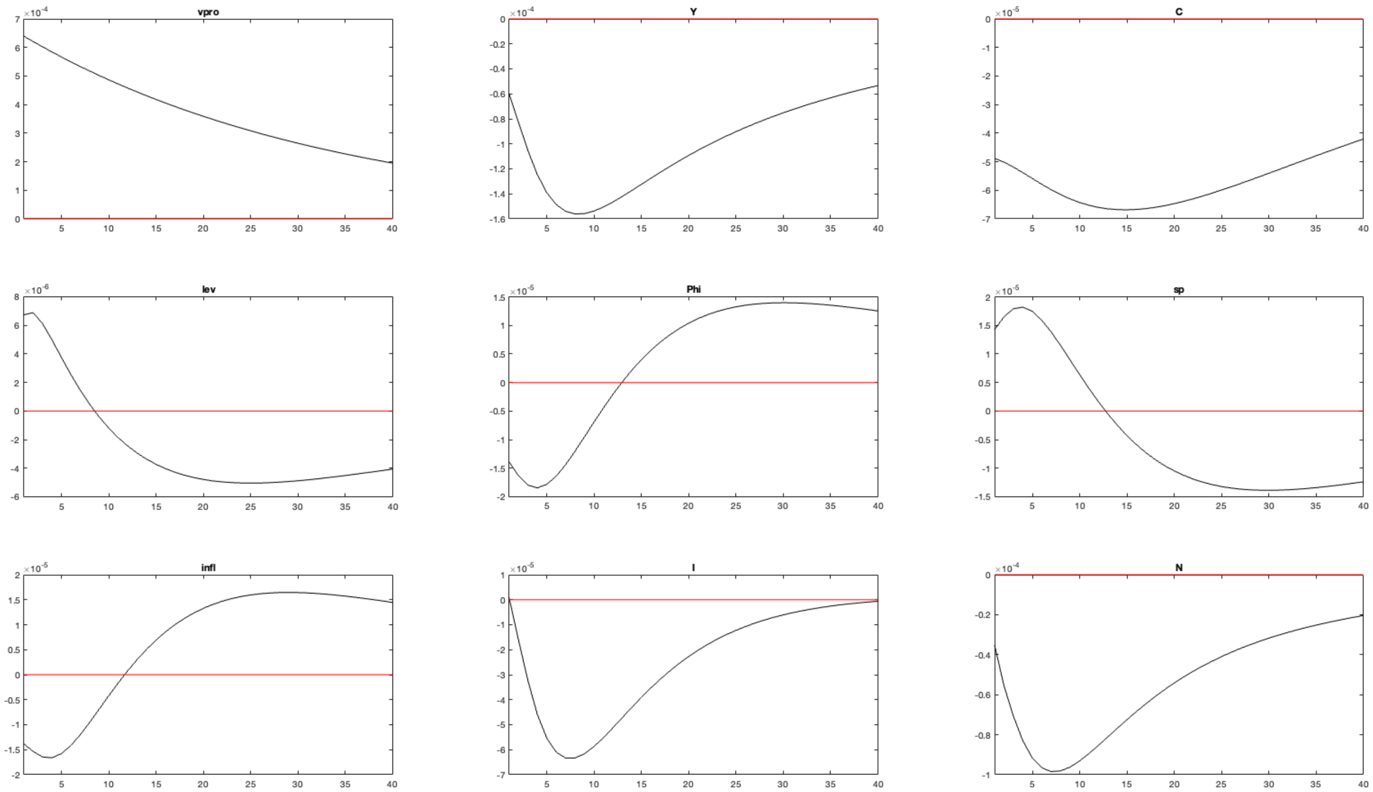


Note: This figure provides impulse response functions of the model key variables to one-standard-deviation positive default shock, i.e., unexpected increase in default rates. The plots are obtained by first solving the model using first-order local perturbations around the steady-state and then by simulating the economy.

consumption drops. Households also work less given lower wages – persistent drops in labor and output. As a result, investments and inflation drop. Since firms do not rely on investments in such environment, they borrow more – the model predicts an increase in corporate leverage and hence, elevated default rates and increased spreads. Notably, effects are more persistent than in the case with the TFP shock, although the absolute changes are smaller.

Finally, Figure 5 shows IRFs to a government spending shock – unexpected increase in government spending. Government spending is part of GDP, hence, we see a persistent increase in output and labor. As a result, inflation increases. Consumption and investments drop due to a substitution effect. Increased labor makes firms less depen-

Figure 4: Impulse Response Functions to a Wage Stickiness Shock



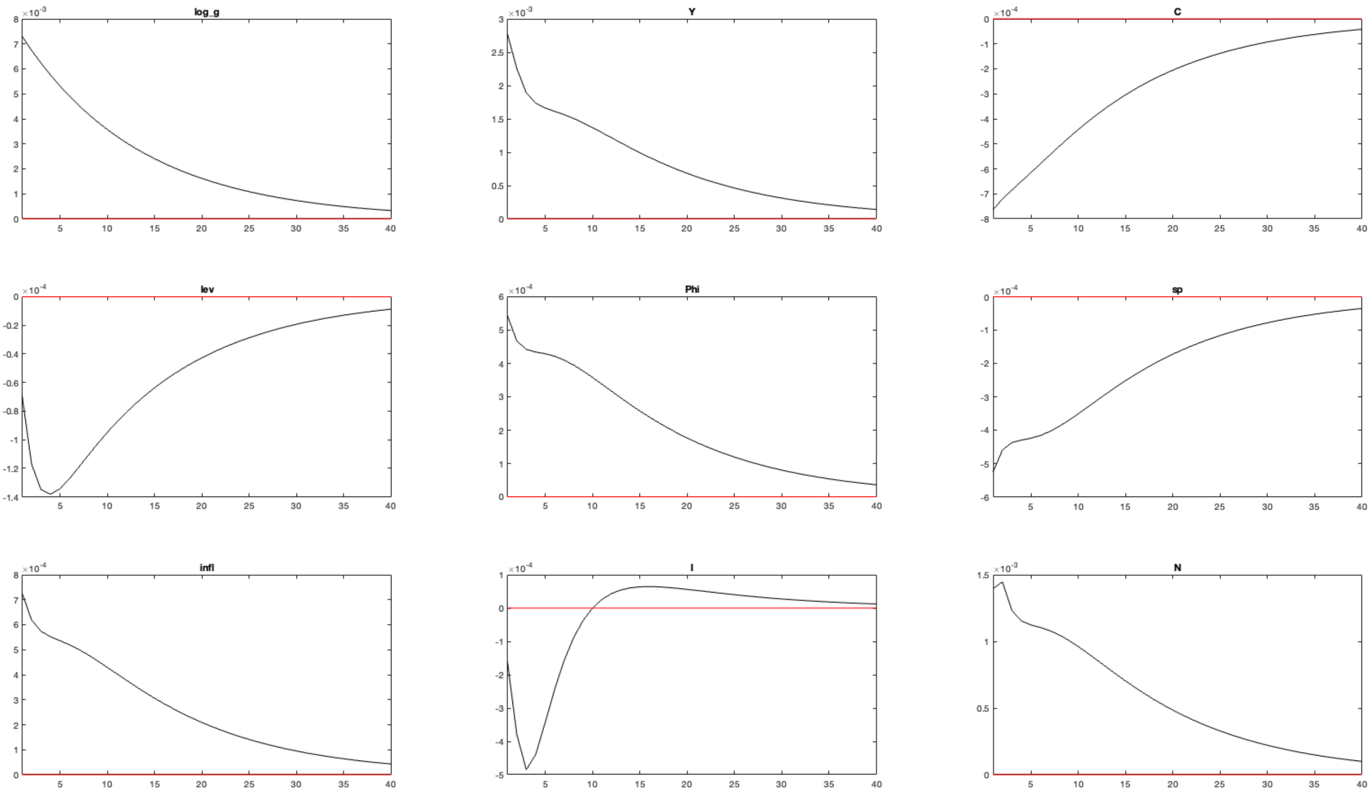
Note: This figure provides impulse response functions of the model key variables to one-standard-deviation wage stickiness shock. The plots are obtained by first solving the model using first-order local perturbations around the steady-state and then by simulating the economy.

dent on leverage – hence, corporate leverage drops, as well as default rates and corporate spreads. All effects are small relative to TFP and default shocks but at the same time, they are persistent.

The results above are with the standard Taylor rule that includes inflation and output gap. We now modify the Taylor rule by setting $\psi_3 = 0.1$. It means that if corporate spreads are 1 p.p. above their steady-state, policy rate should decrease by 10 b.p. We check how model responses to TFP and default shocks change when Taylor rule is modified.

Figure 6 shows the results for the negative productivity shock. First, since spreads are in the Taylor rule, they increase less in the case of the modified Taylor rule that in

Figure 5: Impulse Response Functions to a Government Spending Shock

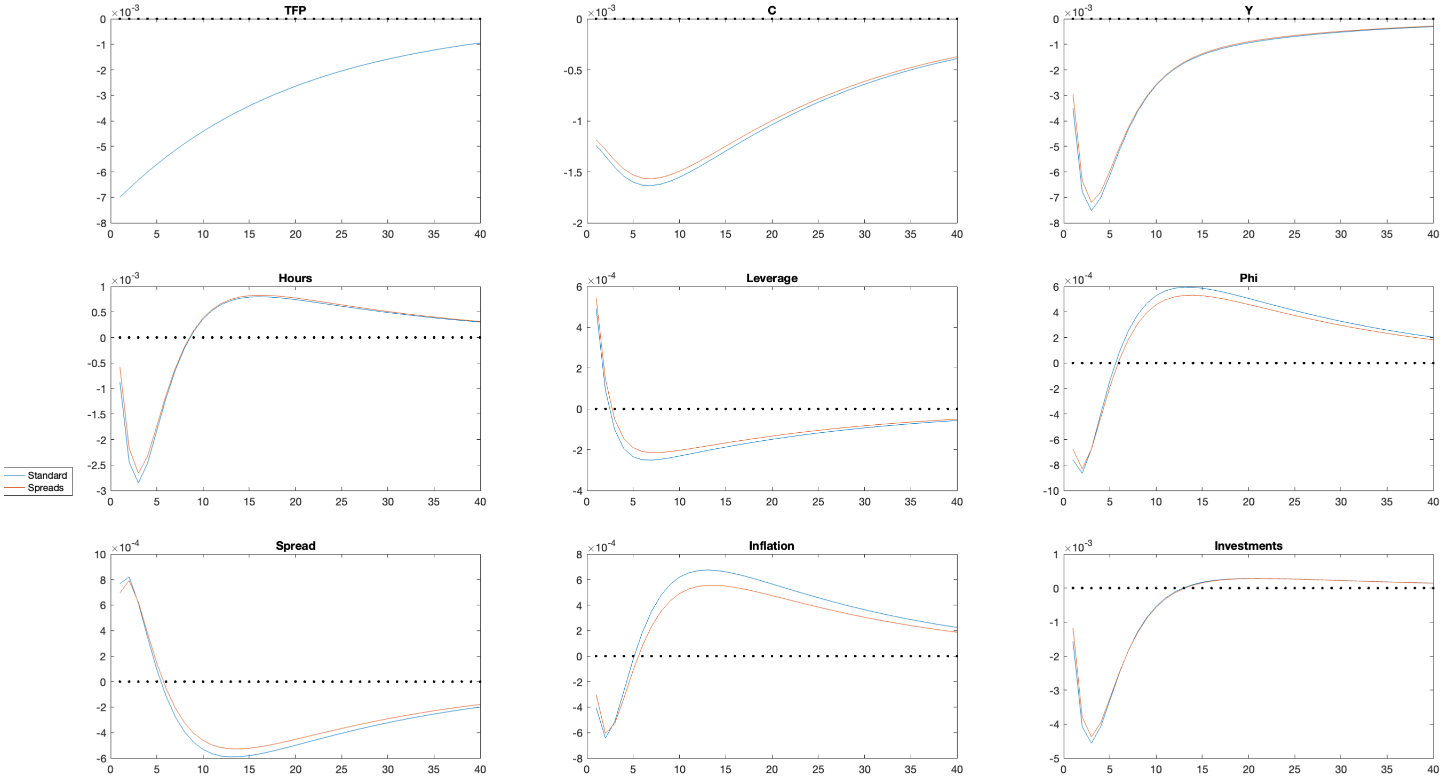


Note: This figure provides impulse response functions of the model key variables to one-standard-deviation positive government spending shock, i.e., unexpected increase in government spending. The plots are obtained by first solving the model using first-order local perturbations around the steady-state and then by simulating the economy.

the standard case, as well as, the default rates increase less with spreads in the utility function. More importantly, consumption, output, investments, and labor drop less with the modified rule. Hence, including spreads in the Taylor rule improves losses in real variables over time, potentially being welfare-improving. It is important to note that we do not yet consider other changes to the Taylor rule (e.g., increased output gap parameter), we will consider these scenarios in the next section.

Next, we compare IRFs to the default shock between the model with the standard Taylor rule and the model with the modified Taylor rule that includes corporate spreads. Figure 7 shows the results. As in the case with TFP shocks, including spreads in the Taylor rule leads to smaller drop in corporate leverage and less increase in spreads and

Figure 6: Impulse Response Functions to a TFP Shock with Standard and Modified Taylor Rules

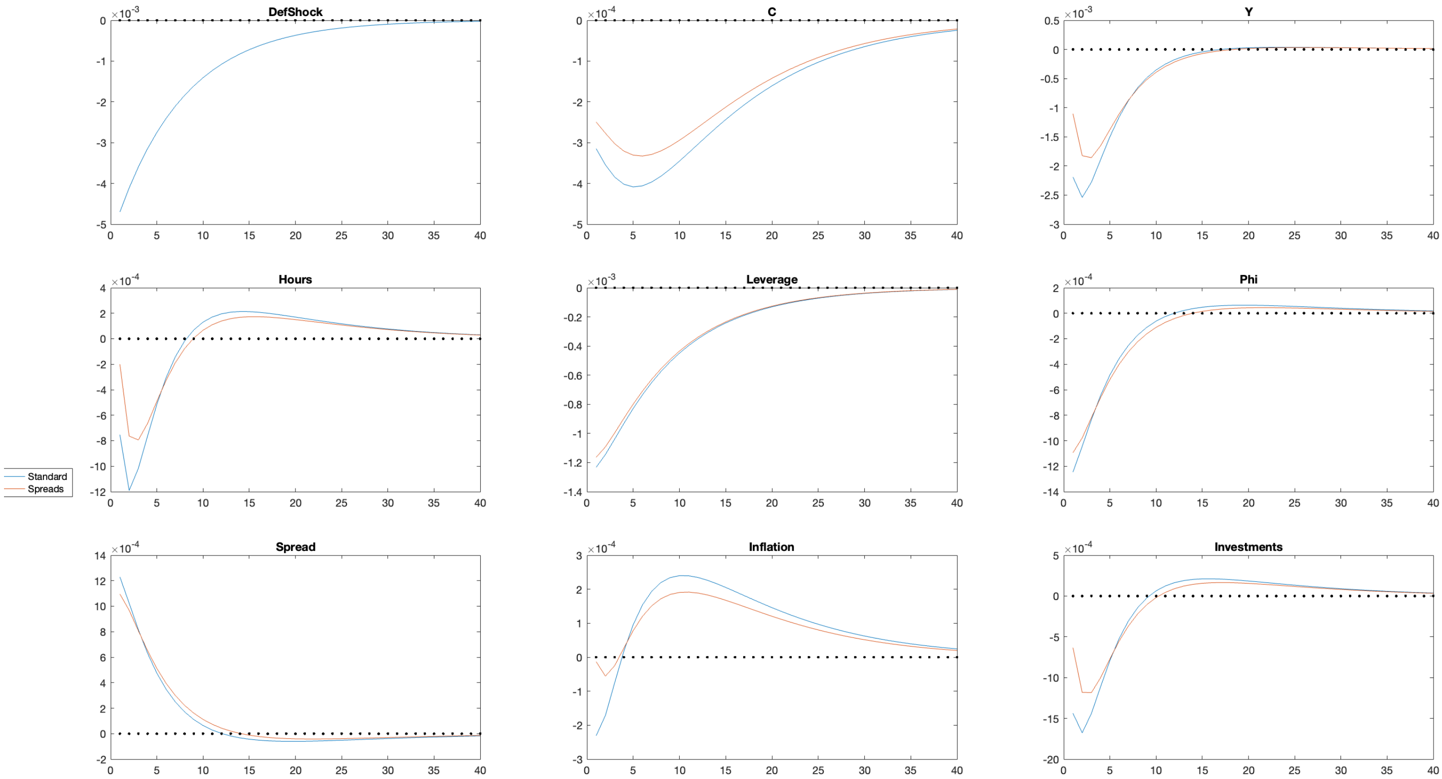


Note: This figure provides impulse response functions of the model key variables to one-standard-deviation negative productivity shock. Blue line shows IRFs in the case of the standard Taylor rule, while orange line corresponds to IRFs in the case of the modified Taylor rule that includes corporate spreads. The plots are obtained by first solving the model using first-order local perturbations around the steady-state and then by simulating the economy.

default rates. We then see an impact on real variables – consumption, output, investments, and labor drop less when spreads are includes in the policy rule than in the standard case. Moreover, the differentials are bigger when the economy faces the default shock than when it is hit by the TFP shock. For example, consumption drop due to the default shock is significantly smoothed, whereas consumption losses due to the TFP shocks are not very different.

Overall, the evidence in this section showed that including spreads in the Taylor rule mitigates the negative consequences of the shocks. However, it is not clear that the effects of including spreads are welfare-improving, since the analysis above does not

Figure 7: Impulse Response Functions to a Default Shock with Standard and Modified Taylor Rules



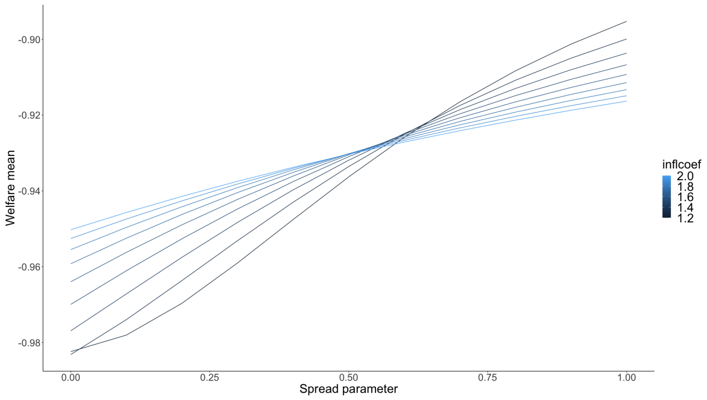
Note: This figure provides impulse response functions of the model key variables to one-standard-deviation positive default shock, i.e., unexpected increase in default rates. Blue line shows IRFs in the case of the standard Taylor rule, while orange line corresponds to IRFs in the case of the modified Taylor rule that includes corporate spreads. The plots are obtained by first solving the model using first-order local perturbations around the steady-state and then by simulating the economy.

take volatilities into account. In addition, it is possible that there are better ways to mitigate the consequences of the shocks by targeting inflation stricter or by increasing the weight of output gap in the Taylor rule. We conduct a formal welfare analysis in the next subsection.

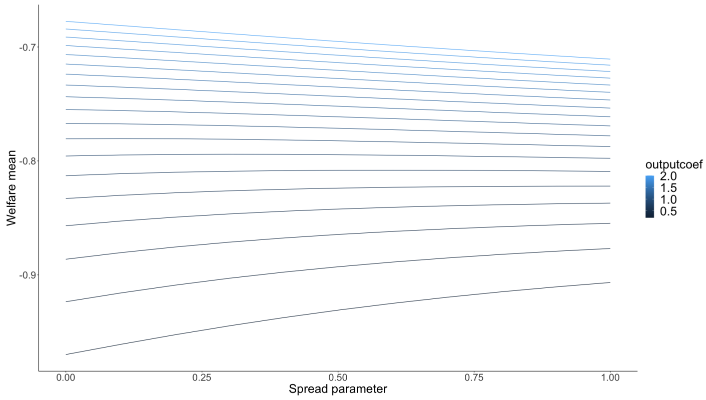
5.3 Welfare analysis

We compare welfare losses due to TFP and default shocks for different values of Taylor rule parameters. We change the value of inflation parameter from 1.1 to 2, the value of

Figure 8: Welfare Losses due to a Negative TFP Shock for Different Taylor Rule Parameters



(a) Inflation vs Spreads



(b) Output vs Spreads

Note: This figure provides welfare losses due to a negative productivity shock for different values of Taylor rule parameters. The welfare losses are obtained by taking a second-order Taylor approximation of households' welfare in the model. Panel (a) shows the welfare losses across different inflation and spread parameters, whereas Panel (b) shows the welfare losses across different output and spread parameters.

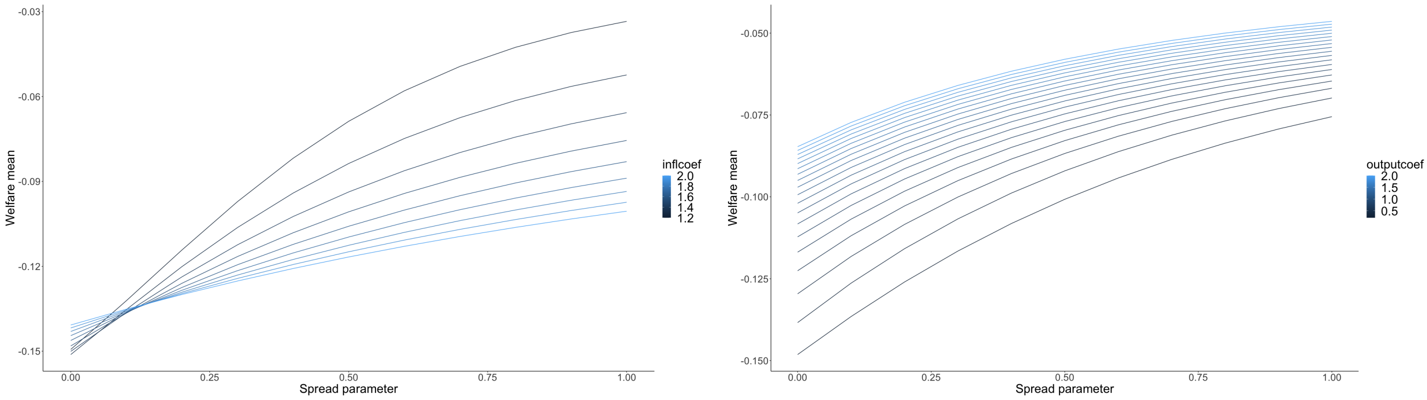
the output gap parameter from 0.2 to 2, and the value of the spread parameter from 0 to 1.

Figure 8 shows the results of the welfare analysis in response to a negative TFP shock. Panel (a) shows the welfare losses across different inflation and spread parameters. For low values of the spread parameter it is welfare improving to target both inflation and spreads but for higher values of the spread parameter targeting inflation is no longer welfare-improving. It shows that potentially central banks can pay more attention to financial markets than to prices even when they react to productivity shocks.

Panel (b) shows the welfare losses across different output and spread parameters. Although for low values of the output parameter, it is welfare-improving to include spreads, the first-best is to increase the output parameter without including spreads in the Taylor rule. This results speaks to the fact that targeting more variables distracts central banks from their main goal. In the case of recession, the main goal is to stabilize the economy – hence, central banks should stabilize the output gap, rather than increasing their attention to the financial markets.

Figure 9 shows the results of the welfare analysis in response to a shock that increases

Figure 9: Welfare Losses due to a Default Shock for Different Taylor Rule Parameters



(a) Inflation vs Spreads

(b) Output vs Spreads

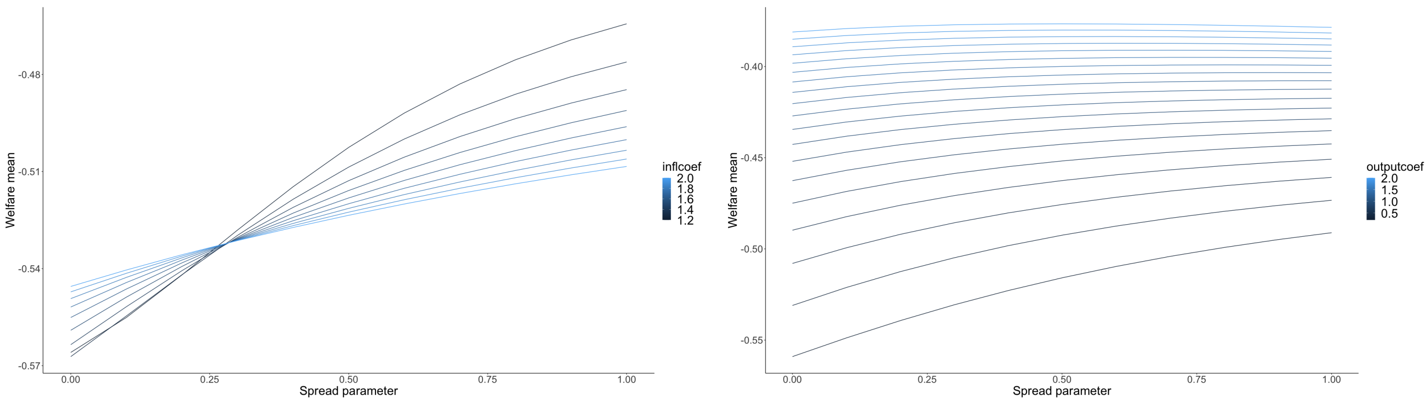
Note: This figure provides welfare losses due to a default shock for different values of Taylor rule parameters. The welfare losses are obtained by taking a second-order Taylor approximation of households' welfare in the model. Panel (a) shows the welfare losses across different inflation and spread parameters, whereas Panel (b) shows the welfare losses across different output and spread parameters.

the default rates of the economy. Not surprisingly, Panel (a) shows that it is always welfare-improving to target corporate spreads and even for low values of corporate spread parameter, it becomes beneficial to replace inflation with corporate spreads in the policy rule.

Panel (b) results indicate that when addressing the default shock, it is beneficial to increase both output and spread parameter in Taylor rule. The reason is that high defaults decrease production due to shortage or producers and recovery dead weight losses. We must note that the shortcoming of out analysis is that we do not model central bank costs of targeting different variables. Central bank can observe corporate spreads and inflation but observing and targeting output gap is difficult and imprecise. In addition, central bank has limited tools to affect the production – the only way to do it is through interest rate changes.

Finally, we treat the economy with both TFP and default shocks to compare them based on our estimation of the shocks. Figure 10 shows the results. First, it is always welfare-improving to include spreads in the Taylor rule when the economy is hit by both shocks, even though the volatility of the default shock is smaller than the volatility of the

Figure 10: Welfare Losses due to Negative TFP and Default Shocks for Different Taylor Rule Parameters



(a) Inflation vs Spreads

(b) Output vs Spreads

Note: This figure provides welfare losses due to both negative productivity and default shocks for different values of Taylor rule parameters. The welfare losses are obtained by taking a second-order Taylor approximation of households' welfare in the model. Panel (a) shows the welfare losses across different inflation and spread parameters, whereas Panel (b) shows the welfare losses across different output and spread parameters.

TFP shock. Second, for spreads parameters above 0.3, it is always beneficial to replace inflation target with targeting of corporate spreads.

Results in this section show that targeting spreads is welfare-improving if the economy is hit by the default shock. However, when the economy is hit by the negative TFP shock, it is beneficial to increase the output gap parameter rather than include spreads in the Taylor rule. We also find that for both TFP and default shocks, it is welfare-improving to stop targeting inflation and target corporate spreads instead but relatively aggressively. In the economy that is hit by both shocks, central banks benefit households by increasing the corporate spread parameter above 0.3 and removing the inflation target.

6 Conclusion

In this paper, we provide a theoretical evidence that including credit spreads to the monetary policy rule is welfare-improving when mitigating the impact of default shocks. We also show that including spreads increases welfare and mitigates the negative consequences even when the economy is hit by a negative productivity shock, but it is sub-optimal to increasing the weight of the output gap parameter in Taylor rule.

Our results have important implications for monetary policy. Since 2008 and especially during the Covid-19 recovery, the Fed was cautious in stabilizing inflation and output gap when credit spreads were high. We provide a rationale for considering corporate spreads in the policy rule and show welfare implications of such a policy.

References

An, S. and F. Schorfheide (2007). Bayesian Analysis of DSGE Models. *Econometric Reviews 26*(2-4), 113–172.

Aoki, K. (2003). On the Optimal Monetary Policy Response to Noisy Indicators. *Journal of Monetary Economics 50*(3), 501–523.

Bernanke, B., M. Gertler, and S. Gilchrist (1999). The Financial Accelerator in a Quantitative Business Cycle Framework. *Handbook of Macroeconomics 1*, 1341–1393.

Bhamra, H. S., A. J. Fisher, and L.-A. Kuehn (2011). Monetary Policy and Corporate Default. *Journal of Monetary Economics 58*(5), 480–494.

Calvo, G. A. (1983). Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics 12*(3), 383–398.

Carlstrom, C. and T. Fuerst (1997). Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. *The American Economic Review 87*(5), 893–910.

Chen, H. (2010). Macroeconomic Conditions and the Puzzles of Credit Spreads and Capital Structure. *The Journal of Finance 65*(6), 2171–2212.

Christiano, L., M. Eichenbaum, and C. Evans (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy 113*(1), 1–45.

Clarida, R., J. Gali, and M. Gertler (2000). Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. *The Quarterly Journal of Economics 115*(1), 147–180.

Clarida, R. and M. Gertler (1999). The Science of Monetary Policy : A New Keynesian Perspective. *XXXVII*(December), 1661–1707.

Cooley, T., R. Marimon, and V. Quadrini (2004). Aggregate Consequences of Limited Contract Enforceability. *Journal of Political Economy 112*(4), 817–847.

Curdia, V. and M. Woodford (2010). Credit Spreads and Monetary Policy. *Journal of Money, Credit and Banking 42*, 3–35.

Dobbie, W. and J. Song (2020). Targeted Debt Relief and the Origins of Financial Distress: Experimental Evidence from Distressed Credit Card Borrowers. *American Economic Review 110*(4), 984–1018.

Doepke, M. and M. Schneider (2006). Inflation and the Redistribution of Nominal Wealth. *Journal of Political Economy 114*(6), 1069–1097.

Elenev, V., T. Landvoigt, and S. Van Nieuwerburgh (2021). A Macroeconomic Model With Financially Constrained Producers and Intermediaries. *Econometrica 89*(3), 1361–1418.

Fernández-Villaverde, J. (2010). Fiscal Policy in a Model With Financial Frictions. *American Economic Review 100*(2), 35–40.

Fiore, F. D., P. Teles, and O. Tristani (2011). Monetary Policy and the Financing of Firms. *American Economic Journal: Macroeconomics 3*(4), 112–142.

Gertler, M. and P. Karadi (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics 58*(1), 17–34.

Giannoni, M. and M. Woodford (2003). Optimal Inflation Targeting Rules. Technical report, National Bureau of Economic Research, Cambridge, MA.

Gomes, J., U. Jermann, and L. Schmid (2016). Sticky Leverage. *American Economic Review 106*(12), 3800–3828.

Gomes, J. F. and L. Schmid (2021). Equilibrium Asset Pricing with Leverage and Default. *The Journal of Finance 76*(2), 977–1018.

Gourio, F. (2013). Credit Risk and Disaster Risk. *American Economic Journal: Macroeconomics 5*(3), 1–34.

Jermann, U. and V. Quadrini (2012). Macroeconomic Effects of Financial Shocks. *American Economic Review 102*(1), 238–271.

Kiyotaki, N. and J. Moore (1997). Credit Cycles. *Journal of Political Economy 105*(2), 211–248.

Krishnamurthy, A. and T. Muir (2017). How Credit Cycles across a Financial Crisis. Technical report, National Bureau of Economic Research, Cambridge, MA.

Mertens, T. M. and J. C. Williams (2021). What to Expect from the Lower Bound on Interest Rates: Evidence from Derivatives Prices. *American Economic Review 111*(8), 2473–2505.

Mian, A. and A. Sufi (2014). What Explains the 2007-2009 Drop in Employment? *Econometrica 82*(6), 2197–2223.

Orphanides, A. (2001). Monetary Policy Rules Based on Real-Time Data. *American Economic Review 91*(4), 964–985.

Orphanides, A. (2003). Monetary Policy Evaluation with Noisy Information. *Journal of Monetary Economics 50*(3), 605–631.

Reinhart, C. M. and K. S. Rogoff (2011). From Financial Crash to Debt Crisis. *American Economic Review 101*(5), 1676–1706.

Smets, F. and R. Wouters (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association 1*(5), 1123–1175.

Smets, F. and R. Wouters (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review 97*(3), 586–606.

Taylor, J. and J. Williams (2008). A Black Swan in the Money Market. Technical report, National Bureau of Economic Research, Cambridge, MA.

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

Woodford, M. (2001). The Taylor Rule and Optimal Monetary Policy. *American Economic Review 91*(2), 232–237.