Financial shocks, financial stability, and optimal Taylor rules*

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Abstract

We assess the performance of optimal Taylor-type interest rate rules, with and without reaction to financial variables, in stabilizing an economy following financial shocks. The analysis is conducted in a DSGE model with loan and bond markets, each featuring financial frictions. This allows for a wide set of financial shocks and transmission mechanisms and can be calibrated to match the bond-to-bank finance ratio featured in the US financial system. Overall, we find that monetary policy that reacts to credit growth, a form of the so-called "leaning against the wind", improves the ability of the central bank to achieve its mandate in the wake of financial shocks. The specific policy implications depend partly on the origin and the persistence of the financial shock, but overall not on the assignment of a mandate for financial stability in the central bank's objective function.

Keywords: financial shocks, financial stability, optimal Taylor rules, DSGE model, bond market, loan market

JEL codes: E32, E44, E52

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1 Introduction

The global financial crisis reignited the debate on whether monetary policy should "lean against the wind", *i.e.* whether central banks should react to financial variables in addition to expected inflation and output (see *e.g.* Adrian and Shin, 2010, Mishkin, 2011, Blanchard et al., 2013, Borio, 2014b, and Stein, 2014a). First, as the transmission of stimulative policy is hampered during severe and long recessions associated with financial disruptions (Cerra and Saxena, 2008, Reinhart and Rogoff, 2009, Claessens et al., 2012, and Gulan et al., 2014), the argument has arisen that monetary policy should lean against financial booms to avoid being overburdened during busts (see *e.g.* Borio, 2014b). Second, as frictions and shocks in the financial sector are important sources of business cycle fluctuations (see *e.g.* Gerali et al., 2010, Gilchrist and Zakrajsek, 2012a, Jorda et al., 2013, Christiano et al., 2014 and Kaihatsu and Kurozumi, 2014), it has increasingly been argued that policymakers should take financial factors into account. Hence, a thread of research has emerged on appropriate monetary policy reactions to financial shocks (see *e.g.* de Fiore et al., 2011, Davis and Huang, 2013, and Angelini et al., 2014), in addition to the standard analyses of optimal monetary policy responses to technology or cost-push shocks.

At least in the case of the US, there is substantial empirical evidence that the central bank has often, and sometimes systematically, reacted to changes in financial variables (see *e.g.* Lubik and Schorfheide, 2007, Castelnuovo and Nistico, 2010, Furlanetto, 2011, Castelnuovo, 2013, Finocchiaro and von Heideken, 2013, and Galí and Gambetti, 2015). There is no consensus, however, on whether "leaning against the wind" (LATW) effectively improves the outcome of monetary policy. Some papers find that LATW allows for substantial macroeconomic stabilization or social welfare gains relative to standard Taylor-type policy rules (see *e.g.* Curdia and Woodford, 2010, Gilchrist and Zakrajsek, 2012b, Nistico, 2012, de Fiore and Tristani, 2013, Davis and Huang, 2013, Finocchiaro and von Heideken, 2013, Andrés et al., 2013, Gambacorta and Signoretti, 2014, Adrian and Duarte, 2016, and Adrian and Liang, 2017). Others find no significant gains when financial variables are included in monetary policy rules (see *e.g.* Iacoviello, 2005, Faia and Monacelli, 2007, Gelain et al., 2013, Svensson, 2014, 2016, and Melina and Villa, 2015). Still others find that the impact of LATW depends on a number of factors such as the financial variable included in the policy rule (see *e.g.* Quint and Rabanal, 2014), the uncertainty about the probability and the severity of the financial crisis (see *e.g.* Ajello et al., 2016), the nature of the underlying disturbance and the financial variable included in the central bank's objective function (see *e.g.* Hirakata et al., 2013).

Discussion of the optimality of LATW is obviously model-dependent and the theoretical research has been conducted using three alternative macroeconomic models with financial frictions. The first model augments the workhorse New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) model of Smets and Wouters (2003) with a debt-

contracting framework of Townsend (1979) (*e.g.* Christiano et al., 2014). The second introduces financial frictions in the form of constrained borrowers (households or entrepreneurs) into the NK DSGE model of Woodford (2003) (*e.g.* Iacoviello, 2005 and Curdia and Woodford, 2010). The third model enhances the second model with monopolistic competition in the banking sector (*e.g.* Gerali et al., 2010). The specific model setup determines the nature of the financial shocks that can be analyzed. For example, the first model is suitable for excess bond premium shock as in Gilchrist and Zakrajsek (2012a) and risk shock as in Christiano et al. (2014). Shocks to the interest rate spread between patient and impatient agents in Curdia and Woodford (2010) arise in the second and third models. The third model setup is also appropriate for shocks originating in the banking sector as in Gerali et al. (2010).

While these models feature a single mechanism of financial intermediation, and thus a limited set of financial frictions and shocks, modern financial systems typically feature market (bond) finance alongside banking finance. In particular, the US economy has a largely market-based financial system, with a sizable fraction of (large) firms obtaining finance directly through issuing securities rather than resorting to traditional banking finance. This is documented in Figure 1. In the US between 1952:I and 2013:IV, the bond-to-bank finance ratio remained well above one, and, if anything, has trended upward since the late 1960s. As Woodford (2010) puts it, US macroeconomic and monetary policy analysis need a framework that accounts for the fact that the US financial sector is largely market-based.

Against this background, this paper contributes to the debate about the desirability of LATW in an environment of financial frictions and shocks that considers the dual composition of the US financial sector and is adequately calibrated to match the bond-to-bank finance ratio in the US economy. We use the model developed by Verona et al. (2013), which features both a loan market, modeled along the lines of the Bernanke et al. (1999) financial accelerator mechanism that provides financing to small entrepreneurs, and a bond market, populated by monopolistic competitive investment banks in the spirit of Gerali et al. (2010), that provides financing to large entrepreneurs.

Our key research question is whether augmenting the Taylor-type monetary policy rule with a reaction of the policy interest rate to financial variables can improve macroeconomic stabilization following financial shocks. In particular, the structure of our model makes it possible to assess the performance of alternative policy rules in reaction to two financial shocks, one arising in the bond market and the other in the loan market, that affect the borrowing costs of different entrepreneurs. The bond spread shock (calibrated according to the US corporate bond spread data) is akin to the measure of financial distress (a component of the corporate bond spread that measures the pricing of overall default risk) suggested and used by Gilchrist and Zakrajsek (2012a). The loan shock resembles the risk shock suggested and used by Christiano et al. (2014). Furthermore, we assess the performance of alternative policy rules when the economy is affected simultaneously by both shocks, which is closer to the case of real-world policymakers

dealing with multiple, hard-to-disentangle shocks.

Our approach may be summarized as follows. Given a specific central bank's objective function (in terms of a loss function), we find the coefficients of a benchmark Taylor rule (forward-looking on inflation and including interest-rate smoothing) that minimizes the objective function following a financial shock. Next, we find the coefficients of Taylor rules augmented with financial variables that minimize the same loss function. Finally, we compare the losses under the benchmark Taylor rule and the various augmented Taylor rules. The structure of our model allows us to consider financial variables in the augmented Taylor rules that are related to both segments of the financial system and in line with the nature of the shocks analyzed. In the case of a bond shock, for example, we consider rules alternatively augmented with the rate of credit growth (the stock of bonds issued and loans granted), with the deviation of the bond spread from its steady-state level, as well as with both credit growth and bond spread deviations. In the case of the loan shock, we examine rules alternatively augmented with the rate of credit growth, the deviation between the loan spread and its steady-state level, as well as credit growth and loan spread deviations together.

Note that we do not allow monetary policy to react to asset prices. This is in keeping with the recent literature showing that excessive credit is the best predictor of financial crises in the current financial era, which is characterized by a decoupling of credit from money (Schularick and Taylor, 2012), and that the severity of recessions is systematically related to the intensity of the build-up of excessive leverage (excessive credit growth relative to GDP) during the preceding expansion (see *e.g.* Jorda et al., 2013, 2015). Our choice is further motivated by the fact that credit-driven bubbles seem easier to monitor and predict than asset price bubbles (see *e.g.* Adrian and Shin, 2010). This is thus consistent with the modern approach of defining financial stability in terms of risk, spreads, credit, and leverage (see *e.g.* Gertler and Kiyotaki, 2010 and Curdia and Woodford, 2010).

The second main contribution of this paper is that it addresses the case where the central bank's loss function explicitly includes a financial stability target in addition to targeting inflation and output stability. Such analysis is motivated by a strand of literature that advocates for assigning the central bank a specific mandate of financial stability to prevent financial crises or reduce their ex-post severity (Reis, 2013). This is consistent with recent papers showing that, in models with financial frictions, a financial stability concern arises as an additional independent target in the central bank's objective function and is welfare-improving (see *e.g.* Carlstrom et al., 2010, Andrés et al., 2013, de Fiore and Tristani, 2013, and Nistico, 2016).

An alternative strand of literature considers separate monetary and macroprudential policy authorities, but such analysis is beyond the scope of this paper as our model does not include a macroprudential policy authority or

instruments such as loan-to-value limits or capital requirements. Notably, some theoretical papers find little role for monetary policy in achieving financial stability (see *e.g.* Alpanda and Zubairy, 2016). Moreover, even in the presence of a risk-taking channel of monetary policy that creates an effect of monetary policy on financial stability, optimal policy can still be implemented by assigning a financial-stability mandate to the macroprudential authority and a macroeconomic-stability mandate to the monetary authority (see *e.g.* Collard et al., 2017). Even so, there is no consensus about institutional frameworks (authorities, instruments, targets, etc.) and the extent to which monetary and macroprudential policy should be separated or interlinked. Several authors argue that financial stability should be strictly allocated to macroprudential policy as the costs of using monetary policy for financial stability either outweighs the benefits (see *e.g.* Svensson, 2014, 2016) or the effects are negligible (see *e.g.* Benes and Kumhof, 2011). Others argue that a financial stability objective in monetary policy is useful because of its encompassing nature (the ability to "get in all of the cracks" and reach corners that supervision and regulation cannot, see *e.g.* Stein, 2014b), because macroprudential policy faces long implementation lags (Adrian et al., 2015), is leaky (Aiyar et al., 2014), fails to avoid extreme circumstances of financial stress that must be dealt with monetary policy (Cecchetti, 2016), or is redundant when monetary policy reacts to financial variables (Rubio and Carrasco-Gallego, 2015). Still others suggest that the relevance of macroprudential policy relative to a monetary policy with a concern for financial stability depends on the nature of shocks (see *e.g.* Kannan et al., 2012 and Quint and Rabanal, 2014), or the interaction and coordination of both policies (see *e.g.* Angelini et al., 2014 and Gelain and Ilbas, 2017). A few authors emphasize the complementarity between monetary and macroprudential policy (see *e.g.* Brunnermeier and Schnabel, 2015, Bruno et al., 2015, and Cecchetti, 2016). Reviewing the theoretical and empirical literature, Smets (2014) argues that financial stability should be an explicit objective of monetary policy, provided that price stability remains the primary objective of policy and financial stability follows in a lexicographic ordering to avoid financial dominance (*i.e.* risks of loss of independence, credibility, and time-inconsistency problems arising from trade-offs between macro and financial stabilization).

Because we i) simulate the effects of two financial shocks, ii) compare the benchmark Taylor rule with up to four alternative Taylor-type rules augmented with financial variables, and iii) assess stabilization gains in the context of five alternative central bank loss functions, we obtain a rich set of results. The main lessons can be summarized in five points.

- Following financial shocks, a LATW policy overall improves the ability of the monetary policymaker to achieve its mandate.
- Those gains overall do not depend on the inclusion of an explicit target for financial stability (*i.e.* credit

growth volatility) in the central bank's objective function.

- Responding to aggregate credit growth is consistently more effective than responding to financial spreads. A reaction of policy to the quantity of credit systematically generates larger gains than a reaction to the price of credit.
- The scope for improving the attainment of the central bank's mandate through LATW is overall larger when the economy is affected by a shock in the bond market than when it is affected by a shock in the loan market.
- The case for LATW increases with the persistence of the financial shock that affects the economy.

The rest of the paper is organized as follows. In section 2, we present the main features of our model and describe the two financial shocks that cause fluctuations in our simulations. In section 3, we describe our augmented Taylor rules, the method used to assess their performance, present the results, and provide some sensitivity analyses. Section 4 concludes.

2 The model

Figure 2 sketches the structure of the model. We follow Verona et al. (2013) who, in a nutshell, introduce a bond market into the Christiano et al. (2014) model, which in turn introduces a loan market (modeled along the lines of the Bernanke et al., 1999 financial accelerator mechanism) into a standard NK DSGE framework (*e.g.* Smets and Wouters, 2003 and Christiano et al., 2005).

The economy is composed of households, final- and intermediate-good firms, capital producers, entrepreneurs, banks, and government. Households consume, save, and supply labor services monopolistically. They allocate their savings between time deposits and corporate bonds.[1] On the production side, monopolistically competitive intermediate-good firms use labor (supplied by households) and capital (rented from entrepreneurs) to produce a continuum of differentiated intermediate goods. Perfectly competitive final-good firms buy intermediate goods and produce the final output, which is then converted into consumption, investment, and government goods. Capital producers combine investment goods with undepreciated capital purchased from entrepreneurs to produce new capital, which is then sold back to entrepreneurs. Entrepreneurs own the stock of physical capital and rent it to intermediate-good firms. They purchase capital using their own resources and external finance sources (bank loans or bonds issuance). Government expenditures represent a constant fraction of final output. These are financed through lump-sum taxes on households and the government budget is systematically balanced.

[1] The return on corporate bonds equals the return on time deposits, which in turn is equal to the central bank nominal interest rate.

The central bank sets the nominal interest rate according to Taylor-type interest rate rules. Equation (1) is the benchmark Taylor rule (BTR), which, as usual, includes interest-rate smoothing and responses of the nominal interest rate to deviations in expected inflation ($E_t\pi_{t+1}$) and current output from their steady states:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) \right] \ , \tag{1}$$

where R^e, $\bar{\pi}$ and $\bar{Y}$ are the steady-state values of R_t^e, π_t and Y_t, respectively, ϕ_π is the coefficient associated to expected deviations of inflation from the target, ϕ_y is the one associated to the output gap, and $\tilde{\rho}$ captures interest-rate smoothing. When analyzing the benchmark impulse response functions, we follow a standard calibration in the literature also used by Verona et al. (2013) and set $\tilde{\rho} = 0.88$, $\phi_\pi = 1.82$ and $\phi_y = 0.11$.

In the following subsections, we describe the financial system of the model. Because the remaining part is standard in the literature, we present that material in the online appendix.

2.1 The financial system

The financial system intermediates the flow of resources from households to entrepreneurs, who finance purchases of physical capital that exceeds their net worth. The financial system has two financial markets (a bond and a loan market), each with financial intermediaries (investment and retail banks) that intermediate financial flows (underwriting bonds and granting loans) between households (lenders) and two groups of entrepreneurs (borrowers). Each group of entrepreneurs has access to one source of external funding. Following the corporate finance literature (see *e.g.* Repullo and Suarez, 2000 and Bolton and Freixas, 2006), we assume that small (usually riskier) entrepreneurs obtain financing via retail bank loans, while large (usually safer) entrepreneurs have access to bond financing and issue bonds via investment banks.

To replicate the financial structure of the US economy, we calibrate the model so that the weight of bond finance is larger than that of bank finance. Following de Fiore and Uhlig (2011), we set the bond-to-bank finance ratio at 1.52. To do so, we calibrate the share of small entrepreneurs η (with large entrepreneurs representing the remaining fraction $1-\eta$) so as to match such bond-to-bank finance ratio in the steady state, just as in Verona et al. (2013). In what follows, the superscripts "L" ("S"), and "L, l" ("S, s") refer to variables associated with large (small) entrepreneurs.

2.1.1 The bond market

The large entrepreneur's profit maximization problem

At the beginning of period t, the representative l-th large entrepreneur determines the utilization rate, $u_t^{L,l}$, of its effective capital ($\bar{K}_t^{L,l}$) and supplies to intermediate-good firms an amount of capital services, $K_t^{L,l} = u_t^{L,l}\bar{K}_t^{L,l}$ for a competitive rental rate denoted by $r_t^{k,L}$. To choose the utilization rate, the entrepreneur faces an utilization cost function $a\left(u_t^{L,l}\right)$ that denotes, in units of final goods, the cost of setting the utilization rate to $u_t^{L,l}$.[2]

At the end of period t, the entrepreneur sells the undepreciated capital to capital producers at price $Q_{\bar{k}',t}$, pays the nominal coupon rate (R_t^{coupon}) on bonds issued, and buys new capital from capital producers at price $Q_{\bar{k}',t}$. To finance the difference between capital expenditures ($Q_{\bar{k}',t}\bar{K}_{t+1}^{L,l}$) and his net worth ($N_{t+1}^{L,l}$), the entrepreneur issues an amount $BI_{t+1}^{L,l}$ of bonds given by

$$BI_{t+1}^{L,l} = Q_{\bar{k}',t}\bar{K}_{t+1}^{L,l} - N_{t+1}^{L,l} \quad . \tag{2}$$

The entrepreneur's time-t profits, $\Pi_t^{L,l}$, are given by:

$$\begin{aligned}\Pi_t^{L,l} = &\left[u_t^{L,l}r_t^{k,L} - a\left(u_t^{L,l}\right)\right]\bar{K}_t^{L,l}P_t + (1-\delta)\,Q_{\bar{k}',t}\bar{K}_t^{L,l} \\ &-Q_{\bar{k}',t}\bar{K}_{t+1}^{L,l} - R_t^{coupon}\left(Q_{\bar{k}',t-1}\bar{K}_t^{L,l} - N_t^{L,l}\right) \qquad ,\end{aligned}$$

where P_t is the price of the final good and δ the depreciation rate.

In period t, the entrepreneur chooses the capital utilization rate and the desired capital to use in period $t+1$ so as to maximize $\Pi_t^{L,l}$. The first order conditions with respect to $u_t^{L,l}$ and $\bar{K}_{t+1}^{L,l}$ are, respectively:

$$r_t^{k,L} = a'\left(u_t^{L,l}\right) \tag{3}$$

$$Q_{\bar{k}',t} = \beta E_t\left\{\left[u_{t+1}^{L,l}r_{t+1}^{k,L} - a\left(u_{t+1}^{L,l}\right)\right]P_{t+1} + (1-\delta)\,Q_{\bar{k}',t+1} - R_{t+1}^{coupon}Q_{\bar{k}',t}\right\} \quad . \tag{4}$$

Equation (3) states that the rental rate on capital services equals the marginal cost of providing those services. The capital Euler equation (4) equates the value of a unit of installed capital at time t to the expected discounted return of that extra unit of capital in period $t+1$.

[2] Following Christiano et al. (2014), we assume that $a\left(u_t^{L,l}\right) = \frac{r^{k,L}}{\sigma_a^L}\left[\exp^{\sigma_a^L\left(u_t^{L,l}-1\right)} - 1\right]$, where $r^{k,L}$ denotes the steady-state real rental rate of capital, $a(1) = 0$, $a''(1) > 0$ and $\sigma_a^L = a''(1)/a'(1)$ controls the degree of convexity of costs.

The entrepreneur's equity at the end of period t, $V_t^{L,l}$, is given by

$$V_t^{L,l} = \left\{ \left[u_t^{L,l} r_t^{k,L} - a\left(u_t^{L,l}\right) \right] P_t + (1-\delta) Q_{\bar{k}',t} \right\} \bar{K}_t^{L,l} - (1 + R_t^{coupon}) \left(Q_{\bar{k}',t-1} \bar{K}_t^{L,l} - N_t^{L,l} \right) \quad .$$

The first term represents the profits from renting capital (net of utilization costs) and from selling the undepreciated capital to capital producers. The second term represents the payment (coupon and principal) of the bonds issued in period $t-1$.

To avoid a situation where the entrepreneur accumulates enough net worth to become self-financed, in each period the entrepreneur exits the economy with the probability $1-\gamma^L$ and his equity is rebated to households as a lump sum. To keep the population of entrepreneurs constant, a new entrepreneur is born with probability $1-\gamma^L$.

The total entrepreneur's net worth $N_{t+1}^{L,l}$ combines total equity and a transfer, $W_t^{e,L,l}$, received from households, which corresponds to the initial net worth necessary to buy capital. The law of motion for the entrepreneur's net worth is: $N_{t+1}^{L,l} = \gamma^L V_t^{L,l} + W_t^{e,L,l}$.

The large entrepreneur's financing cost minimization problem

There is a continuum of investment banks, indexed by $z \in [0,1]$, and each investment bank z has some market power when conducting its intermediation services. An entrepreneur aiming to issue an amount of bonds for period $t+1$ equal to $BI_{t+1}^{L,l}$, defined by (2), divides this amount among various investment banks, $BI_{t+1}^{L,l}(z)$, so as to minimize the total repayment due. At the end of period t, the entrepreneur chooses the amount of borrowing from bank z by solving the following problem:

$$\min_{BI_{t+1}^{L,l}(z)} \int_0^1 \left[1 + R_{t+1}^{coupon}(z)\right] BI_{t+1}^{L,l}(z)\, dz$$

$$subject\ to\ \ BI_{t+1}^{L,l} = \left\{ \int_0^1 \left[BI_{t+1}^{L,l}(z)\right]^{\frac{\varepsilon_{t+1}^{coupon}-1}{\varepsilon_{t+1}^{coupon}}} dz \right\}^{\frac{\varepsilon_{t+1}^{coupon}}{\varepsilon_{t+1}^{coupon}-1}} ,$$

where $R_{t+1}^{coupon}(z)$ is the interest rate set by the z-th bank and $\varepsilon_{t+1}^{coupon} > 1$ is the time-varying interest rate elasticity of the demand for funds. The first order condition results in the following entrepreneur's demand for funds: $BI_{t+1}^{L,l}(z) = \left(\frac{1+R_{t+1}^{coupon}(z)}{1+R_{t+1}^{coupon}}\right)^{-\varepsilon_{t+1}^{coupon}} BI_{t+1}^{L,l}$, where R_{t+1}^{coupon} is the nominal average coupon rate prevailing in the market at time $t+1$, defined as: $1 + R_{t+1}^{coupon} = \left\{\int_0^1 \left[1 + R_{t+1}^{coupon}(z)\right]^{1-\varepsilon_{t+1}^{coupon}} dz\right\}^{\frac{1}{1-\varepsilon_{t+1}^{coupon}}}$. As expected, the entrepreneur's demand for funds depends negatively on the relative interest rate of each investment bank z.

Investment banks

The investment banks are owned by households. We assume perfect competition in the deposit market in these banks (see *e.g.* Kobayashi, 2008) and we rule out the entry and exit of investment banks. The investment bank maximizes its profits, taking as given the return due to households. In the online appendix, we show that the required return on bonds by households is equal to the risk-free rate, *i.e.* the central bank nominal interest rate (R_t^e).

At the end of period t, the z-th investment bank solves the following profit maximization problem:

$$\max_{R_{t+1}^{coupon}(z)} \Pi_{t+1}^{IB}(z) = \left\{ \left[1 + R_{t+1}^{coupon}(z)\right] BI_{t+1}^{L,l}(z) - \left[1 + R_{t+1}^{e}\right] BI_{t+1}^{L,l}(z) \right\}$$

$$\textit{subject to} \qquad BI_{t+1}^{L,l}(z) = \left(\frac{1 + R_{t+1}^{coupon}(z)}{1 + R_{t+1}^{coupon}} \right)^{-\varepsilon_{t+1}^{coupon}} BI_{t+1}^{L,l} \quad .$$

Taking the first-order condition, imposing a symmetric equilibrium and rearranging yields

$$1 + R_{t+1}^{coupon} = \frac{\varepsilon_{t+1}^{coupon}}{\varepsilon_{t+1}^{coupon} - 1} \left(1 + R_{t+1}^{e}\right) \quad , \tag{5}$$

which shows that the coupon rate is a time-varying markup, $\frac{\varepsilon_{t+1}^{coupon}}{\varepsilon_{t+1}^{coupon} - 1}$, over the policy interest rate.

The spread in bond finance, *i.e.* the spread between the bond coupon rate and risk-free nominal interest rate is

$$\textit{bond spread}_{t+1} \equiv R_{t+1}^{coupon} - R_{t+1}^{e} = \frac{1}{\varepsilon_{t+1}^{coupon} - 1} \left(1 + R_{t+1}^{e}\right) \quad . \tag{6}$$

Equation (6) implies that if the elasticity of the demand for funds in the bond market is constant, the bond spread should only depend on the policy interest rate. Yet, it is well known that corporate bond spreads co-move with the business cycle (see *e.g.* Gilchrist and Zakrajsek, 2012a). We do not attempt to establish micro-foundations for the counter-cyclical behavior of the spread in bond finance, as their multiple and complex determinants would be hard to pin down in a DSGE model. Rather, we adopt an empirical approach and specify the following relation between the elasticity of the demand for funds and the cyclical state of the economy, summarized by the output gap (*i.e.* the difference between current output Y_t and its steady-state value):

$$\varepsilon_{t+1}^{coupon} = \bar{\varepsilon} + \alpha_1 \left(Y_t - \bar{Y}\right) \quad , \tag{7}$$

where $\bar{\varepsilon}$ is calibrated so as to match the average annual bond spread in the data (following Chen et al., 2007), and

α_1 to match the cyclical sensitivity of the bond spread (as given by VAR evidence from very long historical US time series).[3]

As further detailed in subsection 2.2.1, we define the shock to bond finance as a shock to the elasticity $\varepsilon_{t+1}^{coupon}$. In particular, a positive shock to this elasticity reduces the markup on the bond rate, the bond coupon rate and the bond spread.

2.1.2 The loan market

At the end of period t, the entrepreneur uses his available net worth, $N_{t+1}^{S,s}$, to finance his capital expenditures, $Q_{\bar{k}',t}\bar{K}_{t+1}^{S,s}$. To finance the difference between expenditures and net worth, he borrows an amount $B_{t+1}^{S,s} = Q_{\bar{k}',t}\bar{K}_{t+1}^{S,s} - N_{t+1}^{S,s}$ from a retail bank.

After the purchase, the entrepreneur experiences an idiosyncratic productivity shock, $\omega_{t+1}^{S,s}$, that transforms the purchased capital $\bar{K}_{t+1}^{S,s}$ into $\omega_{t+1}^{S,s}\bar{K}_{t+1}^{S,s}$. Following Bernanke et al. (1999), $\omega^{S,s}$ is independently and identically distributed over time and across entrepreneurs and follows a log-normal distribution, $\ln\left(\omega^{S,s}\right) \sim N\left(-\frac{1}{2}\sigma_t^2\,,\,\sigma_t^2\right)$. We refer to σ_t as a loan market shock, and present details of its modeling in subsection 2.2.2.

Financial frictions arise from asymmetric information between the entrepreneur and the bank. The entrepreneur costlessly observes his idiosyncratic shock. For the bank to observe the shock, it must pay a monitoring cost that represents a fraction μ, $0 < \mu < 1$, of the entrepreneur's gross return. The optimal financing mechanism is a debt contract that gives the lender the right to all liquidation proceeds of the entrepreneur defaults.

At the end of time t, the bank offers the debt contract to the entrepreneur. It specifies the loan amount, $B_{t+1}^{S,s}$, and the gross interest rate on the loan, $Z_{t+1}^{S,s}$. At time $t+1$, the entrepreneur declares bankruptcy if $\omega_{t+1}^{S,s}$ is smaller than the default threshold level, $\bar{\omega}_{t+1}^{S,s}$, defined by $\bar{\omega}_{t+1}^{S,s}\left(1+R_{t+1}^{k,S}\right)Q_{\bar{k}',t}\bar{K}_{t+1}^{S,s} = Z_{t+1}^{S,s}B_{t+1}^{S,s}$, where $R_{t+1}^{k,S}$ is the expected average nominal gross rate of return on capital. If $\omega_{t+1}^{S,s} > \bar{\omega}_{t+1}^{S,s}$, the entrepreneur pays the lender the amount $Z_{t+1}^{S,s}B_{t+1}^{S,s}$ and keeps the remaining $\left(\omega_{t+1}^{S,s} - \bar{\omega}_{t+1}^{S,s}\right)\left(1+R_{t+1}^{k,S}\right)Q_{\bar{k}',t}\bar{K}_{t+1}^{S,s}$. On the other hand, if $\omega_{t+1}^{S,s} < \bar{\omega}_{t+1}^{S,s}$, the entrepreneur defaults and receives nothing, while the bank monitors the entrepreneur and receives all of the residual net worth $(1-\mu)\left(1+R_{t+1}^{k,S}\right)\omega_{t+1}^{S,s}Q_{\bar{k}',t}\bar{K}_{t+1}^{S,s}$.

The bank raises the funds necessary to finance entrepreneur activities by issuing time deposits to households, paying them a nominal rate of return R_{t+1}^{e}. Perfect competition in the banking sector implies that the bank's zero-profit condition holds in each period.

[3] See the online appendix and Verona et al. (2013) for further details on the calibration of this elasticity.

As shown by Bernanke et al. (1999), the first order condition of the contracting problem yields the following relationship linking the expected return on capital relative to the risk-free interest rate and the entrepreneur's leverage ratio ($\frac{Q_{\bar{k}',t}\bar{K}^S_{t+1}}{N^S_{t+1}}$):

$$\frac{E_t\left(1+R^{k,S}_{t+1}\right)}{1+R^e_{t+1}} = \Psi\left(\frac{Q_{\bar{k}',t}\bar{K}^S_{t+1}}{N^S_{t+1}}\right) \quad ,$$

where Ψ is such that $\Psi^{'} > 0$ for $N^S_{t+1} < Q_{\bar{k}',t}\bar{K}^S_{t+1}$. The ratio $\frac{E_t\left(1+R^{k,S}_{t+1}\right)}{1+R^e_{t+1}}$, which Bernanke et al. (1999) interpreted as the external finance premium faced by the entrepreneur, depends positively on the entrepreneur's leverage ratio. All else equal, higher leverage means higher exposure, implying a higher probability of default and higher credit risk that leads the bank to demand a higher return on lending.

2.2 Financial shocks

The model comprises two financial shocks, one in each of the financial market segments. Both are credit supply shocks that, when positive, may be thought of as a favorable shock to the financial intermediation process in its market segment, shifting the respective supply curve to the right. In this subsection, we present our modeling approach to both shocks and describe the dynamic response to each shock.

2.2.1 The bond market shock

In the bond market, we assume a shock ν_t that follows an AR(1) process:

$$\nu_t = \rho_\nu \nu_{t-1} + \sigma^\nu_t \quad .$$

The shock influences the elasticity of demand for bonds $\varepsilon^{shock}_{t+1} = \varepsilon^{coupon}_{t+1}\left(1+\nu_t\right)$ and thus the bond coupon rate

$$1+R^{coupon,shock}_{t+1} = \frac{\varepsilon^{shock}_{t+1}}{\varepsilon^{shock}_{t+1}-1}\left(1+R^e_{t+1}\right)$$

and the bond spread

$$bond\ spread^{shock}_{t+1} = \frac{1}{\varepsilon^{shock}_{t+1}-1}\left(1+R^e_{t+1}\right) \quad .$$

A positive shock to ν_t increases the elasticity of the demand for bond finance and reduces the markup, the bond coupon rate, and the bond spread. We calibrate the autoregressive coefficient $\rho_\nu = 0.9$ in line with long-run data for the US financial bond spread. Specifically, our calibration corresponds to the AR(1) regression coefficient of the

difference between (quarterly averages) the Moody's Seasoned Baa Corporate Bond yields and the 10-year Treasury constant maturity yields, from 1953:I to 2011:IV. We adjust the size of the shock σ_t^{ν}, so that the bond spread decreases by 25 basis points (annual rate) on impact.

Blue solid lines in Figure 3 are the impulse response functions of selected variables to a favorable bond market shock. The top panel reports aggregate variables, the middle panel variables relate to the large entrepreneurs (who have access to bond finance), and the bottom panel variables relate to the small entrepreneurs (who rely on bank finance).

Following a positive shock, large entrepreneurs increase their demand for credit (bonds), as they face a lower interest rate for a prolonged period of time. The rise in capital purchases by large entrepreneurs more than compensates for the increase in their net worth, so their leverage rises above the steady-state level. At the aggregate level, given that large entrepreneurs represent a larger share of the total population of entrepreneurs, there is a credit boom driven by the increase in the demand for bond finance. The increase in the demand of large entrepreneurs for capital pushes up aggregate demand (investment and output), as well as the price of capital.

The cost of financing also drops for small entrepreneurs, due to the decline in their leverage as a consequence of the large increase in the price of capital. Nevertheless, bank finance is relatively more expensive than bond finance (as the loan spread only falls by around 12 basis points on impact). As a result, there is a drain of the available resources from small to large entrepreneurs, and, thus, capital expenditures by small entrepreneurs and the amount of borrowing from retail banks decline.

The decrease in the price of finance (for both large and small entrepreneurs) leads to a fall in marginal costs for producing firms, and thus a decline in inflation. The central bank, following a standard Taylor-type policy rule with a strong response to inflation and a weak response to the output gap, cuts the nominal interest rate in response to the fall in inflation. Overall, the bond finance shock and the dynamic responses of most variables are very persistent. (Later in the discussion, we check the sensitivity of the results to various calibrations of ρ_{ν}.)

2.2.2 The loan market shock

In the loan market, we consider an AR(1) shock to the standard deviation of the entrepreneur's idiosyncratic productivity:

$$\sigma_t = \bar{\sigma}\left(1 - \sigma_t^{\sigma}\right) + \rho_{\varepsilon}\left(\sigma_{t-1} - \bar{\sigma}\right) \quad .$$

A positive shock to σ_t reduces the idiosyncratic uncertainty, the credit risk and the loan spread.[4] We calibrate $\rho_\varepsilon = 0.722$, which is the value estimated by Christiano et al. (2010) using aggregate US data. The size of the shock σ_t^σ is adjusted so that the loan spread $(Z - R^e)$ decreases by 25 basis points (annual rate) on impact. Red dashed lines in Figure 3 report the impulse response functions of selected variables to this shock.

Facing a lower cost of financing, small entrepreneurs sharply increase their borrowing and leverage. In contrast to the long-lasting effects after a bond shock, the effects of the loan shock on borrowing and leverage of small entrepreneurs is fairly short-lasting. (Later in the discussion, we check the sensitivity of the results to various calibrations of ρ_ε.) For the large entrepreneurs, their required rate of return on capital goes up as bond finance becomes relatively more expensive than bank finance. At the aggregate level, this increase in the price of finance for large entrepreneurs dominates the decrease in the price of finance for small entrepreneurs. The marginal cost of production of intermediate goods increases as firms rent physical capital from both entrepreneurs. Inflation rises, so the central bank responds by hiking the nominal interest rate, leading to a drop in output. The increase in the interest rate results in an increase in the bond coupon rate and in the bond spread, and thus a decline in the amount of bonds issued in the economy. In our market-based economy, the relatively larger increase in bank loans is essentially offset by the relatively smaller decline in bond issuance, so that aggregate total credit and investment only fluctuate slightly.

Overall, the loan market shock plays a rather small role as a driver of aggregate macro fluctuations (especially compared to the bond shock). These findings are similar to those of Chugh (2016) for a frictionless real business cycle model augmented with the agency-cost framework of Carlstrom and Fuerst (1998), and contrasts with the results obtained with NK DSGE models by Christiano et al. (2014) and Gilchrist and Zakrajsek (2011, 2012b). This difference is explained by the fact that, in the latter set of papers, the loan market corresponds to the entire financial system, while here the loan market is smaller than the bond market.[5]

Having presented the model, the financial shocks, and the baseline dynamic responses of our economy to these shocks, we now move to the core question. Does a reaction of monetary policy to financial variables improve macroeconomic stabilization in our economy following financial shocks?

[4] A similar interpretation of this shock is given by de Fiore et al. (2011), Davis and Huang (2013), and Quint and Rabanal (2014). In contrast, Christiano et al. (2014) and Chugh (2016) interpret this as a risk shock, since risk is high in periods when σ_t is high, due to a widened dispersion in capital outcomes across entrepreneurs. Gilchrist and Zakrajsek (2011) model this shock by introducing a direct shock to the effective cost of financial intermediation.

[5] If we shut down the bond market in our model, the impulse response functions to a loan spread shock would be identical to those in Christiano et al. (2010) or Christiano et al. (2014). This would depend, of course, on the specific calibration of the model parameters and on the size of the shock. In the two mentioned papers, the researchers simulate a 250-basis-point spread shock. Here, we simulate 25-basis-point spread shocks.

3 "Leaning against the wind" and financial (in)stability

We now evaluate whether a reaction of monetary policy to financial variables improves policy outcomes. The reaction of monetary policy and the criterion for policy evaluation are described in subsection 3.1 and 3.2, respectively. We present the results in subsection 3.3 and some sensitivity analyses in subsection 3.4.

3.1 Taylor rules with "leaning against the wind"

The policy outcomes of the benchmark Taylor rule (equation 1) is compared with those of rules augmented with financial variables. In this regard, a crucial issue is *which* variable or variables should be included in the policy rule. Taylor rules have been augmented with: asset prices (*e.g.* Faia and Monacelli, 2007); growth in asset prices (*e.g.* Nistico, 2012, Gelain et al., 2013, Finocchiaro and von Heideken, 2013, and Lambertini et al., 2013); exchange rate (*e.g.* Kollmann, 2002, Adolfson et al., 2007, Lubik and Schorfheide, 2007, and Molodtsova et al., 2011); credit level (either the credit-to-GDP ratio or percentage deviation from steady state, as in *e.g.* Curdia and Woodford, 2010, Badarau and Popescu, 2014, and Quint and Rabanal, 2014); credit growth (*e.g.* Christiano et al., 2010, Gelain et al., 2013, and Lambertini et al., 2013); credit spreads (*e.g.* Curdia and Woodford, 2010, Gilchrist and Zakrajsek, 2011, 2012b, Davis and Huang, 2013, Hirakata et al., 2013, and Stein, 2014a); and financial sector leverage (Woodford, 2012).

The preferred variable should (a) be easy to measure, (b) relate closely to overall economic stability, and (c) be controllable by monetary policy. A substantial literature suggest that asset prices fail criterion (a) as it is hard to identify deviations from their fundamental values (bubbles) in real time. They also fail criterion (c) as it is not easy for policy to control bubbles without pricking them and suffering damaging consequences. Exchange rates fail criterion (b) as the exchange rate movements of the US dollar are not central to the performance of the US economy. In contrast, the literature emphasizes that the most grave macroeconomic crises since the mid-20th century have been driven by excessive credit growth (and leverage). These were typically associated with abnormally low spreads driven by unrealistic assessments of risk (see *e.g.* Schularick and Taylor, 2012 and Jorda et al., 2013, 2015). Accordingly, credit-driven bubbles are considered to be more relevant (criterion b), easier to monitor and predict (criterion a), and easier to control (criterion c) than asset price bubbles (see *e.g.* Adrian and Shin, 2010). Hence the modern approach of defining financial stability in terms of risk, spreads, credit growth, and leverage (see *e.g.* Gertler and Kiyotaki, 2010 and Curdia and Woodford, 2010).

We thus assess the performance of Taylor-type rules augmented with three financial variables. Our first rule is augmented with aggregate credit growth (ATR1), which comprises total bond issuance and credit granted. Our

second rule is augmented with credit spreads, split into two sub-rules relevant for bond and loan shocks respectively, one augmented with the bond spread, (ATR2a), the other augmented with the loan spread (ATR2b). Our third rule is augmented with both financial variables and split into two sub-rules, one augmented with total credit and the bond spread, (ATR3a), the other augmented with total credit and the loan spread (ATR3b):

- ATR1:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) + \phi_{\Delta credit} \left(\frac{B_{t+1} - B_t}{B_t} \right) \right] \tag{8}$$

  where B_t is aggregate credit (the sum of bonds and bank loans);

- ATR2a:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) - \phi_{bs} \left(bond\ spread_t - \overline{BS} \right) \right] \tag{9}$$

  where $\overline{BS} = R^{coupon} - R^e$ and R^{coupon} is the steady-state value of the bond coupon rate;

- ATR2b:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) - \phi_{ls} \left(loan\ spread_t - \overline{LS} \right) \right] \tag{10}$$

  where $loan\ spread_t = Z_{t+1} - R_t^e$, $\overline{LS} = Z - R^e$ and Z is the steady-state value of the contractual interest rate on bank loans;

- ATR3a:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) + \phi_{\Delta credit} \left(\frac{B_{t+1} - B_t}{B_t} \right) - \phi_{bs} \left(bond\ spread_t - \overline{BS} \right) \right] \ ; \tag{11}$$

- ATR3b:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) + \phi_{\Delta credit} \left(\frac{B_{t+1} - B_t}{B_t} \right) - \phi_{ls} \left(loan\ spread_t - \overline{LS} \right) \right] \ . \tag{12}$$

3.2 Central bank preferences

To compare the performances of the augmented Taylor rules relative to the baseline Taylor rule, our assessment criterion is the ability of the central bank to achieve its mandate. Here, we define this as the minimization of a loss function.[6] The preferences of the policymaker include price stability and stabilization of output (around its potential level) as primary goals. This corresponds to the flexible inflation targeting that characterizes modern central banks and well describes the Federal Reserve's dual mandate of achieving price stability and maximum employment (Debortoli et al., 2016).

Moreover, we consider loss functions with either an objective of minimizing the volatility of the policy interest rate, which is consistent with the FED (third) mandate of maintaining moderate long-term interest rates (see *e.g.* Sala et al., 2008) and with the evidence of interest-rate smoothing (see *e.g.* Casares, 2007 and Coibion and Gorodnichenko, 2012), or an objective of financial stability, which is consistent with the motivation suggested in section 1.

Analytically, we assume that the central bank's mandate consists of minimizing a weighted average of the variances of inflation, output gap, policy interest rate changes, and total credit growth:

$$Loss\ Function = var\left(\pi\right) + \alpha_y var\left(y\right) + \alpha_r var\left(\Delta R^e\right) + \alpha_{fs} var\left(\frac{B_{t+1} - B_t}{B_t}\right) \quad . \tag{13}$$

The general loss function (13) is flexible enough to encompass a wide range of policy regimes, corresponding to different emphases on price, output, and financial stability as a function of the specific weights α_y, α_r, and α_{fs}. In the empirical literature, some studies provide estimates for these weights (see *e.g.* Lippi and Neri, 2007, Adolfson et al., 2011 and Ilbas, 2012). In practice, monetary policy regimes differ considerably across economies and over time, so it is not possible to quantify with certainty the relative weights of the central bank LF, even for the specific case of the US. Moreover, we want to assess LATW comprehensively, *i.e.* in a variety of alternative plausible policymaker preferences. Thus, for the sake of completeness, we conduct our simulations considering three policy

[6] Our approach to the concept of optimal monetary policy follows a tradition used by many researchers (see *e.g.* Castelnuovo and Surico, 2004, Dieppe et al., 2005, Jung et al., 2005, Lippi and Neri, 2007, Sala et al., 2008, Adolfson et al., 2011, Nistico, 2012, and Gelain et al., 2013). An alternative approach follows Woodford (2003) and assesses the social welfare maximizing policy, *i.e.* the policy that maximizes (a second-order approximation of) the households' utility function (see *e.g.* Faia and Monacelli, 2007, Kobayashi, 2008, Curdia and Woodford, 2010, and Gertler and Karadi, 2011). While this second approach has the advantage of allowing for theory-consistent Ramsey policy and analytical social welfare analyses, it has multiple disadvantages. As noted by *e.g.* Adolfson et al. (2011), it is more complex, less robust, not necessarily implementable, difficult to verify, and sensitive to all distortions in the economy. The last drawback is especially important in models with financial frictions such as the one we use here, because social welfare depends on the misallocation of resources arising from financial distortions. Moreover, the issue of implementability is crucial when the objective of the research is to identify augmented policy rules that central banks may actually pursue and which are beneficial for macroeconomic stabilization. These are the main reasons for our choice of following the tradition that considers the minimization of a loss function. Moreover, no central bank has ever been explicitly mandated to maximize social welfare.

regimes and five different parameterizations of their relative weights. These weights, reported in table 1, are in line with those commonly used in the literature (see *e.g.* Ehrmann and Smets, 2003 and Levin and Williams, 2003).

The first policy regime is a flexible inflation targeting regime, in which the central bank aims at stabilizing both inflation and the output gap (we consider two alternative values for the coefficient attached to output, LF1 and LF2). LF3 is a flexible inflation targeting regime in which the central bank further aims at reducing the volatility of the policy interest rate. LF4 and LF5 include a term – the unconditional variance of aggregate credit growth – to reflect the central bank's concern for financial stability, and could be interpreted as the case of a coordination between monetary and macroprudential policy. Central bank objective functions with a direct concern for financial stability have already been used in the literature by *e.g.* Angelini et al. (2014), Gambacorta and Signoretti (2014), Nistico (2016) and Gelain and Ilbas (2017). In LF4, we start by assuming a weight of financial stability similar to the one of interest-rate smoothing in LF3 (0.10). In LF5, we increase the relative weight of financial stability to 0.50 so that it has the same relevance of real output stabilization as analytically derived by Nistico (2016).

3.3 Optimal Taylor rules

We now present the key results of our analysis, optimizing over all the parameters in rules (1) and (8)-(12) to find the combination of coefficients that minimizes each loss function following a financial shock that arises either in the bond or the loan market. We do so by means of a multi-dimensional grid search, conducted over the following ranges: $0 \leq \tilde{\rho} \leq 0.9$, $1 < \phi_\pi \leq 4$, $0 < \phi_y \leq 1$ and $0 \leq \phi_{\Delta credit}$; ϕ_{bs} ; $\phi_{ls} \leq 2$.[7]

Table 2 reports the results for the case of a shock in the bond market. The rows relate to the five monetary policy regimes and the four relevant Taylor-type rules for each regime. Columns 3-5 show the optimal coefficients for the lagged interest rate, expected inflation, and the output gap, in the optimized rule of each regime. Columns 6 and 7 report the optimal coefficients for the relevant financial variable in the respective rule and regime. Column 8 shows the percent gain in the loss function implied by each augmented Taylor rule over the benchmark Taylor rule.

The coefficients of the optimal benchmark Taylor Rule are remarkably stable across monetary policy regimes, and quite in line with the baseline calibration that we borrowed from the literature in section 2, except for a smaller coefficient associated with inflation. Optimal Taylor rules augmented with a reaction to financial variables overall improve the ability of the central bank to fulfill its mandate. There are positive gains in 14 out of the 15 possible combinations of rules and regimes. However, such gains are only substantial (between 11 and 18%) when policy

[7] Our restriction to the grid search and truncation of the policy coefficients in the Taylor rule follows procedures that are standard in the literature (see *e.g.* Schmitt-Grohe and Uribe, 2007, Faia and Monacelli, 2007, and Quint and Rabanal, 2014). The grid step is 0.1 for all the coefficients. As regards ϕ_y and ϕ_π, the lower limits are precisely 0.01 and 1.01 to satisfy the Taylor principle and avoid indeterminacies.

reacts to credit growth (ATR1), while reaction to bond spreads alone (ATR2a) yields smaller gains (between 5 and 9%). Inspection of the optimal policy rules with a reaction to both credit growth and bond spreads (ATR3a) shows the dominant role of credit growth. For all policy regimes, the coefficient associated with credit growth in optimal augmented policy rules is consistently larger than the coefficient associated to the output gap, ranging from 0.8 in LF2 to 0.3 in LF4 and LF5. Compared with the respective benchmark optimal rule, the rules augmented with a reaction to credit growth in each policy regime feature a larger reaction to inflation and a much smaller (even null) degree of interest-rate smoothing. Moreover, the magnitude of the coefficients associated with credit growth in the optimal augmented policy rules, as well as the magnitude of the gains with respect to the respective benchmark optimal policy rule, do not depend on the explicit inclusion of credit growth volatility in the central bank's objective function.

Our analyses thus suggest that LATW, in particular against credit growth, helps the central bank achieve its mandate following bond spread shocks, even if the central bank only cares about inflation and output stabilization (LF1 and LF2). Moreover, LATW should be coupled with a more aggressive reaction to inflation and somewhat replaces the need of interest-rate smoothing, even if the central bank cares explicitly for the stability of interest rates (LF3).

Figure 4 plots selected impulse response functions (IRF) following a 25-basis-point bond spread shock for optimal Taylor rules in the traditional dual mandate regime (LF2, top panel) and a regime that further incorporates a concern for financial stability (LF5, bottom panel). Black lines depict the IRFs under the benchmark optimal rule (BTR), while red and blue lines are the IRFs under the optimal rules augmented with credit growth (ATR1) and with bond spreads (ATR2a), respectively (note that the IRFs under ATR3a are equal to those of ATR1). The top panel (LF2) shows that the gains from LATW come from a smaller impact and a much quicker return of inflation to its steady state, as well as from a smaller medium-run expansion of output, obtained with a sharper, but much less persistent, reaction of the interest rate. These dynamics, which are consistent with the stronger reaction to inflation and irrelevant interest-rate smoothing noted in Table 2, yield higher gains when policy reacts to credit (red lines) than to spreads (blue lines). The bottom panel (LF5) shows similar dynamics as regards inflation and output, but with a smaller impact and medium-run expansion of output under ATR1 (reaction to credit growth, red line) than under ATR2a (reaction to bond spreads, blue line). Moreover, given that in this policy regime the central bank cares as much about credit growth stabilization as it does about output stabilization, there is an additional source of gain coming from a much smaller expansion of total credit under the policy with a direct reaction to credit growth (ATR1, red line). Such gains imply a much sharper (and less persistent) reaction of the policy interest rate under ATR1, in which interest-rate smoothing is zero, in contrast with the path of the policy interest rate in the rule with

a reaction to bond spreads (ATR2a, blue line), which features a standard degree of interest-rate smoothing.

Table 3 reports the results in the case of a shock in the loan market. The structure of this table is similar to that of the previous table, but for each policy regime, in addition to BTR and ATR1, we now consider ATR2b (policy reaction to the loan spread) and ATR3b (reaction to credit growth and the loan spread).

The coefficients of the optimal benchmark Taylor Rule are unstable across monetary policy regimes and most frequently diverge from the baseline calibration used in section 2, except for the interest-rate smoothing coefficient. The coefficients on inflation are much larger (except for LF1) and those on output are somewhat larger (LF1-LF3) or much larger (LF4-LF5). Overall, optimal Taylor rules augmented with a reaction to financial variables fail to improve the ability of the central bank to fulfill its mandate. The only exception occurs in regime LF5, in which the policymaker weights credit growth stabilization as much as output stabilization. In such regime, optimal policy features a reaction of the policy interest rate to credit growth (ATR1) with a very large coefficient (1.6), yielding a gain of 18%. Reaction to loan spreads alone (ATR2b) yields no comparable gains, and the optimal policy rule with a reaction to both credit growth and loan spreads (ATR3b) confirms the dominant role of credit growth as the coefficient on spread collapses to 0.

Therefore, our simulations suggest that LATW does not improve the fulfillment of the central bank's mandate following loan spread shocks, unless the central bank has a substantial third mandate of credit growth stabilization and responds substantially to credit growth. Such LATW should be coupled with an aggressive reaction to inflation (coefficient of 3), a larger than usual reaction to output (0.4) and a rather small degree of interest-rate smoothing (0.6). The ineffectiveness of LATW in the case of a loan shock may be related with the relative small weight of the retail banking sector in our model, but may also be related with the persistence of the loan shock, as further discussed in subsection 3.4.1.

Figure 5 plots selected IRFs following a 25-basis-point loan spread shock for optimal Taylor rules in the traditional dual mandate regime (LF2, top panel) and a regime enhanced with a concern for financial stability (LF5, bottom panel). Black lines depict the IRFs under the benchmark optimal rule (BTR) and red lines are IRFs under the optimal rule augmented with credit growth (ATR1), while blue lines are IRFs from optimal rules augmented with bond spreads (ATR2b) (note that the IRFs from ATR3b and ATR1 are identical). The top panel (LF2) shows that the dynamic responses of inflation and output are almost identical under the benchmark optimal policy rule, the optimal policy rule augmented with credit growth and the optimal rule augmented with a reaction to the loan spread, consistently with the nonexistence of gains from LATW when the central bank aims at stabilizing inflation and output after a loan spread shock. Consistent with the small magnitude of the coefficient associated with credit

growth and the virtually identical coefficients on inflation, output, and the lagged interest rate in the augmented policy rules, the dynamic paths of the policy interest rate and credit are also exceedingly close for all three optimal rules considered in the figure. The bottom panel shows why LATW generates substantial gains only when the central bank cares as much about credit growth stabilization as it does about output stabilization (LF5). Indeed, following a loan spread shock, the dynamic responses of inflation and output are not much more favorable under LATW. Inflation features a smaller impact, but a slower return to the steady state, while output features a larger impact, but quicker return to the steady state and smoother overall dynamics. Even so, credit is more effectively stabilized under LATW, which contributes favorably to a positive gain in the central bank's objective function compared with a policy with no LATW or a policy in which LATW targets the loan spread. Consistent with the similar coefficients on lagged interest rate with and without LATW, such gains are associated with the dynamics of the policy interest rate under ATR1, which is even smoother than under the benchmark policy rule and much smoother than under a policy that reacts to bond spreads (ATR2a).

3.4 Sensitivity analyses

In this subsection, we assess the sensitivity of our findings to changes in some assumptions that, in the light of the literature, may be considered contentious: the degree of persistence of financial shocks, the orthogonality of financial shocks, and the forecast horizon of monetary policy.

3.4.1 Persistence of financial shocks

Even though financial shocks are increasingly seen as important drivers of business cycle fluctuations, there is only a small amount of fairly ambiguous evidence regarding their empirical properties, particularly with regard to their persistences.

For loan shocks, Christiano et al. (2010), using aggregate US macro and financial data, estimate a coefficient of persistence of 0.722, while Christiano et al. (2014), using the same model, but with a longer sample period, obtain an estimate of 0.97. Chugh (2016), using firm-level data, obtains a persistence coefficient of 0.83.

For the bond market shock, we estimate, using US aggregate financial data, a value for the AR(1) regression coefficient of the bond spread of 0.9, while Gilchrist and Zakrajsek (2011), using US corporate data, estimate a value of 0.75.

In this subsection, we redo the simulations reported in subsection 3.3 to investigate the sensitivity of our results to changes in the degree of persistence of financial shocks.

Table 4 reports the results of the simulation exercises assuming a persistence of the bond market shock ρ_ν of 0.722 instead of the baseline value of 0.9. The results are quite similar in the case of central banks with the typical dual mandate (LF1 and LF2). The optimal augmented policy rules allow for gains of about 15%, feature a reaction of the policy interest rate to credit growth slightly larger than that associated with the output gap, and display no interest-rate smoothing. When interest-rate smoothing is a direct concern (LF3), the gains of augmenting the Taylor rule with a reaction to credit growth are smaller, the corresponding coefficient on the rule is smaller and similar to the output gap coefficient, and the interest-rate smoothing coefficient only falls slightly. When credit growth volatility is a direct target for the central bank (LF4 and LF5), the coefficient on credit growth in the optimal augmented rules is quite large (between 1 and 1.9), the gain is similar to LF3 (LF4) or increases substantially when the weight on credit growth is very large (LF5); in this specific case, a reaction of the policy rate to the bond spread becomes quantitatively relevant (gain of 16%).

Overall, reducing the persistence of the bond shock does not qualitatively alter our main findings that LATW yields positive gains in achieving the central bank's mandate and that such gains are larger when policy reacts to credit growth. One difference, however, is that when the relative weight of financial stability in the central bank objective function is large (0.5), a reaction to the bond spread becomes beneficial.

Table 5 reports the results of the optimization exercises assuming a persistence of the loan market shock ρ_σ of 0.9 rather than the baseline value of 0.722. The results do not change in the case of a central bank with a balanced dual mandate (LF1), but do change (in a similar way) when the relative weight of the output gap is smaller (LF2), and when there is a moderate additional concern for stability of interest rates (LF3) or credit growth (LF4): optimal augmented policy rules allow for larger gains (of about 8%), typically obtained with a reaction of the policy interest rate to credit growth much larger than the reaction to the output gap, but with smaller coefficients than under more persistent shocks (optimal coefficients of 0.2). Overall, reaction of policy interest rates to loan spreads would not entail a sizable gain, for the vast majority of the central bank's loss functions. In contrast, when the central bank attaches a higher weight to credit growth stabilization (LF5), the gain from LATW falls markedly with the persistence of the loan shock (from 18 to about 10%), as do the optimal coefficients associated with credit growth (from 1.6 to 0.3 or even 0.1 when combined with a reaction to the loan spread). Under more persistent shocks, the results obtained for LF5 turn out to be closer to those obtained for all other loss functions in which there is a smaller concern for financial variables (LF3, LF4), *i.e.* results turn out to be more similar across most loss functions: LATW yields somewhat larger gains for most objective functions, although still smaller than in the case of a reaction to bond spread shocks. Furthermore, while it is clearer that policy would better react to credit growth rather than to loan spreads, the coefficients attached to credit growth are overall smaller than under less persistent

shocks.

Overall, our analyses suggest that the higher the persistence of the financial shocks, the stronger the case for a reaction of monetary policy to financial variables. Therefore, our results emphasize the need for further empirical analyses of the persistence of financial shocks.

3.4.2 Optimal unconditional Taylor rules

Throughout the paper, we simulate the effects of bond and loan shocks independently. However, in the real world, policymakers need to react to shocks that are most likely multiple and not easy to disentangle. While it is beyond the scope of this paper to assess non-financial shocks, in this subsection we study the effectiveness of augmented policy rules when both financial shocks simultaneously impact the economy. Technically, we move from policies that are conditional on a specific shock, to optimized Taylor rules that are unconditional on the source of the financial shock. Besides adding realism and comprehensiveness to our analysis, this subsection allows for a clearer summary of some key results of this paper.

Table 6 indicates that when the economy is buffeted by a variety of financial shocks considered in our model, it becomes even more clear that augmenting the benchmark Taylor rule with a reaction to credit growth yields better results in terms of fulfilling the central bank's mandate. Across the entire range of loss functions considered, the gains from enhancing the policy rule with a reaction to credit growth are typically between 13 and 17%, which are clearly larger than the gains when spreads alone are added to the benchmark rule. Moreover, allowing for a reaction of policy to any financial spread (when it already reacts to credit growth) gives no additional gain. The optimal coefficients associated to credit growth turn out to be quite stable across loss functions and policy rules, typically between 0.5 and 0.6. While considerably below the coefficients associated with inflation, such sizable and stable coefficients on credit growth are consistently larger than those associated with the output gap. Furthermore, they induce a substantial reduction of the interest-rate smoothing coefficient, in the cases when the central bank has a direct concern for interest rate or credit stability (LF3, LF4, and LF5), and even the absence of interest-rate smoothing when the central bank only cares about stabilizing inflation and output (LF1 and LF2).

A final note on the results presented in this subsection is warranted. Overall, they are close to those obtained in the case of a bond market shock, described in Tables 2 and 4, and rather different from those obtained in the case of a loan market shock presented in Tables 3 and 5. This is simply the result of the relative weight of the two segments of the financial market in our model which, as discussed above, mimics the relative weight of bond and bank finance in the US economy.

3.4.3 Optimal policy forecast horizons

Borio (2014a,b) recently argued that if the policy horizon is extended beyond typical inflation targeting regimes, monetary policy could counteract slow-building financial vulnerabilities, rendering unnecessary a direct reaction of policy interest rates to financial variables. Therefore, in our final test we assess the sensitivity of our results to longer policy forecast horizons (results not shown, for space limitations, but available upon request).

Specifically, we repeat the simulations of section 3.3, replacing in the benchmark policy rule the one-quarter-ahead inflation forecast underlying the policy rules of our model (as in most NK DSGE models) with expectations of inflation 2, 3, 4, 8, 12 and 16 quarters ahead. We do so separately for each financial shock as well as for the unconditional policy, across all five policy regimes. The optimal forecast horizon turns out to be one quarter in nearly all cases, and never exceeds three quarters. In particular, benchmark policy rules with extended policy forecast horizons never outperform augmented rules featuring the usual one-quarter-ahead policy horizon. The only exception is policy regime LF5 (when a larger weight is attached to credit growth stabilization). In this case, the benchmark policy rule with a three-quarters-ahead policy forecast horizon slightly outperforms the augmented Taylor rules featuring the usual one-quarter-ahead horizon. In any case, the result, which could be related to the well-documented phenomena that financial cycles tend to be longer than economic cycles (Borio, 2014a and Verona, 2016), is marginal. Moreover, it arises when the central bank attaches the same weight to the stabilization of credit growth and the output gap, and is obtained in a comparison that may underestimate the reaction to financial variables (we do not allow for extended-horizon augmented rules).

Our results therefore suggest that extending the horizon of inflation forecast targeting is typically not a valuable alternative to an explicit response to financial variables. This contradicts the evidence in Borio (2014a,b), but is consistent with Levin et al. (2003) for the US economy. It contrast with results for the euro area obtained by Smets (2003) and Dieppe et al. (2005). Using five models with different dynamics, Levin et al. (2003) generally find very short optimal horizons that never exceed four quarters. Dieppe et al. (2005) find optimal forecast horizons between 10 and 12 quarters with a mostly backward-looking model, while Smets (2003) finds optimal forecast horizons of not less than 16 quarters with an estimated backward-and-forward-looking model.

4 Concluding remarks

In this paper, we asked whether "leaning against the wind" (LATW) improves the ability of the central bank to accomplish its mandate when the economy is affected by financial shocks. We compared the performance of optimal

standard Taylor rules with optimal Taylor rules augmented with a reaction to credit growth, financial spreads, or both, in a DSGE model with financial frictions.

Our main contribution to the rapidly growing literature on LATW in economies with financial frictions and shocks is to develop the analysis in a model with a dual financial system that is calibrated to match the bond-to-bank finance ratio of the US economy. Our model usefully describes the US financial boom and bust of the 2000s in Verona et al. (2013), and in this paper allows for the simulation of shocks arising alternatively (and simultaneously) in the bond market and in the loan market, as well as assessment of policy rules with a reaction to financial variables in both segments (individually or simultaneously) of the financial system.

The paper also addresses our research question in the context of a variety of central bank loss functions. In addition to variants of the standard dual mandate of inflation and output stabilization, with and without some preference for interest rates gradualism, we consider objective functions with a concern for stabilization of credit growth, thus assessing whether the relevance of LATW depends on assigning the central bank a third mandate of financial stability.

In a nutshell, our simulations indicate that LATW policies are widely applicable for financial shocks that occur in the larger segment of the US financial system (the bond market), irrespective of the mandate given to the central bank. LATW may also be relevant in the case of a shock arising in the loan market, but only if the central bank has been assigned a strong preference for credit growth stability or, alternatively (and more moderately), if the shock is highly persistent. Finally, LATW yields substantial gains when the optimal policy rule features a reaction to credit growth, while the gains from reacting to spreads are usually smaller.

Overall, our analysis suggests that research on the optimal design of monetary policy in environments of financial frictions and shocks would, at least for the US, benefit from considering models with diverse segments of the financial system. It further points to the need of strengthening our knowledge about sources and characteristics of modern financial shocks. While it shows that financial stability and financial shocks may be parsimoniously addressed purely in the context of optimal monetary policy, it does not negate the benefits from deepening the analysis using models that feature monetary and macroprudential authorities, targets, and instruments.

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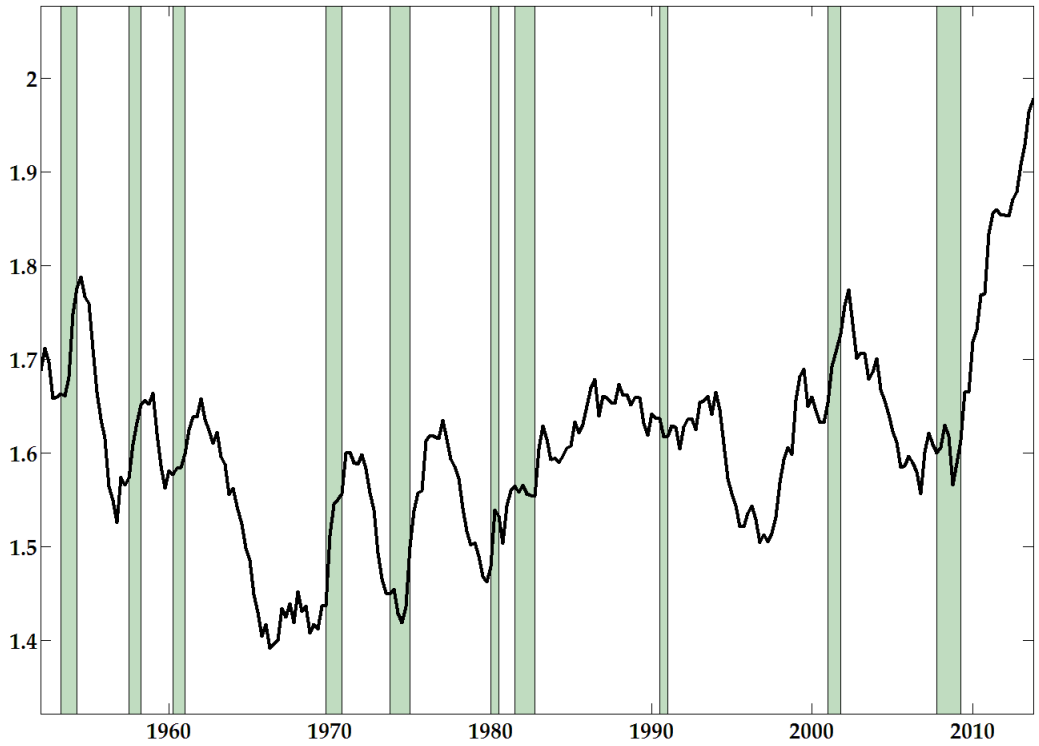

Figure 1: Bond-to-bank finance ratio over the US business cycle (1952:Q1–2013:Q4)
Source: Contessi et al. (2015). Bond finance: business borrowing gross flows of publicly traded companies; bank finance: bank lending gross flows of commercial banks. Shaded areas denote NBER recessions.

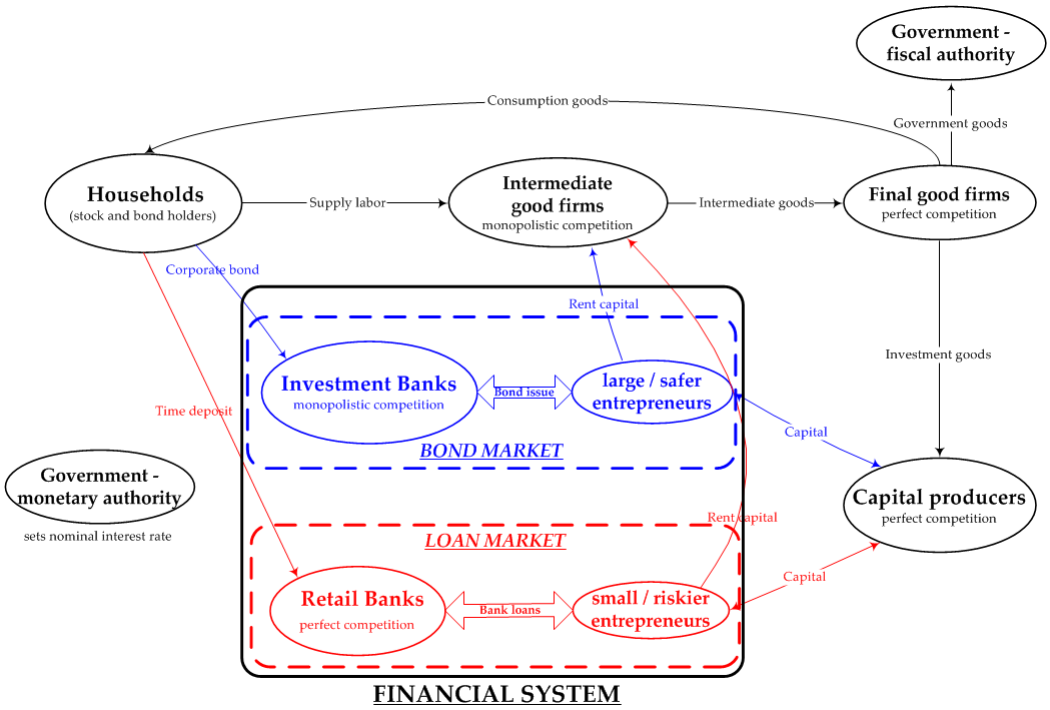

Figure 2: Structure of the model

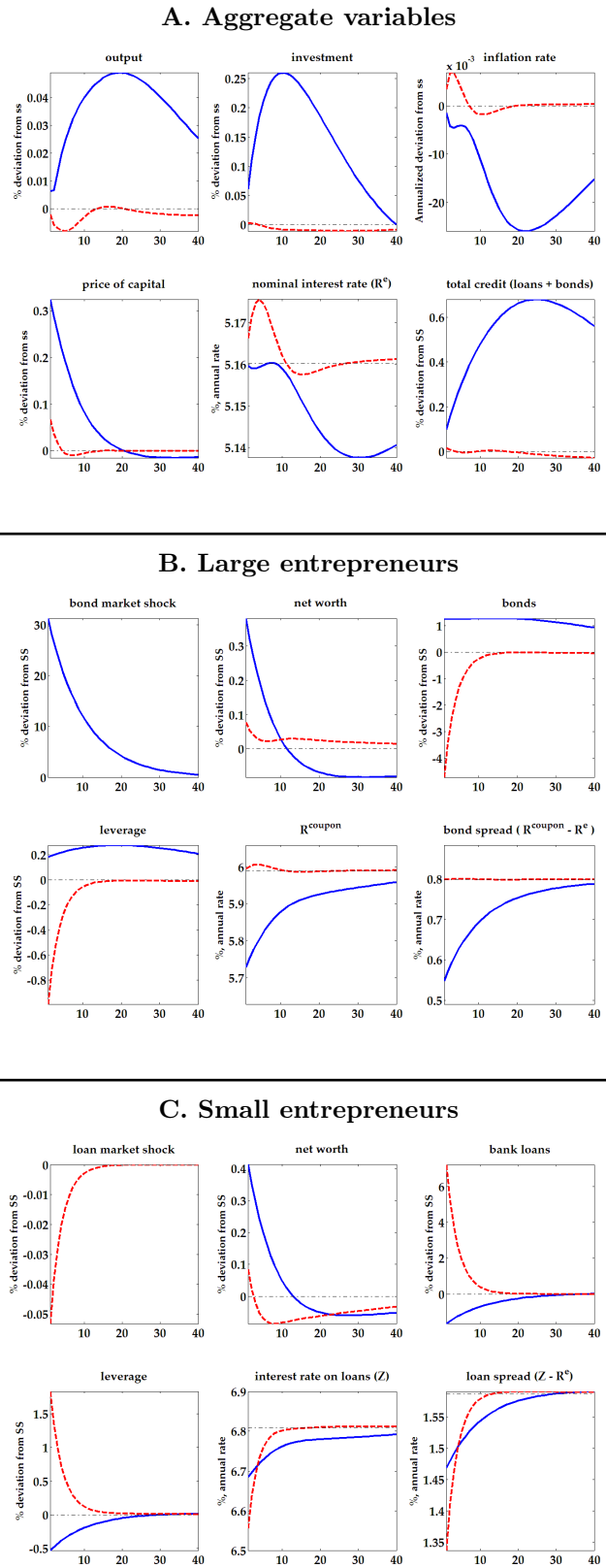

Figure 3: Impulse response functions to financial shocks. Blue solid lines: shock in the bond market ($\rho_\nu = 0.9$), red dashed lines: shock in the loan market ($\rho_\sigma = 0.722$)

Note: Values expressed as percentage deviation from steady-state values. Inflation is expressed as annualized percent deviation from its steady state, and spreads and interest rates are expressed as annual percentage points.

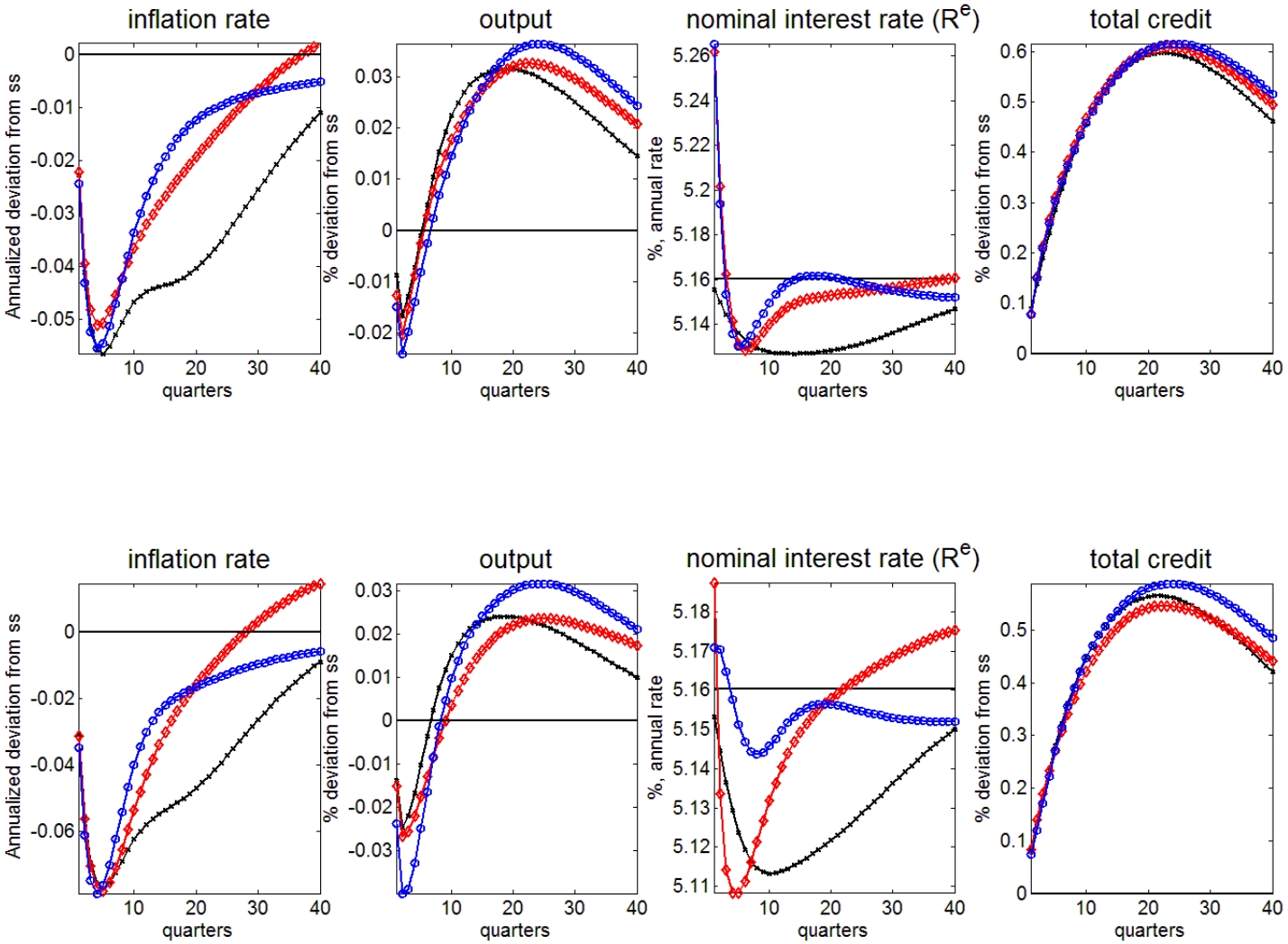

Figure 4: Impulse response functions to a bond market shock ($\rho_\nu = 0.9$) under optimal Taylor rules

Note: Top panel: LF 2 $= var(\pi) + 0.5var(y)$. Bottom panel: LF 5 $= var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Black lines: BTR. Red lines: ATR1. Blue lines: ATR2a. Inflation is expressed as annualized percent deviation from its steady state, output and total credit as percentage deviation from their steady state, and nominal interest rate as annual percentage points.

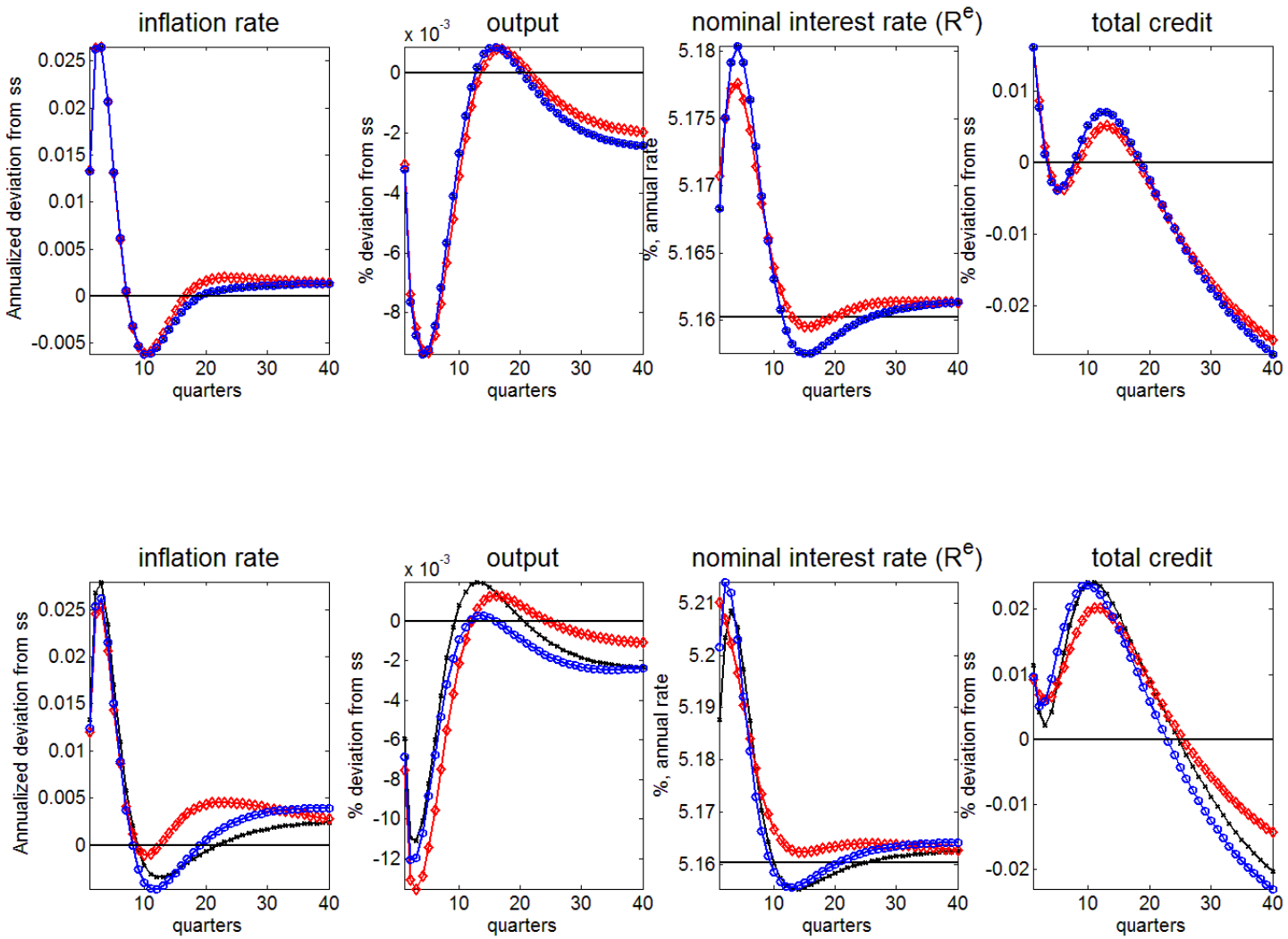

Figure 5: Impulse response functions to a loan market shock ($\rho_\sigma = 0.722$) under optimal Taylor rules

Note: Top panel: LF 2 $= var(\pi) + 0.5var(y)$. Bottom panel: LF 5 $= var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Black lines: BTR. Red lines: ATR1. Blue lines: ATR2b. Inflation is expressed as annualized percent deviation from its steady state, output and total credit as percentage deviation from their steady state, and nominal interest rate as annual percentage points.

Loss function (LF)	α_y	α_r	α_{fs}
LF1	1	0	0
LF2	0.5	0	0
LF3	0.5	0.1	0
LF4	0.5	0	0.1
LF5	0.5	0	0.5

Table 1: Loss functions and monetary policy regimes

Loss function	Taylor rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable $\phi_{\Delta credit}$	ϕ_{bs}	Gain (%)
1	BTR	0.9	1.01	0.2			
	ATR1	0	2.3	0.4	0.7		14
	ATR2a	0.9	1.01	0.2		0	0
	ATR3a	0	2.3	0.4	0.7	0	14
2	BTR	0.9	1.01	0.1			
	ATR1	0	3.5	0.3	0.8		18
	ATR2a	0	4	0.01		1.1	9
	ATR3a	0	3.5	0.3	0.8	0	18
3	BTR	0.9	1.01	0.1			
	ATR1	0.3	2.7	0.2	0.6		17
	ATR2a	0.3	4	0.01		1.1	8
	ATR3a	0.3	2.7	0.2	0.6	0	17
4	BTR	0.9	1.01	0.1			
	ATR1	0.2	1.5	0.1	0.3		13
	ATR2a	0.4	3.9	0.01		1.1	6
	ATR3a	0.2	1.5	0.1	0.3	0	13
5	BTR	0.9	1.01	0.2			
	ATR1	0	1.2	0.1	0.3		11
	ATR2a	0.9	4	0.01		1.4	5
	ATR3a	0	1.2	0.1	0.3	0	11

Table 2: Optimal Taylor rules, central bank gain; shock in the bond market ($\rho_\nu = 0.9$)

Note: Loss Function 1 $= var(\pi) + var(y)$; Loss Function 2 $= var(\pi) + 0.5var(y)$; Loss Function 3 $= var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 4 $= var(\pi) + 0.5var(y) + 0.1var(\Delta credit)$; Loss Function 5 $= var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule $(100 * (Loss\,|_{BTR} - Loss\,|_{ATR})\,/Loss\,|_{BTR})$. A positive number means that the augmented rule outperforms the benchmark.

Loss function	Taylor rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable $\phi_{\Delta credit}$	ϕ_{ls}	Gain (%)
1	BTR	0.9	1.7	0.3			
	ATR1	0.8	1.3	0.1	0.2		2
	ATR2b	0.9	1.7	0.3		0	0
	ATR3b	0.8	1.3	0.1	0.2	0	2
2	BTR	0.9	3.1	0.3			
	ATR1	0.9	2.7	0.2	0.5		1
	ATR2b	0.9	3.1	0.3		0	0
	ATR3b	0.9	2.7	0.2	0.5	0	1
3	BTR	0.9	2.7	0.2			
	ATR1	0.9	2.2	0.1	0.4		1
	ATR2b	0.9	2.7	0.2		0	0
	ATR3b	0.9	2.2	0.1	0.4	0	1
4	BTR	0.9	4	0.5			
	ATR1	0.8	2.3	0.1	0.6		4
	ATR2b	0.8	2.1	0.2		0.1	0
	ATR3b	0.7	1.3	0.01	0.2	0.1	4
5	BTR	0.7	4	0.8			
	ATR1	0.6	3	0.4	1.6		18
	ATR2b	0.5	1.3	0.1		0.2	8
	ATR3b	0.6	3	0.4	1.6	0	18

Table 3: Optimal Taylor rules, central bank gain; shock in the loan market ($\rho_\sigma = 0.722$)

Note: Loss Function 1 $= var(\pi) + var(y)$; Loss Function 2 $= var(\pi) + 0.5var(y)$; Loss Function 3 $= var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 4 $= var(\pi) + 0.5var(y) + 0.1var(\Delta credit)$; Loss Function 5 $= var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule $(100 * (Loss\,|_{BTR} - Loss\,|_{ATR})\,/Loss\,|_{BTR})$. A positive number means that the augmented rule outperforms the benchmark.

Loss function	Taylor rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable $\phi_{\Delta credit}$	ϕ_{bs}	Gain (%)
1	BTR	0.9	1.1	0.2			
	ATR1	0	1.6	0.4	0.5		15
	ATR2a	0.9	1.1	0.2		0	0
	ATR3a	0	1.6	0.4	0.5	0	15
2	BTR	0.9	1.1	0.1			
	ATR1	0	2.4	0.3	0.6		16
	ATR2a	0	4	0.3		0.2	6
	ATR3a	0	2.4	0.3	0.6	0	16
3	BTR	0.9	1.1	0.1			
	ATR1	0.7	1.2	0.1	0.2		9
	ATR2a	0.5	4	0.3		0.2	4
	ATR3a	0.7	1.2	0.1	0.2	0	9
4	BTR	0.9	1.01	0.1			
	ATR1	0.6	3.3	0.4	1		10
	ATR2a	0.2	4	0.01		0.4	6
	ATR3a	0.6	3.3	0.4	1	0	10
5	BTR	0.9	1.01	0.3			
	ATR1	0.7	4	0.2	1.9		18
	ATR2a	0.4	3.6	0.01		0.6	16
	ATR3a	0.7	4	0.2	1.4	0.2	18

Table 4: Optimal Taylor rules, central bank gain; shock in the bond market ($\rho_\nu = 0.722$)

Note: Loss Function 1 $= var(\pi) + var(y)$; Loss Function 2 $= var(\pi) + 0.5var(y)$; Loss Function 3 $= var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 4 $= var(\pi) + 0.5var(y) + 0.1var(\Delta credit)$; Loss Function 5 $= var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule $(100 * (Loss\,|_{BTR} - Loss\,|_{ATR})\,/Loss\,|_{BTR})$. A positive number means that the augmented rule outperforms the benchmark.

Loss function	Taylor rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable $\phi_{\Delta credit}$	ϕ_{ls}	Gain (%)
1	BTR	0.9	1.4	0.2			
	ATR1	0.9	1.5	0.2	0.1		3
	ATR2b	0.9	1.4	0.2		0	0
	ATR3b	0.9	1.5	0.2	0.1	0	3
2	BTR	0.9	2.8	0.2			
	ATR1	0.9	1.8	0.1	0.2		8
	ATR2b	0.9	1.8	0.2		0.1	4
	ATR3b	0.9	1.8	0.1	0.2	0	8
3	BTR	0.9	2.8	0.2			
	ATR1	0.9	1.8	0.1	0.2		8
	ATR2b	0.9	1.8	0.2		0.1	4
	ATR3b	0.9	1.8	0.1	0.2	0	8
4	BTR	0.9	2.8	0.1			
	ATR1	0.9	1.5	0.01	0.2		9
	ATR2b	0.9	1.3	0.1		0.1	6
	ATR3b	0.9	1.5	0.01	0.2	0	9
5	BTR	0.9	3.5	0.01			
	ATR1	0.9	1.6	0.01	0.3		10
	ATR2b	0.9	1.01	0.01		0.1	7
	ATR3b	0.9	1.01	0.01	0.1	0.1	11

Table 5: Optimal Taylor rules, central bank gain; shock in the loan market ($\rho_\sigma = 0.9$)

Note: Loss Function 1 = $var(\pi) + var(y)$; Loss Function 2 = $var(\pi) + 0.5var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 4 = $var(\pi) + 0.5var(y) + 0.1var(\Delta credit)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule ($100 * (Loss\,|_{BTR} - Loss\,|_{ATR})\,/Loss\,|_{BTR}$). A positive number means that the augmented rule outperforms the benchmark.

Loss function	Taylor rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable $\phi_{\Delta credit}$	ϕ_{bs}	ϕ_{ls}	Gain (%)
1	BTR	0.9	1.1	0.2				
	ATR1	0	1.8	0.3	0.5			13
	ATR2a	0.9	1.1	0.2		0		0
	ATR2b	0.9	1.01	0.1			0.1	0
	ATR3a	0	1.8	0.3	0.5	0		13
	ATR3b	0	1.8	0.3	0.5		0	13
2	BTR	0.9	1.01	0.1				
	ATR1	0	2.7	0.2	0.6			17
	ATR2a	0	4	0.01		1.1		8
	ATR2b	0.9	1.2	0.1			0.2	2
	ATR3a	0	2.7	0.2	0.6	0		17
	ATR3b	0	2.7	0.2	0.6		0	17
3	BTR	0.9	1.01	0.1				
	ATR1	0.6	2.4	0.2	0.5			17
	ATR2a	0.5	4	0.01		1.1		7
	ATR2b	0.9	1.2	0.1			0.2	2
	ATR3a	0.6	2.4	0.2	0.5	0		17
	ATR3b	0.6	2.4	0.2	0.5		0	17
4	BTR	0.9	1.01	0.1				
	ATR1	0.6	2.5	0.2	0.6			13
	ATR2a	0.6	3.9	0.01		1.1		5
	ATR2b	0.9	1.1	0.1			0.2	2
	ATR3a	0.6	2.5	0.2	0.6	0		13
	ATR3b	0.6	2.5	0.2	0.6		0	13
5	BTR	0.9	1.01	0.2				
	ATR1	0.4	1.5	0.1	0.4			11
	ATR2a	0.9	4	0.01		1.4		5
	ATR2b	0.9	1.01	0.1			0.3	4
	ATR3a	0.4	1.5	0.1	0.4	0		11
	ATR3b	0.3	1.3	0.1	0.3		0.1	12

Table 6: Optimal unconditional Taylor rules, central bank gain

Note: Loss Function 1 = $var(\pi) + var(y)$; Loss Function 2 = $var(\pi) + 0.5var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 4 = $var(\pi) + 0.5var(y) + 0.1var(\Delta credit)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.5var(\Delta credit)$. Gain is= the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule $(100 * (Loss\,|_{BTR} - Loss\,|_{ATR})\,/Loss\,|_{BTR})$. A positive number means that the augmented rule outperforms the benchmark.