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Financial Shocks and Optimal Monetary Policy 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 the macroeconomy following financial shocks. We use a DSGE model that comprises both a loan and a bond market, which best suits the contemporary structure of the U.S. financial system and allows for a wide set of financial shocks and transmission mechanisms. Overall, we find that targeting financial stability – in particular credit growth, but in some cases also financial spreads and asset prices – improves macroeconomic stabilization. The specific policy implications depend on the policy regime, and on the origin and the persistence of the financial shock.

Keywords: financial shocks, optimal monetary policy, Taylor rules, DSGE models, bond market, loan market

JEL codes: E32, E44, E52

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1 Introduction

The 2007 crisis and the events that followed raised a number of lessons for macroeconomic modeling and for the strategy of monetary policy (Mishkin, 2011). In this paper we jointly address the implications of three of those lessons: (i) price and output stability do not ensure financial stability, (ii) cleaning up the effects of financial crises is very costly and (iii) developments in the financial sector have a far greater impact on economic activity than previously realized.

Lessons (i) and (ii) relate to the design of monetary policy. As output and inflation stability during the Great Moderation concealed growing economic and financial imbalances that eventually caused the crisis, and as the Great Recession has been particularly severe and hard to reverse, the debate on whether monetary policy should also target financial stability has been reignited (see *e.g.* Blanchard, Dell'Ariccia, and Mauro 2013). While the pre-crisis consensus on a dual central bank mandate to stabilise output and inflation still prevails (see *e.g.* Bernanke, 2013), the case for including a measure of financial vulnerability in the monetary policy reaction function has grown stronger (see *e.g.* Borio, 2014b and Stein, 2014), and it has even been argued that a third mandate may eventually be needed (Reis, 2013). One crucial open issue is what specific measure of financial stability should be targeted, with suggestions spanning through financial sector or overall leverage, credit or bond spreads, asset (house) prices and overall credit (see *e.g.*, Woodford, 2012, Gilchrist and Zakrajsek, 2012b, Borio, 2014a and the references in subsection 1.1).

Lesson (iii) relates to macroeconomic modeling, and encompasses the potential role of financial factors in the generation of shocks and their propagation to the aggregate economy. In recent years, economists embedded financial frictions into general equilibrium models, acknowledging that such frictions are crucial in macroeconomic analysis. There are three main traditions in the literature. One augments the workhorse New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) model of Smets and Wouters (2003) with a perfect competition banking sector that lends to entrepreneurs as a function of their leverage (*e.g.* Christiano, Motto, and Rostagno, 2014). Another enhances the model with monopolistic competition in the banking sector (*e.g.* Gerali, Neri, Sessa, and Signoretti, 2010). The third introduces financial frictions into the baseline NK DSGE model of Woodford (2003) with patient and impatient agents, rather than formally modeling a financial sector (*e.g.* Iacoviello, 2005 and Curdia and Woodford, 2010). Regarding generation of shocks, the literature has shown that financial shocks – the excess bond premium shock in Gilchrist and Zakrajsek (2012a), the risk shock in Christiano, Motto, and Rostagno (2014) or shocks originating in the banking sector in Gerali, Neri, Sessa, and Signoretti (2010) – account for a large share of business cycle fluctuations, in particular the bulk of recent recessions in the U.S. and euro area.

The combined consideration of the lessons (i)-(iii) leads to a research question that compiles three ingredients: how do monetary policy rules augmented with financial variables perform in an economy featuring financial frictions, following aggregate fluctuations caused by financial shocks? Such a threefold research programme has not been thoroughly explored so far, as further reviewed in subsection 1.1 (notable exceptions are Gilchrist and Zakrajsek, 2012b and Davis and Huang, 2013). In the literature featuring the first two ingredients, which dominates the research field, the performance of monetary policy when the central bank reacts to financial variables depends largely on the specific model and type of financial friction considered (in addition to the financial variable in the policy rule). Most importantly, if a common feature of research in the field could be underscored, it would be that all models consider an economy with only one financial sector and a very limited set of financial frictions and shocks.

However, the U.S. financial system is increasingly composed of two rather different sectors: a traditional banking system and a non-traditional system, largely non-regulated, highly associated with securitization and harder to measure – often called the shadow banking system. Most estimates indicate that the latter was larger than the former in the U.S. economy at the outset of the 2007 crisis, and may still be (see *e.g.* Pozsar, Adrian, Ashcraft, and Boesky, 2010 and Gorton and Metrick, 2012). Moreover, it is well-established that non-traditional-bank financial factors have been particularly relevant in the 2007 financial crisis (see *e.g.* Akerlof, 2013). So, as Woodford (2010, p. 26) points out, "*what is needed is a framework for macroeconomic analysis in which intermediation plays a crucial role and in which frictions that can impede an efficient supply of credit are allowed for, a framework which also takes account of the fact that the U.S. financial sector is now largely market-based.*"

Hence the motivation for this paper. Using the model previously built by Verona, Martins, and Drumond (2013), we provide an answer the above stated threefold research question, taking into account the dual composition of the U.S. financial sector, *i.e.* the co-existence of a traditional and a non-traditional banking sector. In section 2 we briefly describe the model. Here, we emphasize that our DSGE model features a financial system with a loan and a bond market and accordingly two different different financial intermediaries – retail and investment banks – that intermediate financial flows between households (savers) and two groups of entrepreneurs (borrowers) with different average risk. The retail banking sector is modeled along the lines of the standard Bernanke, Gertler, and Gilchrist (1999) financial accelerator mechanism, while the bond market is populated by a continuum of monopolistic competitive investment banks (in the spirit of Gerali, Neri, Sessa, and Signoretti, 2010) that set the coupon rate on bonds. For realism, we calibrate the model to match the bond-to-bank finance ratio in the U.S. and the cyclical sensitivity of the spread in bond finance.

The main contributions of the paper are the following. First, we address the relevance of financial stability targets in the central bank's policy rule in a model in which a loan and a bond market coexist and which thus features a wider and arguably more realistic set of transmission mechanisms. Second, we assess the performance of alternative monetary policy rules in reaction to two different financial shocks, one arising in the bond market and one in the loan market, which affect the cost of borrowing for different entrepreneurs. Third, we seek financial variables that may improve the ability of monetary policy to stabilize the economy, looking at both segments of the financial system, the traditional banking sector and the bond market.[1]

The flavor of our main results can be given in five points. First, an explicit target for financial stability usually improves the ability of monetary policy to stabilize the aggregate economy. Second, targeting credit growth seems to be the most effective policy, as compared to other financial indicators (financial spreads and asset prices). Third, the role of monetary policy appears to be larger following shocks in the bond market than following shocks in the loan market. Fourth, the case for a monetary policy targeting financial stability increases with the persistence of the financial shocks that cause the economic fluctuations. Fifth, if the central bank aimed at maximizing social welfare rather than fulfilling its mandate, policy would respond even more aggressively to financial variables and less so to inflation.

The rest of the paper is organized as follows. In the next subsection we briefly review the related literature. In section 2 we present the main distinctive features of our model, and then describe the two financial shocks that are the source of fluctuations in our simulations. In section 3, we describe the method used to assess the performance of alternative monetary policy rules, present the results of our simulations, and provide some sensitivity analyses. Section 4 concludes.

1.1 Related literature

Our paper is closely related to three strands of literature. First, at a more general level, is the literature on the relation between financial and business cycles, emphasizing how the 2007 crisis reopened the debate on the reaction of monetary policy to financial (in)stability, changed the perception and measurement of financial disruptions, and stimulated research that puts financial shocks at the center of business cycles. Second, and more specific, is the literature that has assessed the performance of monetary policy rules that include reactions to financial variables, in the context of different DSGE models with financial frictions. Finally, at a more technical level, is the literature on the concept and implementation of optimal policy, which distinguishes between analyses based on fulfillment of the central bank mandate and analyses based on social welfare measures.

[1] It should be stressed that the focus of our paper is to assess whether monetary policy should take into account financial variables for macroeconomic stabilization purposes. It does not attempt to address the macroprudencial policy role, and, consequently, the recent debate on establishing the right balance between monetary policy and macroprudencial policy in the pursuit of financial stability.

1.1.1 Financial and business cycles: policy, measurement and shocks

Macroeconomists are now well aware that recessions associated with financial disruptions tend to be sharper and to be followed by slower recoveries than other recessions, as correction of financial imbalances is typically long and difficult, and the transmission of stimulative policy is hampered by financial rebalancing (Cerra and Saxena, 2008, Claessens, Kose, and Terrones, 2009, Reinhart and Rogoff, 2009, and Claessens, Kose, and Terrones, 2012). Before the 2007 crisis, when financial stability was usually defined in terms of deviations of asset prices from fundamentals (*i.e.* asset price bubbles), the dominant view was that monetary policy should not lean against asset bubbles, but rather clean the effects of bubbles once they burst (see *e.g.* Cecchetti, Genberg, Lipsky, and Wadhwani, 2000 and Borio and Lowe, 2002). The crisis has now reopened this debate.

On the one hand, the accumulated loss of output has been exceedingly large and policy particularly ineffective in the wake of massive deleveraging. Consistently, recent research has shown that the ability of monetary policy to induce recoveries from recessions caused by financial crises is very limited and often insignificant, with deleveraging paying a more important role (see *e.g.* Bech, Gambacorta, and Kharroubi, 2014). Hence, while it has been acknowledged that financial cycles tend to be longer than economic cycles (Borio, 2014a), it has increasingly been argued that monetary policy should lean more aggressively against financial booms, so that policy would not be overburdened during busts (see *e.g.* Borio, 2014b).

On the other hand, it has been realized that more than in asset prices misalignments, the crisis was marked by excessive credit growth and leverage, associated with too much risk-taking and abnormally narrow spreads. Indeed, recent research has highlighted the fact that credit is the main predictor of financial crises, at least since the "new financial era" that began in 1945, characterised by a decoupling of credit from money (Schularick and Taylor, 2012). In the same vein, Jorda, Schularick, and Taylor (2011) showed that the severity of recessions is systematically related to the intensity of the build-up of excessive leverage during the preceding expansion, as measured by excessive growth of credit relative to GDP. Accordingly, credit-driven bubbles came to be considered more important, and easier to monitor and predict, 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). Overall, the events following the 2007 crisis as well as the accumulated knowledge about financial crises, moved the prescription that monetary policy should react to financial booms, and not only to busts, to the center of discussions in academic and policymaker circles.

At a more theoretical level, the recent events and empirical research led to the suggestion that, in the presence of financial frictions, financial shocks explain a significant part of the business cycle. Christiano, Motto, and Rostagno

(2014) suggest that risk shocks (*i.e.* fluctuations in the volatility of the idiosyncratic shocks faced by leveraged entrepreneurs) account for a large share of business cycle fluctuations. Estimating a similar model, Kaihatsu and Kurozumi (2014) show that for both Japan and the U.S. financial shocks are at least as important for investment fluctuations as technology shocks, and that favorable and subsequent unfavorable shocks to the external finance premium induced the boom and bust cycles of investment during the late 1980s and the 1990s in Japan and since 2004 in the U.S. With a similar model, but using the excess bond premium suggested by Gilchrist and Zakrajsek (2012a) as the measure of financial distress (a component of the corporate bond spread that measures the pricing of overall default risk), Gilchrist and Zakrajsek (2011, 2012b) find that changes in such a measure of financial stress cause changes in credit spreads that transmit to the aggregate economy, explaining the bulk of recent U.S. recessions as well as the investment booms of 1995-2000 and 2003-06.

1.1.2 Monetary policy and financial (in)stability: models and results

Given the renewed interest in the reaction of monetary policy to financial (in)stability, several papers in recent years have assessed the performance of monetary policy rules augmented with financial variables. Whereas asset prices dominated this literature in its earlier stages, financial measures such as spreads and credit have gradually gained in importance, in line with the course of events described in 1.1.1. Research has essentially been conducted in the context of three main classes of DSGE models with financial frictions.

First, the Smets and Wouters (2003) NK DSGE model augmented with a perfect competition banking sector and a Townsend (1979) debt contract (with the resulting Bernanke, Gertler, and Gilchrist, 1999 financial accelerator effects). With such a model, Faia and Monacelli (2007) find that the policy interest rate should not react significantly to asset prices, as the gains in output and inflation stabilization would be negligible. More recently, Gilchrist and Zakrajsek (2012b) and de Fiore and Tristani (2013) find that augmenting the monetary policy rule with a reaction to credit spreads effectively dampens the effects of financial disruptions, with gains in macro stabilization. Yet more recently, Davis and Huang (2013) find that as credit frictions or risk shocks become more severe (and the output-inflation tradeoff less favorable), inclusion of the credit spread in the central bank policy rule (even with no explicit target for financial stability in the central bank's loss function) results in a policy closer to its optimal path, with lower volatility of both output and inflation.

Secondly, models that introduce financial frictions in the NK DSGE model of Woodford (2003) without a formal financial sector. Iacoviello (2005) develops a model with patient and impatient households, as well as entrepreneurs, in which there are collateral constraints tied to housing values on both the firm and the household side, finding that a response of monetary policy to asset prices does not yield significant gains in terms of output and inflation stabilization. Curdia and Woodford (2010) consider a time-varying spread (wedge) between the interest rate received by patient households (lenders) and the interest rate payed by impatient households (borrowers), and find that adjusting the standard Taylor rule for variations in credit spreads improves welfare, with the magnitude of the adjustment depending on the source and persistence of shocks. Nistico (2012) considers an economy with heterogeneity in households related to the accumulated stock of financial wealth, and a financial friction caused by the interplay between households with and without wealth, finding that policy reactions to deviations in the stock-price growth rate may imply substantial stability gains.

Third, the Smets and Wouters (2003) model augmented with a monopolistically competitive banking sector, as in Gerali, Neri, Sessa, and Signoretti (2010), where the banks' loan margins depend on their capital-to-assets ratio. Such a model adds frictions on the side of lenders (bank lending channel) to the Iacoviello (2005) collateral channel on the side of borrowers. Using this model, Gambacorta and Signoretti (2014) find that augmenting a Taylor-type policy rule with a target for credit and, even more so, for asset prices, improves output and inflation stabilization under supply shocks, with the stabilization gains increasing with the degree of leverage in the economy. Hirakata, Sudo, and Ueda (2013) develop a model with interest rate spreads between lenders, financial intermediaries and borrowers that depend on entrepreneurs' and financial intermediaries' net worth, and find that in many cases (depending on the nature of shocks and the specific financial spread considered) spread-adjusted rules dominate simple Taylor-type rules.

1.1.3 Optimal monetary policy: central bank's mandate *vs* social welfare

As regards the concept and implementation of optimal monetary policy, there are two main traditions in the literature. One follows Woodford (2003) and studies the social welfare-maximizing policy, *i.e.* the policy that maximizes (a second order approximation to) the households' utility function (see *e.g.* Faia and Monacelli, 2007, Kobayashi, 2008, Curdia and Woodford, 2010, Gertler and Karadi, 2011, Woodford, 2012, de Fiore and Tristani, 2013, Hirakata, Sudo, and Ueda, 2013, Lambertini, Mendicino, and Punzi, 2013 and Quint and Rabanal, 2014). The other considers that the optimal policy is the one that best achieves the central bank's mandate, *i.e.* that intertemporally minimizes the central bank's loss function, usually defined as the weighted sum of the variances of inflation, output gap and of nominal interest rate changes (see *e.g.* Castelnuovo and Surico, 2004, Dieppe, Kuster, and McAdam, 2005, Jung, Teranishi, and Watanabe, 2005, Lippi and Neri, 2007, Sala, Soderstrom, and Trigari, 2008, Adolfson, Laseen, Linde, and Svensson, 2011, Nistico, 2012, Davis and Huang, 2013, and Gelain, Lansing, and Mendicino, 2013).

While the first approach has the advantage of allowing for theory-consistent Ramsey policy and analytical social welfare analyses, it has several disadvantages. In particular, it is more complex, less robust, not necessarily implementable, difficult to verify, and sensitive to all distortions in the economy (Adolfson, Laseen, Linde, and Svensson, 2011). The latter is especially important in models with financial frictions such as ours, as social welfare surely 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 the second approach as the main approach in this paper. But we also provide additional insights from a welfare analysis based on numerical approximations.

The simulations presented in section 3 consider alternative financial variables in augmented Taylor-type policy rules (as in the literature reviewed in 1.1.2) and check their relative performance among the possible set of policy regimes (those that best mimic the central bank's mandate, as reviewed in this subsection) when the economy is buffeted with financial shocks (as some literature reviewed in 1.1.1). Before conducting these simulations, in section 2 we briefly present the distinctive features of the model, as well as its baseline dynamics following financial shocks.

2 The model

Figure 1 sketches the structure of the model, which follows very closely Verona, Martins, and Drumond (2013). 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.[2] 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 as well as external finance (bank loans or bonds issuance). Government expenditures represent a constant fraction of final output and are financed by lump-sum taxes imposed on households, with the government budget being systematically balanced. The central bank sets the nominal interest rate according to a Taylor-type interest rate rule.

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

Except for entrepreneurs and financial intermediaries, the model is a standard NK DSGE model in the vein of Smets and Wouters (2003) and Christiano, Eichenbaum, and Evans (2005). We refer the reader to Verona, Martins, and Drumond (2012, appendix A) for a detailed description. In what follows, we describe the financial system of the model.

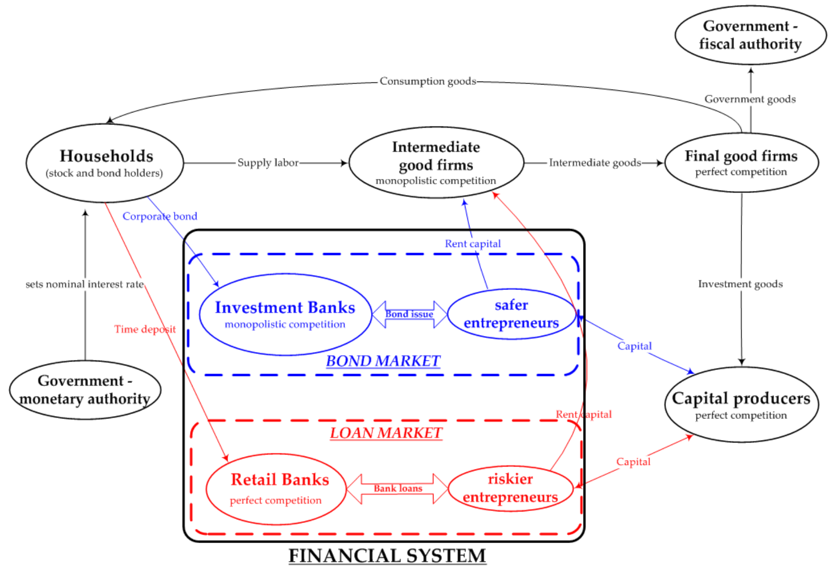

Figure 1: Structure of the model

2.1 The financial system

The financial system finances the fraction of the entrepreneurs' purchases of physical capital that goes beyond their net worth. It is composed of two different financial markets – bond and loan market – with different 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 of the sources of external funding. Following the corporate finance literature (see *e.g.* Bolton and Freixas, 2006), riskier entrepreneurs obtain financing via retail bank loans, while safer entrepreneurs have access to bond financing and issue bonds via investment banks.

A key feature of our model is the relative weight of the two financial market segments, the bond and the loan market. In particular, we calibrate the model to replicate the U.S. bond-to-bank finance ratio, and thus our economy has a rather market-based financial system, with bond finance accounting for a large share of total corporate debt finance. According to de Fiore and Uhlig (2011), the bond-to-bank finance ratio in the U.S. is 1.52. We calibrate the share of riskier entrepreneurs so as to match this ratio in the steady state.

2.1.1 The bond market

The bond market is populated by a continuum of monopolistic competitive investment banks. Each investment bank has some market power when conducting its intermediation services with safer entrepreneurs, but we assume perfect competition in the market for households' deposits. Let $\varepsilon_{t+1}^{coupon} > 1$ be the time-varying interest rate elasticity of the demand for funds in the bond market. Under the above assumptions, the bond coupon rate R_{t+1}^{coupon} is given by

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

that is, the coupon rate is a time-varying markup, $\frac{\varepsilon_{t+1}^{coupon}}{\varepsilon_{t+1}^{coupon}-1}$, over the nominal interest rate R_{t+1}^{e}. The spread in bond finance, *i.e.* the spread between the bond coupon rate and nominal interest rate is

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

Equation (1) shows that the bond spread is time-varying. In fact, corporate bond spread co-moves with the business cycle (see *e.g.* Gilchrist and Zakrajsek, 2012a). To determine the behavior of the bond spread, we specify the following baseline 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 $\bar{Y}$):

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

As detailed in Verona, Martins, and Drumond (2013), $\bar{\varepsilon}$ is chosen to match the average annual bond spread in the data, and α_1 to match the cyclical sensitivity of the bond spread according to very long historical U.S. time series.

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

Our modeling of the loan market follows closely Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2014). A riskier entrepreneur purchases K units of physical capital, which then turns into ωK units of effective capital, where $\omega > 0$ is a unit mean, lognormally distributed random variable, drawn independently by each entrepreneur. The standard deviation of $\log \omega$ is denoted by σ_t and is assumed to be the realization of a stochastic process.

The realization of ω is observed by the entrepreneurs at no cost, while the retail bank has to incur in a monitoring cost to observe it. To deal with this problem of asymmetry of information, the entrepreneurs and bank sign a debt contract, according to which the entrepreneur commits to pay back the loan principal and a non-default interest rate Z, unless he defaults. In this later case, the bank undertakes a costly verification of the value of the entrepreneur's assets and takes in all of the entrepreneur's net worth. Financial frictions – reflecting the costly state verification problem between entrepreneurs and the bank – imply that the bank hedges against credit risk by charging a premium over the riskless nominal interest rate. As shown by Bernanke, Gertler, and Gilchrist (1999), the credit spread (*i.e.*, the wedge between the cost of external finance and the risk-free rate) depends positively on the entrepreneur's leverage ratio. All else equal, higher leverage means higher exposure, implying a higher probability of default and thus a higher credit risk, which leads the bank to charge a higher lending rate.

The credit spread also fluctuates with changes in σ_t. In particular, an increase in idiosyncratic uncertainty raises the cost of external finance, and so reduces the amount of credit extended to riskier entrepreneurs. With fewer financial resources, these entrepreneurs acquire less physical capital, and the price of their capital falls. We refer to σ_t as the loan market shock, and present details of its modeling in subsection 2.2.2.[3]

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 of our economy 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:

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

[3] A similar interpretation of this shock is given by de Fiore, Teles, and Tristani (2011), Davis and Huang (2013) and Quint and Rabanal (2014). In contrast, Christiano, Motto, and Rostagno (2014) and Chugh (2014) interpret this as a risk shock, since risk is high in periods when σ_t is high, as there is a wider dispersion in capital outcomes across entrepreneurs. Gilchrist and Zakrajsek (2011) model this shock in an alternative way, introducing a direct shock to the effective cost of financial intermediation.

The shock influences the elasticity of demand for bonds

$$\varepsilon_{t+1}^{shock} = \varepsilon_{t+1}^{coupon} (1 + \nu_t)$$

and thus the bond coupon rate

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

and the bond spread

$$bond\ spread_{t+1}^{shock} = \frac{1}{\varepsilon_{t+1}^{shock} - 1} \left(1 + R_{t+1}^{e}\right) \quad .$$

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 U.S. financial bond spread. Specifically, our calibration corresponds to the AR(1) regression coefficient of the difference between (quarterly averages of) the Moody's Seasoned Baa Corporate Bond yields and the 10-Year Treasury constant maturity yields, from 1953:I to 2011:IV. We set the size of the shock σ_t^ν so that, on impact, the bond spread decreases by 50 basis points (annual rate).

Blue solid lines in figure 2 are the impulse response functions of selected variables to a favorable bond market shock (red dashed lines are the impulse response functions to a favorable loan market shock, which will be discussed in the next subsection). The top panel reports aggregate variables, the middle panel variables relative to the safer entrepreneurs (who have access to bond finance), and the bottom panel variables relative to the riskier entrepreneurs (who obtain bank finance).

Following a positive shock to σ_t^ν, safer entrepreneurs increase markedly their demand for credit (bonds), as they face a markedly lower interest rate for a prolonged period of time. The rise in capital purchases by safer entrepreneurs more than compensates for the increase in their net worth, so their leverage rises noticeably above the steady-state level.

As regards the riskier entrepreneurs, even though their cost of financing also drops (because of the decline in their leverage), bank finance is nevertheless more expensive than bond finance (the loan spread falls by around 25 basis points on impact, while the bond spread falls by 50 basis points), and so riskier entrepreneurs cut their capital expenditures and the amount of borrowing from retail banks declines considerably.

At the aggregate level, given that safer 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 safer entrepreneurs' demand for capital pushes up aggregate demand (investment and output) as well as the price of capital, while the decrease in the price of finance leads to a fall in inflation. The central bank, who follows a Taylor-type policy rule with a strong response to inflation and a weak response to the output gap (see equation 2 below), cuts the nominal interest rate in response to the fall in inflation.

The bond finance shock, as well as the dynamic responses of the economy, are very persistent (later in the paper we check the sensitivity of the results to different calibrations of ρ_ν). At the aggregate level, output peaks about 20 quarters after the shock and inflation falls until a few quarters later, the price of capital takes more than 20 quarters to resume its steady-state level and total credit peaks around 25 quarters after the shock. As regards the variables related to safer entrepreneurs, the bond spread takes about 40 quarters to resume its steady-state level and both leverage and bond issuance peak somewhat after 20 quarters but remain above their steady-state levels throughout the 40-quarter horizon. As regards riskier entrepreneurs, the loan spread, the amount of loans and leverage return to their steady-state levels by 30 quarters after the shock.

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. We calibrate $\rho_\varepsilon = 0.722$, which is the value estimated by Christiano, Motto, and Rostagno (2010) using aggregate U.S. data. The size of the shock σ_t^{σ} is chosen so that, on impact, the loan spread, $Z - R^e$, decreases by 50 basis points (annual rate).

Red dashed lines in figure 2 plot the impulse response functions of selected variables to this shock. Facing a lower cost of financing, riskier entrepreneurs borrow aggressively and their leverage increases markedly. In contrast to what happens in the reaction of safer entrepreneurs' borrowing to a favorable bond shock, the effects of the loan shock on borrowing and leverage of riskier entrepreneurs is short-lasting, *i.e.* the financial variables related to the set of entrepreneurs that use bank finance return swiftly to their steady states (later in the paper we check the sensitivity of the results to different calibrations of ρ_ε).

Regarding safer entrepreneurs, bond finance becomes relatively more expensive than bank finance, as the bond spread barely changes and the loan spread takes about 10 quarters to return to its steady-state level, so there is a large decline in the amount of bonds issued in the economy. Accordingly, their leverage falls markedly for about 10 quarters.

At the aggregate level, there is not much action, because of the small weight of riskier entrepreneurs in our market-based economy (that, recall, aims at resembling the structure of the U.S. financial system). The increase in bank loans is totally compensated by the decline in bond issuance, even though the magnitude of the former is much larger than the magnitude of the latter, so that total credit barely changes. Accordingly, the loan market shock plays virtually no role as a driver of aggregate macro fluctuations: output and investment barely move, while inflation increases only slightly for a few quarters, which leads to only a tiny reaction of the policy interest rate for a very limited period after the shock. The neutrality of the loan shock in our model is similar to the findings of Chugh (2014) for a frictionless real business cycle model augmented with the agency-cost framework of Carlstrom and Fuerst (1998), but contrasts with the results obtained with NK DSGE models by Christiano, Motto, and Rostagno (2014) and Gilchrist and Zakrajsek (2011, 2012b). Such contrast is explained by the fact that in these papers the loan market corresponds to the whole financial system, while in our paper the loan market is smaller than the bond market.

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 of our paper: does a reaction of monetary policy to financial variables improve macroeconomic stabilization in our economy, following financial shocks?

3 Optimal monetary policy rules and financial (in)stability

In order to assess whether a reaction of monetary policy to financial vulnerability improves policy outcomes, one has to (i) model the reaction of policy, (ii) measure financial vulnerability and (iii) establish a criterion for policy effectiveness. In what follows we address (i) and (ii). In subsection 3.1 we explain and use our main criterion for policy evaluation (iii), namely the performance of the policymaker in fulfilling its mandate. Then, in subsection 3.2 we explore an alternative criterion – maximization of social welfare. Finally, subsection 3.3 presents some sensitivity analyses.

We follow, in our analyses, the standard assumption that monetary policy is effectively modeled with Taylor-type interest rate rules, considering equation (2) as the benchmark Taylor rule (BTR). It 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:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) \right] \quad , \tag{2}$$

where R^e and $\bar{\pi}$ are the steady-state values of R_t^e and π_t, respectively, α_π and α_y are the weights assigned to expected inflation and output, and $\tilde{\rho}$ captures interest rate smoothing.

The policy outcomes of this benchmark rule will be compared with those of rules augmented with a measure of financial vulnerability. In this regard, a crucial issue is what specific indicator of financial vulnerability should be included. The preferred indicator should i) be easy to measure, ii) relate closely to overall economic stability and iii) be controllable by monetary policy. There is a wide variety of financial indicators in the literature, and the issue is clearly still open. Taylor rules have been augmented with asset prices (*e.g.* Faia and Monacelli, 2007), credit-growth (*e.g.* Christiano, Motto, and Rostagno, 2010, Gelain, Lansing, and Mendicino, 2013 and Lambertini, Mendicino, and Punzi, 2013), credit spreads (*e.g.* Curdia and Woodford, 2010, Merola, 2010, Gilchrist and Zakrajsek, 2011, 2012b, Davis and Huang, 2013, Hirakata, Sudo, and Ueda, 2013 and Stein, 2014), asset prices growth (Nistico, 2012, Gelain, Lansing, and Mendicino, 2013 and Lambertini, Mendicino, and Punzi, 2013), the level of credit (either the credit-to-GDP ratio or percentage deviation from steady state, as in Curdia and Woodford, 2010 and Quint and Rabanal, 2014), and financial sector leverage (Woodford, 2012).

All considered, we assess the performance of Taylor-type rules augmented with four alternative measures of financial vulnerability: a rule augmented with asset prices (ATR1), which in our model correspond to the price of capital goods; a rule augmented with credit growth (ATR2), which in our model comprises the total bond issuance and credit granted; and a rule augmented with credit spreads, split into two sub-rules, one augmented with the bond spread, (ATR3a), the other augmented with the loan spread (ATR3b).[4]

- ATR1:
$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) + \phi_q \left(\frac{q_t - \bar{q}}{\bar{q}} \right) \right] \tag{3}$$
where q_t is the price of capital and $\bar{q}$ is its steady-state value;

- ATR2:
$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) + \phi_{\Delta credit} \left(\frac{B_{t+1} - B_t}{B_t} \right) \right] \tag{4}$$
where B_t is aggregate credit (the sum of bonds and bank loans);

- ATR3a:
$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) - \phi_{bs} \left(BS_t - \overline{BS} \right) \right] \tag{5}$$

[4] We have also conducted simulations with the growth rate of asset prices, and some measures that capture the level of credit, but those indicators turned out not to improve economic stabilization in our model.

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

- ATR3b:

$$R_t^e = \tilde{\rho} R_{t-1}^e + (1-\tilde{\rho}) \left[R^e + \phi_\pi \left(E_t \pi_{t+1} - \bar{\pi} \right) + \phi_y \left(\frac{Y_t - \bar{Y}}{\bar{Y}} \right) - \phi_{ls} \left(LS_t - \overline{LS} \right) \right] \tag{6}$$

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

3.1 Policymakers' preferences and optimal rules

In this subsection we compare the performances of rules ATR1, ATR2, ATR3a and ATR3b relative to the baseline rule (BTR), for an economy hit by financial shocks, using as the assessment criterion the ability of the central bank to achieve its mandate, *i.e.* to intertemporally minimize its loss function. The preferences of the policymaker include a primary goal of price stability and a goal of stabilization of output around potential, which corresponds to the flexible inflation targeting that characterizes modern central banks (see *e.g.* Svensson, 2010). There is also an objective of minimizing the volatility of changes in the policy interest rate, consistent with the fact that central banks typically feature interest rate smoothing (see *e.g.* Aguiar and Martins, 2005). Analytically, we assume that the central bank's mandate may be described as the objective of minimizing a weighted average of the variances of inflation, output gap and policy interest rate changes:

$$Loss\ Function = \alpha_\pi var\left(\pi\right) + \alpha_y var\left(y\right) + +\alpha_r var\left(\Delta R^e\right).$$

This general loss function (LF) is flexible enough to encompass a wide range of policy regimes, corresponding to different emphases on price, output and interest rates stability, as a function of the specific weights α_π, α_y and α_r. In the empirical literature, many studies provide estimates for these weights (see *e.g.* Lippi and Neri, 2007, Adolfson, Laseen, Linde, and Svensson, 2011 and Ilbas, 2012). In practice, monetary policy regimes differ considerably across economies and along time, and so for completeness we conduct our simulations for a set of policymakers' preferences, considering three policy regimes and six different parameterizations of their relative weights, as reported in Table 1 (our weights are in line with those often used in the literature, see *e.g.* Ehrmann and Smets, 2003). The first policy regime (LF1) is a strict inflation targeting regime, pursued by a central bank that is only concerned with inflation stability. The second policy regime is one of flexible inflation targeting, in which the central bank also aims at stabilizing the output gap (here we consider three alternative values for the coefficient attached to output,

Loss function	α_π	α_y	α_r
LF1	1	0	0
LF2	1	1	0
LF3	1	0.5	0
LF4	1	0.1	0
LF5	1	0.5	0.1
LF6	1	0.1	0.1

Table 1: Loss functions and monetary policy regimes

LF2, LF3 and LF4). Finally, LF5 and LF6 are flexible inflation targeting regimes in which the central bank further aims at reducing the volatility of the nominal policy interest rate.

We conduct two experiments, proceeding in steps towards optimized Taylor-type rules.

In the first experiment, we hold the coefficients in the benchmark Taylor rule at the baseline values, $\tilde{\rho} = 0.88$, $\phi_\pi = 1.82$ and $\phi_y = 0.11$ (as in Verona, Martins, and Drumond, 2013), and allow the coefficients associated with the financial variable, namely asset prices (ϕ_q), credit growth ($\phi_{\Delta credit}$), loan spread (ϕ_{bs}) and bond spread (ϕ_{bs}) in (3)-(6), to vary between 0 and 1. Figure 3 plots the value of the loss functions for all policy regimes (LF1-LF6) in the case of a shock in the bond market, for all possible values of the coefficients associated to ϕ_q, $\phi_{\Delta credit}$, and ϕ_{bs} in the top, middle and bottom panel respectively. Figure 4 depicts the results of the same exercise for a loan market shock (there, the bottom panel plots the losses as a function of ϕ_{ls}). In all graphs, we normalize to 1 the value of the loss implied by the benchmark Taylor rule.

Figure 3 shows that attaching a non-null weight to a financial variable in the interest rate rule allows for an improvement in economic stabilization, *i.e.* it increases the ability of the central bank to fulfill its mandate, for most policy regimes. The gains in policy effectiveness are larger for policy regimes in which there is a substantial weight attached to output stabilization (LF2, LF3 and LF5) and less so in the case of policy regimes in which the policymaker does not care much about output stabilization (LF1, LF4 and LF6). Moreover, when a financial variable considerably improves economic stabilization, the minimization of the central bank's loss function is achieved with larger weights for credit growth and the bond spread than for asset prices; and, in those policy regimes, the gains in terms of loss minimization (overall economic stabilization) are larger when the central bank reacts to credit growth and to bond spreads, and somewhat smaller when it reacts to asset prices.

The results are markedly different when the economy is hit by a shock in the loan market (figure 4). First, the magnitude of the additional minimization of the central bank's loss function is overall very small, except if the central bank attaches a small weight to output stabilization (LF1, LF4 and LF6) and reacts to asset prices and to the loan spread (with the larger gain obtained for LF1 and a reaction to the loan spread). Although having fairly large coefficients for credit growth improves economic stabilization if the loss function includes a large weight for the output gap (LF2, LF3 and LF5), the gain is very small and not at all comparable to that obtained in the case of a bond market shock. In contrast, having monetary policy react to asset prices and loan spread usually improves the ability of the central bank to fulfill its mandate in regimes with a null or small weight attached to output (LF1, LF4 and LF6). While in all these three regimes the loss function is minimized for relatively large coefficients for asset prices and loan spread, the former are somewhat larger than the latter.

The qualitative differences between the results in the case of a bond market shock and those obtained in the case of a loan market shock reinforce the motivation for using our model with these two financial market segments.

To offer an alternative perspective of our results so far, figures 5 and 6 report the impulse response functions under different Taylor rules to a bond and loan market shock, respectively. Black lines give the responses under the BTR, while the blue, red and green lines are for responses under ATR1, ATR2 and ATR3a (or ATR3b), respectively. The coefficients of financial variables are set at the values that minimize LF5 (top panels) and LF6 (bottom panels), which are the most encompassing monetary policy regimes for which there are visible gains in economic stabilization with reactions to financial variables in the case of bond shocks (LF5) and loan shocks (LF6).[5] Figure 5 shows that after a bond market shock, rules augmented with financial variables markedly improve the ability of the central bank to stabilize inflation and, when the policymaker cares substantially about output stabilization (LF5), also improve its ability to stabilize output. Moreover, the advantage of rules with reactions to credit growth (red lines) comes essentially from improved stabilization of the policy interest rate (which matters, although not much, in both LF5 and LF6), but also from a better stabilization of inflation in the medium run. Figure 6 confirms that the gains from monetary policy reaction to financial variables is smaller in the case of a loan market shock. It further indicates that such gains come from improved stabilization of inflation, irrespective of the targeted financial variable, while, in contrast, the responses of output and the policy interest rate are actually larger when policy reacts to spreads and asset prices (although such effects are quantitatively very small).

In the second experiment, we optimize over all the parameters in the rules (2)-(6), finding the combination of coefficients that yield the lowest values of the loss functions. 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 $0 \leq \phi_q$; $\phi_{\Delta credit}$; ϕ_{bs} ; $\phi_{ls} \leq 1$.[6]

Table 2 reports the results for the case of a shock in the bond market. The lines report the six monetary policy regimes and the four Taylor-type rules for each regime. Columns 3-5 show the optimal coefficients for the lagged

[5] The values that minimize LF5 are: $\phi_q = 0.135$, $\phi_{\Delta credit} = 0.33$ and $\phi_{bs} = 0.35$ (bond market shock), and $\phi_q = 0.23$, $\phi_{\Delta credit} = 0.28$ and $\phi_{ls} = 0.015$ (loan market shock). The values that minimize LF6 are: $\phi_q = 0.06$, $\phi_{\Delta credit} = 0.18$ and $\phi_{bs} = 0.06$ (bond market shock), and $\phi_q = 0.495$, $\phi_{\Delta credit} = 0.07$ and $\phi_{ls} = 0.235$ (loan market shock).

[6] The grid step is 0.1 for all the coefficients. As regards ϕ_y and ϕ_π, the lower limits are, more precisely, 0.01 and 1.01, to satisfy the Taylor principle and avoid indeterminacies.

interest rate, expected inflation and the output gap, in the optimized rule of each regime. Columns 6-8 report the optimal coefficients for the relevant financial variable in the respective rule and regime. Column 9 shows the percent gain in the loss function implied by each augmented rule over the benchmark Taylor rule, which is the optimizing criterion in this section (the last column relates to the welfare analysis discussed in the next subsection).

A first conclusion is that, overall (in 15 out of 18 possible combinations of rule and regime), monetary policy reactions to financial variables allow the central bank to better achieve its mandate (the few exceptions occur with a policy reaction to asset prices in LF1 and LF2 and to the bond spread in LF2). Furthermore, the augmented policy rules that allow for an improvement in the central bank loss function typically include a very strong reaction to inflation and a very moderate reaction to the output gap (there is less of a pattern regarding interest rate smoothing).

Second, for the whole spectrum of optimized interest rate rules, the largest gains are always obtained when policy reacts to credit growth (ATR2): for most policy regimes (LF2-LF6) the gains are substantial, very similar and falling within an interval of 14 to 18 percent, while in the regime of strict inflation targeting (LF1) it reaches the outstanding value of 71 percent.

Third, while typically more moderate, the gains obtained from a reaction to asset prices or to the bond spread are also non-negligible, ranging from 7 to 8 percent in the regimes LF3 and LF5, and amounting to 12 percent in the regimes LF4 and LF6. Moreover, in the strict inflation targeting regime (LF1) a reaction of the policy interest rate to the bond spread allows for a 37 percent gain relative to the benchmark policy rule.

Table 4 reports the results in the case of a shock in the loan market. A first conclusion is that in the majority of policy regimes and rules (12 of 18), the reaction of monetary policy to financial variables does not yield notable loss function gains. In particular, in policy regimes LF2, LF3 and LF5 the optimized augmented rules do not yield any significant gain over the benchmark rule. These optimized rules feature a relatively small coefficient of reaction to inflation and a relatively large reaction to the output gap, as well as very high degrees of interest rate smoothing, which contrasts with the very large weight on inflation relative to the output gap that occurs when optimized augmented rules improve macroeconomic stabilization (LF1, LF4 and LF6).

Second, optimized augmented interest rate rules only allow for noticeable gains relative to the benchmark rule in policy regimes in which the central bank does not care much about output gap stabilization (LF1, LF4 and LF6). Such a result is consistent with the results displayed in figure 6, namely that improving inflation stabilization via a reaction to a financial variable, after a loan market shock, ends up increasing the variability of the output gap. Moreover, in these regimes, the optimal weights for inflation are invariably very large, while the optimal weights for the output gap are very close to zero. There is less of a pattern as regards the coefficients of interest rate smoothing, with very low values in the case of strict inflation targeting (LF1), intermediate values in the case of LF4 (a regime in which the central bank does not target the variability of the policy rate), and higher values in the case of LF6 (a regime in which the central bank has direct concerns for stabilization of the nominal interest rate).

Third, when optimized augmented policy rules allow for any noticeable improvement in the central bank's loss function, the largest gains occur in the case of rules augmented with a reaction to the loan spread. In policy regimes LF4 and LF6 the gains amount to 11 and 13 percent, respectively. For a regime of strict inflation targeting (LF1) the loss function improvement amounts to an outstanding 92 percent. In this case, the very high degree of reaction to the spread ends up reducing the coefficient associated with the goal of interest rate smoothing.

Finally, while much more moderate, there are some loss gains obtained from a policy reaction to credit growth: in regimes LF4 and LF6, the gains are 6 and 5 percent, respectively, while in the regime of strict inflation targeting (LF1) credit growth targeting allows for an improvement of 25 percent (again, with a very large coefficient for the financial variable replacing the reaction of policy to the lagged policy interest rate).

To sum up: (i) a "leaning-against-the-wind" policy has scope for improving the ability of the central bank to achieve macroeconomic stabilization; (ii) the case for monetary policy reactions to financial variables is stronger when the financial shock originates in the bond market, compared to a shock in the loan market, as in the latter stabilization of inflation comes at a cost in terms of stabilization of output and interest rates; (iii) the best performing optimized policy rules following a bond shock include a reaction to credit growth, although reactions to asset prices and bond spreads may also be helpful in some policy regimes; and (iv) the best optimized policy rules following a loan shock include a reaction to loan spreads, although credit growth targeting may also be helpful, if the policymaker does not have a relevant preference for output stabilization.

3.2 Social welfare and optimal rules

We now compare the performance of augmented interest rate rules relative to the baseline rule, using social welfare as the assessment criterion. Our goal is to supplement the analysis of the previous subsection, by examining the robustness of the results therein when policy is assessed with a criterion also used in some literature.

The welfare function, written in a recursive way, is the conditional expectation of lifetime household utility as of time 0:

$$Welf_{0,t} = U\left(c_t\,,\,h_t\right) + \beta E_t Welf_{0,t+1}\ \ ,$$

where β is the households' discount factor.

We compute social welfare numerically, as a second-order approximation to the households' utility function, conditional on the initial state being the non-stochastic steady state. Since the steady state of our model is independent of the monetary policy regime or rule, our computation of social welfare is comparable across all policy rules.

Following Schmitt-Grohe and Uribe (2007), among many others, we compute the welfare cost of alternative specifications of the monetary policy rule relative to the benchmark Taylor rule as follows. Consider two interest rate rules, the benchmark rule denoted by b and an alternative rule denoted by a. The welfare associated with rule b is defined as

$$Welf_0^b = E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t^b - bc_{t-1}^b\, ,\, h_t^b\right) \quad ,$$

where c_t^b and h_t^b denote the contingent plans for consumption and hours under rule b. Similarly, the welfare associated with rule a is

$$Welf_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t^a - bc_{t-1}^a\, ,\, h_t^a\right) \quad .$$

Let λ denote the welfare gain from following rule a rather than the benchmark rule b. We measure λ as the fraction of rule b's consumption process that a household would be willing to pay so as to be as well off under rule b as under rule a. That is, λ is implicitly defined by

$$Welf_0^a = U\left(\left(c_0^b - bc_{-1}\right)(1+\lambda)\, ,\, h_0^b\right) + E_0 \sum_{t=1}^{\infty} \beta^t U\left(\left(c_t^b - bc_{t-1}^b\right)(1+\lambda)\, ,\, h_t^b\right) \quad .$$

Using the particular functional form assumed for the period utility function, one can show that

$$Welf_0^a - Welf_0^b = \frac{\ln(1+\lambda)}{1-\beta} \quad .$$

Therefore

$$\lambda = \exp\left\{(1-\beta)\left(Welf_0^a - Welf_0^b\right)\right\} - 1 \quad .$$

Table 3 reports the coefficients of the Taylor rules that maximize welfare, as well as the respective value of λ, when there is a shock in the bond market. Following a bond shock, policy rules featuring a strong reaction to financial variables may improve social welfare. In particular, the best outcome (a gain of more than 5 percent in intertemporal consumption compared with the benchmark rule) would be obtained if monetary policy reacts strongly to credit growth. While the superiority of a policy rule with a strong response to credit growth is consistent with the main findings of the previous subsection, a closer look at the welfare-based results shows that their policy implications are quite different from those of the analysis based on the central bank's loss function. First, as the last column of table 2 indicates, even though the policy rules that maximize the ability of the central bank to fulfill its mandate always prescribe a reaction to credit growth, they either reduce social welfare or keep it almost unchanged. Second, for all regimes, the policy rules that maximize the ability of the central bank to achieve its mandate feature a smaller reaction to credit growth and a much stronger reaction to inflation than the rule that allows for maximization of social welfare: indeed, social welfare maximization entails a reaction of the policy interest rate to credit growth of the same order of magnitude as the reaction to inflation.

As regards a loan shock, table 5 shows that only a policy rule featuring a strong reaction to the loan spread improves social welfare. The gain, amounting to about 4.25 percent of intertemporal consumption, would be obtained if policy interest rates reacted with the same order of magnitude to the loan spread and to inflation, with no interest rate smoothing and virtually no reaction to the output gap. The supremacy of a policy rule including a strong response to the loan spread is consistent with the main findings of the previous subsection, namely for the policy regimes (LF1, LF4 and LF6) in which the policymaker attaches no significant weight to output stabilization, but the specific policy implications of the social welfare-based results are, again, quite different from those of the analysis based on the policymaker's ability to achieve its mandate. First, as the last column of table 4 indicates, the policy rules that maximize the ability of the central bank to fulfill its mandate do not change social welfare, even in the cases in which a reaction to the loan spread is prescribed. Second, for the relevant regimes, the policy rules that maximize the ability of the central bank to achieve its mandate feature a smaller reaction to the loan spread and a much stronger reaction to inflation.

3.3 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 optimal policy.

3.3.1 Persistence of financial shocks

Even though financial shocks are increasingly seen as important drivers of business cycle fluctuations, there is still little and ambiguous evidence regarding their empirical properties, in particular their persistence. Regarding the loan shock, on the one hand, using aggregate macro and financial data Christiano, Motto, and Rostagno (2010) estimate a coefficient of persistence of 0.722, while Christiano, Motto, and Rostagno (2014), using the same model but with a longer sample period obtain an estimate of 0.97; on the other hand, using firm-level data, Chugh (2014) obtains a persistence coefficient of 0.83. For the bond market shock, using U.S. aggregate financial data we estimate a value for the AR(1) regression coefficient of the bond spread of 0.9, while with U.S. corporate data Gilchrist and Zakrajsek (2011) estimate a value of 0.75.

In this subsection we thus redo the simulations reported in subsections 3.1 and 3.2 to investigate the sensitivity of our results to changes in the degree of persistence of financial shocks.

Figure 7 and table 6 report the results of the simulation exercises assuming a persistence of the bond market shock ρ_ν of 0.7 (closer to the value reported by Gilchrist and Zakrajsek, 2011) replacing the baseline value of 0.9. Figure 7 shows that the central bank may improve the effectiveness in achieving its mandate by reacting significantly to credit growth, in the regimes with a substantial weight attached to output stabilization (LF2, LF3 and LF5). However, gains are smaller and moreover no longer substantial when policy responds to asset prices and bond spreads in such regimes. Overall, table 6 confirms the previous results: in the context of optimized rules, most of the coefficients for asset prices and the bond spread tend to 0, while the coefficients for credit growth are positive and provide gains, with both the absolute value of the optimized coefficients for credit growth and the loss function gains smaller in most policy regimes. The welfare-based analysis, shown in table 7, confirms the magnitude of the coefficients for the optimal policy rule, but points to much smaller welfare gains and favors bond spread targeting over credit growth targeting. Overall, a smaller persistence of the bond shock leads to a weaker case for a policy of "leaning against the wind", even though some advantages of credit growth targeting still hold.

Figure 8 and table 8 report the results of the optimization exercises assuming a persistence of the loan market shock ρ_σ of 0.9 (which lies between the values estimated by Christiano, Motto, and Rostagno, 2014 and Chugh, 2014) replacing the baseline value of 0.722. Figure 8 confirms our previous results that the ability of the central bank to achieve its mandate is improved with a reaction to financial variables, provided the central bank does not attach a substantive weight to output stabilization (LF1, LF4 and LF6), with the qualification that the advantages of targeting the loan spread are now less clear and those of targeting credit growth are more apparent. Table 8 shows that when the loan market shock is more persistent, the gains from a reaction of policy to financial variables is larger (except only for the regime LF2), although with smaller reaction coefficients overall, and further indicates a decrease in the relative importance of targeting the loan spread and some increase in the advantage of targeting asset prices. The welfare-based analysis, shown in table 9, strengthens the conclusions drawn from the analogous analysis made with the baseline parametrization: a strong reaction of the policy interest rate to the loan spread, and a reaction of the same order of magnitude to inflation (which is smaller than the central bank would choose to best fulfill its mandate) create a substantial gain in social welfare. Overall, a higher persistence of the loan market shock leads to a stronger case for a policy of "leaning against the wind".

In short, our sensitivity analysis suggests that the higher the persistence of the financial shocks, the stronger the case for a policy of "leaning against the wind".

3.3.2 Optimal unconditional monetary policy rules

Throughout the paper, we assume that only financial shocks affect the economy, and 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. In this subsection we thus study the effectiveness of augmented policy rules when both financial shocks impact the economy. Technically, we move from policies that are conditional on a specific shock, to optimised monetary policy rules that are unconditional on the source of the shock.

Table 10 indicates that for most policy regimes (LF2 to LF6) augmenting the Taylor-type policy rule with a reaction to credit growth is the policy of "leaning against the wind" with better results in terms of fulfilling the central bank mandate, provided that such policy is combined with a strong reaction to inflation. In regimes LF4 and LF6, in which the central bank does not focus so much on output stabilization, a reaction of policy to asset prices or spreads also generates sizeable gains. In the regime of strict inflation targeting (LF1) a reaction of the policy rate to loan spreads further improves the success of the central bank relative to a rule with a reaction to credit growth. Overall, the results in this table are (with the exception of those relative to the regime of strict inflation targeting) quite close to those reported in table 2, which is surely explained by the large weight of the bond market in our model.

Table 11 also confirms the results described in table 3 relative to welfare-based analyses of optimal policies after a bond shock. If monetary policy reacts strongly to credit growth and by the same order of magnitude to inflation, social welfare increases more than 5 percent relative to the benchmark Taylor rule. The result that seems to differ more from the baseline concerns policies with a reaction to the loan spread: if the policymaker reacts strongly to this spread, moderates his reaction to inflation (to a similar coefficient, close to 1), reacts very little to output and does not react to lagged interest rates, social welfare would increase markedly.

Overall, the results in this section robustly suggest that a policymaker who has little information about which financial shocks are hitting the economy and is focused in meeting its mandate, should combine a strong reaction to expected inflation with a moderate reaction to actual credit growth, and either a moderate reaction to real output or some interest rate smoothing. They further suggest that in most policy regimes replacing the reaction to credit growth by a reaction to asset prices or spreads would still provide gains, albeit smaller, in the ability of the policymaker to achieve its goals. If the policymaker is focused instead on social welfare, a policy of "leaning against the wind" is still advisable, but in such case the reaction to inflation should be moderate, the reaction to output almost null, and there should be a modest degree of gradualism.

3.3.3 Optimal policy forecast horizons

It has recently been argued that "leaning against the wind" could be pursued through an extension of the policy horizon beyond that of the typical inflation targeting regimes, so that monetary policy would counteract slowly building-up financial vulnerabilities (Borio, 2014a,b) with no need to directly react to financial variables. Therefore, in our final tests 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 subsection 3.1, replacing 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, for each financial shock individually as well as for the unconditional policy, across all six policy regimes. The optimal forecast horizon turns out to be 1 quarter in nearly all cases, and never exceeds 3 quarters. Moreover, benchmark policy rules with extended policy forecast horizons never outperform augmented rules featuring the usual one-quarter ahead policy horizon.

Our results are thus robust and suggest that extending the horizon of inflation forecast targeting is not a valuable alternative to an explicit targeting of financial vulnerability, in contrast with what Borio (2014a,b) has argued. They are consistent with those of Levin, Wieland, and Williams (2003) for the U.S. economy but contrast with results for the euro area obtained by Smets (2003) and Dieppe, Kuster, and McAdam (2005). Using five models with different dynamics, Levin, Wieland, and Williams (2003) generally find very short optimal horizons that never exceed 4 quarters. Dieppe, Kuster, and McAdam (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 contribute to the debate on whether monetary policy should "lean against the wind", assessing the performance of optimized Taylor-type policy rules augmented with reaction to a financial variable, when an economy with a wide set of financial frictions faces aggregate fluctuations caused by financial shocks.

Our research has been motivated by lessons drawn from the recent financial crisis, namely the observation that output and price stability *per se* do not ensure financial stability, that recovering from financial crises is very costly, and that events in the financial sector – both shocks and transmission mechanisms – have far greater importance than previously realized.

Given this latter lesson, and given that the market-based non-traditional banking sector is larger than the traditional retail banking sector in the U.S., we conducted our analysis using a model with a dual financial system, in which safer entrepreneurs have access to bond finance while riskier entrepreneurs rely on retail banking.

Our main contributions stem from the theoretical environment provided by our model, with its wider and arguably more realistic set of transmission mechanisms than standard NK DSGE models. First, we thoroughly analyse policy reactions to two alternative financial shocks, a risk shock in the loan market and a spread shock in the bond market. Second, we search for useful indicators of financial vulnerability not only in the aggregate economy – asset prices and credit growth (bank loans plus bonds issued) – but also specifically in the retail banking sector and in the investment banking sector – namely loans and bonds' spreads.

The key criterion for assessing the relative performance of augmented Taylor-type policy rules (versus the benchmark rule that does not take into account financial vulnerability) has been the ability of the central bank to fulfill its mandate. Even not including financial stability directly in the policymakers' preferences (in line with the literature and policy regimes thus far), there is a wide set of possible policy regimes, and so for completeness we considered six alternative combinations of weights for inflation, output and lagged policy interest rates. For each regime, each financial shock and each indicator of financial vulnerability, we searched for the coefficients of the policy rule until the point of optimization.

We emphasize the following main conclusions. In our model, following a bond spread shock, it is optimal for the central bank to react strongly to inflation, very moderately to the output gap, and substantially to a financial variable. For most policy regimes, the largest improvement in the fulfillment of the central bank's mandate arises when policy reacts to credit growth, but responding to the bond spread and asset prices also provides some gains. In turn, when there is a shock in the loan market, the model implies more muted gains from a reaction of monetary policy to financial variables. The only visible improvements in the fulfillment of the policymaker's mandate appear in policy regimes in which output stabilization is not relevant, given that stabilization of inflation with a reaction to a financial variable increases the volatility of output. In such regimes, the best policy rules feature a reaction to the loan spread, although a reaction to credit growth also allows for some gains relative to the benchmark Taylor-type rule.

In addition, we checked whether policy implications would differ if the policymaker chooses to maximize social welfare, rather than the achievement of his mandate. Overall, we found that welfare-based optimal policies would react less intensively to inflation and more strongly to financial variables. Among these, the larger welfare gains would typically arise from a reaction to spreads and, to a lesser extent, credit growth, while asset prices turn out to be irrelevant.

We further performed a number of sensitivity analyses, from which we emphasize three main robust findings. First, the case for a monetary policy of "leaning against the wind" increases with the degree of persistence of the financial shock, irrespective of its origin. Second, policymakers who face possibly multiple financial shocks and have little information about their origin, maximize the fulfillment of their mandate following a policy rule with a strong reaction to forecast inflation and a moderate reaction to credit growth, and either a moderate reaction to output or some interest rate smoothing (depending on the specific policy regime). Finally, extension of the horizon of inflation forecasts in the policy rule does not appear to be a worthy alternative to the combination of the usual short-term inflation forecast with explicit targeting of a financial variable, *i.e.* extending the horizon of inflation targeting is inferior to "leaning against the wind".

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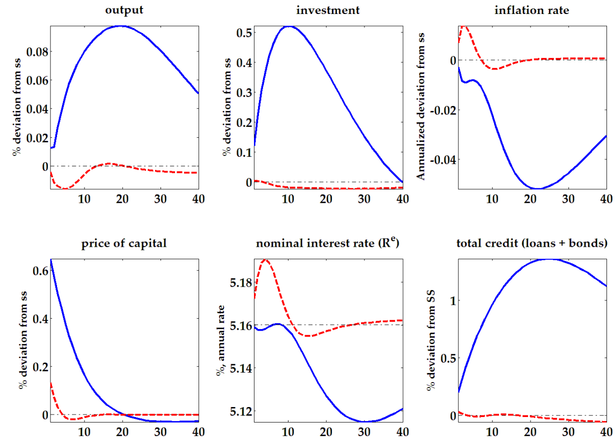
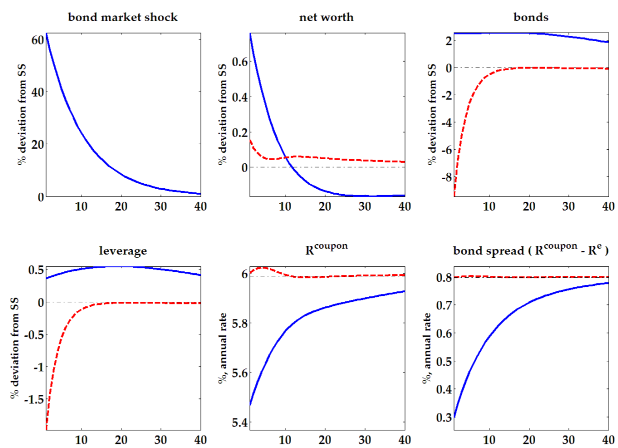
A. aggregate variables



B. Safer entrepreneurs



C. Riskier entrepreneurs

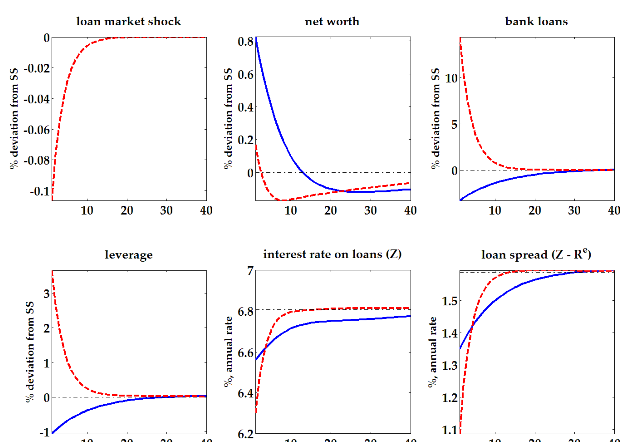
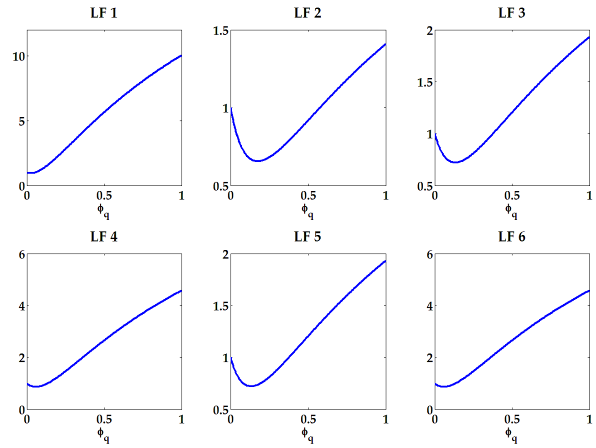


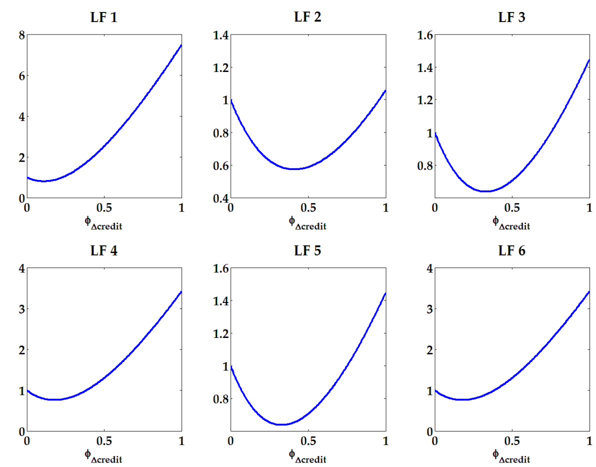
Figure 2: Impulse response functions to financial shocks. Blue solid lines: shock in the bond market ($\rho_\nu = 0.9$), red dashed lines: shock in the loan market ($\rho_\sigma = 0.722$)

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.

A. ATR1 - response to asset prices



B. ATR2 - response to credit growth



C. ATR3a - response to bond spread

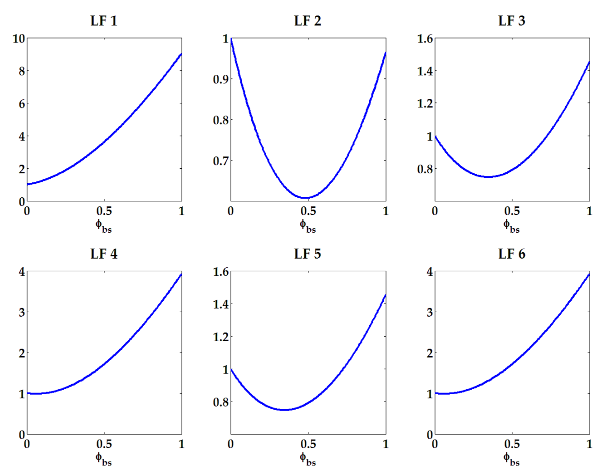
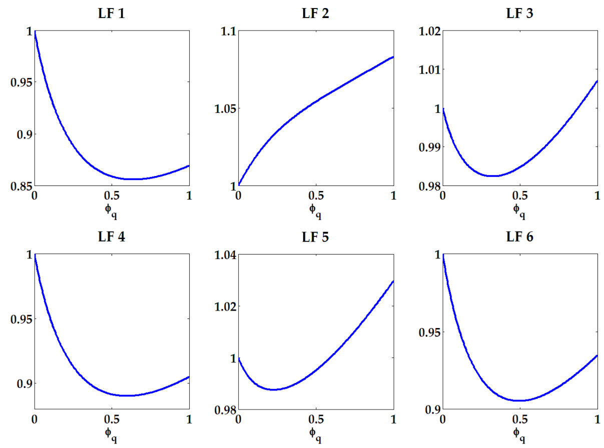


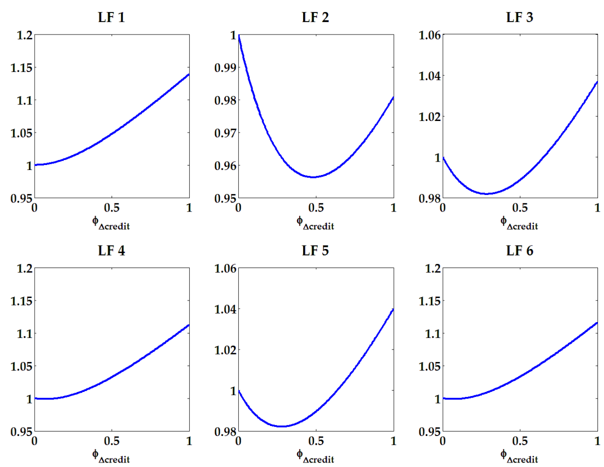
Figure 3: Standardized loss implied by alternative augmented Taylor rules for different policy regimes (shock in the bond market, $\rho_\nu = 0.9$).

Note. LF 1 $= var(\pi)$; LF 2 $= var(\pi) + var(y)$; LF 3 $= var(\pi) + 0.5var(y)$; LF 4 $= var(\pi) + 0.1var(y)$; LF 5 $= var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; LF 6 $= var(\pi) + 0.1var(y) + 0.1var(\Delta R^e)$.

A. ATR1 - response to asset prices



B. ATR2 - response to credit growth



C. ATR3b - response to loan spread

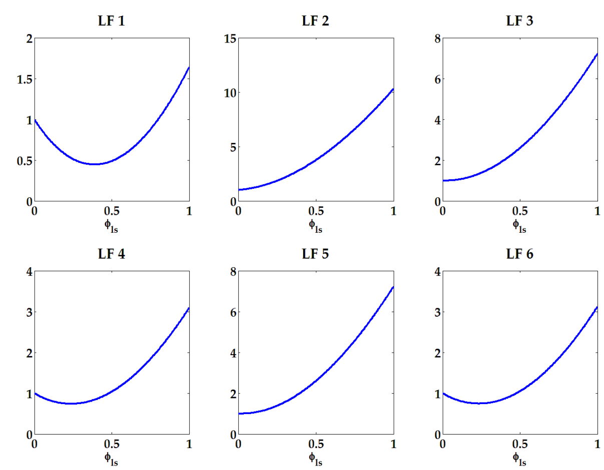


Figure 4: Standardized loss implied by alternative augmented Taylor rules for different policy regimes (shock in the loan market, $\rho_\sigma = 0.722$).

Note. LF 1 = $var(\pi)$; LF 2 = $var(\pi) + var(y)$; LF 3 = $var(\pi) + 0.5var(y)$; LF 4 = $var(\pi) + 0.1var(y)$; LF 5 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; LF 6 = $var(\pi) + 0.1var(y) + 0.1var(\Delta R^e)$.

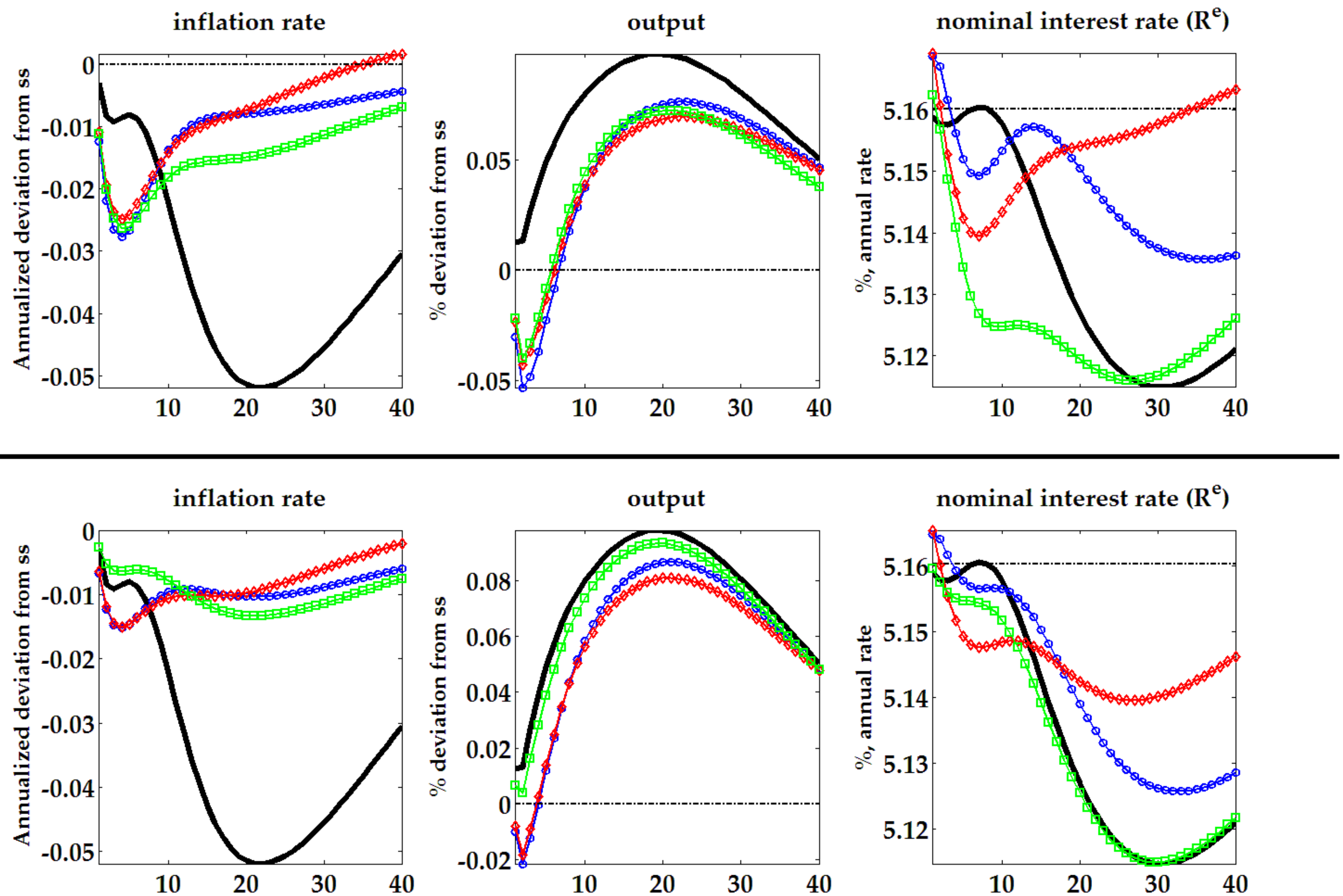


Figure 5: Impulse response functions to a bond market shock ($\rho_\nu = 0.9$) under different Taylor rules

Note. Black lines: BTR. Blue lines: ATR1 (top panel: $\phi_q = 0.135$; bottom panel: $\phi_q = 0.06$). Red lines: ATR2 (top panel: $\phi_{\Delta credit} = 0.33$; bottom panel: $\phi_{\Delta credit} = 0.18$). Green lines: ATR3a (top panel: $\phi_{bs} = 0.35$; bottom panel: $\phi_{bs} = 0.06$). Inflation is expressed as annualized percent deviation from its steady state, output as percentage deviation from its steady state, and nominal interest rate as annual percentage points.

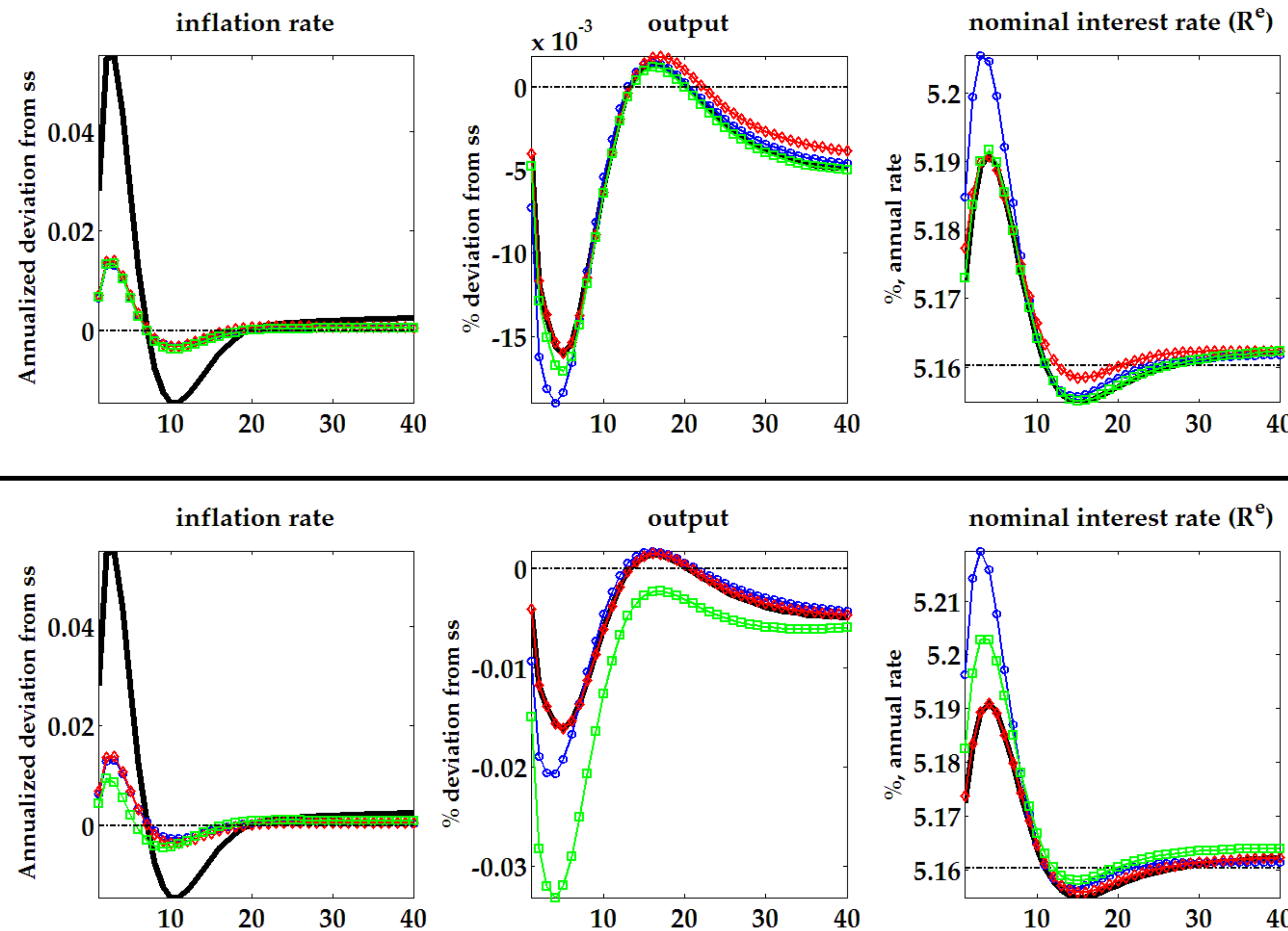
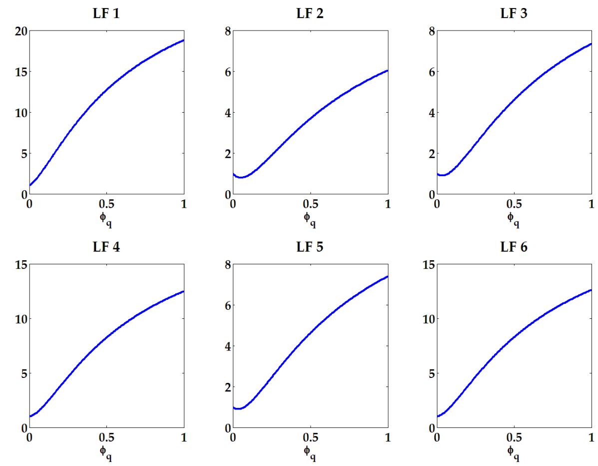


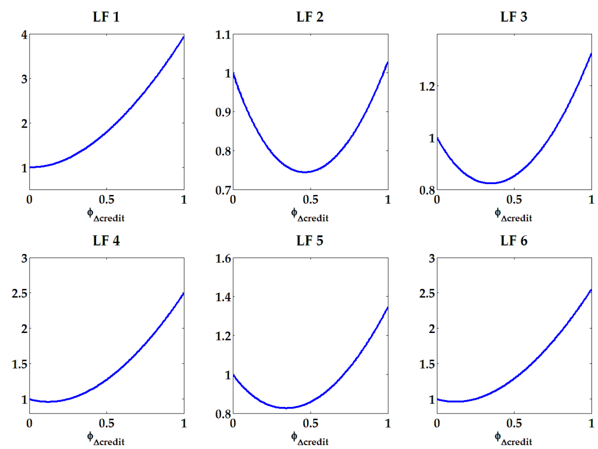
Figure 6: Impulse response functions to a loan market shock ($\rho_\sigma = 0.722$) under different Taylor rules

Note. Black lines: BTR. Blue lines: ATR1 (top panel: $\phi_q = 0.23$; bottom panel: $\phi_q = 0.495$). Red lines: ATR2 (top panel: $\phi_{\Delta credit} = 0.28$; bottom panel: $\phi_{\Delta credit} = 0.07$). Green lines: ATR3a (top panel: $\phi_{ls} = 0.015$; bottom panel: $\phi_{ls} = 0.235$). Inflation is expressed as annualized percent deviation from its steady state, output as percentage deviation from its steady state, and nominal interest rate as annual percentage points.

A. ATR1 - response to asset prices



B. ATR2 - response to credit growth



C. ATR3a - response to bond spread

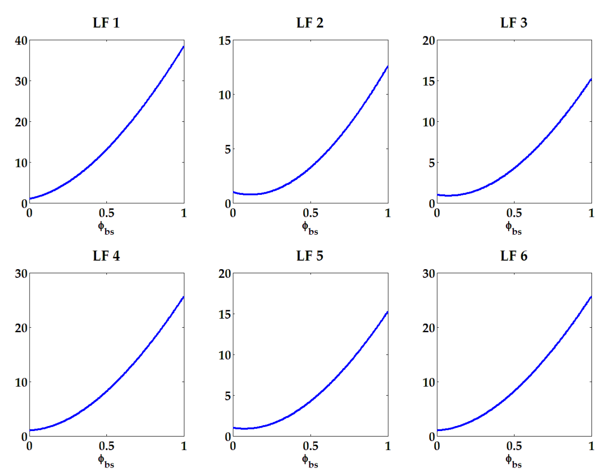


Figure 7: Standardized loss implied by alternative augmented Taylor rules for different policy regimes (shock in the bond market, $\rho_\nu = 0.7$).

Note. LF 1 $= var\,(\pi)$; LF 2 $= var\,(\pi) + var(y)$; LF 3 $= var\,(\pi) + 0.5var(y)$; LF 4 $= var\,(\pi) + 0.1var(y)$; LF 5 $= var\,(\pi) + 0.5var(y) + 0.1var\,(\Delta R^e)$; LF 6 $= var\,(\pi) + 0.1var(y) + 0.1var\,(\Delta R^e)$.

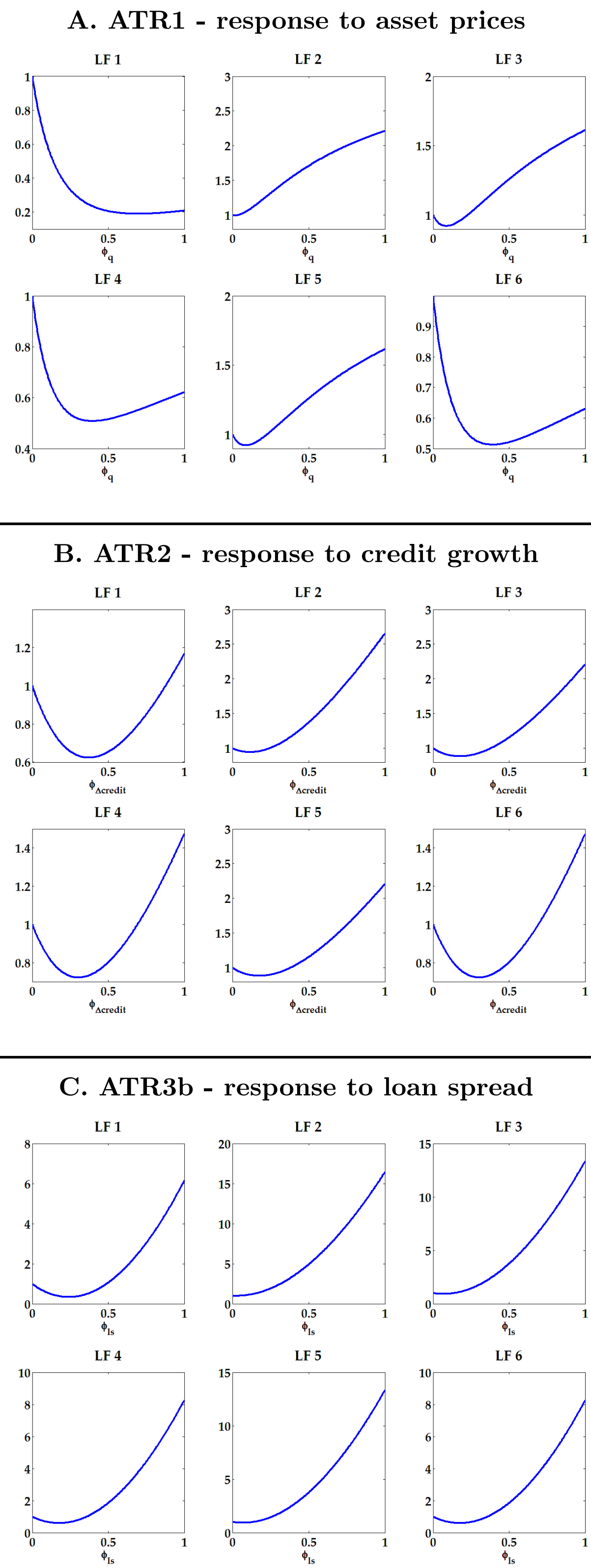


Figure 8: Standardized loss implied by alternative augmented Taylor rules for different policy regimes (shock in the loan market, $\rho_\sigma = 0.9$).

Note. LF 1 $= var\,(\pi)$; LF 2 $= var\,(\pi) + var(y)$; LF 3 $= var\,(\pi) + 0.5var(y)$; LF 4 $= var\,(\pi) + 0.1var(y)$; LF 5 $= var\,(\pi) + 0.5var(y) + 0.1var\,(\Delta R^e)$; LF 6 $= var\,(\pi) + 0.1var(y) + 0.1var\,(\Delta R^e)$.

Loss Function	Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{bs}	Gain (%)	Welfare (λ)
1	BTR	0,50	4,00	0,01					
	ATR1	0,50	4,00	0,01	0,00			0	0,000
	ATR2	**0,80**	**4,00**	**0,01**		**0,10**		**71**	0,012
	ATR3a	0,80	4,00	0,01			0,10	37	**0,017**
2	BTR	0,90	1,01	0,20					
	ATR1	0,90	1,01	0,20	0,00			0	**0,000**
	ATR2	**0,00**	**2,30**	**0,40**		**0,70**		**14**	-1,938
	ATR3a	0,90	1,01	0,20			0,00	0	**0,000**
3	BTR	0,90	1,01	0,10					
	ATR1	0,00	3,90	0,30	0,30			7	-2,282
	ATR2	**0,00**	**3,50**	**0,30**		**0,80**		**18**	-2,256
	ATR3a	0,00	3,80	0,01			1,00	9	-2,364
4	BTR	0,00	4,00	0,10					
	ATR1	0,90	3,90	0,01	0,10			12	-0,009
	ATR2	**0,00**	**4,00**	**0,10**		**0,30**		**16**	**0,052**
	ATR3a	0,40	4,00	0,01			0,40	12	0,039
5	BTR	0,90	1,01	0,10					
	ATR1	0,90	4,00	0,40	0,30			7	-2,230
	ATR2	**0,30**	**2,70**	**0,20**		**0,60**		**17**	-2,256
	ATR3a	0,30	3,80	0,01			1,00	8	-2,362
6	BTR	0,00	4,00	0,10					
	ATR1	0,90	3,90	0,01	0,10			12	-0,009
	ATR2	**0,90**	**3,30**	**0,01**		**0,30**		**16**	-0,003
	ATR3a	0,80	4,00	0,01			0,40	12	**0,035**

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

Note. Loss Function 1 = $var(\pi)$; Loss Function 2 = $var(\pi) + var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y)$; Loss Function 4 = $var(\pi) + 0.1var(y)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 6 = $var(\pi) + 0.1var(y) + 0.1var(\Delta R^e)$. 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 performs better than the benchmark one. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{bs}	Welfare (λ)
BTR	0,00	1,01	0,01				
ATR1	0,00	1,01	0,01	1			0,139
ATR2	**0,60**	**1,01**	**0,01**		**1**		**5,338**
ATR3a	0,60	1,01	0,01			1	2,299

Table 3: Taylor rules that maximize welfare; shock in the bond market ($\rho_\nu = 0.9$)

Note. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Loss Function	Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{ls}	Gain (%)	Welfare (λ)
1	BTR	0,80	4,00	0,01					
	ATR1	0,80	4,00	0,01	0,00			0	0,000
	ATR2	0,20	4,00	0,01		1,00		25	0,000
	ATR3b	**0,10**	**4,00**	**0,01**			**1,00**	**92**	**0,009**
2	BTR	0,90	1,70	0,30					
	ATR1	0,90	1,70	0,30	0,00			0	0,000
	ATR2	**0,80**	**1,30**	**0,10**		**0,20**		**2**	**0,001**
	ATR3b	0,90	1,70	0,30			0,00	0	0,000
3	BTR	0,90	3,10	0,30					
	ATR1	0,90	1,50	0,10	0,50			1	-0,001
	ATR2	**0,90**	**2,70**	**0,20**		**0,50**		**1**	**0,000**
	ATR3b	0,90	3,10	0,30			0,00	0	0,000
4	BTR	0,80	4,00	0,01					
	ATR1	0,80	4,00	0,01	0,00			0	0,000
	ATR2	0,60	4,00	0,01		0,90		6	0,000
	ATR3b	**0,70**	**3,60**	**0,01**			**0,30**	**13**	**0,001**
5	BTR	0,90	2,70	0,20					
	ATR1	0,90	1,50	0,10	0,40			1	-0,001
	ATR2	**0,90**	**2,20**	**0,10**		**0,40**		**1**	**0,001**
	ATR3b	0,90	2,70	0,20			0,00	0	0,000
6	BTR	0,80	4,00	0,01					
	ATR1	0,80	4,00	0,01	0,00			0	0,000
	ATR2	0,80	4,00	0,01		0,60		5	0,000
	ATR3b	**0,80**	**4,00**	**0,01**			**0,20**	**11**	**0,000**

Table 4: Optimal Taylor rules, central bank gain and welfare; shock in the loan market ($\rho_\sigma = 0.722$)

Note. Loss Function 1 = $var(\pi)$; Loss Function 2 = $var(\pi) + var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y)$; Loss Function 4 = $var(\pi) + 0.1var(y)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 6 = $var(\pi) + 0.1var(y) + 0.1var(\Delta R^e)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule ($100 * (Loss\mid_{BTR} - Loss\mid_{ATR})/Loss\mid_{BTR}$). A positive number means that the augmented rule performs better than the benchmark one. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{ls}	Welfare (λ)
BTR	0,00	4,00	0,01				
ATR1	0,00	4,00	0,01	0			0,000
ATR2	0,00	4,00	0,01		0,1		0,000
ATR3b	**0,00**	**1,01**	**0,01**			**1**	**4,249**

Table 5: Taylor rules that maximize welfare; shock in the loan market ($\rho_\sigma = 0.722$)

Note. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Loss Function	Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{bs}	Gain (%)	Welfare (λ)
1	**BTR**	**0,80**	**4,00**	**0,01**					
	ATR1	0,80	4,00	0,01	0,00			0	0,0000
	ATR2	0,80	4,00	0,01		0,00		0	0,0000
	ATR3a	0,80	4,00	0,01			0,00	0	0,0000
2	BTR	0,90	1,40	0,40					
	ATR1	0,00	3,90	1,00	0,10			3	-0,2144
	ATR2	**0,00**	**1,60**	**0,40**		**0,50**		**16**	-0,0906
	ATR3a	0,00	4,00	1,00			0,30	4	-0,2116
3	BTR	0,90	1,10	0,10					
	ATR1	0,00	4,00	0,40	0,10			5	-0,3469
	ATR2	**0,00**	**2,30**	**0,30**		**0,60**		**16**	-0,2924
	ATR3a	0,00	4,00	0,30			0,20	7	-0,3620
4	BTR	0,60	4,00	0,10					
	ATR1	0,60	4,00	0,10	0,00			0	0,0000
	ATR2	**0,00**	**4,00**	**0,01**		**0,40**		**5**	-0,0219
	ATR3a	0,60	4,00	0,10			0,00	0	0,0000
5	BTR	0,90	1,10	0,10					
	ATR1	0,60	4,00	0,40	0,10			2	-0,3467
	ATR2	**0,70**	**1,20**	**0,10**		**0,20**		**8**	-0,1612
	ATR3a	0,50	4,00	0,30			0,20	5	-0,3619
6	BTR	0,70	4,00	0,10					
	ATR1	0,70	4,00	0,10	0,00			0	0,0000
	ATR2	**0,70**	**4,00**	**0,10**		**0,10**		**2**	**0,0003**
	ATR3a	0,70	4,00	0,10			0,00	0	0,0000

Table 6: Optimal Taylor rules, central bank gain and welfare; shock in the bond market ($\rho_\nu = 0.7$)

Note. Loss Function 1 = $var(\pi)$; Loss Function 2 = $var(\pi) + var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y)$; Loss Function 4 = $var(\pi) + 0.1var(y)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 6 = $var(\pi) + 0.1var(y) + 0.1var(\Delta R^e)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule ($100 * (Loss\mid_{BTR} - Loss\mid_{ATR})/Loss\mid_{BTR}$). A positive number means that the augmented rule performs better than the benchmark one. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{bs}	Welfare (λ)
BTR	0,00	1,01	0,01				
ATR1	0,90	1,01	0,01	1			0,018
ATR2	0,00	1,01	0,01		1		0,165
ATR3a	**0,00**	**1,01**	**0,01**			**1**	**0,901**

Table 7: Taylor rules that maximize welfare; shock in the bond market ($\rho_\nu = 0.7$)

Note. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Loss Function	Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{ls}	Gain (%)	Welfare (λ)
1	BTR	0,70	4,00	0,01					
	ATR1	0,70	4,00	0,01	0,80			72	-0,001
	ATR2	0,40	4,00	0,01		0,50		63	-0,001
	ATR3b	**0,40**	**4,00**	**0,01**			**0,30**	**87**	**0,002**
2	BTR	0,90	1,40	0,20					
	ATR1	0,90	1,40	0,20	0,00			0	0,000
	ATR2	**0,90**	**1,50**	**0,20**		**0,10**		**3**	**0,002**
	ATR3b	0,90	1,40	0,20			0,00	0	0,000
3	BTR	0,90	2,80	0,20					
	ATR1	0,90	1,40	0,10	0,10			7	-0,005
	ATR2	**0,90**	**1,80**	**0,10**		**0,20**		**8**	0,000
	ATR3b	0,90	1,80	0,20			0,10	4	-0,002
4	BTR	0,80	4,00	0,01					
	ATR1	**0,90**	**4,00**	**0,10**	**0,40**			**13**	-0,001
	ATR2	0,80	4,00	0,01		0,30		12	0,000
	ATR3b	0,80	4,00	0,10			0,20	11	0,000
5	BTR	0,90	2,80	0,20					
	ATR1	0,90	1,40	0,10	0,10			7	-0,005
	ATR2	**0,90**	**1,80**	**0,10**		**0,20**		**8**	0,000
	ATR3b	0,90	1,80	0,20			0,10	4	-0,002
6	BTR	0,80	4,00	0,01					
	ATR1	**0,90**	**4,00**	**0,01**	**0,30**			**13**	0,000
	ATR2	0,90	4,00	0,01		0,30		12	0,000
	ATR3b	0,90	4,00	0,01			0,10	10	**0,001**

Table 8: Optimal Taylor rules, central bank gain and welfare; shock in the loan market ($\rho_\sigma = 0.9$)

Note. Loss Function 1 = $var(\pi)$; Loss Function 2 = $var(\pi) + var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y)$; Loss Function 4 = $var(\pi) + 0.1var(y)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^e)$; Loss Function 6 = $var(\pi) + 0.1var(y) + 0.1var(\Delta R^e)$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule ($100 * (Loss\mid_{BTR} - Loss\mid_{ATR})/Loss\mid_{BTR}$). A positive number means that the augmented rule performs better than the benchmark one. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Taylor Rule	$\tilde{\rho}$	ϕ_π	ϕ_y	Financial variable ϕ_q	$\phi_{\Delta credit}$	ϕ_{ls}	Welfare (λ)
BTR	0,90	1,60	0,01				
ATR1	0,90	1,60	0,01	0			0,000
ATR2	0,00	1,01	0,01		0,70		0,684
ATR3b	**0,00**	**1,01**	**0,01**			**1**	**9,215**

Table 9: Taylor rules that maximize welfare; shock in the loan market ($\rho_\sigma = 0.9$)

Note. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Loss Function	Taylor Rule	$\tilde{\rho}$	ϕ_{π}	ϕ_{y}	Financial variable ϕ_{q}	$\phi_{\Delta credit}$	ϕ_{bs}	ϕ_{ls}	Gain (%)	Welfare (λ)
1	BTR	0,70	4,00	0,01						
	ATR1	0,70	4,00	0,01	0,00				0	0,000
	ATR2	0,80	4,00	0,01		0,10			24	0,018
	ATR3a	0,80	4,00	0,01			0,10		12	0,023
	ATR3b	**0,80**	**4,00**	**0,01**				**0,40**	**54**	**0,032**
2	BTR	0,90	1,10	0,20						
	ATR1	0,90	1,10	0,20	0,00				0	0,000
	ATR2	**0,00**	**1,80**	**0,30**		**0,50**			**13**	-0,977
	ATR3a	0,90	1,10	0,20			0,00		0	0,000
	ATR3b	0,90	1,01	0,10				0,10	0	**0,940**
3	BTR	0,90	1,01	0,10						
	ATR1	0,90	4,00	0,40	0,30				7	-2,212
	ATR2	**0,00**	**2,70**	**0,20**		**0,60**			**17**	-2,241
	ATR3a	0,00	3,80	0,01			1,00		8	-2,344
	ATR3b	0,90	1,20	0,10				0,20	2	-1,728
4	BTR	0,60	4,00	0,10						
	ATR1	0,90	4,00	0,01	0,10				13	-0,004
	ATR2	**0,70**	**4,00**	**0,01**		**0,30**			**17**	0,000
	ATR3a	0,80	4,00	0,01			0,40		13	**0,041**
	ATR3b	0,00	4,00	0,01				0,80	14	0,015
5	BTR	0,90	1,01	0,10						
	ATR1	0,90	4,00	0,40	0,30				7	-2,212
	ATR2	**0,60**	**2,40**	**0,20**		**0,50**			**17**	-2,200
	ATR3a	0,50	3,80	0,01			1,00		7	-2,340
	ATR3b	0,90	1,20	0,10				0,20	2	-1,728
6	BTR	0,70	4,00	0,10						
	ATR1	0,90	4,00	0,01	0,10				13	-0,001
	ATR2	**0,80**	**4,00**	**0,01**		**0,30**			**17**	0,000
	ATR3a	0,80	4,00	0,01			0,40		14	0,044
	ATR3b	0,80	4,00	0,10				0,60	11	**0,048**

Table 10: Optimal unconditional Taylor rules, central bank gain and welfare

Note. Loss Function 1 = $var(\pi)$; Loss Function 2 = $var(\pi) + var(y)$; Loss Function 3 = $var(\pi) + 0.5var(y)$; Loss Function 4 = $var(\pi) + 0.1var(y)$; Loss Function 5 = $var(\pi) + 0.5var(y) + 0.1var(\Delta R^{e})$; Loss Function 6 = $var(\pi) + 0.1var(y) + 0.1var(\Delta R^{e})$. Gain is the percentage difference between the minimum loss under the benchmark Taylor rule and the augmented Taylor rule ($100 * (Loss\mid_{BTR} - Loss\mid_{ATR})/Loss\mid_{BTR}$). A positive number means that the augmented rule performs better than the benchmark one. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.

Taylor Rule	$\tilde{\rho}$	ϕ_{π}	ϕ_{y}	Financial variable ϕ_{q}	$\phi_{\Delta credit}$	ϕ_{bs}	ϕ_{ls}	Welfare (λ)
BTR	0,00	1,01	0,01					
ATR1	0,00	1,01	0,01	1				0,144
ATR2	0,60	1,01	0,01		1			5,341
ATR3a	0,60	1,01	0,01			1		2,307
ATR3b	**0,00**	**1,01**	**0,01**				**1**	**14,291**

Table 11: Unconditional Taylor rules that maximize welfare

Note. Welfare is calculated as conditional to the initial deterministic steady state. λ is the % fraction of consumption required to equate welfare under the BTR to the one under the ATR.