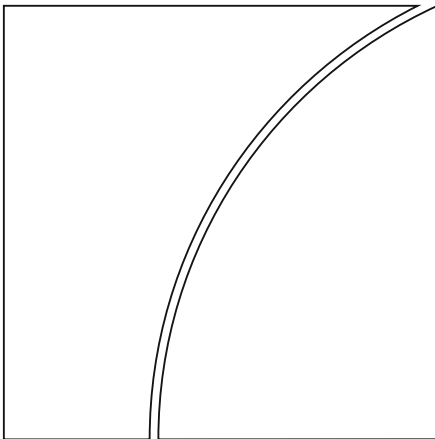# BIS Working Papers

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Should monetary policy lean against the wind?
An analysis based on a DSGE model with banking[*]

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Abstract

The global financial crisis has reaffirmed the importance of financial factors for macroeconomic fluctuations. Recent work has shown how the conventional pre-crisis prescription that monetary policy should pay no attention to financial variables over and above their effects on inflation may no longer be valid in models that consider frictions in financial intermediation (Cúrdia and Woodford, 2009). This paper analyzes whether Taylor rules augmented with asset prices and credit can improve upon a standard rule in terms of macroeconomic stabilization in a DSGE with both a firms' *balance-sheet channel* and a *bank-lending channel* and in which the spread between lending and policy rates endogenously depends on banks' leverage. The main result is that, even in a model in which financial stability does not represent a distinctive policy objective, leaning-against-the-wind policies are desirable in the case of supply-side shocks whenever the central bank is concerned with output stabilization, while both strict inflation targeting and a standard rule are less effective. The gains are amplified if the economy is characterized by high private sector indebtedness.

JEL: E30, E44, E50
Keywords: DSGE, monetary policy, asset prices, credit channel, Taylor rule, leaning-against-the-wind

1   Introduction

Before the global financial crisis the consensus view on the conduct of monetary policy was that the central bank should pay no attention to financial variables over and above their effects on inflation; an aggressive inflation-targeting policy was considered sufficient to guarantee macroeconomic stability. This conclusion emerged from a debate which focused exclusively on how central banks should deal with asset price bubbles and relied on several arguments explaining why monetary policy was, at best, ineffective.[1] The theoretical underpinnings of the pre-crisis consensus were the works by Bernanke and Gertler (2000, 2001), Gilchrist and Leahy (2002) and Iacoviello (2005). A crucial characteristic of these papers is that their results are based on models that consider financial frictions only on the *borrowers' side* of credit markets. Credit-supply effects stemming from financial intermediaries' behavior were completely neglected.

The financial crisis has instead shown how shifts in credit supply can indeed have a crucial role in macroeconomic fluctuations. Empirical research has pointed out how in many advanced economies loose credit conditions have contributed to amplifying the business cycle prior to the financial crisis, while the tightening of lending standards in the aftermath of the Lehman's collapse has contributed to the strong decline in output recorded in 2008-09 (Adrian and Shin, 2010; Ciccarelli *et al.*, 2010; Gilchrist *et al.*, 2009). More recently, fears of a credit crunch have resurged in connection with the European sovereign debt crisis (Draghi, 2011). Theoretical analysis has turned its attention to the implications of the credit-supply channel for the conduct of monetary policy (Meh and Moran, 2010; Gertler and Karadi, 2012); recent work that considers financial frictions on the *side of lenders*, has stressed how "*decisions about interest-rate policy should take account of changes in financial conditions*"(Woodford, 2011, p. 39).

In a formal characterization of these ideas, Cúrdia and Woodford (2009, 2010; henceforth CW) have introduced, in an otherwise standard New Keynesian model, an ad hoc friction in financial intermediation that gives rise to a spread between the loan and the policy rate. In that context, they have shown that spread- or credit-augmented rules are a better approximation to the optimal policy than the standard Taylor rule, for a number of different shocks.[2]

Taking stock of this debate, in this paper we ask if "*leaning-against-the-wind*" (henceforth LATW) — defined as monetary policy following an "augmented" Taylor rule, which takes into account asset prices or credit — may improve upon a standard rule in terms of macroeconomic stabilization in the context of a model that combines frictions on *both* the borrowers' and the lenders' side; in our model, in particular, loan spreads endogenously

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[1]These arguments consisted in the inability of the central bank to correctly identify bubbles, the lack of effectiveness of the policy rate as an instrument to contain asset price movements and the idea that a strong easing of policy would be sufficient to "clean up"after the burst of a bubble (Mishkin, 2011).

[2]After the crisis, policymakers have also reconsidered the so called "Greenspan doctrine "i.e., the prescription that asset prices should have no role in the conduct of monetary policy over and above that implied by their foreseeable effect on inflation and employment (Mishkin, 2011). In this respect, evidence is mixed. Borio and Lowe (2004) find that the response is asymmetrical to the build-up and unwinding of financial imbalances. Some papers show that the Federal Reserve adjusted interest rates in response to equity price misalignments and changes in bank capital requirements even in the pre-crisis period (Cecchetti, 2003, 2008).

depend on banks' leverage. Our main contribution to the existing literature is thus to analyze how different instrument rules perform in a model with the simultaneous presence of a borrower balance-sheet and a bank credit-supply channel. In doing so we show that, when credit supply effects are present, responding to financial variables allows the central bank to achieve a better trade-off between inflation and output stabilization; we thus corroborate CW's results using a richer model of the financial sector and analyzing a different range of financial variables that the central bank might want to look at.

Our model is a simplified version of Gerali *et al.* (2010), who estimated a medium-scale model for the euro area. In particular, we share with that paper the main characteristics of the financial sector. A *bank lending channel* arises due to the presence of a target level for banks' leverage; as a consequence, the loan-supply schedule is positively sloped and shifts procyclically with changes in the policy rate and with banks' profitability and capital. As pointed out by Woodford (2011), a loan supply curve with these characteristics could be motivated in several ways. For example intermediaries may have costs for originating and servicing loans, with marginal costs increasing with the volume of lending; or leverage could be bounded by regulatory limits or market-based constraints. The *balance-sheet channel* is modelled along the lines of Iacoviello (2005), assuming that entrepreneurs' borrowing capacity is linked to the value of the assets that they can pledge as collateral. On the other hand, the fact that we use a simplified (and calibrated version) of Gerali *et al.* (2010) implies that our quantitative results should be take with caution; indeed, we aim at obtaining qualitative indications on whether LATW may improve macroeconomic stabilization in a model that provides a sufficiently rich representation of the credit market.

Our analysis focuses on aggregate supply shocks, which create a trade-off for a central bank that aims at stabilizing output and inflation since, conditional on the shocks, the two variables tend to move in opposite directions. Our main results support the view that LATW is indeed desirable when the economy is driven by supply-side shocks and the central bank is concerned with output stabilization. In this case, both strict inflation targeting and a standard Taylor rule are less effective. Consider first strict inflation targeting or, equivalently, a standard rule with a very aggressive response to inflation. In this case, the strong response to inflation reduces inflation volatility less than it increases that of output, due to the impact of policy rates on credit-market developments. Following a positive technology shock, for example, this type of policy calls for a reduction of the policy rate, which tends to counteract the fall in consumer prices. In the presence of a broad credit channel, however, the easing of policy has a very strong expansionary effect on output, due to its impact on asset prices and loan supply, which in turn sustains a boom in consumption and investment by borrowing agents. In one word, this type of rules implies that monetary policy is "too loose" in the face of a positive supply shock, generating a procyclical behavior by financial sector variables which, in turn, amplifies volatility in the real economy. Consider now a standard rule with a non-negligible response to output or with a response to financial variables. In this case, the response of monetary policy is less accommodative, possibly becoming countercyclical, and partly counteracts the amplification effects stemming from the presence of financial frictions. Simulations show that in this case, a rule that entails LATW delivers superior results in terms of macroeconomic stabilization as compared to a standard rule, suggesting that

financial variables are better indicators than output of the procyclical effects stemming from financial frictions.

Assuming that the objective of monetary policy is the minimization of a weighted sum of inflation and output volatility, we can calculate that — if the economy is hit by technology and price mark-up shocks — the gains from LATW can be as high as 20-30%, depending on the shock considered and the central bank's preferences assumed. The gains tend to be larger the greater the weight the central bank assigns to output stabilization. Moreover, we find that gains from LATW are amplified in an economy characterized by a high degree of private sector indebtedness. As for the specific variables that the central bank should look at, in general a rule responding to asset prices performs better than a rule responding to credit; this reflects the fact that in our model LATW does a better job in stabilizing inflation, because it reduces the fluctuations of investment, the return to capital and thus marginal cost.

Since the onset of the financial crisis, other contributions have reassessed the case for LATW also in models that do not have a credit-supply channel, focusing on shocks on expected future economic conditions (Lambertini *et al.*, 2011 and Christiano *et al.*, 2010).[3] Compared with these studies, our results are more general. First, we show that LATW is also desirable when the economy is hit by current (rather than expected) supply shocks; the reason is that credit supply conditions in our model are affected by the current state of the business cycle and that expansions of economic activity are associated with a boom in bank leverage and lending. Second, we evaluate optimal rules considering a wider range of variables and possible coefficients for the central bank's response to inflation, output and financial variables and a variety of central bank's relative preferences for inflation *versus* output stabilization.

It is important to stress that our results indicate that LATW is desirable even when the central bank is concerned only with macroeconomic objectives; indeed, by using a linearized model where all variables eventually return to their steady state level, we rule out any consideration regarding financial (in)stability. Nonetheless, it can be argued that LATW would likely bring about even more social benefit if the central bank (or any other public authority) were also concerned about financial stability; as a simple hint in this direction it is worth noticing that, in our model, LATW has the effect of reducing the variability of many financial variables besides that of output and inflation.

The remainder of the paper is organized as follows. Section 2 discusses the dynamic stochastic general equilibrium (DSGE) model used in the simulations; Section 3 analyzes the main financial channels at work; Section 4 describes the simulations of a technology shock and a cost-push shock; Section 5 examines whether a policy of leaning-against-the-wind is more effective in economies with highly leveraged borrowers; the final section summarizes the main conclusions.

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[3]Other papers have studied the link between macroprudential and monetary policies and the importance of co-operation between the central bank and the supervisory authority (Kannan *et al.*, 2012 and Angelini *et al.*, 2011).

2   A sketch of the model

The framework we use is a simplified version of Gerali *et al.* (2010; henceforth GNSS), which introduces a monopolistically competitive banking sector into a DSGE model with financial frictions (à la Iacoviello, 2005). With respect to GNSS we simplify the model in order to focus our attention on two financial frictions: (a) the presence of a borrowing constraint, which depends on the value of collateral; and (b) the presence of a constraint on the level of bank leverage.

The model is populated by two types of agents, plus banks, each of unit mass: (patient) households and (impatient) entrepreneurs. Banks intermediate the funds that flow from households to entrepreneurs due to their different degree of impatience. We assume that all debts are indexed to current inflation.[4] Frictions in the lending relationship imply that the amount of lending depends on both the quantity and the price of assets (physical capital) that the borrowers own and can post as collateral. Entrepreneurs carry out production of a wholesale good using households' labor and own physical capital. As is standard in this class of models, we assume that some agents (called retailers) buy the intermediate goods from entrepreneurs in a competitive market, brand them at no cost and sell the differentiated good at a price which includes a mark-up over the purchasing cost; prices are sticky *à la* Rotemberg (1992), implying the existence of a New Keynesian Phillips curve. In addition, we assume that fixed-capital creation is subject to some adjustment costs and is carried out by capital-good producers. These agents are introduced as a modelling device for deriving an explicit expression for the price of capital, which enters entrepreneurs' borrowing constraint.

Banks issue loans (B_t) to the entrepreneurs, collect deposits (D_t) from households and accumulate own capital (K_t^b) out of reinvested earnings. We assume that banks are perfectly competitive in the deposit market (i.e. the interest rate on deposits equals the policy rate), but there is monopolistic competition in the loan market. In particular, banks may charge a constant mark-up on the retail loan rate spread due to market power. In addition, we assume that banks target a given level of capital-to-asset ratio and modify lending margins — tightening or loosening loan supply conditions — in order to attain that level.

Finally, a monetary policy rule closes the model. In the rest of this section we will sketch the key model equations for households and entrepreneurs and for the banking sector; for the rest of the model, and for a full description of the model equations, refer to Appendix A. In the next section we will focus on the functioning of the credit market and on its interactions with the real economy.

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[4]This assumption is an important distinction with respect to GNSS, which eliminates the *nominal-debt channel* from the model. This simplification is motivated by the desire to isolate the role of the financial frictions; the nominal-debt turns out to be quite important in GNSS and in many other papers with a collateral channel (for example, Iacoviello, 2005). The way in which this channel could affect the results is likely to depend on the shock considered; its main effect on macroeconomic developments is related to the fact that unexpected changes in the price level redistribute real resources between borrowers and lenders.

2.1 Households and entrepreneurs

Household i maximizes the following utility function:

$$\max_{\left\{c_t^P(i), l_t^P(i), d_t^P(i)\right\}} E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\log(c_t^P(i)) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right],$$

subject to the budget constraint:

$$c_t^P(i) + d_t^P(i) \leq w_t l_t^P(i) + \left(1 + r_{t-1}^{ib}\right) d_{t-1}^P(i) + J_t^R(i) \tag{1}$$

where $c_t^P(i)$ is current consumption, $l_t^P(i)$ is labor supply, $d_t^P(i)$ is bank deposits in real terms, which are remunerated at a rate equal to the policy rate r_t^{ib}, w_t is real wage and $J_t^R(i)$ are retailers' profits in real terms. As standard in models with a borrowing constraint, it is assumed that households' discount factor β_P is greater than the entrepreneurs' one (β_E, see below), so as to ensure than in the steady state (and its neighborhood) the constraint is always binding (Iacoviello, 2005); as a result, households are net lenders and entrepreneurs are net borrowers. The relevant first-order conditions for households are the consumption Euler equation and the labor-supply decision:

$$\frac{1}{c_t^p(i)} = E_t \frac{\beta_P \left(1 + r_t^{ib}\right)}{c_{t+1}^p(i)} \tag{2}$$

$$l_t^P(i)^\phi = \frac{w_t}{c_t^p(i)} \tag{3}$$

Entrepreneurs maximize consumption according to the utility function:

$$\max_{\left\{c_t^E(i), l_t^{P,d}(i), b_t^{EE}(i)\right\}} E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i)) \tag{4}$$

subject to budget and borrowing constraints:

$$c_t^E(i) + \left(1 + r_{t-1}^b\right) b_{t-1}^{EE}(i) + w_t l_t^{P,d}(i) + q_t^k k_t^E(i) \leq$$
$$\frac{y_t^e(i)}{x_t} + b_t^{EE}(i) + q_t^k (1 - \delta^k) k_{t-1}^e(i) \tag{5}$$

$$b_t^{EE}(i) \leq \frac{m^E q_{t+1}^k k_t^e(i)(1 - \delta^k)}{1 + r_t^b} . \tag{6}$$

In the above, $c_t^E(i)$ is entrepreneurs' consumption, $l_t^{P,d}(i)$ is labor demand, $k_t^E(i)$ is the entrepreneurs' stock of capital, q_t^k is the price of capital, y_t^e is the output of intermediate goods produced by the entrepreneurs, x_t is the mark-up of the retailer sector, δ^k is depreciation of capital, $b_t^{EE}(i)$ is the amount of bank loans taken by entrepreneurs, m^E is a parameter that can be interpreted as the loan-to-value (LTV) ratio chosen by the banks (i.e., the ratio between the amount of loans issued and the discounted next-period value

of entrepreneurs' assets) and r_t^b is the interest rate on bank loans. The relevant first-order conditions for the entrepreneurs are the consumption- and investment-Euler equations, and the labor demand condition:

$$\frac{1}{c_t^E(i)} - s_t^E(i) = \beta_E \frac{(1 + r_t^b)}{c_{t+1}^E(i)} \tag{7}$$

$$\frac{s_t^E(i) m_t^E q_{t+1}^k (1 - \delta^k)}{1 + r_t^b} + \frac{\beta_E}{c_{t+1}^E(i)} \left[q_{t+1}^k (1 - \delta^k) + r_{t+1}^k \right] = \frac{q_t^k}{c_t^E(i)} \tag{8}$$

$$\frac{(1 - \xi) y_t^e(i)}{l_t^{P,d}(i) x_t} = w_t. \tag{9}$$

where the variable $s_t^E(i)$ is the Lagrange multiplier on the borrowing constraint (and thus represents the marginal value of one unit of additional borrowing by the entrepreneurs) and $1 - \xi$ is the output elasticity of labor in the production function (see equation (A.7) in the Appendix).

2.2 The banking sector

The banking sector is sketched along the lines of GNSS. In particular, we assume that each bank j is composed of two units: a wholesale branch and a retail branch.

The wholesale unit collects deposits $d_t(j)$ from households, on which it pays the interest rate set by the central bank r_t^{ib} and issues wholesale loans $b_t(j)$, on which it earns the wholesale loan rate $R_t^b(j)$. Moreover, the bank has own funds $K_t^b(j)$, which are accumulated out of reinvested profits. We assume that the bank has a target leverage ratio ν and that it pays a cost for deviating from that target. The target can be interpreted as an exogenously given constraint stemming, for example, from prudential regulation, or as capturing the trade-offs that, in a more structural model, would arise in the decision regarding the amount of own resources to hold. The existence of a penalty for deviating from ν implies that bank leverage affects loan interest rates, generating a feedback loop between the developments in the real economy — which affect bank profits —, bank leverage and borrowers financing conditions.

More in details, the *wholesale* unit's problem is choosing $b_t(j)$ and $d_t(j)$ so as to maximize profits subject to a balance-sheet constraint:

$$\max_{\{b_t(j), d_t(j)\}} R_t^b b_t(j) - r_t^{ib} d(j) - \frac{\theta}{2} \left(\frac{K_t^b(j)}{b_t(j)} - \nu \right)^2 K_t^b(j) \tag{10}$$

$$\text{s.t. } b_t(j) = d_t(j) + K_t^b(j) \tag{11}$$

In the above, bank profits consist of the net interest margin (loan minus deposit interest payments) minus the (quadratic) cost that the bank is assumed to pay for deviating from its target leverage ν. This cost is proportional to $K_t^b(j)$ and is parametrized by θ. The first order condition is:

$$R_t^b = r_t^{ib} - \theta \left(\frac{K_t^b(j)}{b_t(j)} - \nu \right) \left(\frac{K_t^b(j)}{b_t(j)} \right)^2 \tag{12}$$

Note that equation (12) implies that the cost of loans equals the policy rate plus an endogenous spread, which is positively related to the degree of bank leverage, with elasticity equal to θ.

The *retail* loan branche is assumed to operate in a regime of monopolistic competition. This unit buys wholesale loans, differentiates them at no cost and resells them to final borrowers. In the process, the retail unit fixes the retail loan rate, applying a constant mark-up ($\bar{\mu}^b$) on the wholesale loans rate.[5] The retail loan rate (r_t^b)is thus equal to:

$$r_t^b = r_t^{ib} - \theta \left(\frac{K_t^b(j)}{b_t(j)} - \nu \right) \left(\frac{K_t^b(j)}{b_t(j)} \right)^2 + \bar{\mu}^b \tag{13}$$

Rewriting equation (13) in linear form we obtain:[6]

$$\widetilde{r}_t^b = \widetilde{r}_t^{ib} + \widehat{spr}_t = \widetilde{r}_t^{ib} + \frac{\theta \nu^3}{1 + r^{ib}} \widehat{lev}_t \tag{14}$$

where $\widehat{spr}_t$ is the loan spread and $\widehat{lev}_t \equiv \widehat{B}_t - \widehat{K}_t^b$ is banks' leverage.

3   The transmission channels

The model described above is characterized by the presence of two financial frictions: (i) entrepreneurs' borrowing capacity is constrained by the value of the assets that they hold; and (ii) banks have a target level for their leverage and pay a cost if they deviate from it.

These frictions modify the way in which shocks propagate in the model; in particular, they establish a link between the real and the financial side of the economy, making movements in asset prices, entrepreneurs' net wealth, bank capital, the policy rate, and real activity relevant for the determination of equilibrium in the credit market. These frictions also imply, viceversa, that changes in the loan demand and supply schedules become important for the outcomes in the real economy. From a theoretical point of view, with respect to a standard New Keynesian model, we can categorize the impact of these financial frictions into two additional transmission channels, which interact together, but which can be discussed in isolation: (i) a *collateral channel*, which has its underpinnings on the presence of a borrowing constraint and a (ii) *credit-supply channel*, which is linked

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[5]This choice implies that the modellization of monopolistic competition does not affect the cyclical properties of bank profits (and thus bank capital). In GNSS, the monopolistic-competition mark-up in the loan market was multiplicative, inducing a positive correlation between the bank unit margin (the loan-deposit rate differential) and the policy rate, which in turn affected the correlation between bank profits and the policy rate.

[6]Here and in the rest of the paper, hat (tilde) indicates that the variable is expressed in percentage (absolute) deviation from its steady state. For the complete set of equations of the banking sector see the Appendix.

to the presence of a positively-sloped loan-supply curve which shifts with changes in the policy rate and bank capital.[7]

3.1 The collateral channel

The existence of a collateral channel is a well-known consequence of the presence of a borrowing constraint and operates via the impact of changes of asset valuations on debtors' balance-sheet conditions. In the literature it is well-known that this channel is able to generate a financial-accelerator effect (Bernanke and Gertler, 1995). Suppose that, due to agency problems, some agents in the economy can only borrow a fraction of the value of the assets that they can post as collateral and consider, for example, the case of a positive technology shock, which increases aggregate output as well as asset prices. The increase in asset prices pushes up the borrowing limit and induces an increase in lending to those agents for which the constraint was binding. In turn, constrained agents may use this additional lending to finance more consumption and investment, generating an extra kick to aggregate demand which reinforces the initial rise in output.

In order to see how this channel operates in the model presented here, it is convenient to rewrite the entrepreneurs' first-order conditions taking into account the fact that they are constrained. Indeed, as shown by Iacoviello (2005), since $\beta^E < \beta^P$, the borrowing constraint for entrepreneurs is always binding; in that case — following Andrés et al. (2010) — it is possible to show that: (i) entrepreneurs' consumption is a constant fraction of their net wealth; (ii) entrepreneurs' capital is also a linear function of net wealth; the coefficient is time-varying, and depends on asset prices, the LTV ratio and the loan interest rate. The equations (using aggregate-variable notation) are:[8]

$$c_t^E = \left(1 - \beta^E\right) NW_t^E \tag{15}$$

$$K_t = \frac{\beta^E}{q_t^k - \chi_t} NW_t^E \tag{16}$$

where NW_t^E is entrepreneurs' net worth and χ_t is the (endogenous) entrepreneurs' leverage (note that we can rewrite the borrowing constraint as: $B_t = \chi_t K_t$), which depends positively on the parameter m^E and on future asset prices and negatively on the loan interest rate. These two variables are defined as:

$$NW_t^E \equiv q_t^k \left(1 - \delta^k\right) K_{t-1} - \left(1 + r_{t-1}^b\right) B_{t-1} + \xi \frac{Y_t}{x_t} \tag{17}$$

$$\chi_t \equiv \frac{m^E q_{t+1}^k \left(1 - \delta^k\right)}{1 + r_t^b}. \tag{18}$$

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[7]In the more complicated model by GNSS, additional channels stemmed from the effects on general equilibrium of nominal debt contracts, imperfect competition in banking and incomplete interest rate pass-through.

[8]Their derivation is obtained in Appendix B.

Equations (15) and (16) describe the key insight of the collateral channel, that is, the fact that asset prices and lending rates have a crucial impact on consumption and investment decisions by entrepreneurs. The impact on consumption occurs only through the effect that these two variables have on entrepreneurs' net worth. For capital accumulation there is also an effect via the multiplier of net worth, i.e., the extent to which net worth can be leveraged in order to obtain loans.

More in detail the *current level of asset prices* (q_t^k) has a positive effect on consumption, since it is positively related with net worth due to the valuation effect of past holdings of capital. The impact on investment is instead ambiguous, since the positive effect on net worth is counteracted by a negative one on the multiplier of net worth, which comes from the impact on the cost of purchasing new capital. *Expectations on future asset prices*, instead, have an unambiguously positive effect on investment, because they are positively related to the value of the net-worth multiplier. As regards the *loan interest rate*, the effect is unambiguously negative, on both consumption and investment: a rise in loan rates, in fact, reduces net wealth by increasing interest payments and limits capital accumulation by reducing borrowing capacity.

3.2 The credit-supply channel

The credit-supply channel is activated by shifts of the loan supply schedule that produce changes in the equilibrium levels of loan financing and real output. Credit intermediaries target an exogenously given capital-to-asset ratio (the inverse of a leverage ratio) and actively manage supply conditions (i.e. lending spreads) in order to bring this ratio back to the desired level whenever it deviates from it. This mechanism aims at replicating the stylized fact — documented in the surveys conducted by various central banks in advanced countries — that banks adjust lending standards in response to their balance-sheet conditions, tightening when capital constraints are binding and easing when, instead, there are no concerns about the level of their capitalization.

This structure gives rise to an inverse loan-supply schedule, which is described by equation (14) and can be rewritten as:

$$\widetilde{r}_t^b = \widetilde{r}_t^{ib} + \frac{\theta \nu^3}{1 + r^{ib}} \widehat{B}_t - \frac{\theta \nu^3}{1 + r^{ib}} \widehat{K}_t^b \tag{19}$$

A number of implications are worth mentioning. First, the loan supply schedule is positively sloped with respect to the loan rate. Second, the elasticity of supply increases with the level of the bank's target capital-to-asset ration (ν) and with the cost for deviating from that target θ. Third, loan supply depends positively on the level of bank capital. Since bank capital accumulation, in turn, depends positively on bank's profits, an increase in bank profitability shifts the loan supply schedule in the next period; in other words, an increase in bank profits determines a reduction of the loan rate (in the subsequent period) for any given level of loans to the economy. Fourth, loan supply also shifts with the level of the policy rate. In particular, an easing of policy shifts supply to the right; this feature is consistent with the existence of a bank-lending channel in the model.

The fact that changes in credit supply affect the equilibrium level of interest rates in the loan market highlights the interaction between the credit-supply and collateral

channels. Since the lending rate affects entrepreneurs' net wealth and thus consumption and investment decisions, procyclical shifts of loan supply may tend to increase the amplification effect, due to the collateral channel described above.

3.3 Equilibrium in the credit market

In this section we provide a graphical representation of partial equilibrium in the credit market, which can be obtained by using the equations derived in the previous two sections (see Figure 1). It is important to stress that the purpose of this exercise is merely illustrative, since it is based — like all the analyses of this type — on the assumption of "all other things being equal". Despite these limitations, this exercise allows us to outline the impact of the collateral and the credit-supply channels on macroeconomic developments and their interaction with the policy rules; it is therefore important in order to understand the simulation results illustrated in the next section.[9]

First, substituting the (log-linear version of the) optimal decision for K_t and the definition of NW_t^e — equations (16) and (17) — into the borrowing constraint, we obtain a(n inverse) demand curve for loans, from the entrepreneurs' first order conditions:

$$\widetilde{r}_t^b = -(1-\chi)\widehat{B}_t + E_t\widehat{q}_{t+1}^k - \delta^k\widehat{q}_t^k - \beta_E(1+r^b)\chi\left(\widetilde{r}_{t-1}^b + \widehat{B}_{t-1}\right)$$
$$+\beta_E(1-\delta^k)\widehat{K}_{t-1} + \beta_E\frac{\xi Y}{xK}\left(\widehat{Y}_t - \widehat{x}_t\right) \tag{20}$$

Equation (20) provides an inverse relation between the level of the loan rate and the amount of loans, based on the optimal behavior of entrepreneurs. In particular, loan demand shifts with the level of entrepreneurs' net worth and with current and expected asset prices: an increase in net worth or in future expected prices increases demand for any given level of the loan rate, while a rise in current asset prices reduces it.[10]

Second, we can identify the loan supply schedule with equation (19), which establishes a positive relationship between loans (B_t) and the loan rate (r_t^b). The slope of this curve depends on a number of parameters and its position in the plan $\{B_t, r_t^b\}$ shifts with changes in the policy rate and the level of bank capital.

The intersection between the demand and the supply curves determines the equilibrium in the credit market. Assuming that the initial equilibrium of the model is the steady

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[9]An additional caveat that is useful to stress here is that this partial equilibrium analysis assumes that the shock is permanent while simulations will be carried out for transitory shocks.

[10]For the sake of completeness, it is worth mentioning that one might argue that talking about loan *demand* here is somewhat improper, since the microfoundation of the collateral channel itself takes into account both demand and supply-side considerations. In Hart and Moore (1994) and Kiyotaki and Moore (1997) the collateral constraint arises as an equilibrium outcome in a model with agency problems. They assume that, whenever a borrower defaults on their debt, all their assets are sized by the lender, who can resell those assets at market prices. In this setup, the borrowers have an incentive to default — or to renegotiate the terms of the debt — whenever the value of their assets is lower than the value of their debt obligations. Given that borrowers are assumed not to be able to pre-commit to repaying their debts, lenders will be willing to lend only up to the (expected) value of the borrowers' assets at the moment when obligations fall due. In practical terms, all lending in the economy must be fully collateralized and the amount of loans that an agent can obtain depends on the value of the collateral that they can pledge.

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state (point E_0), where both the amount and the rate of loans (in deviations from the steady state) are equal to 0, we will analyze how the equilibrium adjusts in response to a positive technology shock. For simplicity, we will assume that the shock is permanent, so that we do not have to worry in the graphical representation about the economy returning slowly to the steady state. In order to see how the outcomes in the credit market are affected by the different rules that a central bank may adopt, we will consider a number of policies.

We start by considering the case in which:

$$\widetilde{r}_t^{ib} = 0 \tag{21}$$

i.e., a baseline situation in which the central bank does not change the policy rate, keeping it fixed at the steady state level. In this case, the technology shock raises both current and future asset prices and the entrepreneurs' net worth. Due to the collateral channel, the demand curve shifts to the right (from B_0^d to B_1^d).[11] On impact, bank capital is fixed (the increase in loans is matched by a corresponding increase in deposits); the loan supply schedule doesn't move ($B_0^s \equiv B_1^s$) and a new equilibrium is attained at point E_1, with higher lending (B_1) and a higher leverage for banks, which is reflected in a higher equilibrium loan rate (r_1^b).[12]

Let us now consider the case in which the central bank adopts a strict inflation targeting, by following a Taylor rule in which the policy rate responds (only) to deviations of inflation from the steady state:

$$\widetilde{r}_t^{ib} = \phi_\pi \widehat{\pi}_t \tag{22}$$

In standard NK models, after a positive technology shock inflation declines and output rises. Thus, since the central bank is particularly aggressive towards inflation, the policy rate falls following the shock. In this case, the reduction of the policy rate will also make the loan supply schedule shift to the right (B_2^s). The result is that the equilibrium (point E_2) is characterized by a lower level of the loan rate and a higher level of loans in the economy than we had in the case of inaction by the central bank, i.e., $B_2 > B_1$ and $r_2^b < r_1^b$.

Next we consider a rule that responds — beyond inflation — to deviation of asset prices from the respective steady state level:

$$\widetilde{r}_t^{ib} = \phi_\pi \widehat{\pi}_t + \phi_q \widehat{q}_t^k \tag{23}$$

In this case, the position of the loan supply schedule is indicated by the line B_3^s. The shift of the supply schedule is now more contained with respect to the strict inflation targeting case. The reason is that, as discussed above, asset prices increase after the shock. This implies that a rule that responds to asset prices would prescribe a more moderate

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[11]Given that the shock is assumed to be permanent, asset prices do not directly affect loan demand, as $E_t \widehat{q}_{t+1} = \widehat{q}_t$ but only indirectly, i.e., through the positive impact on NW_t.

[12]The rise in the loan rate and the expansion of banks' balance sheets boosts bank profits and thus increases bank capital available next period. In turn, the increase in capital allows intermediaries to expand loan supply in the next period, shifting the supply schedule further to the right. For the sake of simplicity we neglect this further shift in the figure.

reduction of the policy rate than the one where only inflation (and output) are considered. As a result, such a rule would limit the rightward shift of the loan supply curve, resulting in a less pronounced increase of lending and in a higher loan rate (the equilibrium point E_3 is above and to the left of its position in the case of the standard rule). Moreover, it is interesting to note that if one considers general equilibrium effects, the more aggressive monetary stance in the case in which the central bank follows an asset-price augmented rule would likely bring about a smaller impact increase in asset prices after the shock, thus also limiting the initial shift of the demand curve. This suggests that responding to asset prices might reduce the volatility of credit and thus that of the real economy.[13]

Having discussed the key mechanisms at work in the model in a simplified way, we now move on to the simulation exercises, which allow us to study the implications of leaning-against-the-wind, taking into account general equilibrium effects.

4   Simulations

In the previous section we described the functioning of the credit market in a partial equilibrium setup, showing how equilibrium is affected by asset price developments, banks' capital and monetary policy. We found that monetary policy rules that take into account developments in financial variables may — at least partly — counteract the amplification effects stemming from the presence of financial frictions. In this section, we test the desirability of an LATW policy in the context of the full general equilibrium model described in Section 2. This is the key question of the paper.

In particular, we study whether an augmented Taylor rule with financial variables allows the central bank to improve — in terms of macroeconomic stabilization — upon a standard Taylor rule, i.e. a rule that responds only to inflation and output. Our analysis will focus on supply-side shocks and will consider separately a technology and a cost-push shock. A general reason for considering aggregate supply shocks is that these — in contrast to demand-side shocks — create a trade-off for a central bank that aims at stabilizing output and inflation as the two variables tend to move in opposite directions in response to the exogenous disturbance. More specifically, we choose to study a technology shock as this is one of the main drivers identified by the DSGE literature on the business cycle; we also analyze a cost-push shock as a robustness check of the results obtained for the technology shock, because in this case also the output gap (and not only the output) moves in the opposite direction of inflation. The two shocks are analyzed separately in

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[13]For the sake of brevity, we do not report the results for a rule with credit as an additional variable. Such a rule would take the form: $\widetilde{r}_t^{ib} = \phi_\pi \widehat{\pi}_t + \phi_B \widehat{B}_t$. Targeting this variable would determine a change in the *slope* of the loan supply curve, rather than simply acting as a shifter. Substituting the rule with the response to credit into the loan supply equation (19), we obtain:

$$\widetilde{r}_t^b = \left(\frac{\theta \nu^3}{1 + r^{ib}} + \phi_B \right) \widehat{B}_t - \left(\frac{\theta \nu^3}{1 + r^{ib}} \right) \widehat{K}_t^b + \phi_\pi \widehat{\pi}_t$$

The fact that $\phi_B \neq 0$ implies that the loan supply curve is steeper in this case than the one obtained under a standard rule. As a consequence, a shock to the credit demand schedule results in a smaller increase in credit and a greater increase in the lending rate after the technology shock.

order to have a clear understanding of the transmission mechanism of each shock and of the trade-offs that each of them entails for the conduct of monetary policy.

The methodology we use is based on Taylor curves, which represent the central bank's frontier of possibilities, that is the efficient outcomes of inflation and output variability that can be obtained under a wide range of parameters for the Taylor rule. These curves are obtained in the following way. First, we assume that the central bank follows a general-form Taylor rule of the type (in linear form):

$$\widetilde{r}_t^{ib} = \rho^{ib}\widetilde{r}_{t-1}^{ib} + (1 - \rho^{ib})\left[\phi_\pi\widehat{\pi}_t + \phi_y\widehat{Y}_t + \phi_B\widehat{B}_t + \phi_q\widehat{q}_t^k\right] \tag{24}$$

Second, we make the parameters in the above rule vary within a grid of values, with each combination of values defining a different Taylor rule. For computational reasons, we need to restrict our attention to a limited space of parameter values; as a baseline grid we allow the response to inflation to vary between 0 and 5 and the response to the other variables to vary between 0 and 2.5.[14] It is important to stress that the objective here is not to provide quantitative prescriptions on what are the optimal coefficients that should be assigned to asset prices or credit in an operational rule; rather, we aim at obtaining qualitative indications on whether these variables may improve macroeconomic stabilization in a model that provides a sufficiently rich representation of the credit market.[15]

Third, for each specification of the rule thus obtained, we simulate the model and calculate the asymptotic variance of output and inflation. We then represent the result of each rule as a point in the plan $[Var(\pi), Var(y)]$. Finally, we take the envelope of all the points, in order to consider only the rules with the minimum inflation variance for any given value of output variance (and vice versa). This envelope is a Taylor curve, which graphically represents the efficient trade-off attainable by the central bank within the range of parameters considered. When only ϕ_π and ϕ_y are allowed to vary while all other coefficients are imposed to be equal to 0, the resulting Taylor curve will display the trade-off (for a given model) faced by a central bank following a standard Taylor rule. When instead one (or more) of the other parameters are allowed to vary, the Taylor curve will represent the possibility frontier faced by a bank which follows an augmented Taylor rule, i.e. a rule that also considers the response to one (or more) financial variables.

4.1 Calibration

As for the calibration, a number of parameters are standard and are set as in GNSS. They are reported in Table 1. The households' discount factor β_P is set at 0.996, which implies a steady-state policy rate of roughly 2 % (annualized). The entrepreneurs' discount factor β_I has to be smaller than β_P and is set at 0.975, as in Iacoviello (2005). The inverse of the Frisch elasticity ϕ is set at 1 (Galí, 2008). The share of capital in the production

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[14] The grid step is 0.50 for ϕ_π and 0.25 for the other parameters. The indexation parameter ρ^{ib} is kept fixed at 0.77. Cecchetti et al. (2000), in a similar exercise, build grids ranging between 1.01 and 3 for the response to inflation, 0 and 3 for the response to output and 0 and 0.5 for the response to asset prices.

[15]Nonetheless, in order to be sure that the results we obtain are sufficiently general, we have performed a number of robustness analyses, specifying both a *finer* and a *wider* grid of parameter values, finding qualitatively similar results.

function (α) and the depreciation rate of physical capital (δ^k) are set at 0.20 and 0.05, respectively, in order to match the investment-to-GDP ratio and the entrepreneurs share in consumption in GNSS, which equal 0.11 and 0.09, respectively. The elasticity of substitution across goods ε^y is set at 6, implying a mark-up in the goods market of 1.20. The degree of price stickiness κ_p is set at 28.65, the value estimated by GNSS; given ε^y this corresponds to a Calvo-probability of not being able to adjust prices of 66%, which implies that adjustment occurs, on average, every 3 quarters. A mentioned, the degree of monetary policy inertia is set at 0.77.

As regards the parameters related to the financial frictions/banking sector, we follow GNSS. The LTV ratio set by the banks m^E is set at 0.35, which is similar to what Christensen et al. (2007) estimated for Canada and to the average ratio of long-term loans to the value of shares and other equities for nonfinancial corporations in the euro area (as in GNSS). The target capital-to-asset ratio ν, the cost for managing the bank capital position δ^b and the elasticity of substitution across loan varieties ε^b (which determines the steady-state loan spread) are set at 9%, 0.049 and 3, respectively, as in GNSS. The bank capital adjustment cost θ equals 11, the estimated value in GNSS.

Finally, a separate discussion is warranted for the the parameter governing the investment adjustment cost (κ^i). This parameter is crucial in determining the magnitude of the response of asset prices — and therefore of consumption and investment — to shocks, and is thus set so as to obtain a response similar in magnitude to the one in GNSS, where the price of capital roughly moves one-to-one with GDP. This criterion implies that κ^i has to be different for the technology and the cost push shock and equal, respectively, to 5 and 0.5.[16] In the robustness section, we show that our results do not qualitatively change when we consider a wide range of alternative values of κ^i for both shocks. In particular, results hold if we set κ^i equal for both shocks, both at 0.5 and at 5.

4.2   Technology shock

We begin by analyzing Taylor frontiers after a technology shock. The technology shock is a shock to total factor productivity, i.e. to the variable (A_t^e) in the production function

$$y_t^E(i) = A_t^E(k_t^E)^\xi(l_t^{P,d})^{(1-\xi)} \ . \tag{25}$$

We assume that A_t^e follows an AR(1) process

$$A_t^E = \rho^A A_{t-1}^E + \varepsilon_t^A \tag{26}$$

in which $\rho^A = 0.95$ and the variance of ε_t^A is calibrated so that the variance of A_t^e equals 1 percent.[17]

The results are reported in Figure 2, where the black circles display the best trade-off between output and inflation stabilization attainable by a central bank following a

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[16]Asset prices are much more responsive to a cost push-shock than to a technology shock (of the same magnitude), so that the value of κ^i that implies a one-to-one response of asset prices and output is smaller in the former case.

[17]The value of $\rho^A = 0.95$ is based on the estimated value in GNSS.

standard Taylor rule, and the blue stars and the red diamonds depict, respectively, the trade-offs attainable under rules augmented with credit and asset prices.

The first result is that there is indeed scope for a central bank to improve the policy trade-off by responding to asset prices: the red curve, referring to the asset price-augmented rule, lies to the left of the black line. The rule responding to credit does not instead provide substantial benefits to the central bank, as the blue stars exactly overlap the black circles.

In order to get a better understanding of the reasons for this result, let us first discuss the dynamic response of the model to a positive technology shock under a standard Taylor rule and compare it with the response under a rule that responds to asset prices (see Figure 3).[18] Later on, we will briefly discuss the results regarding the difference between a rule that includes asset prices and one that includes credit.

After the shock, asset prices increase and the borrowing constraint of the entrepreneurs is relaxed.[19] Moreover, under the standard rule both the policy and the loan rate fall on impact. This determines a strong increase in lending demand by entrepreneurs, which induces banks to expand their balance-sheet and leverage; as seen in the graph, the increase in leverage sets out the credit-supply channel, which in turn induces a strong response of investment and entrepreneurs consumption, which spills-over also to patients consumption (as these agents enjoy higher wages).

Under the rule targeting asset prices, instead, monetary policy does not accommodate the shock but the policy rate rises when the shock hits the economy. This reflects the counteracting effect of leaning-against-the-wind, whereby the central bank opposes an over-extension of banks balance-sheets and prevents, at least in part, that the amplification mechanisms connected with the presence of financial frictions are triggered. In practice, the tightening of monetary policy goes hand in hand with an increase of bank lending rates and a smaller expansion of bank leverage. In turn, in this case borrowers financing conditions improve significantly less (as highlighted by the much weaker reduction in the value of the multiplier on the entrepreneurs borrowing constraint under the augmented rules), so that the increase in investment, consumption and output is dampened. It is important to stress that such reduction of output volatility reflects the fact that leaning against the wind dampens both the amplification effect of the traditional collateral channel and the credit supply channel. The limited effectiveness of the latter channel depends on the reduced expansion of banks balance-sheets, as testified by the weaker response of asset prices, banks leverage, profits and capital.

A possible reason why a rule responding to asset prices performs better than a rule responding to credit is that, in our model, asset prices are more directly related to inflation because they affect marginal costs via their impact on investment and the return to

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[18]The figure considers a specific calibration for the underlying parameters of the Taylor rules. In particular, for each rule the calibration corresponds to the optimized values (obtained as described below) for a value $\alpha = 0.50$ of the weight assigned to output in the central bank's loss functions, as reported in Table 2 (see below).

[19]Note that in our setup movements in asset prices only reflect changes in the fundamental value and are not associated with any type of irrational behaviour. Gelain *et al.* (2012) analyze the issue of leaning-against-the-wind in a model in which asset prices exhibit "volatility" due to the assumption that a fraction of agents depart from fully-rational expectations.

capital. When the central bank responds to credit the volatility of inflation increases significantly, because of the strong countercyclical impact on entrepreneurs' consumption and investment.[20]

In order to quantify the potential gains from LATW in terms of macroeconomic stabilization, we need to make some assumptions about central bank's preferences. In particular, we assume that the central bank's objective is the minimization of the weighted sum of the variance of inflation and output:

$$Loss = Var(\pi) + \alpha Var(Y),$$

We let the weighting parameter α vary within the range [0,2], i.e., we allow for a broad range of values for the relative weight of inflation versus output stabilization. For each value of α we calculate the value of the loss function for each point on the envelope of a given policy rule and then pick the minimum value as the best policy outcome attainable under that rule. Figure 4 reports the values of the loss function under both the standard and the asset-price augmented rule, together with the percentage difference between the two rules (we exclude the rule for credit, which would coincide with the standard rule). Table 2 reports the values of the coefficients of the "optimized rules", i.e. of the rules corresponding to the loss functions reported in Figure 4.

The general result is that for each weight α we can find an augmented rule that brings about an improvement in terms of macroeconomic stabilization with respect to a standard rule. In terms of our loss function, gains increase with the importance assigned to output stabilization; they are about 15% for an equal weighting of inflation and output ($\alpha =1.00$). Not surprisingly, the only exception is the case in which the central bank only cares about inflation ($\alpha = 0$); in this case, the optimized rule is one prescribing only a response to inflation, with the highest possible coefficient allowed in the grid (5.01). This result is consistent with the findings of Bernanke and Gertler (2000, 2001) and with the pre-crisis "Jackson Hole consensus"(Mishkin, 2011): if stabilizing inflation is the only objective of the central bank then the optimal response is strict inflation targeting.

Focusing on the values implied by the optimized rules, we note that the standard rule prescribes non-zero coefficients on output for $\alpha \geq 1.00$. However, the optimized response to output is always zero when the central bank has the possibility to respond to asset prices. This suggests that, while output itself indirectly dampens the procyclical effects stemming from financial frictions — as this variable is strongly correlated with lending, leverage and asset prices — asset prices are a better indicator of the procyclical effects stemming from financial frictions. Moreover, the augmented rules prescribe a strong response to asset prices (ϕ_q) also for smaller α (with the exception of $\alpha = 0$).[21]

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[20]Although the above considerations downplay the potential stabilizing role for credit aggregates, we believe that this result should not be overemphasized. Indeed, the relative (in)effectiveness of a credit-augmented rule may be model specific. For example, this result could depend upon the fact that our model is designed for normal times, while the stabilizing role of credit is more often associated to its informative content in anticipating the occurrence of financial crises (Borio and Drehman, 2009).

[21]For low values of α, the optimized coefficients for the standard rule imply that the standard Taylor principle — i.e., that a coefficient of $\phi_\pi > 1$ is a necessary condition for determinacy — does not hold in this type of model. A full-blown analysis of equilibrium determinacy would be interesting but it is

It is important to stress that our results are obtained in the context of a linearized model, where financial frictions amplify business cycle fluctuations but where financial instability is precluded by construction, since after a shock all variables eventually return to their steady state levels. This reinforces the claim in favor of leaning-against-the-wind, which is likely to bring about even greater gains in terms of volatility in a world with sudden regime shifts, non-linear dynamics and default. In the model, a simple short-cut to analyze the potential gains for financial stability from leaning against the wind would be to proxy financial stability itself by including the variance of loans or asset prices in the loss function, as Angelini *et al.* (2011) do. In this case, since policies that lean against the wind reduce the variance of financial variables, the reduction in the loss function due to LATW would be even greater.

All in all, in this section we have shown that in a model with financial frictions, the response of the central bank under a standard Taylor rule may be procyclical, increasing the volatility of entrepreneurs' investment and output. Under an LATW policy, instead, the response of the central bank is less accommodative, possibly even becoming countercyclical, thus dampening the effects connected with the existence of the financial frictions.

4.3 Cost-push shock

We now turn to analyzing a cost-push shock, defined as a shock to the elasticity of substitution between varieties in the goods market (as standard in the New Keynesian literature; see for example, Christiano *et al.*, 2005). A cost-push shock can be considered as an inflation shock caused by a substantial increase in the cost of inputs where no suitable alternative is available (an example is the oil shock of the 1970s). This shock can be considered as a "pure supply"shock, because not only output (as in the technology shock) but also the output gap moves in an opposite direction with respect to inflation. Analyzing the opportunity to leaning against the wind after this shock is thus a robustness check of the results obtained above for the technology shock.

In our framework, the cost-push shock is modelled as an exogenous disturbance to the firms' mark-up mk_t^y in the New Keynesian Phillips curve (see equation (A.20) in the Appendix), according to the expression:

$$mk_t^y = \rho^y mk_{t-1}^y + \varepsilon_t^y$$

in which $\rho^y = 0.50$ and the variance of ε_t^y is calibrated so that the variance of mk_t^y equals 1 percent.[22]

Figure 5 displays the Taylor frontiers for the standard Taylor rule and for the rules augmented with the financial variables. Also in this case responding to asset prices improves the trade-off for the central bank, while again including credit in the Taylor rule does not allow to improve the trade-off.

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beyond the scope of this paper.

[22]The parameter ρ^y is smaller than that used for the technology shock, based on the findings by GNSS. Their estimated value for the persistence of the cost-push shock is about one third of that for the persistence of the technology shock.

The analysis of the model's impulse responses provides once again some guidance to interpret the results (Figure 6).[23] After an adverse inflation shock, the fall in output is significantly more accentuated under the standard rule than under the rule that takes into account a response to asset prices. The difference in output volatility under the various rules reflects the different responses of the central bank to the shock. Under the standard rule, both the policy and the lending rates rise on impact, inducing a strong contraction in banks balance sheets (leverage), a sharp deterioration of entrepreneurs' financing conditions and a marked fall in investment.[24] Under the rule including asset prices, instead, monetary policy is eased on impact, contributing to substantially limiting the deterioration of entrepreneurs' financing conditions by sustaining banks' balance sheets and avoiding a major disruption of credit supply.

The improvement from an asset-price augmented rule is pronounced also in this case. For values of α around 1 gains are indeed greater than after a technology shock, reflecting the fact that the superior performance of asset prices in stabilizing marginal cost is even greater after a cost-push shock, as the innovation directly hits the Phillips curve. In this case, the reduction of the central bank's loss function reaches almost 30% for $\alpha = 0.80$ (Figure 7 and Table 3). As regards the optimized coefficients, the prescribed response to asset prices is strong as in the case of a technology shock.

5 Are macroeconomic gains higher in an economy with more debt?

In the above section, we have shown how the gains in macroeconomic stabilization from responding to financial variables could be significant after supply shocks. We have also discussed how the motivation for this improvement was connected to the effect of LATW on borrowers' and bank leverage and its effect on the credit market equilibrium. In this section we analyze how these results are sensitive to the degree of financial leverage in the economy. In particular, we repeat the simulations presented in Section 4.1 for the technology shock for a higher value of m^E.[25] The main effect of changing this parameter is to increase the steady state value of borrowers' leverage in the model; we will thus analyze whether the case for LATW becomes stronger in an economy that is characterized by higher indebtedness of the private sector and could — as such — be considered more fragile. In particular, an increase in m^E raises the steady state value of χ_t (χ; see equation (18)), which, in turn, has a twofold impact on the loan demand schedule (20): first, it reduces the slope (in absolute value) of the demand curve, which implies that changes in equilibrium loans will be greater for a given shift of loan supply; second, it magnifies the (negative) impact of changes in previous-period loan interest expenditure, which shifts the schedule. These two effects may possibly increase volatility in the credit market and,

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[23]Similarly to Figure 3, this figure is based on the specific calibration for the rule parameters obtained by picking the optimized values for $\alpha = 0.50$, as reported in Table 3.

[24]Note that the strong fall in investment also reflects the small value of the investment adjustment cost κ^i, discussed in Section 4.1.

[25]We limit our discussion to a technology shock for ease of exposition; the results for a cost-push (not reported) are broadly similar.

as a consequence, in the real economy. This is consistent with the fact that economies where banks set higher values of LTV tend to display a stronger response of aggregate consumption to asset price fluctuations (Calza *et al.*, 2009). One may then reasonably expect that the beneficial impact of LATW policies is stronger.

Figure 8 reports the steady state values of some possible model-based measures of entrepreneurs' leverage, as a function of m^E, from which a clear positive relationship emerges. In the baseline calibration, this parameter was set at 0.35, following GNSS, where that choice was based on the empirical estimates provided by Christensen *et al.* (2007) and on the observed ratio of long-term firm loans to the value of shares and other equities in the euro area; the implied debt-to-income ratio is roughly 8 and leverage (defined as loans over firms' capital and equal to χ) is 35%. If, for example, m^E is raised to 0.50, then the corresponding ratios increase to around 13 and 45% respectively.

We repeat the simulations of Section 3 (for the case of a technology shock) under a "high-LTV"calibration of the model, i.e., for $m^E = 0.70$ and we compare the gains obtained from LATW in this case to that in the baseline calibration. As expected, we find that the reduction in macroeconomic volatility from LATW is higher in the high-LTV calibration (Figure 9). This suggests that, by leaning against the wind, the central bank can partly undo the increase in volatility associated with greater leverage in the economy. The differential gain equals 3 percentage points on average (for the reported range of α) and is higher for low values of α (see Table 4).

6   Robustness checks

In this section we investigate the robustness of our results to changes in a number of key parameters, both for the technology and the cost-push shock. In particular, we repeat the simulations reported in Section 4 and check to what extent responding to asset prices reduces the loss-function in the alternative models as opposed to the baseline calibration. We analyze changes in three groups of parameters: (i) two key parameters in the banking sector setup, namely the target level for bank leverage (ν) and the elasticity of the loan interest rate to bank leverage (θ); (ii) two parameters affecting the ability of the economy to adjust to shocks, that is the degree of price stickiness (κ_p) and the degree of investment adjustment cost (κ_i); (iii) the degree of persistence of the monetary policy rule (ρ^{ib}) and that of the exogenous shocks (ρ^A and ρ^y, respectively, for the technology and the cost-push shock).[26] Figures 10 and 11 report the results of the robustness exercise.

First, as regards the two key parameters in the banking sector (upper row in the figures), the results are almost identical to the baseline model both when we change the degree of banking sector capitalization (ν) and the sensitivity of the loan interest rate to shifts in bank leverage (θ). These two parameters, in principle, affect the slope of the loan supply schedule, as evident from equation (19); in quantitative terms, however, their impact on the model dynamics is rather limited: the slope of the loan supply schedule, which depends on the product $\theta\nu^3$, ranges between 0.07 and 0.0007 for the combinations

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[26]Note that the exercise conducted with the LTV in the previous Section can also be considered as a robustness check relative to the parameter m^E.

of calibrations considered in this robustness analysis.

Second, our results are also qualitatively robust to changes in the degree of rigidity in the economy (medium row in the figures), though they somewhat differ from the baseline from a quantitative perspective. Sensitivity to κ_p shows that the gains from LATW after the technology shock tend to be higher the greater the degree of price rigidity: in the calibration where $\kappa_p = 100$, gains reach almost 25%, while gains are always lower than the baseline for $\kappa_p = 15$. Moreover, for both shocks, with high price rigidity the effectiveness of an asset-price augmented rule is stronger for lower values of α, as the curve for the loss function gains becomes more hump-shaped. To understand this result, note that higher values of κ_p imply that the aggregate supply (AS) schedule is flatter. As discussed in Figure 1, when the central bank responds to asset prices, shifts of aggregate demand following the shocks are attenuated, reflecting the fact that stabilizing asset prices does not allow a strong increase in consumption and investment by constrained agents. With a flatter AS, output fluctuates more after a demand shock, thus the beneficial effect of the augmented rule is greater.

Our main result that LATW improves macroeconomic stabilization is also robust to different calibrations of the investment-adjustment cost κ^i. In particular, this is true when we consider the same values of κ^i for the two shocks, confirming that our results do not depend on the choice of having different baseline values for the two shocks.[27] It is worth noting that the quantitative relevance of the gains from LATW significantly reduces when we consider values of κ^i significantly lower than the baseline (e.g., $\kappa^i = 0.05$ for the technology shock and $\kappa^i = 0.005$ for the cost-push shock). This reflects the fact that when κ^i is close to 0 asset prices move very little (indeed, they are constant for $\kappa^i = 0$), and therefore the working of financial frictions in the model is very muted; in those cases, it is not surprising that there is very little utility gain from LATW.

Third, the sensitivity exercise with respect to the degree of persistence of the monetary policy rule (ρ^{ib}; lower right-hand panel in the figures) shows that our results do not depend on the assumption that the central bank gradually adjusts the policy interest rate. Indeed, for the cost-push shock, gains from LATW are even greater when $\rho^{ib} = 0$. Instead, the effectiveness of the rules including asset prices is significantly reduced if the exogenous shocks have a low persistence (lower left-hand panel). Indeed, for the technology shock gains from LATW are almost zero if ρ^A is not high enough. This reflects a typical feature of RBC and NK models, whereby the price of capital displays a positive response to a (level) technology shock only if persistence of the shock is very high. If this is not the case, then again financial frictions do not add any procyclical effects to the shock and therefore there is no advantage in leaning against the wind. For the cost-push shock a smaller amount of exogenous persistence is needed, although also in this case the convenience from LATW reduces if the AR component is zero. At the same time, gains from LATW increase for values of ρ^y higher than the baseline.

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[27]In the figures, the green lines are those where κ^i is set at the same level as the baseline of the other shock (0.05 in Figure 10 and 5 in Figure 11). The purple lines display instead results for $\kappa^i = 0.5$ in both figures.

7   Conclusions

The financial crisis has reaffirmed the importance of financial factors for explaining macroeconomic fluctuations. Empirical research has pointed out how credit boom-bust cycles may affect the business cycle; theoretical analysis has turned its attention to the implications of this channel on the conduct of monetary policy. The pre-crisis consensus on the conduct of monetary policy, namely that the central bank should pay no attention to financial variables over and above their effects on inflation, has been reconsidered.

In this paper we contribute to the existing literature by analyzing how different instrument rules perform in a model with the simultaneous presence of a *balance-sheet* and a *credit-supply channel*. We show that, when credit supply conditions matter for the real economy, responding to financial variables allows the central bank to reach a better trade-off between inflation and output stabilization. In particular, simulations for technology and price mark-up shocks suggest that a central bank which reacts to asset prices may reduce the loss associated with output and inflation fluctuations by between 20 and 30%. These gains are further amplified if the economy is characterized by a high level of the loan-to-value ratio, which mimics an economy with more indebted borrowers (which in turn could reflect institutional factors or a different degree of development in the financial industry). Our study corroborates previous results (Cúrdia and Woodford, 2009, 2010; Lambertini *et al.*, 2011; Christiano *et al.*, 2010) using a richer model of the financial sector and analyzing a different range of financial variables that the central bank might want to look at.

From a policy perspective our results, obtained in the context of a linearized model that rules out financial (in)stability and default, highlight the potential gains from leaning against the wind from a strict macroeconomic stabilization perspective; gains are likely to be larger if financial stability were also to be the concern of policymakers.

Some caution is obviously required when interpreting the results of this paper. First, admittedly, the model studies the conduct of monetary policy in normal times, not during a period of financial stress: many important aspects that are typical ingredients of boom-bust cycles in asset markets, such as sudden shifts in borrowers' credit risk perception and the possibility of banks' default are not modelled. This could hide the information content of some financial variables such as credit, that the literature indicates as a good indicator to detect the development of a financial crisis. Moreover, it would be particularly interesting to analyze the effect of the augmented rules in a model where households — rather than firms — are constrained borrowers, with the constraint tied to the value of housing collateral; this exercise could show whether the presence of a credit-supply channel might challenge the result of irrelevance of asset prices found by Iacoviello (2005).

Second, the typical solution techniques used for the DSGE models, based on log-linearization, does not allow for the non-linear dynamics that typically characterize boom-bust episodes. However, despite the lack of these features, the importance for monetary policy to lean against the wind is fully recognized by simply giving a non-negligible role to financial flows and credit intermediation.

Third, our results should not be interpreted as providing precise quantitative prescriptions of the optimal values to be assigned to asset prices in an operational rule. The

fact that they are obtained from numerically optimized rules, calculated on a finite and discrete grid of possible parameters, and based on a stylized model, suggests that their indications are mainly of a qualitative nature. In addition, our analysis considers technology and cost-push shocks one at a time. This simplification is crucial for understanding how the transmission mechanism of the various shocks works and for studying the trade-offs that each of them entails for the conduct of monetary policy; however, this approach further restricts the ability of our analysis to give quantitative prescriptions, because it implicitly assumes that the central bank can perfectly disentangle the source of business cycle flcutuations.

Finally, our study, focusing on the interaction between asset-price developments and monetary policy, underscores the importance of co-operation between the central bank and the macroprudential authorities (Borio, 2006; Angelini *et al.*, 2011). All these issues are important avenues for future research.

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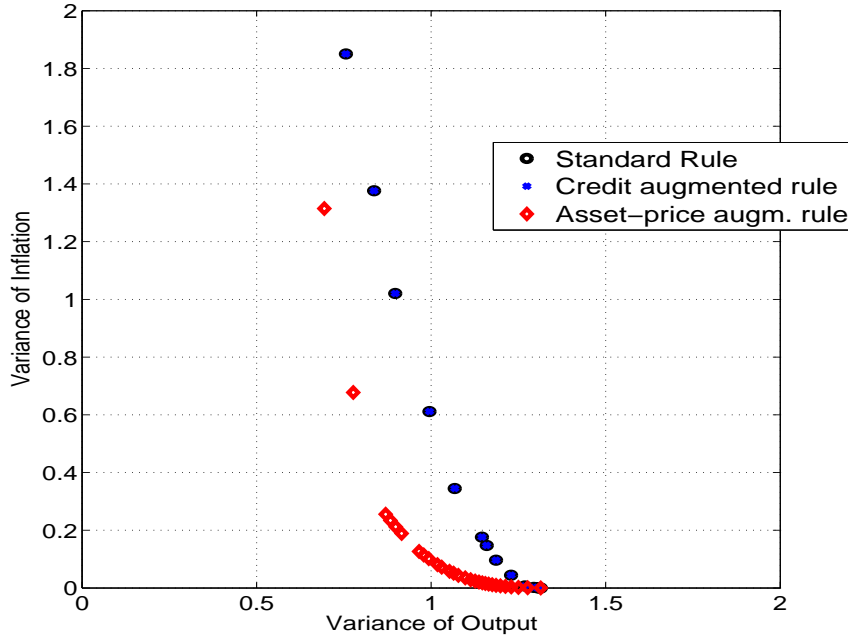**Figure 1. Equilibrium in the credit market**
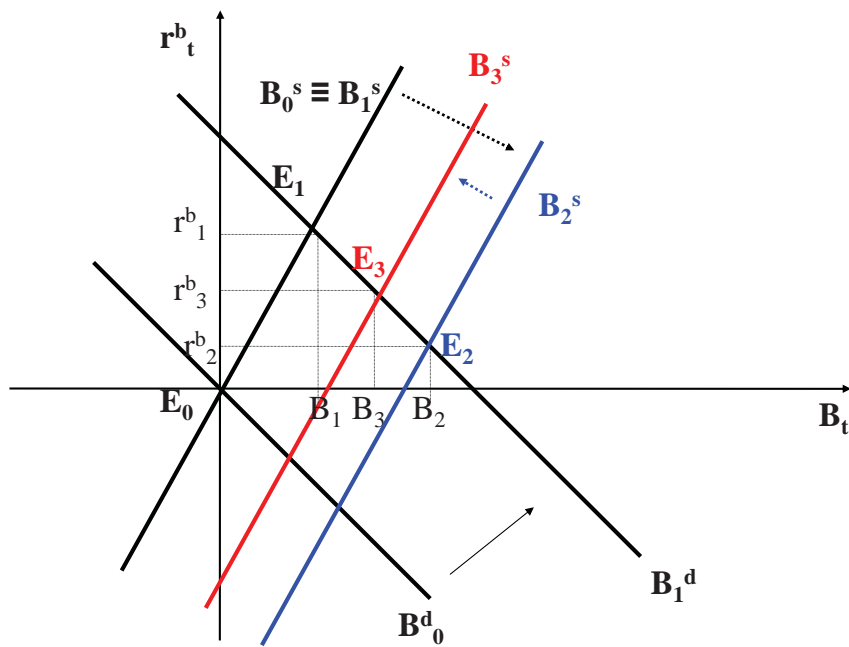
Case 1. no action: $r_t^{ib} = 0 \rightarrow$ Equilibrium E_1.

Case 2. Inflation targeting Taylor rule: $r_t^{ib} = \phi_\pi \pi_t \rightarrow$ Equilibrium E_2.

Case 3. Asset-price augmented rule: $r_t^{ib} = \phi_\pi \pi_t + \phi_q q_t^k \rightarrow$ Equilibrium E_3.

Figure 2. Taylor frontiers after a technology shock

Note: The figure reports the efficient frontier of variance of output and inflation for each monetary policy rule after a technology shock, expressed as a ratio to the variance of the exogenous shock.

Figure 3. Impulse response functions after a technology shock
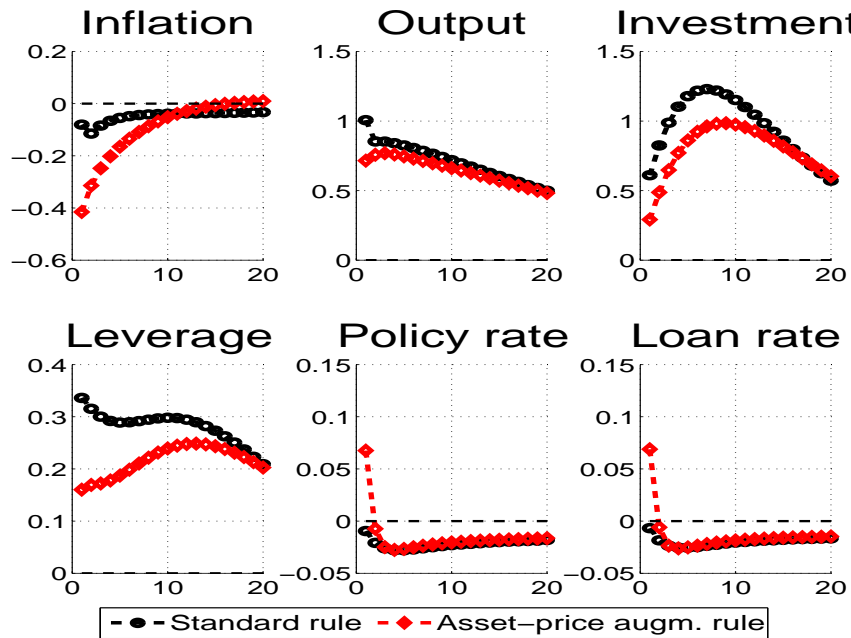
Note: The standard deviation of the shock is 1 %. For the policy and the loan rate, absolute deviations from the steady state, in percentage points; for the other variables, percent deviations from the steady state.

Figure 4. Loss functions after a technology shock

Note: The left-hand panel reports the value of the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$ for different values of the weight α assigned to output, for the standard Taylor rule and for the asset-price augmented rule. The right-hand panel reports the percentage difference from the two lines, for each value of α, which can be interpreted as the gain (reduction of loss) that the central bank may attain by leaning against the wind.
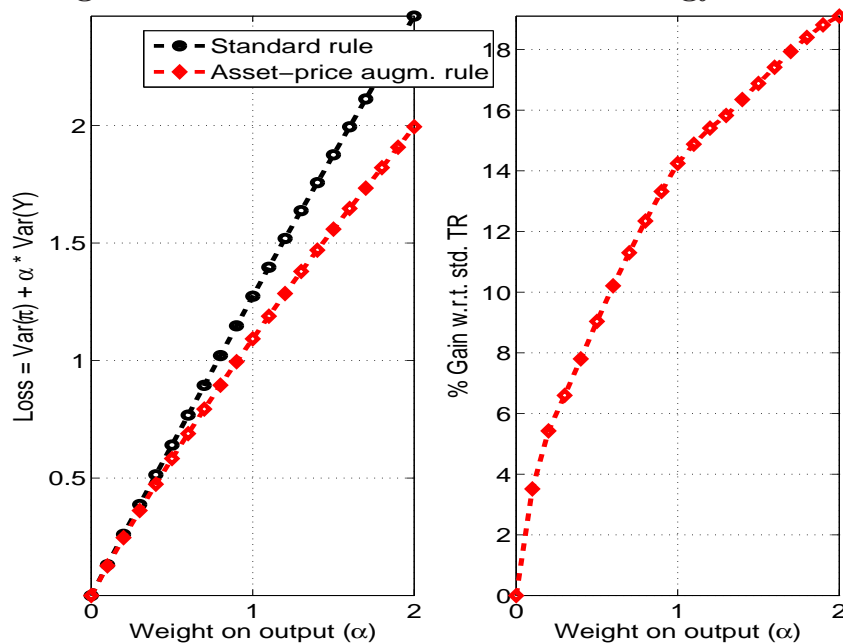
Figure 5. Taylor frontiers after a cost-push shock

Note: The figure reports the efficient frontier of variance of output and inflation for each monetary policy rule after a cost-push shock, expressed as a ratio to the variance of the exogenous shock.

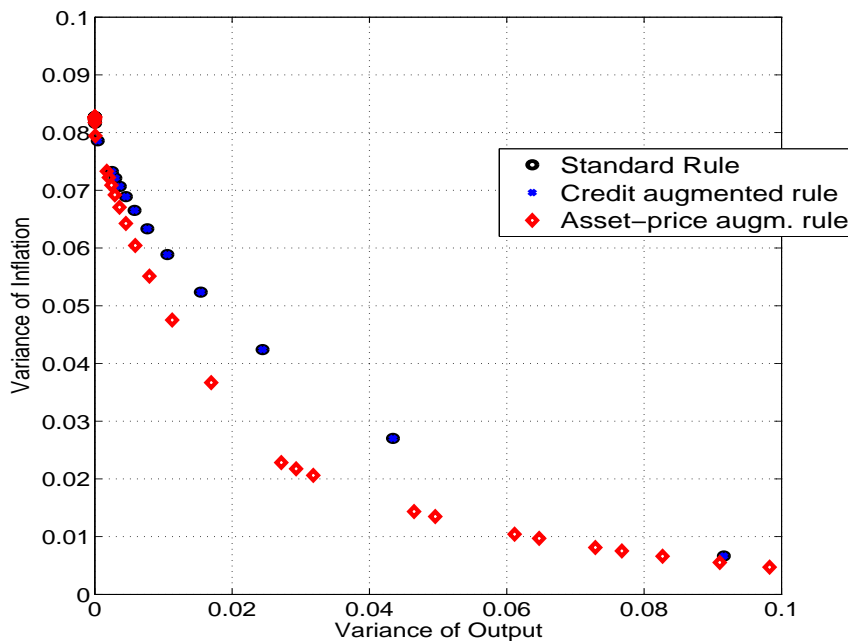## Figure 6. Impulse response functions after a cost-push shock

Note: The standard deviation of the shock is 1 %. For the policy and the loan rate, absolute deviations from the steady state, in percentage points; for the other variables, percent deviations from the steady state.

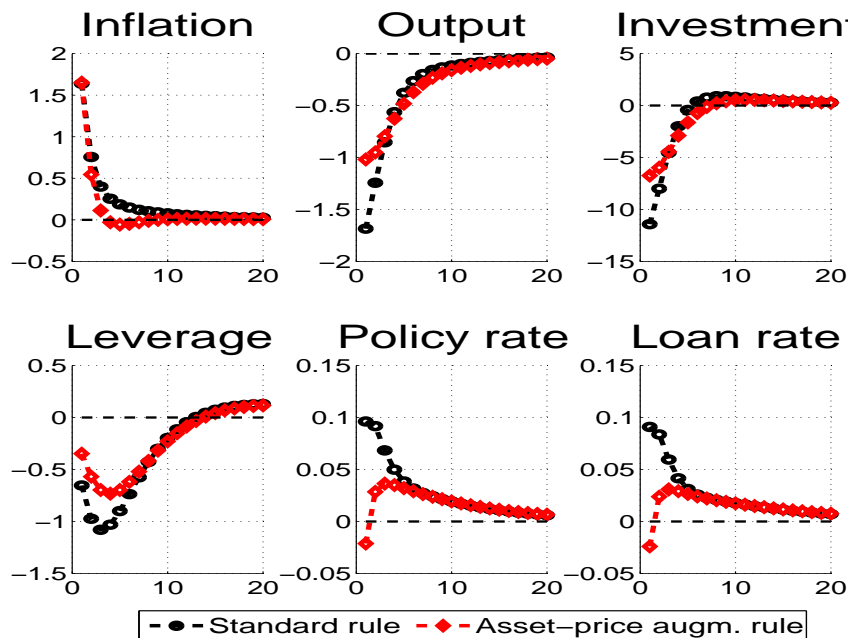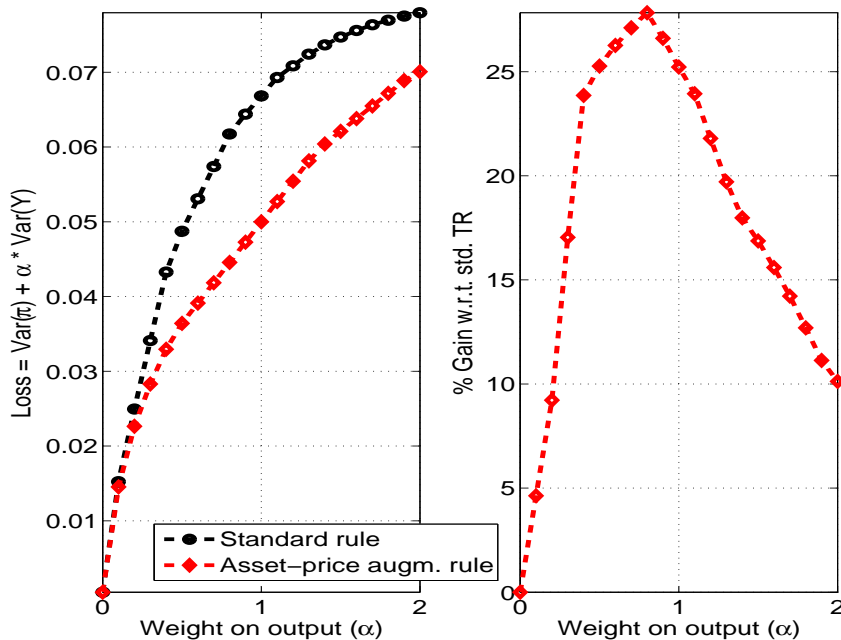## Figure 7. Loss functions after a cost-push shock

Note: The left-hand panel reports the value of the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$ for different values of the weight α assigned to output, for the standard Taylor rule and for the asset-price augmented rule. The right-hand panel reports the percentage difference from the two lines, for each value of α, which can be interpreted as the gain (reduction of loss) that the central bank may attain by leaning against the wind.

Figure 8. Measures of entrepreneurs' leverage, for different m^E
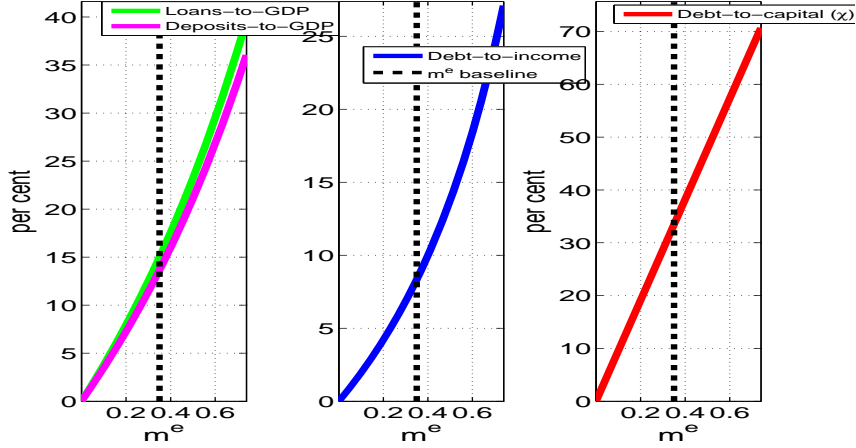
Note: The figure reports the steady state values of different measures of entrepreneurs' leverage, for different values of the loan-to-value ratio chosen by the banks m^E (i.e., the ratio between the amount of loans issued and the discounted next-period value of entrepreneurs' assets).

Figure 9. High LTV: loss functions after a technology shock
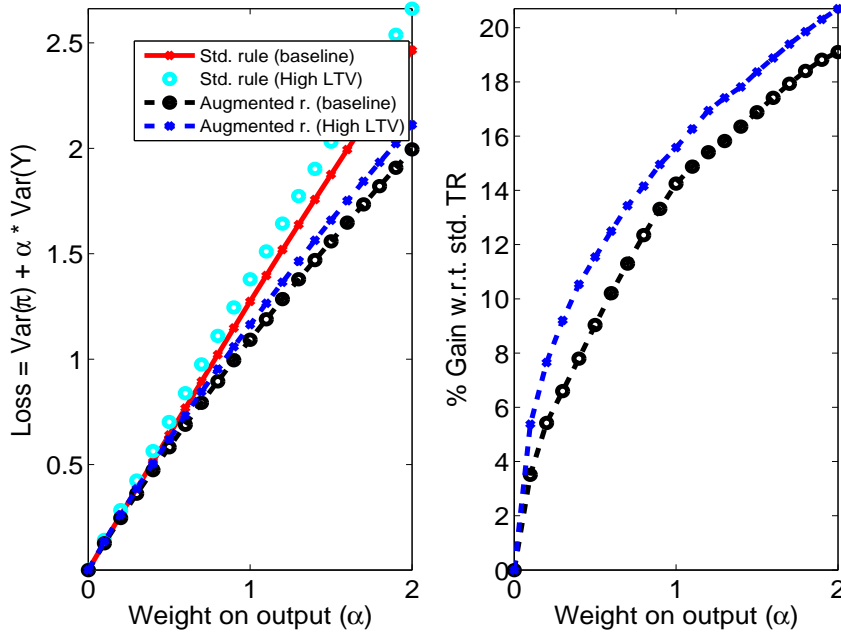

Note: The left-hand panel reports the value of the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$ for different values of the weight α assigned to output, for the standard Taylor rule and for the asset-price augmented rule. The curves are reported for two different calibrations of the LTV (m^E) set by the banks: the baseline calibration ($m^E = 0.35$) and a high LTV calibration ($m^E = 0.70$). The right-hand panel reports the percentage differences between the lines for the baseline and the augmented rules, for both the baseline and the high LTV calibrations, for each value of α; these differences can be interpreted as the gain (reduction of loss) that the central bank may attain by leaning against the wind in each of the two calibrations.

Figure 10. Robustness checks: loss function gains for asset-price augmented rules after a technology shock
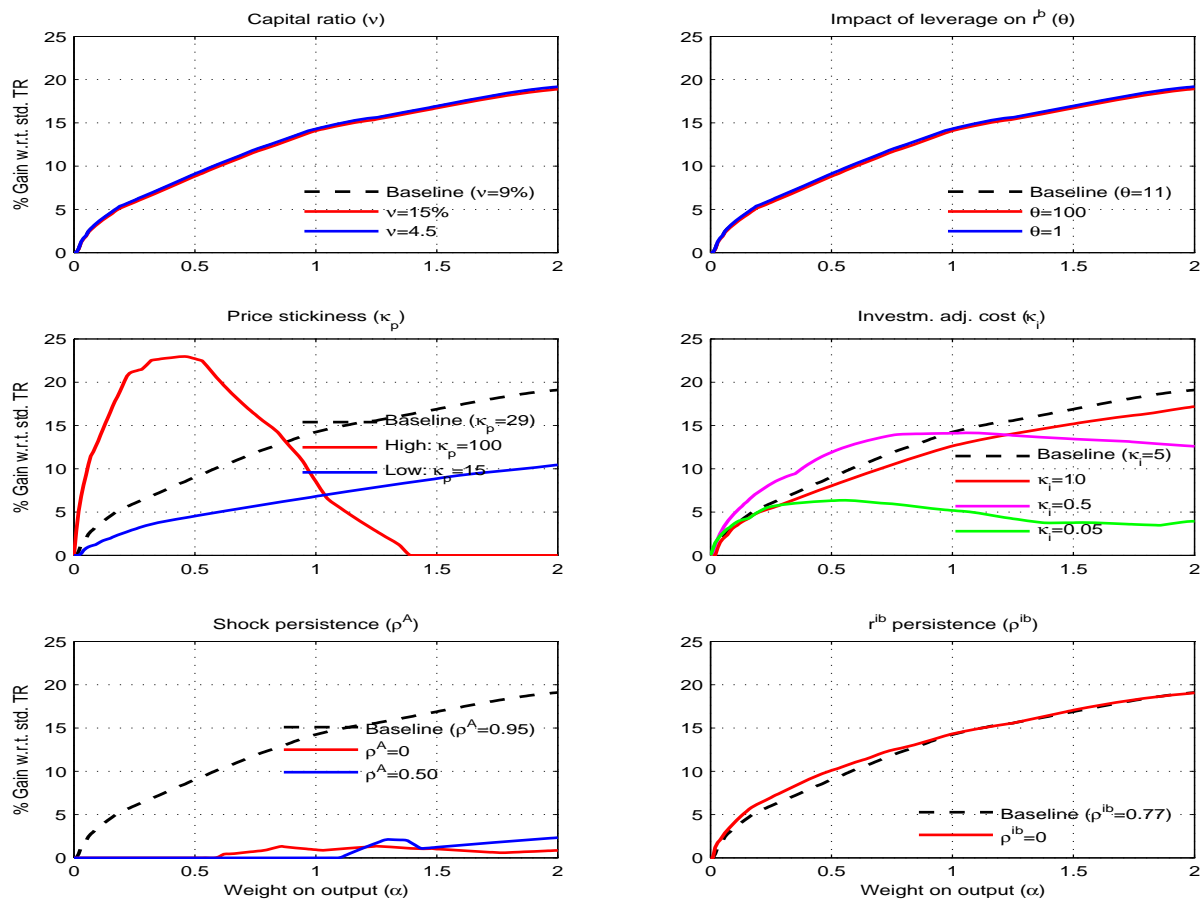
Note: The figure reports the percentage gains from an asset-price augmented rule as compared to a standard Taylor rule, for different values of the weight α assigned to output in the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$. The black dotted line correspond to the baseline calibration; the blue and the red lines to alternative calibrations (reported in the legend of each subplot) for some key model parameters.

Figure 11. Robustness checks: loss function gains for asset-price augmented rules after a cost-push shock
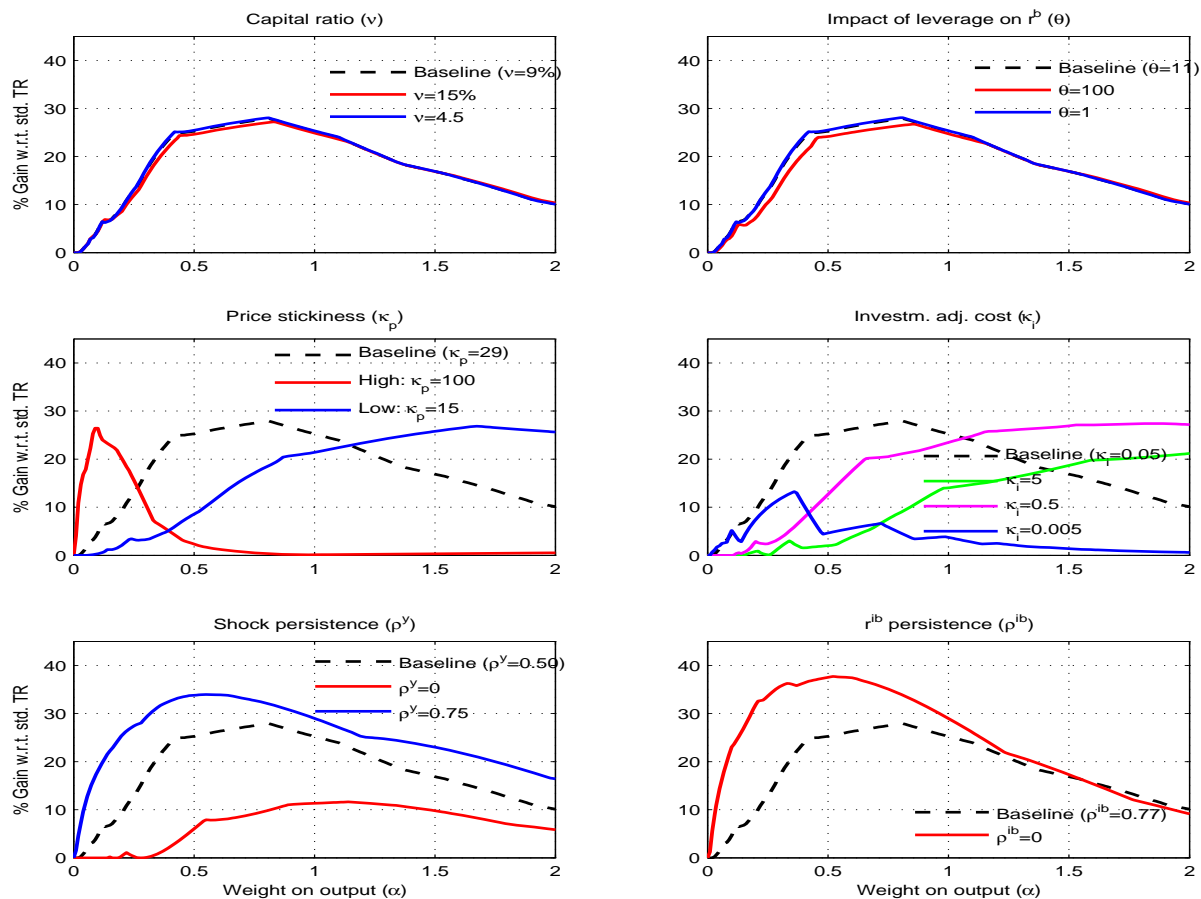
Note: The figure reports the percentage gains from an asset-price augmented rule as compared to a standard Taylor rule, for different values of the weight α assigned to output in the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$. The black dotted line correspond to the baseline calibration; the blue and the red lines to alternative calibrations (reported in the legend of each subplot) for some key model parameters.

Table 1
Model parameters

Parameter	Description	Value
β_P	Patient households discount factor	0.996
β_E	Entrepreneurs discount factor	0.975
ϕ	Inverse of the Frisch elasticity	1
α	Capital share in the production function	0.20
δ^k	Depreciation rate of physical capital	0.050
m^E	Entrepreneurs LTV ratio	0.35
ε^y	$\frac{\varepsilon^y}{\varepsilon^y-1}$ is the markup in the goods market	6
κ_p	Price stickiness	28.65
θ	Bank Capital adjustment cost	11
ν	Target capital-to-asset ratio	0.09
δ^b	Cost for managing the banks capital position	0.049
ε^b	$\frac{\varepsilon^b}{\varepsilon^b-1}$ is the markup on the loan rate	3
ρ^{ib}	Monetary policy inertia	0.77

Table 2

Optimized Taylor rules and central bank losses; technology shock

Output weight	Std Taylor rule			Asset-price augmented rule				
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_q
0.0	0.00	5.00	0	0.00	0.0%	5.00	0	0
0.1	0.13	1.50	0	0.13	3.5%	5.00	0	0.75
0.2	0.26	0.50	0	0.25	5.4%	5.00	0	1.75
0.3	0.39	0.50	0	0.36	6.6%	4.50	0	2.50
0.4	0.51	0.50	0	0.47	7.8%	3.50	0	2.50
0.5	0.64	0.50	0	0.58	9.0%	2.50	0	2.50
0.6	0.77	0.50	0	0.69	10.2%	2.00	0	2.50
0.7	0.89	0.50	0	0.79	11.3%	1.50	0	2.50
0.8	1.02	0.50	0	0.90	12.3%	1.50	0	2.50
0.9	1.15	0.50	0	1.00	13.3%	1.00	0	2.25
1.0	1.27	1.50	0.25	1.09	14.2%	1.00	0	2.50
1.1	1.40	1.50	0.25	1.19	14.9%	1.00	0	2.50
1.2	1.52	1.50	0.25	1.29	15.4%	1.00	0	2.50
1.3	1.64	1.00	0.25	1.38	15.8%	0.50	0	1.75
1.4	1.76	1.00	0.25	1.47	16.4%	0.50	0	2.00
1.5	1.88	1.00	0.25	1.56	16.9%	0.50	0	2.25
1.6	1.99	1.00	0.25	1.65	17.4%	0.50	0	2.50
1.7	2.11	1.00	0.25	1.73	17.9%	0.50	0	2.50
1.8	2.23	1.00	0.25	1.82	18.4%	0.50	0	2.50
1.9	2.35	1.50	0.50	1.91	18.8%	0.50	0	2.50
2.0	2.47	1.50	0.50	1.99	19.1%	0.50	0	2.50

Note: The table reports the value of the minimum loss attainable by the central bank under the standard and the asset-price augmented rules, for different values of the weight α assigned to output in the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$, as well as the corresponding values of the central bank's response to inflation (ϕ_π), output (ϕ_y) and asset prices (ϕ_q). For the asset price augmented rule, we also report the percentage gains (if any) with respect to the standard rule.
[1] Percentage difference between the minimum loss under the standard Taylor rule and the augmented rule.

Table 3

Optimized Taylor rules and central bank losses; cost-push shock

Output weight	Std Taylor rule			Asset-price augmented rule				
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_q
0.0	0.00	5.00	0	0.00	0.0%	5.00	0	0
0.1	0.02	1.00	0	0.01	4.6%	3.50	0	2.50
0.2	0.02	0.50	0	0.02	9.2%	1.50	0	2.25
0.3	0.03	0.50	0	0.03	17.0%	1.00	0	2.50
0.4	0.04	0.50	0	0.03	23.9%	1.00	0	2.50
0.5	0.05	0.50	0.25	0.04	25.3%	0.50	0	2.50
0.6	0.05	0.50	0.25	0.04	26.3%	0.50	0	2.50
0.7	0.06	0.50	0.25	0.04	27.1%	0.50	0	2.50
0.8	0.06	0.50	0.25	0.04	27.8%	0.50	0	2.50
0.9	0.06	0.50	0.50	0.05	26.6%	0.50	0	2.50
1.0	0.07	0.50	0.50	0.05	25.2%	0.50	0	2.50
1.1	0.07	0.50	0.50	0.05	23.9%	0.50	0	2.50
1.2	0.07	0.50	0.75	0.06	21.8%	0.50	0	2.50
1.3	0.07	0.50	0.75	0.06	19.7%	0.50	0	2.50
1.4	0.07	0.50	1.00	0.06	18.0%	0.50	0.25	2.50
1.5	0.07	0.50	1.00	0.06	16.9%	0.50	0.25	2.50
1.6	0.08	0.50	1.25	0.06	15.6%	0.50	0.25	2.50
1.7	0.08	0.50	1.25	0.07	14.2%	0.50	0.25	2.50
1.8	0.08	0.50	1.50	0.07	12.7%	0.50	0.25	2.50
1.9	0.08	0.50	1.75	0.07	11.1%	0.50	0.25	2.50
2.0	0.08	0.50	1.75	0.07	10.1%	0.50	0.50	2.50

Note: The table reports the value of the minimum loss attainable by the central bank under the standard and the asset-price augmented rules, for different values of the weight α assigned to output in the central bank's loss function $Loss = Var(\pi) + \alpha Var(Y)$, as well as the corresponding values of the central bank's response to inflation (ϕ_π), output (ϕ_y) and asset prices (ϕ_q). For the asset price augmented rule, we also report the percentage gains (if any) with respect to the standard rule.
[1] Percentage difference between the minimum loss under the standard Taylor rule and the augmented rule.

Table 4
High-LTV *vs* Baseline model, technology shock

Output weight	Std Taylor rule			Asset-price augmented rule					
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	Diff with BL[2]	ϕ_π	ϕ_y	ϕ_q
0.0	0.00	5.00	0	0.00	0.0%	0.0%	5.00	0	0
0.1	0.14	5.00	0	0.14	5.3%	1.8%	5.00	0	0.75
0.2	0.28	5.00	0.25	0.26	7.7%	2.2%	5.00	0	1.50
0.3	0.42	5.00	0.25	0.39	9.2%	2.6%	5.00	0	2.50
0.4	0.56	5.00	0.25	0.50	10.5%	2.7%	4.00	0	2.50
0.5	0.70	5.00	0.50	0.62	11.5%	2.5%	3.00	0	2.50
0.6	0.84	5.00	0.50	0.73	12.5%	2.3%	2.50	0	2.50
0.7	0.98	5.00	0.75	0.84	13.4%	2.1%	2.00	0	2.50
0.8	1.11	5.00	0.75	0.95	14.2%	1.8%	1.50	0	2.25
0.9	1.25	5.00	0.75	1.06	15.0%	1.6%	1.50	0	2.50
1.0	1.38	5.00	1.00	1.16	15.6%	1.3%	1.00	0	2.00
1.1	1.51	5.00	1.00	1.27	16.3%	1.4%	1.00	0	2.50
1.2	1.64	5.00	1.00	1.36	16.9%	1.5%	1.00	0	2.50
1.3	1.77	5.00	1.25	1.46	17.4%	1.6%	1.00	0	2.50
1.4	1.90	5.00	1.25	1.56	17.8%	1.5%	1.00	0	2.50
1.5	2.03	5.00	1.50	1.66	18.4%	1.5%	0.50	0	1.75
1.6	2.16	5.00	1.50	1.75	18.9%	1.5%	0.50	0	2.00
1.7	2.29	5.00	1.50	1.84	19.4%	1.5%	0.50	0	2.25
1.8	2.41	5.00	1.75	1.93	19.8%	1.5%	0.50	0	2.25
1.9	2.54	5.00	1.75	2.02	20.3%	1.5%	0.50	0	2.50
2.0	2.66	5.00	2.00	2.11	20.7%	1.6%	0.50	0	2.50

Note: The table replicates the exercises of Table 1 for the model with a high LTV calibration ($m^E = 0.70$; under the baseline calibration, $m^E = 0.35$) and, in addition, for the asset-price augmented rule the table reports the differential gain (if any) from leaning against the wind with respect to the baseline calibration, in percentage points.
[1] Percentage difference between the minimum loss under the standard Taylor rule and the augmented rule. [2] Percentage difference between the gain from responding to asset prices in the high LTV calibration as compared to the baseline calibration.

A   The full non-linear model

A.1   Households

Households i maximize the following utility function

$$\max_{\left\{c_t^P(i),l_t^P(i),d_t^P(i)\right\}} E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\log(c_t^P(i)) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right],$$

subject to the budget constraint:

$$c_t^P(i) + d_t^P(i) \leq w_t l_t^P(i) + \left(1 + r_{t-1}^{ib}\right) d_{t-1}^P(i) + J_t^R(i) \tag{A.1}$$

The relevant first-order conditions are the Euler equation and the labor-supply decision:

$$\frac{1}{c_t^p(i)} = E_t \frac{\beta_P \left(1 + r_t^{ib}\right)}{c_{t+1}^p(i)} \tag{A.2}$$

$$l_t^P(i)^\phi = \frac{w_t}{c_t^p(i)} \tag{A.3}$$

A.2   Entrepreneurs

Entrepreneurs' maximize consumption according to the utility function:

$$\max_{\left\{c_t^E(i),l_t^{P,d}(i),b_t^{EE}(i)\right\}} E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i)) \tag{A.4}$$

subject to budget and borrowing constraints:

$$c_t^E(i) + \left(1 + r_{t-1}^b\right) b_{t-1}^{EE}(i) + w_t l_t^{P,d}(i) + q_t^k k_t^E(i) \leq \frac{y_t^e(i)}{x_t} + b_t^{EE}(i) + q_t^k(1 - \delta^k)k_{t-1}^e(i) \tag{A.5}$$

$$b_t^{EE}(i) \leq \frac{m^E q_{t+1}^k k_t^e(i)(1 - \delta^k)}{1 + r_t^b} \tag{A.6}$$

The production function is:

$$y_t^E(i) = A_t^E (k_t^E)^\xi (l_t^{P,d})^{(1-\xi)} \tag{A.7}$$

The definition of the return to capital is:

$$r_t^k \equiv \xi \frac{A_t^E (k_t^E)^{(\xi-1)} (l_t^{P,d})^{(1-\xi)}}{x_t} \tag{A.8}$$

The relevant first-order conditions for the entrepreneurs are the consumption- and investment-Euler equations, and the labor demand condition, equal to, respectively:

$$\frac{1}{c_t^E(i)} - s_t^E(i) = \beta_E \frac{(1+r_t^b)}{c_{t+1}^E(i)} \tag{A.9}$$

$$\frac{s_t^E(i)m_t^E q_{t+1}^k(1-\delta^k)}{1+r_t^b} + \frac{\beta_E}{c_{t+1}^E(i)}\left[q_{t+1}^k(1-\delta^k) + r_{t+1}^k\right] = \frac{q_t^k}{c_t^E(i)} \tag{A.10}$$

$$\frac{(1-\xi)y_t^e(i)}{l_t^{P,d}(i)x_t} = w_t. \tag{A.11}$$

A.3 Banks

As in Gerali *et al.* (2010) we assume that each bank j is composed of two units: a wholesale branch and a retail branch.

The wholesale unit has own funds $K_t^b(j)$, collects deposits $d_t(j)$ from households on which it pays the interest rate set by the central bank r_t^{ib}, and issues wholesale loans $b_t(j)$ on which it earns the wholesale loan rate $R_t^b(j)$. The bank pays a quadratic cost whenever the value of own funds to loans differs from the (exogenous) target leverage ν. The wholesale unit's problem is choosing $b_t(j)$ and $d_t(j)$ so as to maximize profits subject to the balance-sheet constraint

$$\max_{\{b_t(j),d_t(j)\}} R_t^b b_t(j) - r_t^{ib} d_t(j) - \frac{\theta}{2}\left(\frac{K_t^b(j)}{b_t(j)} - \nu\right)^2 K_t^b(j) \tag{A.12}$$

$$\text{s.t. } b_t(j) = d_t(j) + K_t^b(j) \tag{A.13}$$

The first order condition is

$$R_t^b = r_t^{ib} - \theta\left(\frac{K_t^b(j)}{b_t(j)} - \nu\right)\left(\frac{K_t^b(j)}{b_t(j)}\right)^2 \tag{A.14}$$

We assume that the retail loan branches operate in a regime of monopolistic competition. These units buy wholesale loans, differentiate them at no cost and resell them to final borrowers. In the process, each retail unit fixes the retail loan rate, applying a mark-up on the wholesale loans rate. Differently to Gerali *et al.*, and for the sake of simplicity, we assume that the mark-up is constant and additive. The retail loan rate is thus:

$$r_t^b = R_t^b + \bar{\mu}^b = r_t^{ib} - \theta\left(\frac{K_t^b(j)}{b_t(j)} - \nu\right)\left(\frac{K_t^b(j)}{b_t(j)}\right)^2 + \bar{\mu}^b \tag{A.15}$$

Aggregate bank profits are defined as the sum of retail and wholesale banks' profits for all banks j, assuming symmetry:

$$J_t^B = r_t^b B_t - r_t^{ib} D_t - \frac{\theta}{2}\left(\frac{K_t^b}{B_t} - \nu\right)^2 K_t^b \tag{A.16}$$

where K_t^b, B_t, D_t are aggregate bank capital, loans and deposits, respectively.

Assuming that all bank profits are reinvested in banking activity, aggregate bank capital evolves according to:

$$K_t^b = K_{t-1}^b(1 - \delta^b) + J_{t-1}^B \tag{A.17}$$

where δ^b is a fraction of bank capital that is consumed in each period in banking activity.

A.4 Capital good producers and retailers

This follows Gerali *et al.* (2010). The first-order condition for capital goods' producers is

$$1 = q_t^k \left[1 - \frac{\kappa^i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \kappa^i \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta_E E_t \left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \kappa^i \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right] \tag{A.18}$$

and the capital-accumulation equation is:

$$K_t = (1 - \delta^k)K_{t-1} + \left[1 - \frac{\kappa^i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t \tag{A.19}$$

The presence of the retailers implies that there is a standard New Keynesian Phillips curve defined as:

$$1 - \frac{mk_t^y}{mk_t^y - 1} + \frac{mk_t^y}{mk_t^y - 1} mc_t^E - \kappa_p(\pi_t - 1)\pi_t + \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_p(\pi_{t+1} - 1)\pi_{t+1} \frac{Y_{t+1}}{Y_t} \right] = 0 \tag{A.20}$$

where

$$mc_t^E \equiv \frac{1}{x_t} \tag{A.21}$$

A.5 Equilibrium and other definitions

The model is closed by the resource constraint, the equilibrium condition in the credit market (i.e., the aggregate banks' balance-sheet identity) and the labor market clearing condition, respectively:

$$Y_t = C_t + q_t^k \left(K_t - (1 - \delta^k)K_{t-1} \right) + \frac{\delta^b K_{t-1}^b}{\pi_t} \tag{A.22}$$

$$B_t = D_t + K_t^b \tag{A.23}$$

$$\gamma_e l_t^{p,d} = \gamma_p l_t^p \tag{A.24}$$

The definitions of aggregate variables are:

$$C_t = \gamma_p c_t^p + \gamma_e c_t^e \tag{A.25}$$

$$B_t = \gamma_e b_t^{ee} \tag{A.26}$$

$$D_t = \gamma_p d_t^p \tag{A.27}$$

$$K_t = \gamma_e k_t^e \tag{A.28}$$

$$Y_t = \gamma_e y_t^e , \tag{A.29}$$

B   The derivation of entrepreneurs' consumption and capital

In this section, we show how to derive equations (15) and (16), following the discussion by Andrés *et al.* (2010).

First, use equation (7) to substitute for s_t^E in (8) obtaining

$$\frac{\beta_E \left[q_{t+1}^k \left(1 - \delta\right) + \xi Y_{t+1}/K_t - \left(1 + r_t^b\right) \chi_t \right]}{c_{t+1}^E} = \frac{q_t^k - \chi_t}{c_t^E} \tag{B.1}$$

where, as we know, $\chi_t \equiv \frac{m^E q_{t+1}^k \left(1 - \delta^k\right)}{1 + r_t^b}$ and $B_t = \chi_t K_t$.

We can then define entrepreneurs' net worth NW_t^E as net revenues minus wage and interest payments plus the value of the previous period's capital stock:

$$NW_t^E \equiv \frac{y_t^e(i)}{x_t} - w_t l_t^{P,d}(i) + q_t^k (1 - \delta^k) k_{t-1}^e(i) - \left(1 + r_{t-1}^b\right) b_{t-1}^{EE}(i) =$$

$$\xi \frac{y_t^e(i)}{x_t} + q_t^k (1 - \delta^k) k_{t-1}^e(i) - \left(1 + r_{t-1}^b\right) b_{t-1}^{EE}(i) =$$

$$\left[\xi \frac{y_t^e(i)}{x_t k_{t-1}^e} + q_t^k (1 - \delta^k) - \left(1 + r_{t-1}^b\right) \chi_{t-1} \right] k_{t-1}^e \tag{B.2}$$

where the latest equality follows from using the labor demand first-order condition (equation (9) in the main text) and the definition of $B_t = \chi_t K_t$. As a consequence, the entrepreneur's budget constraint can be rewritten as

$$c_t^E + q_t^k k_t^e = NW_t^E + \chi_t k_t^e \tag{B.3}$$

Now, we can guess that entrepreneurs' consumption is a fraction $1 - \beta_E$ of net worth:

$$c_t^E = (1 - \beta_E) NW_t^E \tag{B.4}$$

Using equations (B.4) and (B.2) in (B.1), we obtain

$$\frac{\beta_E}{(1 - \beta_E) k_t^e} = \frac{q_t^k - \chi_t}{c_t^E} \tag{B.5}$$

Finally, combining the latter equation with B.3 we obtain back equation (B.4), which verifies the initial guess.

The derivation of equation (16) is then straightforward, and can be obtained by simply using B.4 to substitute for c_t^E in B.3.

C   Log-linear expressions for some entrepreneurs' key equations

C.1   Entrepreneurs

$$\widehat{c}_t^e = \widehat{NW}_t^E \tag{C.1}$$

$$\widehat{k}_t^e = \Xi^{nw}\widehat{NW}_t^E + \Xi^{\chi}(\widehat{q}_{t+1}^k - \widetilde{r}_t^b) - \Xi^q\widehat{q}_t^k \tag{C.2}$$

$$\widehat{NW}_t^e = \zeta^{kq}(\widehat{k}_{t-1}^e + \widehat{q}_t^k) + \zeta^y(\widehat{y}_t^e - \widehat{x}_t) - \zeta^{rb}(\widetilde{r}_{t-1}^b + \widehat{B}_{t-1}) \tag{C.3}$$

$$\widehat{b}_t^e = \widehat{q}_{t+1}^k - \widetilde{r}_t^b + \widehat{k}_t^e \tag{C.4}$$

$$\widehat{w}_t + \widehat{L}_t = \widehat{Y}_t - \widehat{x}_t \tag{C.5}$$

where I have used the log-linear form of 18, i.e., χ: $\widehat{\chi}_t = \widehat{q}_{t+1}^k - \widetilde{r}_t^b$ and the definitions $\Xi^{nw} \equiv \frac{\beta^E NW}{(1-\chi)k^e}$, $\Xi^{\chi} \equiv \frac{\chi}{1-\chi}$, $\Xi^q \equiv \frac{1}{1-\chi}$, $\zeta^{kq} \equiv \frac{(1-\delta^k)K}{NW}$, $\zeta^y \equiv \xi\frac{Y}{xNW}$ and $\zeta^{rb} \equiv \frac{(1+r_b)B}{NW}$.

The log-linear expression for the return to capital r_t^k is :

$$\widehat{r}_t^k = \widehat{A}_t^e + \widehat{Y}_t - \widehat{K}_{t-1} - \widehat{x}_t = \widehat{A}_t^e + (1-\gamma)\left(\widehat{L}_t - \widehat{K}_{t-1}\right) - \widehat{x}_t \tag{C.6}$$

C.2   Banks and the rest of the model

Bank loan rate, balance-sheet identity, profits and capital accumulation are given by the following equations (in log-linear and aggregate form):

$$\widetilde{r}_t^b = \widetilde{r}_t^{ib} + \widetilde{spr}_t = \widetilde{r}_t^{ib} + \frac{\theta\nu^3}{1+r^{ib}}\widehat{lev}_t \tag{C.7}$$

$$\widehat{B}_t = (1-\nu)\widehat{D}_t + \nu\widehat{K}_t^b \tag{C.8}$$

$$\widehat{J}_t^B = \frac{(r^{ib} + spr^{mc})\widehat{B}_t - r^{ib}\widehat{D}_t + \nu\widetilde{r}_t^{ib} + \theta\nu^3\widehat{lev}_t}{r^{ib}\nu + spr^{mc}} \tag{C.9}$$

$$\widehat{K}_t^b = (1-\delta^b)\widehat{K}_{t-1}^b + \delta^b\widehat{J}_{t-1}^B \tag{C.10}$$

$$\tag{C.11}$$

where $\widehat{lev}_t \equiv \widehat{B}_t - \widehat{K}_t^b$ is banks' leverage. The rest of the model features a standard production function, a standard Phillips curve, capital accumulation equation, capital price equation and the resource constraint.

$$\widehat{Y}_t = \widehat{A}_t^E + \gamma\widehat{K}_t + (1-\gamma)\widehat{L}_t \tag{C.12}$$

$$\widehat{\pi}_t = \beta_P E_t\widehat{\pi}_{t+1} + \psi^{\pi}\widehat{mc}_t^E + \widehat{\varepsilon}_t^y \tag{C.13}$$

$$\widehat{K}_t = (1-\delta^k)\widehat{K}_{t-1} + \frac{I}{K}\widehat{I}_t \tag{C.14}$$

$$\widehat{q}_t^k = \kappa^i\left[\left(\widehat{I}_t - \widehat{I}_{t-1}\right) - \beta_E\left(E_t\widehat{I}_{t+1} - \widehat{I}_t\right)\right] \tag{C.15}$$

$$\widehat{Y}_t = \frac{C}{Y}\widehat{C}_t + \frac{K}{Y}\left[\widehat{K}_t - (1-\delta^k)\widehat{K}_{t-1} + \delta^k\widehat{q}_t^k\right] + \delta^b\frac{K^b}{Y}\widehat{K}_{t-1}^b \tag{C.16}$$

where $\psi^{\pi} \equiv \frac{mc^E mk^y}{\kappa^p (mk^y - 1)}$ and $\chi^{\pi} \equiv \frac{mk^y}{mk^y - 1} \left(1 - \frac{mk^y}{mk^y - 1}\right) (mc^E - 1)$ and $\widehat{C}_t \equiv \Gamma_p \widehat{c}_t^p + (1 - \Gamma_p) \widehat{c}_t^e$ is aggregate consumption, with $\Gamma_p \equiv \frac{c^p}{C}$ being the households' steady state consumption share. Note that the Phillips curve displays a cost-push shock term $(\widehat{\varepsilon}_t^y)$. The model is closed with a monetary policy rule, which will be discussed later.