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

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Abstract

The financial crisis has reaffirmed the importance of credit supply shifts 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 (Curdìa and Woodford, 2009). This paper analyzes whether Taylor rules augmented with asset prices, credit or bank leverage, 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 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 or by the presence of a stylized risk-taking channel.

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1 Introduction

Before the 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, 2010a; Ciccarelli *et al.*, 2010; Gilchirst *et al.*, 2009; Gerali *et al.* 2010). 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; 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, Curdía and Woodford (2009, 2010; CW henceforth) 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, credit or bank leverage — 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 depend on banks' leverage. Our main contribution to the existing literature is thus to analyze, from a positive perspective, how different instrument rules

[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, also policymakers have 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). However, some evidence shows 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).

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 broader range of financial variables that the central bank might want to look at.

Our model is a simplified version of Gerali *et al.* (2010; henceforth GNSS). In that framework, 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 those characteristics could be motivated in several ways. For example intermediaries may have costs of originating and servicing loans, with marginal costs increasing in the volume of lending; or leverage could be bounded by regulatory limits or market-based constraints. The *balance-sheet channel* is modeled 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.

Our main results support the view that LATW is indeed desirable when the economy is driven by supply-side shocks whenever 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 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 sustain a boom in consumption and investment demand 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 of 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

Our results are based on numerically optimized rules, along the lines of Schmitt-Grohé and Uribe (2006). We do not aim at providing quantitative prescriptions on the optimal values to be assigned to credit, asset prices or leverage in an operational simple rule. Rather, we want to qualitatively assess whether there is scope for improvement in macroeconomic stabilization from taking into account developments in the financial sector, in a model with nominal and financial frictions. Nonetheless, assuming that the objective of monetary policy is the minimization of a weighted sum of inflation and output volatility, we find that there are potential gains in macroeconomic performance from LATW. Simulations with technology and price mark-up shocks suggest that a central bank which responds to credit, asset prices or bank leverage may reduce the loss by between 20 and 30%. 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 higher degree of private sector indebtedness or by a (stylized) risk-taking channel, i.e., if banks are allowed to take on more risk when monetary policy is accommodative (Borio and Zhu, 2008).

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, focussing on shocks on expected future economic conditions (Lambertini *et al.*, 2011 and Christiano *et al.*, 2010). As compared to these studies, our results are more general. First, we show that LATW is desirable also 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 much 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 concerned also 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. Moreover, further stretching the interpretation, our results would call for co-operation between monetary policy and macro-prudential policy (Borio, 2006; Angelini *et al.* 2011) as we show that variables such as lending, asset prices or bank's leverage may be relevant both from a monetary policy and a financial stability perspective.

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 and in the case in which banks take on endogenously more risk in periods of low interest rates; the final section summarizes the main conclusions.

2 A sketch of the model

The framework we use is a simplified version of GNSS, which introduce a monopolistically competitive banking sector into a DSGE model with financial frictions. 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) capital regulation.

Two types of agents, plus banks, operate in the model: (patient) households and (impatient) entrepreneurs. Both types of agents have mass equal to 1. Entrepreneurs carry out production using households' labor and own physical capital. We assume that all debts are indexed to current inflation; this is an important distinction with respect to GNSS, motivated by the desire to isolate, as said, the role of the financial frictions. Having a *nominal debt-channel* would complicate the interpretation of the results, as this channel turns out to be quite important in GNSS and in many other papers with a collateral channel (for example, Iacoviello, 2005).[3]

Banks issue loans (B_t) to the private sector, 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 r^{ib}). In the loan market, there is monopolistic competition. We assume that the markup on the retail loan rate spread due to market power does not change over time, but is fixed at the steady-state level μ^b; moreover, we assume that there is no stickiness in bank rates.[4]

Frictions in the lending relationship imply that the amount of lending depends on both the quantity and the price of asset (physical capital) that the borrowers own and can post as collateral. 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.

In the rest of this section we will sketch the key model equations, while the next section will focus on the functioning of the credit market and on its interactions with the real economy. For a full description of the model equations, please refer to the Appendix A.

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, 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 to ensure than in the steady-state (and its neighborhood) the constraint is always (Iacoviello, 2005); as a result, households

[3] 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.

[4] These features also differ from GNSS; for a discussion, see below.

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 a budget and a 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, w_t is real wage, $l_t^{P,d}(i)$ is labor demand, $k_t^E(i)$ is 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 lending 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:

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

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

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

2.2 Banks and the rest of the model

The banking sector is sketched along the line of GNSS. For the sake of simplification, here we assume that the retail banks' loan spread is added to the marginal cost of issuing loans R_t^b (which in turn depends on the policy rate and on the banks' capital position), while in GNSS it was proportional.[5] By doing so, the loan spread only reflects banks' leverage, while in GNSS it was also affected by the level of the policy rate. The relevant loan interest rate setting equation (in linear form) thus becomes:[6]

$$\widetilde{r}_t^b = \widetilde{r}_t^{ib} + \widetilde{spr}_t = \widetilde{r}_t^{ib} + \frac{\theta \nu^3}{1 + r^{ib}} \widehat{lev}_t \tag{10}$$

where r_t^b is the loan rate, r_t^{ib} is the policy rate, $\widetilde{spr}_t$ is the loan spread and $\widehat{lev}_t \equiv \widehat{B}_t - \widehat{K}_t^b$ 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. Monetary policy, characterized by a simple rule for the policy interest rate(which is the object of the paper and will be discussed below), closes the model.

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 in general become 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 relevant 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 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). Consider, for example,

[5] Analytically, the loan rate is $r_t^b = R_t^b + \mu^b$, where μ^b is the constant retail-banking markup.

[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.

[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.

the case of a positive technology shock that increases aggregate output as well as house prices. The increase in house prices will expand borrowing capacity. Constrained agents will find it optimal to borrow more and use those funding to finance more consumption and close - at least partly - the gap between desired and actual consumption. This will generate 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 Andrès et al. (2010) - it is possible to show that: (i) entrepreneurs' consumption is a constant fraction of their net wealth; (ii) entrepreneurs' capital in the next period is also a linear function of net wealth; the coefficient is time-varying, and depends on asset prices, the LTV ratio set by the banks and the loan interest rate. The equations (using aggregate-variable notation) are:[8]

$$c_t^E = \left(1 - \beta^E\right) NW_t^E \tag{11}$$

$$K_t = \frac{\beta^E}{q_t^k - \chi_t} NW_t^E \tag{12}$$

where NW_t^E is entrepreneurs' net worth and χ_t is the (endogenous) entrepreneurs' leverage, 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:

$$NW_t^E \equiv q_t^k \left(1 - \delta^k\right) K_{t-1} - \left(1 + r_{t-1}^b\right) B_{t-1} + \alpha \frac{Y_t}{x_t} \tag{13}$$

$$\chi_t \equiv \frac{m^E q_{t+1}^k \left(1 - \delta^k\right)}{1 + r_t^b} \tag{14}$$

(note that we can rewrite the borrowing constraint as: $B_t = \chi_t K_t$).

Equations 11 and 12 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 with the value of the net-worth multiplier. As regards the *loan interest*

[8]Their derivation is obtained in Appendix B.

rate, the effect is unambiguously negative, on both consumption and investment: a rise in loan rates, in fact, reduces net wealth by rising 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 responding to their balance-sheet conditions, tightening conditions when capital constraints are binding and easing standards when, instead, there are no concerns on the level of their capitalization.

This structure gives rise to an inverse loan-supply schedule, which is described by equation (65) and can be rewritten as:

$$\widetilde{r}_t^b = \widetilde{r}_t^{ib} + \frac{\theta\nu^3}{1+r^{ib}}\widehat{B}_t - \frac{\theta\nu^3}{1+r^{ib}}\widehat{K}_t^b \tag{15}$$

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 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 shifts also with the level of the policy rate. In particular, an easing of policy shifts supply rightward; 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 rate 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 further amplify the amplification effect, due to the collateral channel described above.

3.3 Equilibrium in the credit market

In this section we provide a partial equilibrium graphical representation of the equilibrium in the credit market, which can be obtained by using the relations 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 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 for understanding 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 (12) and (13) - into the borrowing constraint, we obtain a sort of (inverse) demand curve for loans, from the entrepreneurs' first order conditions:

$$\widetilde{r}_t^b = -(1-\chi)\widehat{B}_t + E_t\widehat{q}_{t+1}^k - \delta^k\widehat{q}_t^k - \beta_E(1+r^b)\chi\left(\widetilde{r}_{t-1}^b + \widehat{B}_{t-1}\right) + \beta_E(1-\delta^k)\widehat{K}_{t-1} + \beta_E\frac{\alpha Y}{xK}\left(\widehat{Y}_t - \widehat{x}_t\right) \tag{16}$$

Strictly speaking, talking about loan *demand* is somewhat improper, since the micro-foundation of the collateral channel itself (Hart and Moore, 1994; Kyiotaki and Moore, 1997) takes into account both demand and supply-side considerations.[10] Nonetheless, equation (16) provides an inverse relation between the level of the loan rate and the amount of loans, based on the optimal behavior by 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 increase demand for any given level of the loan rate, while a rise in current asset prices reduces it.

Second, we can identify the loan supply schedule with equation (15), which establishes a positive relation 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 state (point A), 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 don't 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.

In the first panel of the figure (case 1) we consider the case in which:

$$\widetilde{r}_t^{ib} = 0 \tag{17}$$

[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]In Hart and Moore (1994) and Kyotaki 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 borrower has 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 repay their debts, lenders will be willing to lend only up to the (expected) value of the borrowers' assets at the moment when obligations come 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.

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 rightward.[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 and a new equilibrium is attained at the point B, with higher lending (B_1) and a higher leverage for banks, which is reflected into a higher equilibrium loan rate (r_1^b). The rise in the loan rate and the expansion of banks' balance sheet boost bank profits and thus increases bank capital available next period. The increase in capital allows intermediaries to expand loan supply in the next period, shifting the supply schedule rightward (from B_1^s to B_2^s) and reaching a new equilibrium in C. As a result, lending at time 2 is higher (B_2) and the loan rate lower (r_2^b), which is likely to introduce some further amplification on consumption and output, thus increasing the volatility of the real economy.

Let us now consider in the second panel of Figure 1 in which the central bank follows a standard Taylor rule, i.e. where the policy rate responds to deviations of inflation and output from steady-state (case 2):

$$\widetilde{r}_t^{ib} = \phi_\pi \widehat{\pi}_t + \phi_y \widehat{Y}_t \tag{18}$$

In standard NK models, after a positive technology shock inflation declines and output rises. Thus the direction of the change in the policy rate will depend on the relative importance of the two arguments of the Taylor rule. In what follows (and in the figure), we will assume that the central bank is particularly aggressive towards inflation, implying that the policy rate falls following the shock. In this case, the reduction of the policy rate will make the loan supply schedule shift rightward also on impact. The result is that the equilibria at both time 1 (point B) and time 2 (D) are 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).

Next we consider now a rule that responds - beyond output and inflation - to deviation of financial variables from their respective steady-state levels, i.e., to asset prices, bank loans or leverage:

$$\widetilde{r}_t^{ib} = \phi_\pi \widehat{\pi}_t + \phi_y \widehat{Y}_t + \phi_B \widehat{B}_t + \phi_L \widehat{lev}_t + \phi_q \widehat{q}_t^k \tag{19}$$

Let's first discuss the response to asset prices (i.e., assuming $\phi_B = \phi_L = 0$; we do not report this case in the figure), represented in the third panel of Figure 1. The position of the loan supply schedule, both in the period of the shock (B_1^s) and after considering the effect of the increase in bank capital (B_2^s), is indicated by the blue lines; the red dotted lines show, for comparison, the position of the loan supply schedules for the standard rule case. After the shock, as discussed, asset prices increase. This implies that a rule that responds to asset prices would prescribe a more moderate reduction of the policy rate than the one (described above) 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 points B

[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.

and D are above and to the left of their respective position in the case of the standard rule).[12] This suggests that responding to asset prices might reduce the volatility of credit and thus of the real economy.

We now turn to the implications of responding to credit and/or leverage. A rule that targets these variables (in addition to output and inflation) determines a change in the *slope* of the loan supply curve, rather than simply acting as a shifter. Substituting the rule with financial variables into the loan supply equation 15, we obtain:

$$\widetilde{r}_t^b = \left(\frac{\theta \nu^3}{1 + r^{ib}} + \phi_B + \phi_L \right) \widehat{B}_t - \left(\frac{\theta \nu^3}{1 + r^{ib}} + \phi_L \right) \widehat{K}_t^b + \phi_\pi \widehat{\pi}_t + \phi_y \widehat{Y}_t + \phi_q \widehat{q}_t^k \tag{20}$$

The fourth panel of Figure 1 reports the case of a rule augmented with the response to credit (i.e., we assume $\phi_q = \phi_L = 0$). The fact that $\phi_B \neq 0$ implies that the loan supply curve (in green) is steeper in this case than the one obtained under a standard rule (the red dotted lines, displayed in the graph for comparison). As a consequence, a shock to credit demand schedule results in a smaller increase in credit and a greater increase in the lending rate at time 1 (point B in red). Also the equilibrium at time 2 is characterized by a lower level of credit extended and a higher loan rate (point D), as the increase in leverage at time 1 (and thus the ensuing bank profits) are smaller.

Responding to leverage has similar effects on the steepness of the loan supply schedule as simply targeting credit. However, it implies a reinforced effect (with respect to a standard Taylor rule) of the shift in the supply schedule induced by an increase in bank's capital.

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

4 Simulations

In the previous section we have described the functioning of the credit market, showing how the equilibrium is affected by asset price developments, banks' capital and monetary policy. In particular, 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. However, a limit of that analysis was that it was designed in a partial equilibrium set up. In this section, we test the desirability of a 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

[12] Moreover, it is interesting to note that, if one considered 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 even limiting the initial shift of the demand curve.

standard Taylor rule, i.e. a rule that responds only to inflation and output. The methodology we use is based on "Taylor curves", i.e., the efficient outcomes of inflation and output variability that a central bank can obtain under a wide range of parameters for the Taylor rule. These curves - which thus represent the central bank "frontier of possibilities"- 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):

$$\widetilde{r}_t^{ib} = \rho^{ib}\widetilde{r}_{t-1}^{ib} + (1-\rho^{ib})\left[\phi_\pi\widehat{\pi}_t + \phi_y\widehat{Y}_t + \phi_B\widehat{B}_t + \phi_q\widehat{q}_t^k + \phi_L\widehat{lev}_t\right] \tag{21}$$

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 the 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 that to the other variables to vary between 0 and 2.5.[13] 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 the response to credit or other financial variables 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. Nonetheless, in order to be sure that the results we obtain are sufficiently general, we have performed a number of robustness analyses along this dimension, specifying both a *finer* and a *wider* grid of parameter values, finding qualitatively similar results.

Third, for each specification of the rule so 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. The possibility of improving upon a standard Taylor rule is likely to depend on the type of shocks that are considered; in this paper we analyze separately a technology shock and a cost-push shock.

4.1 Technology shock

We begin by analyzing Taylor frontiers after a technology shock (Figure 2). The black line displays the best trade-off between output and inflation stabilization attainable by a central bank following a standard Taylor rule; the blue, red and green lines depict instead

[13] 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 0.70. 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.

the trade-offs attainable under rules augmented with, respectively, credit, asset prices, and leverage.

The first result that emerges by looking at the curves is that there is indeed scope for a central bank to improve the policy trade-off by responding to credit or asset prices: the blue and the red curves, referring to the credit- and asset price-augmented rules lay to the left of the black line. In particular, responding to credit improves the trade-off for low levels of output volatility, while asset prices work for low levels of inflation volatility. The rule responding to leverage does not instead, in this case, provide substantial benefits to the central bank, as the green line exactly overlaps the black curve.

In order to get a better understanding of the reasons for this improvement, Figure 3 plots impulse response functions of the model to a (positive) technology shock, comparing the behaviour of some key variables under the alternative Taylor rules (standard vs augmented). Of course, the figure is only suggestive, as it considers a specific calibration for the underlying parameters of the Taylor rules.[14] The figure shows how, in all cases, the increase in output under the augmented rules tends to be smaller than under the standard Taylor rule, reflecting the smaller increase in investment by entrepreneurs (which actually decreases for the rule with credit) and of consumption (not reported). This reduction in the volatility of output is associated with higher policy and bank lending rates and with a lower expansion of bank leverage. The behavior of the interest rates under the augmented rules - as opposed to the standard rule - highlights the reason why a leaning-against-the-wind policy may improve macroeconomic stabilization. In particular, under the standard rule the policy rate falls significantly on impact following the shock. The same pattern is discernible for the interest rate on bank loans: although the spread incorporated in this rate endogenously increases, the increase is not so strong as to determine an overall tightening of borrowing conditions for entrepreneurs. Following the standard Taylor rule, the easing of policy determines a strong increase in lending demand by entrepreneurs, which induces banks to expand significantly their balance-sheet and their leverage; as seen in the graph, this increase in leverage sets out the credit-supply channel, which induces a strong response of investment and entrepreneurs' consumption, which spills-over also to patients' consumption (as these agents enjoy higher wages).

Under the rules targeting financial variables, instead, the policy stance following the shock is not so loose as under the standard Taylor rule. This reflects the counteracting effect of leaning against-the-wind, whereby the central bank opposes an over-extension of bank's balance-sheets and prevents, at least in part, that the amplification mechanisms connected with the presence of financial frictions are triggered. As a consequence, 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. In this case, it is important to stress that leaning-against-wind does 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 equity price, banks' leverage, profits and capital.

[14]For each rule, the calibration corresponds to the optimized values (obtained as described below) for $\alpha = 1.00$ ($\alpha = 1.25$ for the rule with a response to credit), as reported in Table 1 in the appendix.

So far we have discussed how the augmented rules reduce output volatility. However, Figure 3 shows that after the technology shock inflation becomes indeed more volatile under the augmented rules: leaning against the wind induces an additional trade-off for the central bank. The preferred policy outcome (in terms of macroeconomic stabilization) will depend on central banks' preferences. In order to tackle this issue, we assume a specific (*ad hoc*) functional form for the central banks' preference, which will allow us to get a rough quantification of the gain attainable with each rule; in particular, we assume that the central bank's objective is the minimization of a weighted sum of the variance of inflation and output:

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

We let the weighting parameter α to vary in 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 each class of rules, together with the percentage difference of the "augmented rules"with respect to the standard Taylor rule (we exclude the rule for leverage, which would coincide with the standard rule, as there is no improvement from responding to this variable). Moreover, Table 1 in the appendix 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 augmented rules that bring about an improvement in terms of macroeconomic stabilization with respect to a standard rule. Not surprisingly, the only exception is the case in which $\alpha = 0$, i.e., the case in which the central bank only cares about inflation; 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 "Jackson hole consensus"(Mishkin, 2011) mentioned above: if stabilizing inflation is the only objective of the central bank then the optimal response is a strict inflation targeting. Including asset prices in the Taylor rule brings about substantial gains (up to 25% for α =0.50) for all weights considered (except $\alpha = 0$). Credit instead improves upon the standard rule only for values of α above 1.25; gains reach 10% if α =2. Finally, responding to leverage entails only very modest gains - in the range of 3% - for α in the range 0.25-0.50 (the results are not reported in the figure).

Focusing on the values implied by the "optimized" rules, a number of results emerge. First, even the standard Taylor rule almost never prescribes a response to inflation with a coefficient above 1 (with the exception of the case when α is 0, 0.5 or 1), while the optimized coefficients on output are always non-zero (for $\alpha \neq 0$).

The great importance attached to responding to output in the standard rule suggests that a strong response to output may itself - indirectly - partly dampen the procyclical effects stemming from financial frictions, as this variable is strongly correlated with lending, leverage and asset prices. Second, whenever it is optimal to respond to financial variables, the optimized coefficient on output becomes smaller than in the standard Taylor rule; this indicates that financial variables are better indicators than output of the procyclical effects stemming from financial frictions. Third, the optimized rules prescribe a very strong response to asset prices, with the coefficient ϕ_q always at the upper bound of the grid considered (2.5), while the prescribed response to credit (in the cases in which this augmented rule outperforms the standard rule) is somewhat smaller. Finally, the fact that all variables - for some, and for different, weights of output in the loss function - improve on a standard rule is consistent with the idea that the central bank should take into account a number of different financial indicators - credit expansion, asset prices, leverage of financial institutions - in order to detect and possibly contrast the build-up of costly financial imbalances (Borio and Lowe, 2004; Borio, 2006; Goodhart and Hofmann, 2007; Alessi and Detken, 2009; Mishkin, 2011).

It is important to stress that our results are obtained in the context of a linearized model, where financial frictions do 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. Moreover, further stretching the interpretation, our results would call for co-operation between monetary policy and macro-prudential policy (Borio, 2006; Angelini *et al.* 2011) as we show that variables such as lending, asset prices or bank's leverage may be relevant both from a monetary policy and a financial stability perspective.

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 a LATW policy, instead, the response of the central bank is less accommodative, possibly even becoming counter-cyclical, thus dampening the effects connected with the existence of the financial frictions.

4.2 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 in the 1970s). This shock can be considered as a "pure supply"shock, because not only output (like in the technology shock) but also the output gap moves in an opposite direction as opposed to inflation. Analyzing the opportunity to LATW after this shock is thus a robustness check of the results obtained above for the technology shock.

Figure 5 below displays the Taylor frontiers for the standard Taylor rule and for the rules "augmented"with the financial variables. Also in this case it is evident that responding to financial variables improves the trade-off for the central bank. In particular, the biggest gain stems from targeting asset prices; some improvement comes also from targeting leverage while, in this case, targeting a simple credit aggregate does not allow to reach a lower trade-off.

Again, the analysis of the model's impulse responses provides some guidance to interpret the results (Figure 6).[15] After an adverse inflation shock, the fall in output is significantly more accentuated under the standard rule than under the rules that take into account a response to asset prices or leverage, while, in this case, responding to credit yields no gains to the central bank. Differently to the technology shock, the response to financial variables does not increase inflation volatility and even reduces it for the rule with 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, inducing a strong contraction in banks balance sheets (leverage), a strong deterioration of entrepreneurs' financing conditions and a strong fall in investment and output. Under the rules targeting asset prices and leverage, instead, monetary policy is eased on impact, contributing to substantially limiting the deterioration of entrepreneurs' financing conditions, by sustaining bank' balance sheets and avoiding a major disruption of credit supply.

In terms of the central bank's loss function, gains in this case are even more pronounced than after a technology shock (Figure 7 and Table 2 in the appendix). Gains from responding to asset prices are above 20% for all values of α different from zero and reach 30% for α between 0.50 and 1.00. The reduction in the loss function from responding to leverage is less pronounced and ranges between 5 and 15%. After a cost-push shock, instead, there is no gain from a rule simply responding to credit: the optimized value of the parameter ϕ^B is always 0 (with the exception of the case where $\alpha = 0$. As regards the "optimized"coefficients, the prescribed response to asset prices is strong, like in the case of a technology shock, but not always hitting the upper bound of the selected grid; also the implied response to leverage is in many cases above 2.

5 Are macroeconomic gains sensible to change in the loan to value ratio or bank risk-taking?

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 analyze two possible cases. First, we repeat the simulations presented in Section 4 for the technology shock for a higher value of m^E. 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

[15] Similarly to Figure 3, this chart is merely suggestive as it is based on specific calibrations for the rule parameters. In this case, we pick the optimized values for $\alpha = 1.25$, as reported in Table 2 in the appendix.

economy that is characterized by higher indebtedness of the private sector and could - as such - be considered “more fragile”. Second, we slightly modify the model, analyzing the case in which the LTV set by the banks is no longer constant, but it is adjusted over time depending on the level of the policy rate. In particular, we assume that banks relax collateral requirements (i.e., increase m^E) when monetary policy is loose and tighten them when monetary policy is restrictive. The aim of this exercise is to introduce a stylized “risk taking channel”in the model - in an *ad hoc* but simple way - and to study whether central banks' gains from LATW are even stronger in an economy characterized by this additional element of procyclicality.

5.1 The impact of a higher LTV

The main impact of changing the value of the LTV ratio set by the banks (m^E) is on the (steady-state) value of borrowers' leverage. In particular, an increase in m^E raises the steady state value of χ_t (see equation 14). In turn, a higher χ has a twofold impact on the loan demand schedule (16): first, it reduces the slope (in absolute value) of the demand curve, which implies that change 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, 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). In this case, one may then reasonably expect that the beneficial impact of LATW policies could be 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 relation emerges. In the baseline calibration, this parameter was set at 0.25, 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 share and other equities in the euro area; the implied debt-to-income ratio is roughly 5 and leverage (defined as loans over capital and equal to χ) is 25%. If, for example, m^E is doubled (to 0.50), then the corresponding ratios increase to 13 and 45% respectively.

In this section 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 $m^E = 0.50$ and we compare the gains obtained from LATW in this case to that in the baseline calibration. For ease of exposition, we present the results for an augmented rule that targets all financial variables at the same time, rather than for rules targeting each financial variable separately; however, note that for the different weights attached to output variability in the central bank's loss function (α), the specific (financial) variable that the optimized augmented rules prescribe to target are the same as in the benchmark calibration.

As expected, we find that the reduction in macroeconomic volatility from LATW is higher in the high-LTV calibration (Figure 9). The differential gain equals 3 percentage points on average (for the reported range of α) and reaches a maximum of 6 points for $\alpha = 1.75$ (see Table 3 in the appendix). The greater improvement is the result of both a worse trade-off under a standard rule (between the high-LTV case and the baseline calibration) and a better trade-off under the augmented rule. This suggests that, by leaning against the wind, the central bank can more than undo the increase in volatility associated with greater leverage in the economy.

5.2 The impact of a procyclical LTV: The risk-taking channel

In this section, we modify the model so as to introduce a stylized "risk-taking channel". A number of recent papers have emphasized how during protracted periods of low interest rates banks may have incentives to take on greater amounts of risk and to relax their lending standards; this behavior may in turn lead to an "excessive"expansion of credit, generating boom-bust type of business fluctuations and greater volatility in the economy (Borio and Zhu, 2008; Adrian and Shin 2010b). There are at least two ways in which this channel may operate. The first is through a *search for yield* mechanism (Rajan, 2005), whereby low interest rates may increase incentives for asset managers to take on more risks for contractual, behavioural or institutional reasons (for example, to meet a target nominal return); the second is through the impact of interest rate reductions on banks' asset and collateral values, which in turn can modify bank estimates of probabilities of default, loss given default and volatilities.[16]

Our aim here, similarly to the subsection above, is to analyze how the opportunity of LATW changes in an economy featuring this additional source of volatility.

In order to model a risk-taking channel, we assume that the loan-to-value ratio m^E is no longer a fixed parameter but changes over time. In particular, we postulate that banks adjust it in response to deviations of the policy interest rate from its long-run average: banks relax lending standards when monetary policy is "loose", while they tighten credit conditions when the policy rate is above the steady-state level. The borrowing constraint is now defined as:

$$\widehat{B}_t = E_t \widehat{q}^k_{t+1} - \widetilde{r}^b_t + \widehat{K}_t + \widehat{m}^e_t \tag{22}$$

with the LTV ratio now set according to:

$$\widehat{m}^E_t = \rho^{mE} \widehat{m}^E_{t-1} - \frac{\kappa^{RTC}}{m^E} \widetilde{r}^{ib}_t \, . \tag{23}$$

As a baseline calibration for κ^{RTC} we use 1, which implies that if the interest rate is 1 percentage point below potential, the LTV ratio is increased by 2.5% of its steady state value (or 60 basis points). We also assume that changes in lending standards are somewhat persistent, implying that the return to the steady state is slow: we set the coefficient ρ^{mE} at 0.5.

This modification implies that the equation (16) modifies into:

$$\begin{aligned} \widetilde{r}^b_t = -(1-\chi)\widehat{B}_t + (1-\chi)\widehat{m}^E_t + E_t \widehat{q}^k_{t+1} - \delta^k \widehat{q}^k_t - \beta_E (1+r^b)\chi \left(\widetilde{r}^b_{t-1} + \widehat{B}_t \right) \\ + \beta_E (1-\delta^k) \widehat{K}_{t-1} + \beta_E \frac{\alpha Y}{xK} \left(\widehat{Y}_t - \widehat{x}_t \right) \end{aligned} \tag{24}$$

[16] For a review of the empirical evidence on the existence of the risk-taking channel see, amongst others, Gambacorta (2009).

i.e., now also the credit demand curve shifts with changes in the policy rate. This highlights why it seemed improper to call equation (16) "loan demand schedule", since it is affected by changes in the LTV ratio set by the banks, which should be considered more as related to supply-side conditions in the credit markets.

In order to understand how this modification may affect the model dynamics following a positive technology shock, recall the discussion in Section 3 about the behavior that a central bank following a standard Taylor rule would adopt in that case. Given the fall in inflation, the rule would prescribe a reduction in the interest rate, which would generate an expansion of loan supply, which could result in a procyclical policy. With a risk-taking channel, this amplifying effect of monetary policy on the equilibrium quantity of credit would now be reinforced by a concurrent rightward shift in the "demand curve", triggered by the relaxing of lending conditions. As a consequence, one may expect an increase in macroeconomic volatility and a greater effectiveness of LATW - in terms of reducing macroeconomic volatility - than in the baseline model.

Simulations which replicate the exercise described in the previous subsection, comparing the model with this risk-taking channel to the baseline, do confirm our expectations (Figure 10). The differential gain from leaning-against-the-wind is, on average, 6 percentage points higher in the model with the RTC and reaches 10% for high weights of output α (Table 4 in the appendix).

6 Conclusions

The financial crisis has reaffirmed the importance of shifts in credit supply on 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, from a positive perspective, 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 credit and asset prices may reduce the welfare 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 (due to institutional factors or a different degree of development of the financial industry) or banks tend to take on endogenously more risk when monetary policy is particularly accommodative (risk-taking channel). Our study corroborates previous results (Curdía and Woodford, 2009, 2010; Lambertini *et al.*, 2011; Christiano *et al.*, 2010) using a richer model of the financial sector and analyzing a broader 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 LATW from a strict macroeconomic stabilization perspective; gains are likely to be larger in case financial stability were also a concern of policymakers. In addition, our study underscores the importance of co-operation between the central bank and the macro-prudential authorities (Borio, 2006; Angelini *et al.* 2011), as we show that variables such as lending, asset prices or bank's leverage may be relevant also from a monetary policy perspective.

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 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 modeled. 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 credit, asset prices or leverage in an operational rule; the fact that they are obtained from numerically optimized rules, calculated on a finite and discrete grid of possible parameter, suggests that their indications are mainly of a qualitative nature. All these issues are important avenues for future research.

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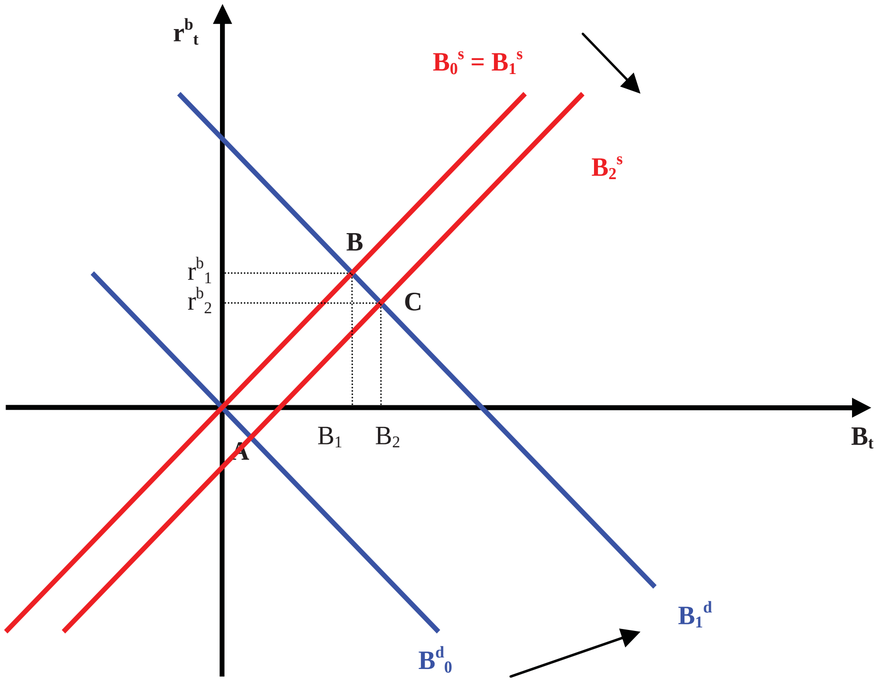
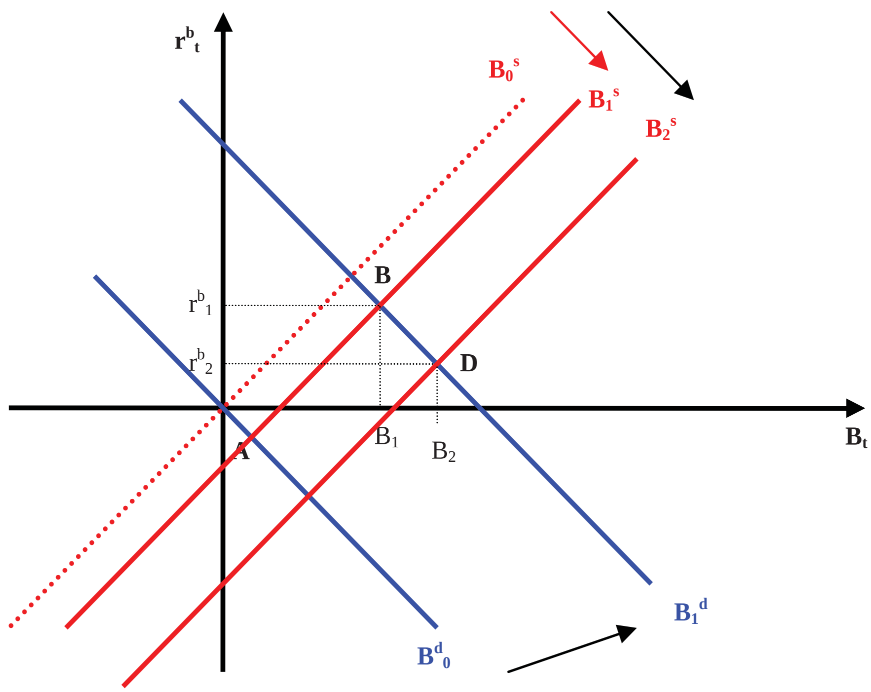
Figure 1. Equilibrium in the credit market

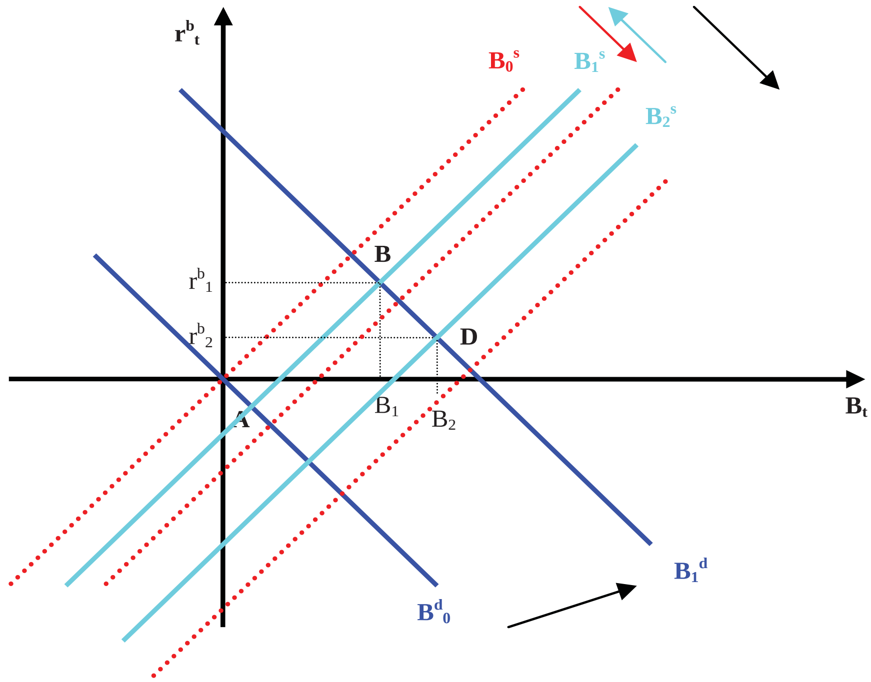
Case 1: $r_t^{ib} = 0$



Case 2: $r_t^{ib} = \phi_\pi \pi_t + \phi_Y Y_t$



Case 3: $r^{ib}_t = \phi_\pi \pi_t + \phi_Y Y_t + \phi_q q^k_t$



Case 4: $r^{ib}_t = \phi_\pi \pi_t + \phi_Y Y_t + \phi_B B_t$

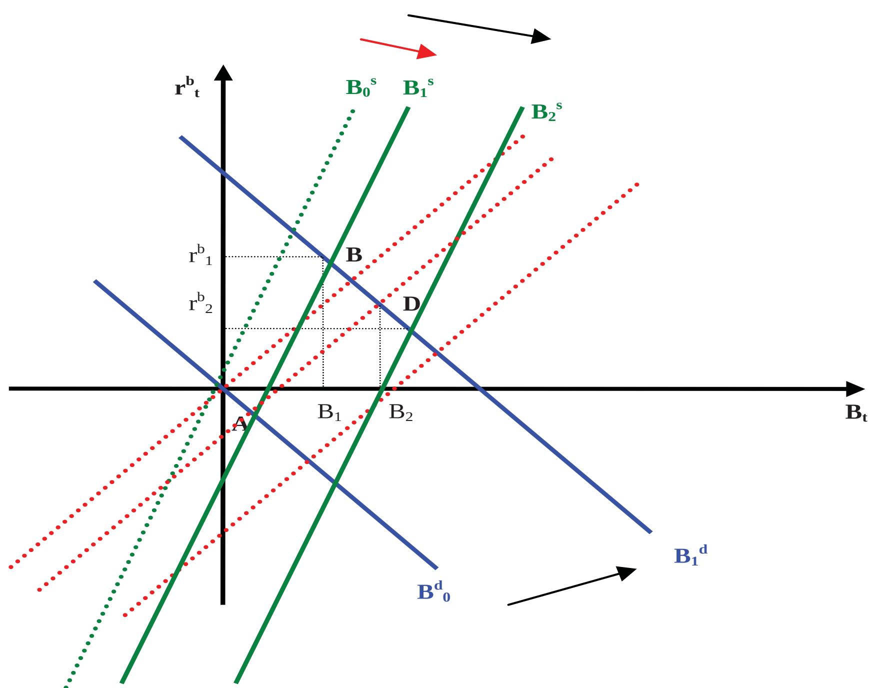


Figure 2. Taylor frontiers after a technology shock

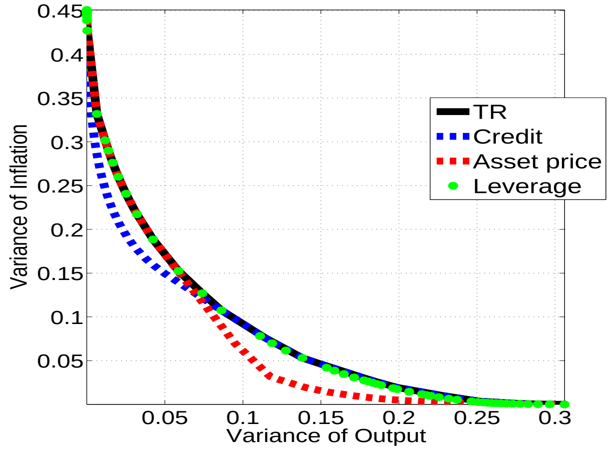


Figure 3. Impulse response functions after a technology shock

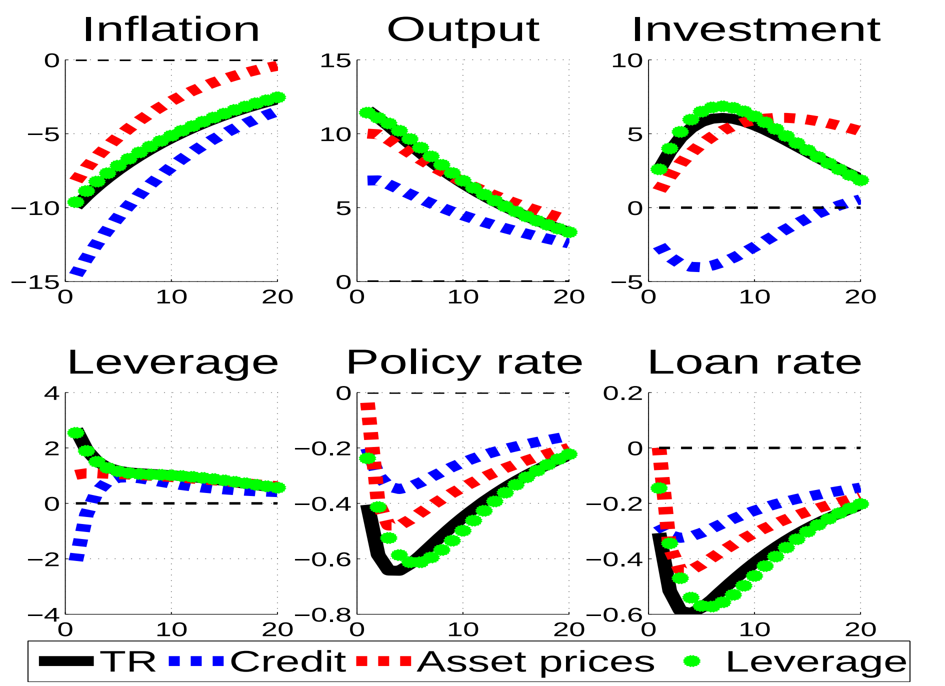


Figure 4. Loss functions after a technology shock

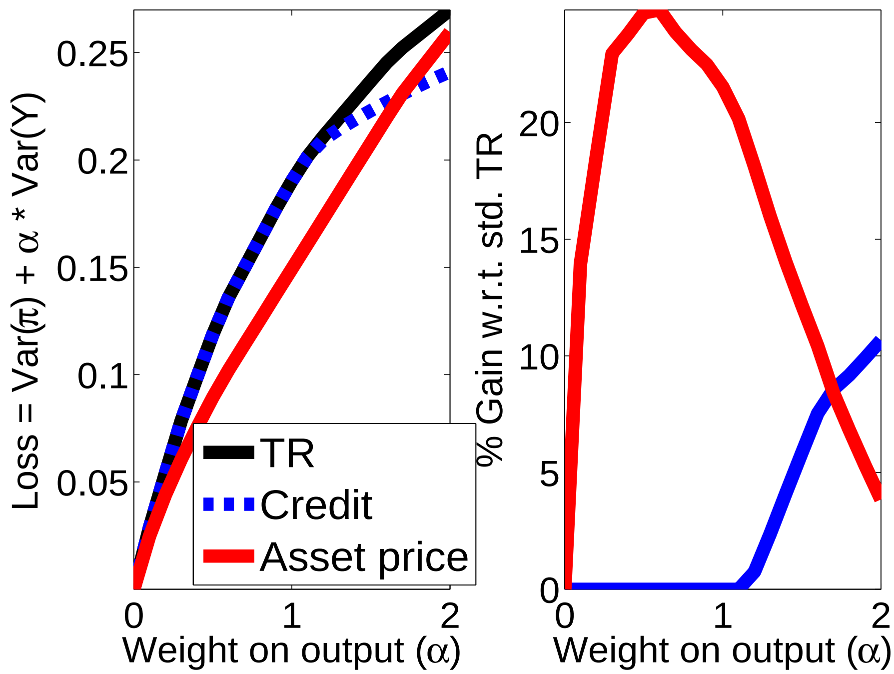


Figure 5. Taylor frontiers after a cost-push shock

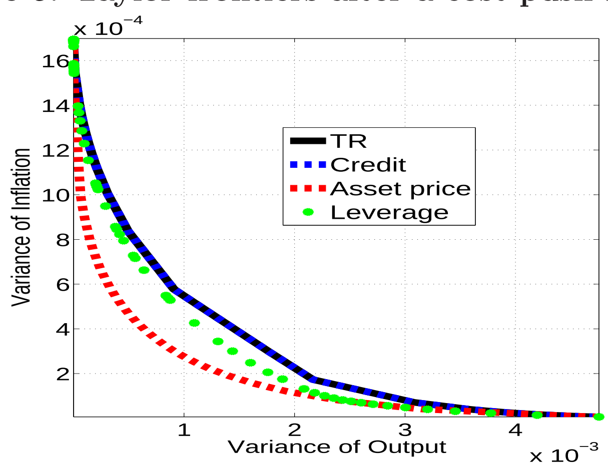


Figure 6. Impulse response functions after a cost-push shock

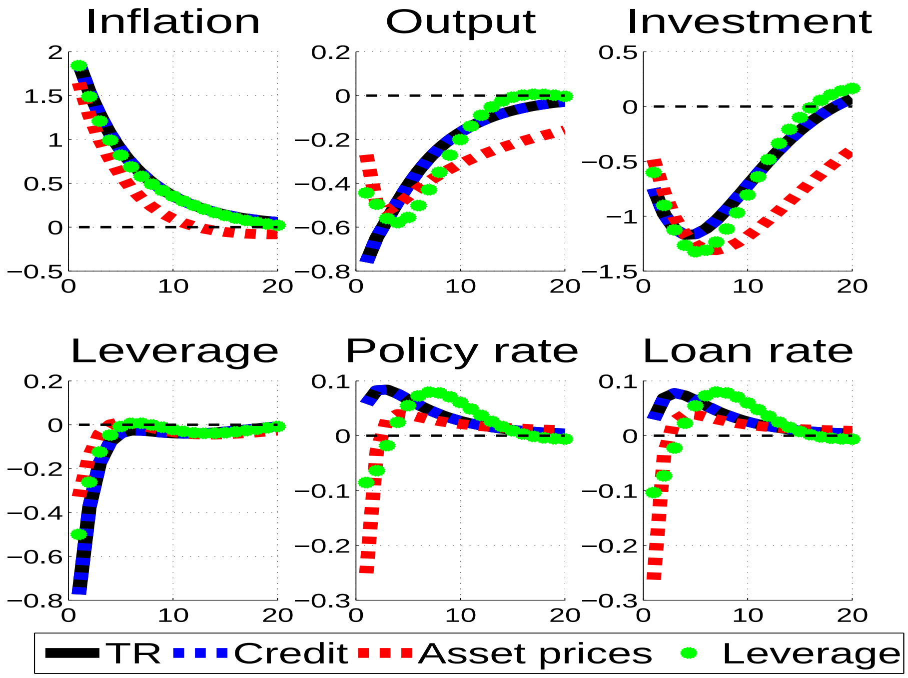


Figure 7. Loss functions after a cost-push shock

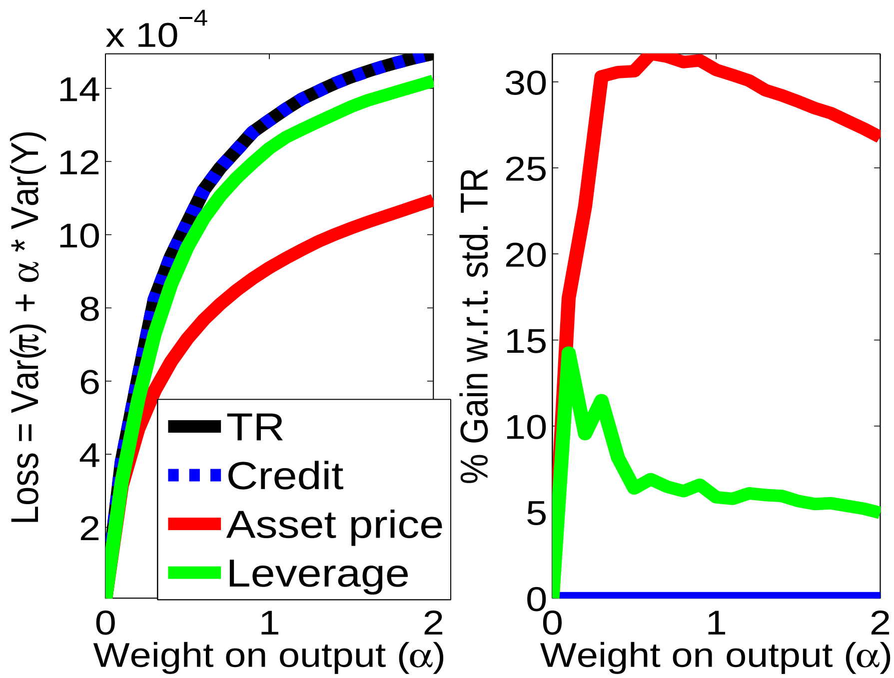


Figure 8. Measures of entrepreneurs' leverage, for different m^E

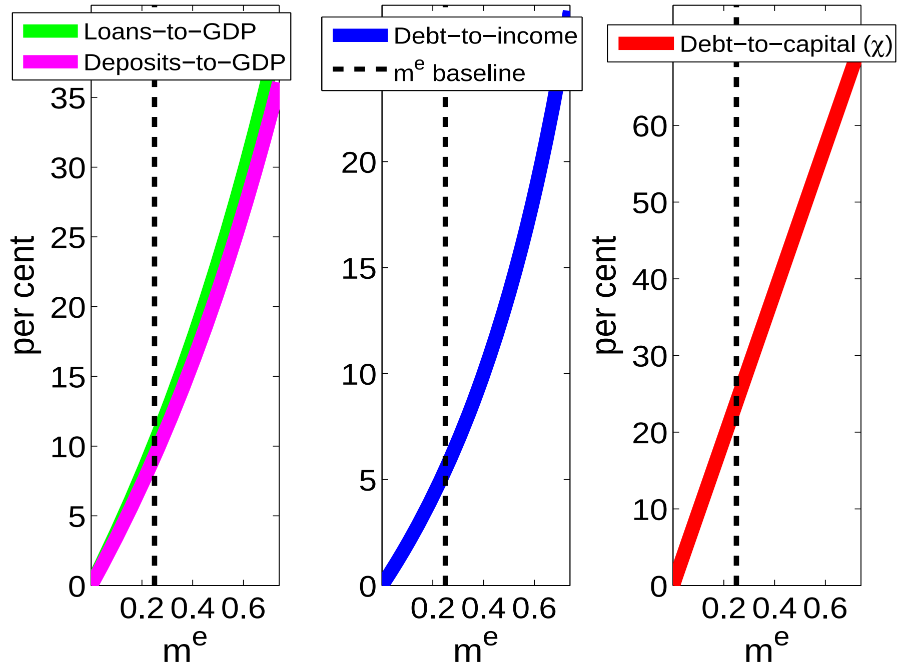


Figure 9. High LTV: Loss functions after a technology shock

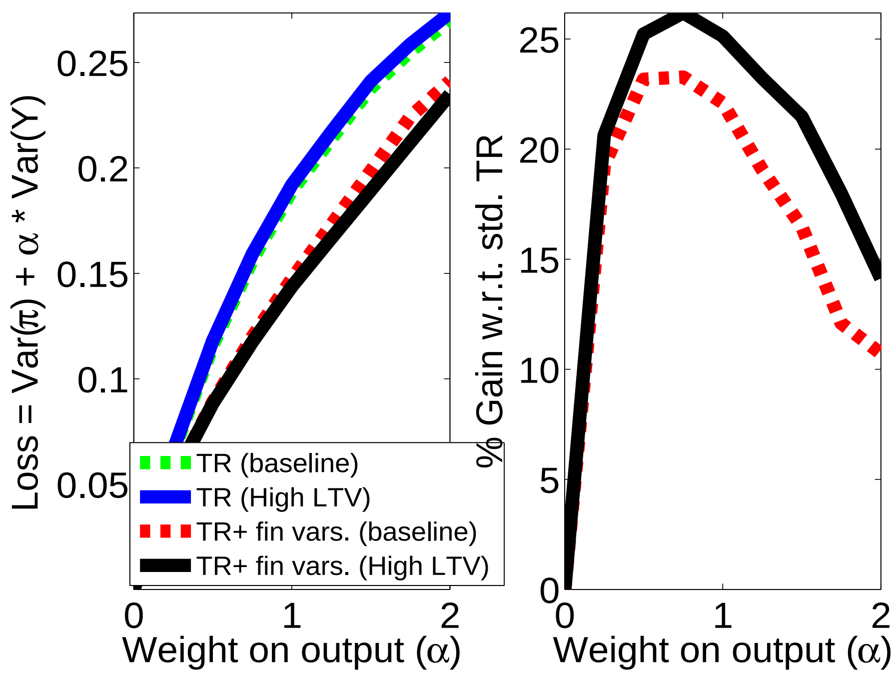


Figure 10. Procyclical LTV: Loss functions after a technology shock

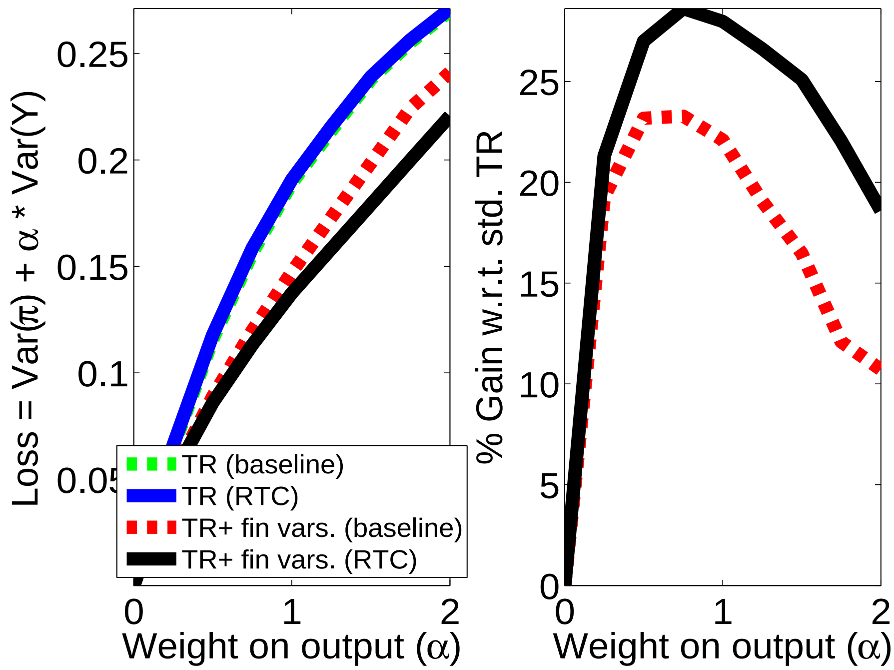


Table 1
Optimized Taylor rules and central bank losses; technology shock

Output weight	Std Taylor rule			Credit-augmented rule				
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_B
0.00	0.0001	5.01	-	0.0001	0.0%	5.01	-	-
0.25	0.0665	0.51	-	0.0665	0.0%	0.51	-	-
0.50	0.1186	1.51	0.50	0.1186	0.0%	1.51	0.50	-
0.75	0.1567	0.51	0.25	0.1567	0.0%	0.51	0.25	-
1.00	0.1903	1.01	0.75	0.1903	0.0%	1.01	0.75	-
1.25	0.2153	0.51	0.50	0.2119	1.6%	0.01	-	0.25
1.50	0.2369	0.51	0.50	0.2231	5.8%	0.01	0.25	0.75
1.75	0.2553	0.51	0.75	0.2327	8.9%	0.01	0.25	0.75
2.00	0.2700	0.51	0.75	0.2412	10.7%	0.01	0.25	0.50

Output weight	Asset-price-augmented rule					Leverage-augmented rule				
α	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_q	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_L
0.00	0.0001	0.0 %	5.01	-	-	0.0001	0.0 %	5.01	-	-
0.25	0.0525	21.1 %	2.01	-	2.50	0.0646	2.9 %	4.01	0.25	2.50
0.50	0.0893	24.7 %	1.01	-	2.50	0.1163	2.0 %	2.51	0.50	2.25
0.75	0.1199	23.5 %	0.51	-	2.50	0.1567	0.9 %	0.51	0.25	-
1.00	0.1493	21.5 %	0.51	-	2.50	0.1886	0.0 %	0.51	0.25	0.50
1.25	0.1787	17.0 %	0.51	-	2.50	0.2153	0.0 %	0.51	0.50	-
1.50	0.2081	12.2 %	0.51	-	2.50	0.2369	0.0 %	0.51	0.50	-
1.75	0.2358	7.6 %	0.51	0.25	2.50	0.2553	0.0 %	0.51	0.75	-
2.00	0.2596	3.8 %	0.51	0.25	2.50	0.2700	0.0 %	0.51	0.75	-

Output weight	All financial variables-augmented rule						
α	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_q	ϕ_B	ϕ_L
0.00	0.0001	0.0	5.01	-	-	-	-
0.25	0.0525	21.1	2.01	-	2.50	-	-
0.50	0.0893	24.7	1.01	-	2.50	-	-
0.75	0.1199	23.5	0.51	-	2.50	-	-
1.00	0.1493	21.5	0.51	-	2.50	-	-
1.25	0.1785	17.1	0.51	-	2.50	-	0.25
1.50	0.2066	12.8	0.51	-	2.50	-	0.50
1.75	0.2327	8.9	0.01	0.25	-	0.75	-
2.00	0.2412	10.7	0.01	0.25	-	0.50	-

Note: Loss functions calculated as: $Loss = Var(\pi) + \alpha Var(Y)$. Monetary policy rule (in general form) is specified in equation 21. [1] Percentage gains over loss under Standard Taylor rule.

Table 2

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

Output weight	Std Taylor rule			Credit-augmented rule				
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_B
0.00	0.0000	5.01	-	0.0000	0.0 %	5.01	-	-
0.25	0.0007	0.51	-	0.0007	0.0 %	0.51	-	-
0.50	0.0010	0.51	0.25	0.0010	0.0 %	0.51	0.25	-
0.75	0.0012	0.51	0.50	0.0012	0.0 %	0.51	0.50	-
1.00	0.0013	0.51	0.75	0.0013	0.0 %	0.51	0.75	-
1.25	0.0014	0.51	1.00	0.0014	0.0 %	0.51	1.00	-
1.50	0.0014	0.51	1.25	0.0014	0.0 %	0.51	1.25	-
1.75	0.0015	0.51	1.50	0.0015	0.0 %	0.51	1.50	-
2.00	0.0015	0.51	1.75	0.0015	0.0 %	0.51	1.75	-

Output weight	Asset-price-augmented rule					Leverage-augmented rule				
α	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_q	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_L
0.00	0.0000	0.0 %	5.01	-	-	0.0000	0.0 %	5.01	-	-
0.25	0.0005	26.5 %	5.01	-	1.75	0.0006	9.8 %	3.01	0.25	2.50
0.50	0.0007	30.6 %	3.51	-	2.50	0.0010	6.4 %	1.51	0.50	2.25
0.75	0.0008	31.2 %	2.01	-	2.25	0.0011	6.1 %	0.51	0.25	1.00
1.00	0.0009	30.7 %	1.51	-	2.25	0.0012	5.9 %	0.51	0.25	1.50
1.25	0.0010	29.7 %	1.51	-	2.50	0.0013	6.0 %	0.51	0.50	2.00
1.50	0.0010	28.9 %	1.01	-	2.25	0.0014	5.6 %	0.51	0.50	2.50
1.75	0.0011	27.9 %	1.01	-	2.50	0.0014	5.4 %	0.51	0.75	2.50
2.00	0.0011	26.8 %	0.51	-	1.50	0.0014	5.0 %	0.51	0.75	2.50

Output weight	All financial variables-augmented rule						
α	Loss	gain[1]	ϕ_π	ϕ_y	ϕ_q	ϕ_B	ϕ_L
0.00	0.0000	0.0 %	5.01	-	-	-	-
0.25	0.0005	26.5 %	5.01	-	1.75	-	-
0.50	0.0007	30.6 %	3.51	-	2.50	-	-
0.75	0.0008	31.2 %	2.01	-	2.25	-	-
1.00	0.0009	30.7 %	1.51	-	2.25	-	-
1.25	0.0010	29.7 %	1.51	-	2.50	-	-
1.50	0.0010	28.9 %	1.01	-	2.25	-	-
1.75	0.0011	27.9 %	1.01	-	2.50	-	-
2.00	0.0011	26.8 %	0.51	-	1.50	-	-

Note: Loss functions calculated as: $Loss = Var(\pi) + \alpha Var(Y)$. Monetary policy rule (in general form) is specified in equation 21. [1] Percentage gains over loss under Standard Taylor rule.

Table 3
High-LTV *vs* Baseline model, technology shock

Output weight	Std Taylor rule			Rule with financial variables						
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	Diff with BL[2]	ϕ_π	ϕ_y	ϕ_q	ϕ_B
0.00	0.00015	3.01	-	0.0001	0.0 %	0.0 %	3.01	-	-	-
0.25	0.06628	0.33	-	0.0526	20.6 %	1.4 %	2.61	-	2.95	-
0.50	0.11803	0.33	0.05	0.0882	25.2 %	2.1 %	1.01	-	2.95	-
0.75	0.15915	0.33	0.10	0.1175	26.2 %	2.9 %	0.66	-	2.95	-
1.00	0.19196	0.33	0.25	0.1437	25.1 %	3.0 %	0.33	-	2.65	-
1.25	0.21701	0.33	0.25	0.1666	23.2 %	4.2 %	0.33	-	2.95	-
1.50	0.24118	0.66	0.85	0.1894	21.5 %	5.0 %	0.33	-	2.95	-
1.75	0.25868	0.66	0.85	0.2122	18.0 %	5.9 %	0.33	-	2.95	-
2.00	0.27350	0.33	0.55	0.2349	14.1 %	3.4 %	0.33	0.01	2.95	-

Note: Loss functions calculated as: $Loss = Var(\pi) + \alpha Var(Y)$. Monetary policy rule (in general form) is specified in equation 21. [1] Percentage gains over loss under Standard Taylor rule. [2] Percentage difference of loss with respect to the baseline model.

Table 4
Risk-taking channel *vs* Baseline model, technology shock

Output weight	Std Taylor rule			Rule with financial variables						
α	Loss	ϕ_π	ϕ_y	Loss	gain[1]	Diff with BL[2]	ϕ_π	ϕ_y	ϕ_q	ϕ_B
0.00	0.00015	3.01	-	0.0001	0.0 %	0.0 %	3.01	-	-	-
0.25	0.06622	0.33	-	0.0521	21.3 %	2.0 %	3.01	-	2.95	-
0.50	0.11776	0.33	0.05	0.0860	27.0 %	3.8 %	1.21	-	2.95	-
0.75	0.15860	0.33	0.10	0.1132	28.6 %	5.3 %	0.66	-	2.95	-
1.00	0.19080	0.33	0.25	0.1374	28.0 %	5.9 %	0.33	-	2.65	-
1.25	0.21571	0.33	0.25	0.1583	26.6 %	7.6 %	0.33	-	2.95	-
1.50	0.23908	0.66	0.85	0.1791	25.1 %	8.6 %	0.33	-	2.95	-
1.75	0.25642	0.66	0.85	0.1999	22.0 %	10.0 %	0.33	-	2.95	-
2.00	0.27107	0.33	0.55	0.2207	18.6 %	7.9 %	0.33	0.01	2.95	-

Note: Loss functions calculated as: $Loss = Var(\pi) + \alpha Var(Y)$. Monetary policy rule (in general form) is specified in equation 21. [1] Percentage gains over loss under Standard Taylor rule. [2] Percentage difference of loss with respect to the baseline model.

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:

$$c_t^P(i) + d_t^P(i) \leq w_t l_t^P(i) + \left(1 + r_{t-1}^{ib}\right) d_{t-1}^P(i) + J_t^R(i) \tag{25}$$

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

$$\frac{1}{c_t^p(i)} = E_t \frac{\beta_P \left(1 + r_t^{ib}\right)}{c_{t+1}^p(i)} \tag{26}$$

$$l_t^P(i)^{\phi} = \frac{w_t}{c_t^p(i)} \tag{27}$$

A.2 Entrepreneurs

Entrepreneurs' maximize consumption according to the utility function:

$$\max_{\left\{c_t^E(i), l_t^{P,d}(i), b_t^{EE}(i)\right\}} E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i)) \tag{28}$$

subject to a budget and a borrowing constraints:

$$c_t^E(i) + \left(1 + r_{t-1}^b\right) b_{t-1}^{EE}(i) + w_t l_t^{P,d}(i) + q_t^k k_t^E(i) \leq \frac{y_t^e(i)}{x_t} + b_t^{EE}(i) + q_t^k (1 - \delta^k) k_{t-1}^e(i) \tag{29}$$

$$b_t^{EE}(i) \leq \frac{m^E q_{t+1}^k k_t^e(i)(1 - \delta^k)}{1 + r_t^b} \tag{30}$$

The production function is:

$$y_t^E(i) = A_t^E (k_t^E)^{\alpha} (l_t^{P,d})^{(1-\alpha)} \tag{31}$$

The definition of the return to capital is:

$$r_t^k \equiv \alpha \frac{A_t^E (k_t^E)^{(\alpha-1)} (l_t^{P,d})^{(1-\alpha)}}{x_t} \tag{32}$$

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

$$\frac{1}{c_t^E(i)} - s_t^E(i) = \beta_E \frac{(1+r_t^b)}{c_{t+1}^E(i)} \tag{33}$$

$$\frac{s_t^E(i) m_t^E q_{t+1}^k (1-\delta^k)}{1+r_t^b} + \frac{\beta_E}{c_{t+1}^E(i)} \left[q_{t+1}^k (1-\delta^k) + r_{t+1}^k \right] = \frac{q_t^k}{c_t^E(i)} \tag{34}$$

$$\frac{(1-\alpha) y_t^e(i)}{l_t^{P,d}(i) x_t} = w_t. \tag{35}$$

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

$$\underset{\{b_t(j), d_t(j)\}}{max} R_t^b b_t(j) - r_t^{ib} d(j) - \frac{\theta}{2} \left(\frac{K_t^b(j)}{b_t(j)} - \nu \right)^2 K_t^b(j) \tag{36}$$

$$\text{s.t. } b_t(j) = d_t(j) + K_t^b(j) \tag{37}$$

The first order condition is

$$R_t^b = r_t^{ib} - \theta \left(\frac{K_t^b(j)}{b_t(j)} - \nu \right) \left(\frac{K_t^b(j)}{b_t(j)} \right)^2 \tag{38}$$

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 markup on the wholesale loans rate. Differently to Gerali *et al.* , and for the sake of simplicity, we assume that the markup is constant and additive. The retail loan rate is thus:

$$r_t^b = R_t^b + spread^{mc} = r_t^{ib} - \theta \left(\frac{K_t^b(j)}{b_t(j)} - \nu \right) \left(\frac{K_t^b(j)}{b_t(j)} \right)^2 + spread^{mc} \tag{39}$$

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

$$J_t^B = r_t^b B_t - r_t^{ib} D_t - \frac{\theta}{2} \left(\frac{K_t^b}{B_t} - \nu \right)^2 K_t^b \tag{40}$$

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:

$$K_t^b = K_{t-1}^b(1-\delta^b) + J_{t-1}^B \tag{41}$$

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

A.4 Capital good's producers and retailers

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

$$1 = q_t^k \left[1 - \frac{\kappa^i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \kappa^i\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] + \beta_E E_t\left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \kappa^i \left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{42}$$

and the capital-accumulation equation is:

$$K_t = (1-\delta^k)K_{t-1} + \left[1 - \frac{\kappa^i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \tag{43}$$

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

$$1 - \frac{mk_t^y}{mk_t^y - 1} + \frac{mk_t^y}{mk_t^y - 1} mc_t^E - \kappa_p(\pi_t - 1)\pi_t + \beta_P E_t\left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa_p(\pi_{t+1} - 1)\pi_{t+1}\frac{Y_{t+1}}{Y_t}\right] = 0 \tag{44}$$

where

$$mc_t^E \equiv \frac{1}{x_t} \tag{45}$$

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:

$$Y_t = C_t + q_t^k\left(K_t - (1-\delta^k)K_{t-1}\right) + \frac{\delta^b K_{t-1}^b}{\pi_t} \tag{46}$$

$$B_t = D_t + K_t^b \tag{47}$$

$$\gamma_e l_t^{p,d} = \gamma_p l_t^p \tag{48}$$

The definitions of aggregate variables are:

$$C_t = \gamma_p c_t^p + \gamma_e c_t^e \tag{49}$$

$$B_t = \gamma_e b_t^{ee} \tag{50}$$

$$D_t = \gamma_p d_t^p \tag{51}$$

$$K_t = \gamma_e k_t^e \tag{52}$$

$$Y_t = \gamma_e y_t^e\ , \tag{53}$$

B The derivation of entrepreneurs‘ consumption and capital

In this section, we show how to derive equation 11 and 12, following the discussion by Andrès *et al.* (2010).

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

$$\frac{\beta_E\left[q_{t+1}^k\left(1-\delta\right)+\alpha Y_{t+1}/K_t-\left(1+r_t^b\right)\chi_t\right]}{c_{t+1}^E}=\frac{q_t^k-\chi_t}{c_t^E} \tag{54}$$

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

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

$$\begin{aligned} NW_t^E \equiv \frac{y_t^e(i)}{x_t}-w_t l_t^{P,d}(i)+q_t^k(1-\delta^k)k_{t-1}^e(i)-\left(1+r_{t-1}^b\right)b_{t-1}^{EE}(i) &= \\ \alpha\frac{y_t^e(i)}{x_t}+q_t^k(1-\delta^k)k_{t-1}^e(i)-\left(1+r_{t-1}^b\right)b_{t-1}^{EE}(i) &= \\ \left[\alpha\frac{y_t^e(i)}{x_t k_{t-1}^e}+q_t^k(1-\delta^k)-\left(1+r_{t-1}^b\right)\chi_{t-1}\right]k_{t-1}^e & \end{aligned} \tag{55}$$

where the latest equality follows from using tne 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

$$c_t^E+q_t^k k_t^e=NW_t^E+\chi_t k_t^e \tag{56}$$

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

$$c_t^E=\left(1-\beta_E\right)NW_t^E \tag{57}$$

Using equations 57 and 55 in 54, we obtain

$$\frac{\beta_E}{\left(1-\beta_E\right)k_t^e}=\frac{q_t^k-\chi_t}{c_t^E} \tag{58}$$

Finally, combining the latter equation with 56 we obtain back equation 57, which verifies the initial guess.

The derivation of equation 12 is then straightforward, and can be obtained by simply using 57 to substitute for c_t^E in 56.

C Log-linear expressions for some entrepreneurs' relevant equations

C.1 Entrepreneurs

$$\widehat{c}_t^e = \widehat{NW}_t^E \tag{59}$$

$$\widehat{k}_t^e = \Xi^{nw}\widehat{NW}_t^E + \Xi^{\chi}(\widehat{q}_{t+1}^k - \widetilde{r}_t^b) - \Xi^q \widehat{q}^k{}_t \tag{60}$$

$$\widehat{NW}_t^e = \zeta^{kq}(\widehat{k}_{t-1}^e + \widehat{q}_t^k) + \zeta^y(\widehat{y}_t^e - \widehat{x}_t) - \zeta^{rb}(\widetilde{r}_{t-1}^b + \widehat{B}_{t-1}) \tag{61}$$

$$\widehat{b}_t^e = \widehat{q}_{t+1}^k - \widetilde{r}_t^b + \widehat{k}_t^e \tag{62}$$

$$\widehat{w}_t + \widehat{L}_t = \widehat{Y}_t - \widehat{x}_t \tag{63}$$

where I have used the log-linear form of 14, i.e., χ: $\widehat{\chi}_t = \widehat{q}_{t+1}^k - \widetilde{r}_t^b$ and the definitions $\Xi^{nw} \equiv \frac{\beta^E NW}{(1-\chi)k^e}$, $\Xi^{\chi} \equiv \frac{\chi}{1-\chi}$, $\Xi^q \equiv \frac{1}{1-\chi}$, $\zeta^{kq} \equiv \frac{(1-\delta^k)K}{NW}$, $\zeta^y \equiv \alpha\frac{Y}{x\,NW}$ and $\zeta^{rb} \equiv \frac{(1+r_b)B}{NW}$.

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

$$\widehat{r}_t^k = \widehat{A}_t^e + \widehat{Y}_t - \widehat{K}_{t-1} - \widehat{x}_t = \widehat{A}_t^e + (1-\gamma)\left(\widehat{L}_t - \widehat{K}_{t-1}\right) - \widehat{x}_t \tag{64}$$

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):

$$\widetilde{r}_t^b = \widetilde{r}_t^{ib} + \widetilde{spr}_t = \widetilde{r}_t^{ib} + \frac{\theta\nu^3}{1+r^{ib}}\widehat{lev}_t \tag{65}$$

$$\widehat{B}_t = (1-\nu)\widehat{D}_t + \nu\widehat{K}_t^b \tag{66}$$

$$\widehat{J}_t^B = \frac{(r^{ib} + spr^{mc})\widehat{B}_t - r^{ib}\widehat{D}_t + \nu\widetilde{r}_t^{ib} + \theta\nu^3\widehat{lev}_t}{r^{ib}\nu + spr^{mc}} \tag{67}$$

$$\widehat{K}_t^b = (1-\delta^b)\widehat{K}_{t-1}^b + \delta^b\widehat{J}_{t-1}^B \tag{68}$$

$$\tag{69}$$

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.

$$\widehat{Y}_t = \widehat{A}_t^E + \gamma\widehat{K}_t + (1-\gamma)\widehat{L}_t \tag{70}$$

$$\widehat{\pi}_t = \beta_P E_t\widehat{\pi}_{t+1} + \psi^{\pi}\widehat{mc}_t^E + \widehat{\varepsilon}_t^y \tag{71}$$

$$\widehat{K}_t = (1-\delta^k)\widehat{K}_{t-1} + \frac{I}{K}\widehat{I}_t \tag{72}$$

$$\widehat{q}_t^k = \kappa^i\left[\left(\widehat{I}_t - \widehat{I}_{t-1}\right) - \beta_E\left(E_t\widehat{I}_{t+1} - \widehat{I}_t\right)\right] \tag{73}$$

$$\widehat{Y}_t = \frac{C}{Y}\widehat{C}_t + \frac{K}{Y}\left[\widehat{K}_t - (1-\delta^k)\widehat{K}_{t-1} + \delta^k\widehat{q}_t^k\right] + \delta^b\frac{K^b}{Y}\widehat{K}_{t-1}^b \tag{74}$$

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.