Credit and Banking in a DSGE Model

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Abstract

We extend the model in Iacoviello (2005) by introducing a stylized banking sector. Loans are supplied by imperfectly competitive banks intermediating funds from both households deposits and the interbank market. Sluggishness in bank interest rates may in principle dampen the effects of monetary policy shocks on borrowing constraints and hence on real activity, resulting in an 'attenuator' effect opposite in sign with respect to the 'financial accelerator' effect. We calibrate the banking parameters to replicate the observed sluggishness in euro area banking rates and show that this attenuator effect can be sizeable but short-lived. The model also allows analyzing the consequences of a tightening of credit conditions that reduces the supply of credit and increases banks' interest rates independently of monetary policy. In such a scenario the effects on output can be sizable, in particular on capital accumulation.

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1 Introduction

Policymakers have often highlighted the importance of financial factors in shaping the business cycle: the possible interactions between credit markets and the real economy are a customary part of the overall assessment on the policy stance. Since the onset of the financial turmoil in August 2007, banks have come again under the spotlight, as losses from subprime credit exposure and from significant write-offs on asset-backed securities raised concerns that a wave of widespread credit restrictions might trigger a severe economic downturn. Past episodes like the U.S. Great Depression, the Savings and Loans crises again in the U.S. in the 1980s or the prolonged recession in Finland and Japan in the 1990s stand as compelling empirical evidence that the banking sector can considerably affect the developments of the real economy.[1]

Despite this relevance for policy-making, most workhorse general equilibrium models routinely employed in academia and policy institutions to study the dynamics of the main macroeconomic variables generally lack any interaction between financial and credit markets, on the one hand, and the rest of the economy, on the other. The introduction of financial frictions in a dynamic general equilibrium (DSGE) framework by Bernanke, Gertler and Gilchrist (1999) and Iacoviello (2005) has started to fill this gap by introducing credit and collateral requirements and by studying how macroeconomic shocks are transmitted or amplified in the presence of these financial elements. These models assume that credit transactions take place through the market and do not assign any role to financial intermediaries such as banks.

But in reality banks play a very influential role in modern financial systems, and especially in the euro area. In 2006 bank deposits in the euro area accounted for more than three-quarters of household short-term financial wealth, while loans equalled around 90 per cent of total households liabilities (ECB, 2008); similarly, for firms, bank lending accounted for almost 90 per cent of total corporate debt liabilities in 2005 (ECB, 2007). Thus, the effective cost/return that private agents in the euro area face when taking their borrowing/saving decisions are well approximated by the level of banks' interest rates on loans and deposits.

In this paper we introduce a banking sector in a DSGE model in order to understand

[1] Recently, for example, in a speech at the "The Credit Channel of Monetary Policy in the Twenty-first Century"Conference held on 15 June 2007 at the Federal Reserve Bank of Atlanta, chairman Bernanke stated that "*...Just as a healthy financial system promotes growth, adverse financial conditions may prevent an economy from reaching its potential. A weak banking system grappling with nonperforming loans and insufficient capital, or firms whose creditworthiness has eroded because of high leverage or declining asset values, are examples of financial conditions that could undermine growth*".

the role of banking intermediation in the transmission of monetary impulses and to analyze how shocks that originate in credit markets are transmitted to the real economy. We are not the first to do this. Recently there has been increasing interest in introducing a banking sector in dynamic models and to analyze economies where a plurality of financial assets, differing in their returns, are available to agents (Christiano *et al.*, 2007, and Goodfriend and McCallum, 2007). But in these cases banks operate under perfect competition and do not set interest rates. We think that a crucial element in modeling banks sector consists in recognizing them a degree of monopolistic power (in both the deposits and the loans markets). This allows us to model their interest rate setting behavior and hence the different speeds at which banks interest rates adjust to changing conditions in money market interest rates. Empirical evidence shows that bank rates are indeed heterogenous in this respect, with deposit rates adjusting somewhat slower than rates on households loans, and those in turn slower than rates on firms loans (Kok Sorensen and Werner, 2006 and de Bondt, 2005). We therefore enrich a standard model, featuring credit frictions and borrowing constraints as in Iacoviello (2005), and a set of real and nominal frictions as in Christiano *et al.* (2005) and Smets and Wouters (2003) with an imperfectly competitive banking sector that collects deposits and then supplies loans to the private sector. These banks set different rates for households and firms, applying a time-varying and slowly adjusting mark-up (or mark-down) over the policy rate. Loan demand is constrained by the value of housing collateral for households and capital for entrepreneurs. Banks obtain funding either by tapping the interbank market at a rate set by the monetary authority or by collecting deposits from patient households, at a rate set by the banks themselves.

We use the model to analyze two issues. First we want to understand what role our banks play in the transmission mechanism of monetary policy. In our model, monetary policy shocks affect the economy through four different channels. Three of them are standard in economies with borrowing constraints: (1) a nominal debt channel, by which realized inflation affects the real ex-post cost of debt service; (2) a borrowing constraint channel, by which an innovation in the policy rate, changing the real rate, alters the value of relaxing the constraint; (3) an asset price channel, by which induced changes in asset prices affect the value of the collateral and hence borrowing. Sluggish (and heterogeneous) pass-through of changes in the monetary policy rate to bank rates brings about a fourth channel, a *banking attenuator effect*. While, absent banks, a change in the policy rate would be transmitted instantaneously and one-for-one into households' and firms' decisions, with sticky bank rates it does so only to the extent, and at the speed, at which banks adjust rates on loans and deposits. Considering the three channels mentioned above, this fact is likely to dampen considerably the effects that work through a change in the real rate or in the value of the collateral. We calibrate the key parameters governing the speed of adjustment of banks interest rates to replicate the average pass-through observed in the euro area banking sector and then use the model to quantify the attenuator effect after a monetary policy shock. Results from impulse response analysis show that the attenuator effect is sizeable on impact but short-lived (3-4 quarters) since bank rates, although sluggish, track quite rapidly changes in the policy rate.

The second issue is related to financial, as opposed to macroeconomic, stability and to the link between the two. Financial shocks can have a relevance of their own for real activity, and banks play a major role in their origin and, probably, in their propagation. The financial turmoil that started in summer 2007 was characterized by a gradual deterioration of banks liquidity and capital positions. Banks report that they reacted by tightening credit standards for lending to the private sector and by increasing both collateral requirements and margins on loans (see, for the euro area, the Bank Lending Surveys published by the ECB). Fears emerged that a "credit crunch"could induce a severe impact on real activity, but exactly how, and to what extent, is still open to debate. As an application of our model we simulate a "financial turmoil"scenario, where banks increase their margins on loans by raising retail rates, independently of monetary policy, and reduce the availability of credit to the private sector, by increasing collateral requirements. Effects on real activity are substantial, particularly on capital accumulation. Most of the adverse impact comes from the restriction on credit to firms, as it quickly spills over and adds up to the household sector, generating a considerable fall in aggregate demand and output.

The rest of the paper is organized as follows. Section 2 reviews the main contributions in the literature on financial frictions in DSGE models. Section 3 outlines the structure of the model, while Section 4 discusses calibration of the main parameters. Section 5 explains the propagation mechanism of the model and presents the results of a monetary policy restriction and a "financial turmoil"experiment. Section 6 concludes.

2 Related literature

Recently, the literature on the role of financial variables in the business cycle has focused on the macroeconomic implications of frictions in the credit market. In order to mitigate the agency costs in lending relations due to asymmetric information, financial agreements usually link the amount or the cost of credit that lenders are willing to grant to borrowers' balance-sheet conditions. Thus, as the financial households and firms income and wealth usually co-move with the business cycle, the conditions at which borrowers can access external financing vary across the cycle. As a result, financial frictions amplify and propagate the conventional transmission mechanism of real and monetary shocks (Bernanke and Gertler, 1995). Shocks originating in financial markets, by affecting borrowers' balance sheets, spill over to the rest of the economy. Beside reinforcing the propagation of exogenous shocks, such a mechanism (the "financial accelerator") endogenously alters the business cycle. For example, with the financial accelerator the dynamics of the fluctuations become highly non-linear, as the intensity of the balance-sheet effects deepens the more the economy moves towards a peak or a trough. Moreover, the distribution of wealth among agents becomes relevant: a transfer of resources towards financially weaker borrowers might increase aggregate investment spending, by improving (average) borrowing terms.

Two main strands can be identified in the literature on the financial accelerator. One has stressed how a strong shocks amplification and propagation mechanism originates from the procyclicality of the external finance premium, i.e. the difference between the cost of external sources of funding and the opportunity cost of funds internal to the borrower (Bernanke and Gertler, 1989 and Carlstrom and Fuerst, 1997).[2] Due to agency problems in lending, which are stronger the lower is borrowers' net worth, such premium rises in bad times and falls in good times, thus amplifying the business cycle and the effects of monetary and financial shocks. Bernanke *et al.* (1999, henceforth BGG) incorporate an external finance premium into a dynamic new-keynesian framework with nominal rigidities and monopolistic competition in goods market. Their model features two groups of agents: households, who consume, work and save, and entrepreneurs, who undertake investment projects by borrowing resources from households. Lending relationships are affected by the presence of asymmetric information and agency costs. In such a framework, at the microeconomic level the optimal financial arrangement prescribes that entrepreneurs demand for capital is proportional to their net worth; in equilibrium, the external finance premium depends inversely on the proportion of the investment that is financed by the entrepreneurs own resources. BGG show that, due to financial frictions, the impact response of output to a monetary policy shocks is around 50 per cent stronger and that of investment is almost twice as large; also the persistence is strongly amplified by the introduction of the financial accelerator.

The second strand of literature has pointed out how financial accelerator effects can

[2] An external finance premium is generated form a costly state verification problem for business projects (Townsend, 1979): in order to obtain repayment from those entrepreneurs who declare bankruptcy, lenders must size up their remaining assets, paying an auditing cost (interpretable as the cost of bankruptcy). The optimal contract, i.e. the one that minimize expected agency costs, features a fixed repayment and auditing only of defaulting entrepreneurs.

be generated by fluctuations in asset prices. Following Kiyotaki and Moore (1995), many authors (e.g., Iacoviello, 2005, and Iacoviello and Neri, 2008) have assumed that agents are constrained in the amount of funds they can borrow by the value of collateral they can pledge as a guarantee to the lenders. In good times, rising asset values allow financially constrained agents to expand their borrowing and increase consumption and investment, thus further stimulating real activity; on the contrary, unfavorable shocks are amplified by ensuing collateral devaluations, which induce agents to additionally cut on their expenditures. Iacoviello (2005) incorporates borrowing constraints into a new-keynesian general equilibrium model. In his model, agents differ in their degree of "impatience" i.e. the utility value they assign to consumption at future dates. In equilibrium, patient households will want to postpone consumption and save, lending funds to more impatient households and entrepreneurs, who nevertheless are constrained in the amount they can borrow by the value of their housing collateral. In the neighborhood of the steady state where such constraint always binds, entrepreneurs' and impatient households' expenditure fluctuates, other things being equal, with the price of the collateral. Since constrained agents have a higher propensity to consume, Iacoviello shows that collateral effects can significantly strengthen the response of the real economy to demand shocks, including those hitting on house prices.[3] Christensen *et al.* (2007) develop and estimate on Canadian data a similar model with capital as entrepreneurs' collateral. They find that including a financial accelerator mechanism does not deliver a significant difference in the fit of the model nor in its ability to replicate the cross correlations of the data.

Despite the important role assigned to credit frictions, the models mentioned so far do not devote much attention to financial intermediaries. Financial transactions are typically assumed to occur through the market; BGG and Carlstrom and Fuerst (1997) mention the existence of a capital mutual fund, collecting resources from lenders and distributing them to borrowers; these intermediary, however, just perform a risk-pooling activity by collecting savings from all households and lending them to all entrepreneurs. Recent contributions to the literature have tried to provide a more realistic and complete model of the banking sector, where intermediaries have an active role in determining the price or the supply of financial assets. An example is the paper by Goodfriend and McCallum (2007), who model a perfectly competitive banking sector which supplies a multiplicity of assets which bear different yields. Banks main activity is the production of loans and deposits, employing work effort and collateral, which consists of risk-free bonds and capital. In this model, the demand for bank loans and deposits is the effect of a deposit-

[3] Iacoviello (2005) assumes that overall supply of housing is fixed. However, Iacoviello and Neri (2008) find similar results in a model in which they allow for endogenous housing investment and variable supply.

in-advance constraint on household consumption and of the timing assumption in the model, according to which households' consumption outlay precedes income cash-flow. The explicit provision of a production function for loans and deposits makes the cost of bank loans higher than the return of a risk free bond; such positive difference is interpreted as an external finance premium originating from the marginal cost of production of loans. A closer model, in spirit, contents and objectives, to the one presented in this paper, is the one by Christiano *et al.* (2007). This paper extends the model in BGG by introducing a perfectly competitive banking sector offering a variety of saving and liquidity services and lending to firms. Each intermediary can be thought of as being comprised of two independent units. One unit collects demand deposits (which provide transaction services but do not transfer resources across periods) from households and issue loans to firms, used to finance working capital expenditure (factors of production must be paid before output sales). The other unit replicates the framework of BGG: it collects time- and saving-deposits (yielding different returns due to differences in their transaction services) and issues loans to entrepreneurs to finance their investment projects. Their model is estimated on euro area data using Bayesian techniques and it is used to study the behavior of the economy under a number of different shocks; consistently with previous results, they show that financial frictions play an important role in the propagation of shocks and that financial factors can be useful to explain past episodes of business cycle fluctuations.

3 The model

The economy is populated by two types of households and by entrepreneurs. Households consume, work and accumulate housing (which is, on aggregate, provided in fixed supply), while entrepreneurs produce an homogenous intermediate good using capital bought from capital-good producers and labor supplied by households. Agents differ in their degree of impatience, i.e. in the discount factor they apply to the stream of future utility. We assume that patient households' discount factor β_P is higher than those of the impatient households β_I and of the entrepreneurs β_E.

Two types of one-period financial instruments, supplied by banks, are available to agents: saving assets (deposits) and loans. When taking on a bank loan, agents face a borrowing constraint, tied to the value of tomorrow collateral holdings: households can borrow against their stock of housing, while entrepreneurs' borrowing capacity is tied to the value of their physical capital. The heterogeneity in agents' discount factors determines positive financial flows in equilibrium: patient households purchase a positive amount of deposits and do not borrow, while impatient and entrepreneurs borrow a positive amount of loans.

The banking sector operates in a regime of monopolistic competition: banks set interest rates on deposits and on loans in order to maximize profits. The amount of loans issued by each intermediary does not have to match necessarily that of the deposits they rise; the difference can be financed by tapping or selling on the interbank market, at an interest rate set by the central bank. Through this channel, policy rate decisions directly affect retail bank interest rates.

Workers supply their differentiated labor services through a union which sets wages to maximize members' utility subject to adjustment costs: services are sold to a competitive labor packer which supplies a single labor input to firms.

Two additional producing sectors exist: a monopolistically competitive retail sector and a capital-good producing sector. Retailers buy the intermediate goods from entrepreneurs in a competitive market, brand them at no cost and sell the final differentiated good at a price which includes a markup over the purchasing cost and is subject to adjustment costs. Capital good producers are used as a modeling device to derive an explicit expression for the price of capital, which enters entrepreneurs' borrowing constraint. At the beginning of each period, capital good producers buy the final good (that can be transformed one to one into investment, subject to investment adjustment costs) from retailers and the stock of old depreciated capital from entrepreneurs. Combining the two inputs, they produce new capital, which is again sold to entrepreneurs.

3.1 Households and entrepreneurs

3.1.1 Patient and impatient households

There exist two groups of households: Patients and Impatients, of mass γ_P and γ_I, respectively. The only difference between agents in the two groups is that patients' discount factor (β_P) is higher than impatients' (β_I). Within each group $T = \{P, I\}$, the representative agent i maximizes the following utility function :

$$E_0 \sum_{t=0}^{\infty} \beta_T^t \left[\log(c_t^T(i) - a^T c_{t-1}^T) + \varepsilon_{j,t}^h \log h_t^T(i) - \frac{l_t^T(i)^{1+\phi}}{1+\phi} \right]$$

Utility depends on consumption c^T, housing services h^T and hours worked l^T. The parameter a^T measures the degree of (external and group-specific) habit formation in consumption; $\varepsilon_{j,t}^h$ captures an exogenous shock to the demand for housing. Household decisions have to match the following budget constraint (with capital letters indicating nominal terms; P_t is the final consumption price index, Q_t^h is housing price):

$$P_t c_t^T(i) + Q_t^h \Delta h_t^T(i) + D_t^T(i) + R_{t-1}^{BH} B_{t-1}^T(i) \leq W_t l_t^T(i) + B_t^T(i) + R_{t-1}^D D_{t-1}^T(i) + Lump_t^T(i) \quad (1)$$

The flow of expenses includes current consumption c_t^T, accumulation of housing Δh_t^T, deposits D_t^T and gross nominal interest paid on last period loans $R_{t-1}^{BH} B_{t-1}^T$. Resources are composed of wage earnings $W_t l_t^T$, borrowing from banks B_t^T, interest repayment on last period deposits $R_{t-1}^D D_{t-1}^T$ and lump-sum transfers, which include the labor union membership fee, the rebate of central bank profits $S_t(i)$ and (only for patients, their sole owners) profits from banks and retail firms $J_{B,t}^T$ and $J_{R,t}^T$.

In addition, households face a borrowing constraint: the expected value of their collateralizable housing stock at period t must be sufficient to guarantee lenders of debt repayment. The constraint is

$$R_t^{BH} B_t^T(i) \leq m^T E_t[Q_{t+1}^h h_t^T(i)] \quad (2)$$

where m^T is the loan-to-value ratio; from a microeconometric point of view, (1-m^T) can be interpreted as the proportional cost of collateral repossession for banks given default. Our assumption on households' discount factors is such that, absent uncertainty, the borrowing constraint of the impatients is binding in a neighborhood of the steady state. As in Iacoviello (2005), we assume that the size of shocks in the model is "small enough" so to remain in such a neighborhood, and we can thus solve our model imposing that the borrowing constraint always binds.

3.1.2 Entrepreneurs

In the economy there is an infinity of entrepreneurs of total mass γ^E. Each entrepreneur i only cares about his own consumption $c^E(i)$, according to the utility function

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E)$$

where a^E, symmetrically with respect to households, measures the degree of consumption habits. Entrepreneurs' discount factor β^E is assumed to be strictly lower than β^P. In order to maximize lifetime consumption, entrepreneurs choose the optimal stock of physical capital k_t^E, the degree of capacity utilization u_t and the desired amount of labor input l^E. Labor and effective capital are combined to produce an intermediate output y^E according to the production function

$$y_t^E(i) = A_t^E [k_{t-1}^E(i) u_t(i)]^{\alpha} l_t^E(i)^{1-\alpha}$$

where A^E is an exogenous process for total factor productivity. The intermediate product is sold in a competitive market at wholesale price P_t^w. Entrepreneurs have access to deposit and loan contracts (D_t^E and B_t^E, respectively) offered by banks, which they use to implement their saving and borrowing decisions. Symmetrically with respect to households, we assume that the amount of resources that banks are willing to lend to entrepreneurs is constrained by the value of their collateral, which is given by their holdings of physical capital. This assumption differs from Iacoviello (2005), where also entrepreneurs borrow against housing (interpretable as commercial real estate), but it seems a more realistic modeling choice, as it is overall balance-sheet conditions to determine the soundness and creditworthiness of a firm. The borrowing constraint is thus

$$R_t^{BE} B_t^E(i) \leq m^E \mathrm{E}_t(Q_{t+1}^k(1-\delta)k_t^E(i)) \tag{3}$$

where m^E is the entrepreneurs' loan-to-value ratio, which, in principle, differs from the one for households. The assumption on the discount factor β^E and of "small uncertainty" allows us to solve the model by imposing an always binding borrowing constraint for the entrepreneurs.

Entrepreneurs' flow budget constraint in nominal terms is the following:

$$\begin{aligned} P_t c_t^E(i) + W_t l_t^E(i) + D_t^E(i) + R_{t-1}^{BE} B_{t-1}^E(i) + Q_t^k k_t^E(i) - Q_t^k(1-\delta)k_{t-1}^E(i) \\ \leq P_t^w y_t^E(i) + B_t^E(i) + R_{t-1}^D D_{t-1}^E(i) + P_t \psi\left[u_t(i)\right] k_{t-1}^E(i) + S_t(i). \end{aligned}$$

In the above, Q_t^k is the price of one unit of physical capital; $S_t(i)$ is lump-sum central bank profits; $\psi[u_t(i)]k_{t-1}^E(i)$ is the cost, in units of consumption goods, of setting a level u_t of utilization rate, with $\psi(u_t) = \xi_1(u_t-1) + \frac{\xi_2}{2}(u_t-1)^2$.

In order to shed light on how the presence of borrowing constraints affects capital accumulation, we can rearrange the budget constraint, after replacing borrowing at time t with the expression obtained by solving for B_t^E under equality in (3). The resulting equation is:

$$k_t^E(i) = \frac{1}{\varphi_t} N_t^E(i) \tag{4}$$

where

$$\varphi_t \equiv q_t^k - \frac{m^E \mathrm{E}_t[q_{t+1}^k \pi_{t+1}(1-\delta)]}{R_t^{BE}} \tag{5}$$

φ_t can be interpreted as the downpayment required to buy one unit of physical capital. N_t^E stands for entrepreneur's net worth and it is given by (after imposing the equilibrium result that $D_t^E = 0$ for all t)

$$N_t^E(i) = \frac{y_t^E(i)}{x_t} - c_t^E(i) - w_t l_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i) - \frac{R_{t-1}^{BE} b_{t-1}^E(i)}{\pi_t} - \psi\left[u_t(i)\right] k_{t-1}^E(i) - S_t(i)$$

The amount of capital that entrepreneurs will accumulate is a multiple of their net worth at the end of the period: for each unit of own resources, they will be able to obtain $1/\varphi_t$ units of capital. The resource gap between own funds and the cost of purchasing new capital is financed through bank loans, which can easily be shown to satisfy

$$b_t^E = (1/\varphi_t - 1)N_t^E \,. \tag{6}$$

From equation 5 it is clear that the required downpayment is a function of the relevant real interest rate for entrepreneurs ($R_t^{BE}/E_t[\pi_{t+1}]$) and present and expected future price of capital. In particular, when the real interest rate rises or the future price of capital fall, one unit of own resources is able to rise a smaller amount of capital: such a mechanism is at the heart of the financial accelerator, according to which monetary policy shock or other types of financial shocks have a stronger effect on real activity when borrowers are financially constrained. It is also interesting to observe how the magnitude of such financial accelerator effects crucially depends on the parameter m^E, which measures the intensity of collateral effects: as m^E rises, an increasing portion of capital is collateralizable, so that the impact of changes in the present discounted value of future capital holdings (via changes in the real interest rate or the future price of capital) becomes more and more important.

3.1.3 Deposit and loan demand

We assume that deposits and loans to households and to entrepreneurs are in fact a composite CES basket of slightly differentiated products, each supplied by a single bank with elasticities of substitution equal to ε_d, ε_b^H and ε_b^E, respectively. Thus (as in the standard Dixit-Stiglitz framework for goods markets), agents have to purchase deposit (loan) contracts by each bank in order to save (borrow) one unit of resources. Although this assumption might seem unrealistic, it is just a useful modeling device to capture the existence of market power in the banking industry.[4] The price of the deposit contract with bank j is given by $1/R_t^D(j)$, so that the demand function is increasing in $R_t^d(j)$. The price of a loan contract is given, instead, by $R_t^{BH}(j)$ and $R_t^{BE}(j)$, for households and entrepreneurs respectively; thus, the corresponding demand will be downward sloping in the respective interest rates.

More in detail, for a given level $\bar{d}_t^T(i)$ of desired deposit "bundle" agent i's demand

[4] A similar shortcut is taken by Benes and Lees (2007). Arce and Andrés (2008) set up a general equilibrium model featuring a finite number of imperfectly competitive banks in which the cost of banking services is increasing in customers' distance.

for bank j deposit, $d_t^T(i,j)$, is obtained by solving the problem

$$\min_{\left\{d_t^T(i,j)\right\}} \int_0^1 \frac{1}{R_t^D(j)} d_t^T(i,j) dj$$

s.t.

$$\left[\int_0^1 d_t^T(i,j)^{\frac{\varepsilon_d - 1}{\varepsilon_d}} dj\right]^{\frac{\varepsilon_d}{\varepsilon_d - 1}} \geq \bar{d}_t^T(i)$$

Analogously, the demand for a loan contract $b_t^T(i,j)$ is obtained as a solution to the following system:

$$\min_{\left\{b_t^T(i,j)\right\}} \int_0^1 R_t^{BT}(j) b_t^T(i,j) dj$$

s.t.

$$\left[\int_0^1 b_t^T(i,j)^{\frac{\varepsilon_b - 1}{\varepsilon_b}} dj\right]^{\frac{\varepsilon_b}{\varepsilon_b - 1}} \geq \bar{b}_t^T(i)\,,$$

with $T = H, E$. From the first-order conditions, aggregating across agents, aggregate deposit demand, household and entrepreneur's loan demands faced by bank j are equal to, respectively:

$$d_t(j) = \left(\frac{R_t^D(j)}{R_t^d}\right)^{\varepsilon_d} d_t \tag{7}$$

$$b_t^H(j) = \left(\frac{R_t^{BH}(j)}{R_t^{BH}}\right)^{-\varepsilon_b^H} b_t^H \tag{8}$$

$$b_t^E(j) = \left(\frac{R_t^{BE}(j)}{R_t^{BE}}\right)^{-\varepsilon_b^E} b_t^E \tag{9}$$

where d_t, b_t^H and b_t^E indicate economy-wide demand for deposits, household loans and entrepreneurial loans respectively.

3.1.4 Labor market

We assume that there exists a continuum of labor types and one union for each labor type n. Each union is representative of the whole household population, i.e. it includes γ^P patients and γ^I impatients. Its discount factor β_U is a weighted average of those of its members. The typical union n sets nominal wages for workers of its labor type by maximizing a weighted average of its members' utility, subject to a constant-elasticity (ϵ_l) demand schedule and to adjustment costs, with indexation to a weighted average of lagged and steady-state inflation. The union equally charges each member household with lump-sum fees to cover adjustment costs. In a symmetric equilibrium, the labor choice for each single household in the economy will be given by the (non-linear) wage-Phillips curve:

$$\left(\frac{\gamma^P}{c_t^P - a^P c_{t-1}^P} + \frac{\gamma^I}{c_t^I - a^I c_{t-1}^I}\right)\left[\kappa_w(\pi_t^w - \pi_{t-1}^{\zeta}\pi^{1-\zeta})\pi_t^w - (1-\varepsilon_l)l_t^T\right] = \tag{10}$$

$$= \left(\gamma^P + \gamma^I\right)\varepsilon_l \frac{l_t^{T\,1+\sigma_l}}{w_t} + \kappa_w \beta_U E_t\left\{\left(\frac{\gamma^P}{c_{t+1}^P - a^P c_t^P} + \frac{\gamma^I}{c_{t+1}^I - a^I c_t^I}\right)(\pi_{t+1}^w - \pi_t^{\zeta}\pi^{1-\zeta})\frac{\pi_{t+1}^{w\ 2}}{\pi_{t+1}}\right\}.$$

We also assume the existence of perfectly competitive "labor packers" who buy the differentiated labor services from unions, transform them into an homogeneous composite labor input and sell it, in turn, to intermediate-good-producing firms. This assumptions yield a demand for each kind of differentiated labor service $l_t(n)$ equal to

$$l_t(n) = \left(\frac{W_t(n)}{W_t}\right)^{-\varepsilon_l} l_t \tag{11}$$

where W_t:

$$W_t = \left[\int_0^1 W_t(n)^{1-\varepsilon_l} di\right]^{\frac{1}{1-\varepsilon_l}}$$

is the aggregate wage in the economy.

3.2 Banks

The banking sector comprises a continuum of monopolistically competitive "commercial" banks (henceforth, just "banks"). Banks' balance sheet is highly stylized but it captures the basic element of financial intermediation and the main link between money and credit aggregates. On the liability side, each bank j can obtain funding by rising deposits $D_t(j)$ or by tapping the interbank market for an amount $M_t(j)$; on the asset side, banks provide loans to households $B_t^H(j)$ and to entrepreneurs $B_t^E(j)$. Since bank j faces a downward sloping demand curve (with constant elasticity) for deposits and loans (see section 3.1.3), it is able to choose its own interest rates $R_t^D(j)$, $R_t^{BH}(j)$ and $R_t^{BE}(j)$ so as to maximize profits; we will show that optimality requires to set rates on deposits and loans, respectively, as a mark-down and as mark-ups over the interest rate prevailing in the interbank market R_t^{IB}. To understand the interest-rate setting mechanism, it is useful to think of a single bank as consisting of two different branches: a "commercial unit" which collects deposits, and an "investment unit" which issues loans. Transfers of cash between the two branches are made at a figurative (gross) revenue/cost equal to R_t^{IB}; moreover, if one unit needs to raise (invest) additional funds on top of those available in the other, it can always go to the interbank market where it can borrow (invest) without limits at the policy rate. Deposits are assumed to be convertible into loans with a linear technology (actually, one-to-one).[5] Bank profits consist of the difference between active and passive rates in the two branches and are rebated, in a lump-sum fashion, to patient households, who are the only owners of the intermediaries.

Banks face quadratic adjustment costs when changing their rates; the parameters determining the speed of adjustment to changes in the policy rate are κ_d, κ_h and κ_e, for deposits, household loans and entrepreneurial loans, respectively, and are calibrated in order to match the stickiness in banking rates observed in the data (see below). More in detail, the problem faced by the "commercial unit" of the bank is to maximize the discounted sum of its future real profits, taking into account the overall demand for its deposits in each period and the presence of adjustment costs. Formally, the problem can be stated as follow:

$$\max_{\{R_t^D(j)\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[R_t^{IB} d_t(j) - R_t^D(j) d_t(j) - \frac{\kappa_d}{2} \left(\frac{R_t^D(j)}{R_{t-1}^D(j)} - 1 \right)^2 R_t^D d_t \right]$$

s.t.

$$d_t(j) = \left(\frac{R_t^D(j)}{R_t^D} \right)^{\varepsilon_d} d_t$$

where $R_t^D(j)$ is the choice variable, R_t^D is the average deposit interest rate prevailing in the market (and taken as given by the single bank when solving the problem), $d_t(j)$ is the demand for this bank deposits at time t and d_t is the economy-wide demand for deposits. The term containing κ_d is the quadratic adjustment cost incurred by the bank if it sets $R_t^D(j)$ to a level different from $R_{t-1}^D(j)$.

After imposing a symmetric equilibrium, a linearized version of the first-order condition is

$$\hat{R}_t^D = \frac{\kappa_d}{1 + \varepsilon_d + (1 + \beta_P)\kappa_d} \hat{R}_{t-1}^D + \frac{\beta_P \kappa_d}{1 + \varepsilon_d + (1 + \beta_P)\kappa_d} E_t \hat{R}_{t+1}^D + \frac{1 + \varepsilon_d}{1 + \varepsilon_d + (1 + \beta_P)\kappa_d} \hat{R}_t^{IB} \tag{12}$$

From the equation above, the deposit interest rate is set by the banks in the model according to a sort of "interest-rate Phillips curve" (hatted values denote percentage deviations from the steady-state). Solving the equation forward, it can be easily shown that the deposit interest rate is set taking into account the expected future level of the policy rate; the speed of adjustment to changes in the policy rate depends inversely on

[5] We are currently working on an extension of the model featuring a more detailed production function for loans which includes work effort and banking capital. The introduction of the latter should have interesting consequences, as it would establish a further link between the state of the economy (from which bank capital would be affected) and financing condition (in particular, loan supply).

the intensity of the adjustment costs (as measured by κ_d) and positively on the degree of competition in the banking sector (as measured by the inverse of ε_d).

It is useful to observe that, with fully flexible rates, R_t^D would be determined as a mark-down on the policy rate:

$$R_t^D = \frac{\varepsilon_d}{\varepsilon_d + 1} R_t^{IB} \tag{13}$$

For banks deposits are essentially an input and the intermediaries are price makers in this factor market, while they take the (figurative) "output" price R_t^{IB} as given; banks thus exploit their market power to lower their marginal cost (and increase profits) as much as possible given the demand constraint. The spread between the policy rate and the cost of deposits thus depends on the elasticity of substitution among deposit varieties; later in the paper, we use this relation to calibrate the parameter ε_d.

As for loans, the "investment unit" of the bank solves a symmetric problem; the interbank rate is, in this case, the (constant) marginal cost. The log-linearized version of the loan-rate setting equations is

$$\hat{R}_t^{Bj} = \frac{\kappa_j}{\varepsilon_b^j - 1 + (1+\beta_P)\kappa_j} \hat{R}_{t-1}^{Bj} + \frac{\beta_P \kappa_j}{\varepsilon_b^j - 1 + (1+\beta_P)\kappa_j} E_t \hat{R}_{t+1}^{Bj} + \frac{\varepsilon_b^j - 1}{\varepsilon_b^j - 1 + (1+\beta_P)\kappa_j} \hat{R}_t^{IB} \tag{14}$$

where $j = H, E$. Also loan rates are set by banks taking into account the expected future path of policy rates. The hybrid nature (both backward- and forward-looking) of interest rate-fixation catches the real-world features that variable-rate loan contracts adjust with lags to changes in the policy rate, as they are reviewed only at periodic intervals and that fixed-rate contracts take into account also expectations on future financing conditions, which depend on the level of the policy rate.

With perfectly flexible rates, assuming different interest rate elasticities of demand between entrepreneurs and all households, $\varepsilon_b^E \neq \varepsilon_b^H$, and different degrees of stickiness, the pricing equations become:

$$R_t^{BE} = \frac{\varepsilon_b^E}{\varepsilon_b^E - 1} R_t^{IB} \tag{15}$$

$$R_t^{BH} = \frac{\varepsilon_b^H}{\varepsilon_b^H - 1} R_t^{IB} \tag{16}$$

As expected, in this case interest rates on loans are set as mark-up over the interbank rate.

3.3 Retailers

Following BGG (1999), we introduce sticky price in the production sector by assuming monopolistic competition at the retail level and quadratic price adjustment costs. Retailers are just "branders" they buy the intermediate good from entrepreneurs at the wholesale price P_t^W and differentiate the goods at no cost. Each retailer j then sales their unique variety at a mark-up over wholesale price. We assume that retailers' prices are indexed to a combination of past and steady-state inflation, with relative weights equal to ζ and $(1-\zeta)$ respectively; if they want to change their price by more than indexation they have to pay a proportional adjustment cost. In a symmetric equilibrium, the (non-linearized) Phillips curve is given by the retailers' problem first-order condition:

$$1-\varepsilon_y+\frac{\varepsilon_y}{x_t}-\kappa_p(\pi_t-\pi_{t-1}^{\zeta}\pi^{1-\zeta})\pi_t+\beta_P E_t\left[\frac{c_t^P-a^P c_{t-1}^P}{c_{t+1}^P-a^P c_t^P}\kappa_p(\pi_{t+1}-\pi_t^{\zeta}\pi^{1-\zeta})\pi_{t+1}\frac{y_{t+1}}{y_t}\right]=0 \quad (17)$$

where $x_t = P_t/P_t^W$ is the gross markup earned by retailers.

3.4 Capital goods producers

Introducing capital good producers (CGPs) is a modeling device to derive a market price for capital, which is necessary to determine the value of entrepreneurs' collateral, against which banks concede loans. We assume that, at the beginning of each period, each capital good producer buys an amount $i_t(j)$ of final good from retailers and the stock of old depreciated capital $(1-\delta)k_{t-1}$ from entrepreneurs (at a nominal price P_t^K). Old capital can be converted into new capital one-to-one, while the transformation of the final good is subject to quadratic adjustment cost; the amount of new capital that CGPs can produce is given by

$$k_t(j) = (1-\delta)k_{t-1}(j) + \left[1-\frac{\kappa_i}{2}\left(\frac{i_t(j)}{i_{t-1}(j)}-1\right)^2\right] i_t(j) \quad (18)$$

The new capital stock is then sold back to entrepreneurs at the end of the period at the nominal price P_t^k. Market for new capital is assumed to be perfectly competitive, so that it can be shown that CPGs' profit maximization delivers a dynamic equation for the real price of capital $q_t^k = P_t^k/P_t$ similar to Christiano*et al.* (2005) and Smets and Wouters (2003).[6]

3.5 Monetary policy

A central bank is able to exactly set the interest rate prevailing in the interbank market R_t^{IB}, by supplying all the demanded amount of funds in excess of the net liquidity position

[6] As pointed out by BGG (1999), a totally equivalent expression for the price of capital can be obtained by internalizing the capital formation problem within the entrepreneurs' problem; the analogous to our q_t^k is nothing but the usual Tobin's q. In using a decentralized modeling strategy, we follow Christiano *et al.* (2005).

in the interbank market.[7] We assume that profits made by the central bank on seignorage are evenly rebated in a lump-sum fashion to households and entrepreneurs. In setting the policy rate, the monetary authority follows a Taylor rule of the type

$$R_t^{IB} = R^{IB(1-\rho^{IB})} R_{t-1}^{IB\ \rho^{IB}} \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\rho^{IB})} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y(1-\rho^{IB})} \varepsilon_t^{R^{IB}} \tag{19}$$

where ϕ_π and ϕ_y are the weights assigned to inflation and output stabilization, respectively, R^{IB} is the steady-state nominal interest rate and $\varepsilon_t^{R^{IB}}$ is an exogenous shock to monetary policy.

3.6 Aggregation and market clearing

Equilibrium in the goods market is expressed by the resource constraint

$$y_t = c_t + q_t^k \left[k_t - (1-\delta)k_{t-1}\right] + k_t \psi \left[u_t\right] + adj_t \tag{20}$$

where c_t denotes aggregate consumption and is given by

$$c_t = c_t^P + c_t^I + c_t^E = \gamma^P c_t^P(i) + \gamma^I c_t^I(i) + \gamma^E c_t^E(i), \tag{21}$$

$y_t = \gamma^E y_t^E(i)$ is aggregate output and $k_t = \gamma^E k_t^E(i)$ is the aggregate stock of physical capital. The term adj_t includes real adjustment costs for prices, wages and interest rates.

Equilibrium in the housing market is given by

$$\bar{h} = \gamma^P h_t^P(i) + \gamma^I h_t^I(i) \tag{22}$$

where $\bar{h}$ denotes the exogenous fixed housing supply stock.

4 Calibration

Standard parameter values are calibrated within the range considered in the New Keynesian/RBC literature, in order to obtain reasonable values for some key steady-state ratios, such as consumption and business investment to GDP (taking into account that the model does not include a public sector; see Tables 1A and 1B). We set the patients' discount factor at 0.9953, in order to obtain a steady-state interest rate on deposits of 1.8 per cent on an annual basis, equal to the average monthly rate on M2 deposits in

[7] From an operational point of view, we are assuming that monetary policy is conducted as in the Eurosystem, but with a zero-width policy-rate corridor.

the euro area between January 1998 and March 2008.[8] As for impatient households' and entrepreneurs' discount factors β^I and β^E, we set them at 0.975, in the range suggested by Iacoviello (2005) and Iacoviello and Neri (2008). Similarly, the mean value of the weight of housing in households' utility function ε_j^h is set at 0.2, close to the value in Iacoviello and Neri (2008). The parameters measuring the degree of habits in consumption are calibrated to 0.6 in line with the available estimates for the euro area (see Smets and Wouters, 2003). The parameter governing price stickiness in the retail sector κ_p is set at 100, in order to obtain the same degree of stickiness as in Iacoviello (2005).[9] In the labor market we assume the same degree of nominal rigidities, so we set also κ_w at 100. As for the loan-to-value (LTV) ratios, we set m^I at 0.7 in line with evidence for mortgages in the main euro area countries (0.7 for Germany, 0.5 for Italy and 0.8 for France and Spain), as pointed out by Calza *et al.* (2007). The calibration of m^E is somewhat more problematic: Iacoviello (2005) estimates a value of 0.89, but, in his model, only commercial real estate can be collateralized; Christensen *et al.* (2007), estimate a much lower value (0.32), in a model for Canada where firms can borrow against business capital. Using data over the period 1999-2007 for the euro area we estimate an average ratio of long-term loans to the value of shares and other equities for the non financial corporations sector of around 0.41; using short-term instead of long-term loans we obtain a smaller value of around 0.2. Based on this evidence, we decided to set m^E at 0.25 in the benchmark model and to conduct in the next Section a sensitivity analysis to study how this and other parameter choices modify the transmission of a monetary policy shock. These LTV ratios imply a steady-state shares of household and entrepreneur loans equal to 49 and 51 per cent, respectively.

For the banking parameters, no corresponding estimates are available in the literature. Thus, we calibrate them so as to replicate some statistical properties of bank interest rates and spreads. Equations (13), (15) and (16) show that steady-state spreads between banking interest rates and the interbank rate depend on the degree of substitution between

[8] The rate on M2 deposits was constructed by taking a weighted average of the rates on overnight deposits, time deposits up to 2 years and saving deposits up to 3 months, with the respective outstanding amounts in each period as weights. Data on interest rates were obtained from the official MIR statistics by the ECB, starting from January 2003; previous to that date, we used monthly variations of non-harmonized interest rates for the EMU-12, provided by the BIS, to reconstruct back the series. Similarly, for loan rates we used ECB official interest rates on new-business loans to non-financial corporations and on loans for house purchase to households since January 2003, and we reconstructed back the series by using variations of non-harmonized rates before that date.

[9] Iacoviello (2005) employs a Calvo-specification for nominal rigidities and he calibrates a 25 per cent probability for firms to adjust prices in each quarter; we set κ_p so as to obtain the same slope for the Phillips curve.

individual banks' loans and deposits; thus, to calibrate ε_d, ε_b^H and ε_b^E we calculate the average monthly spread between banking rates in our sample and the 3-month Euribor. The average rate on deposit is lower than the interbank rate by around 150 basis points on an annual basis, which implies that $\varepsilon_d = 284$. Similarly, the rates on loans to households and firms are above the policy rate by, respectively, 160 and 130 basis points, which means that $\varepsilon_b^H = 253$ and $\varepsilon_b^E = 305$.

As for the parameters governing interest rate stickiness, their calibration is based on the impact response of the corresponding variables obtained using a small scale VAR. The model includes the banks interest rates on deposits, loans to households and loans to firms, the three-month money market rate and a monthly interpolation of the output gap. The latter variables is constructed using real-time estimates of the output gap from the IMF and the OECD interpolated to the monthly frequency using a set of economic indicators including the survey of the European Commission, the Purchasing Managers' Index and the Bank of Italy/CEPR Eurocoin. The VAR, in which the variables enter in levels, has three lags and is estimated using data for the period 1999:1 2008:3. Figure 1 reports the impulse responses to an innovation in the money market rate and the 0.68 and 0.90 probability intervals computed with Monte Carlo methods. The impact response of the interest rate on deposits to an exogenous increase of 25 basis points in the three-month rate is equal to 3.3 basis points. For the interest rates on loans to households and firms the corresponding numbers are, respectively, 7.8 and 10.5 basis points. These results are broadly in line with the findings in de Bondt (2005) for the euro area. The impact responses obtained from our VAR are then used to calibrate the adjustment costs parameter for banks interest rates. These values turn out to be equal to 1800 for deposits (κ_d), 500 for loans to households (κ_H) and 375 for the loans to firms (κ_E). The implied response on impact in the model are equal to respectively, 3.3, 7.9 and 10.4 basis points.

5 The propagation mechanism

In this Section we study the dynamics of the linearized model using impulse responses. To this end we focus on a contractionary monetary policy shock and on a combined experiment in which banks increase their interest rates on loans to firms and households and contemporaneously reduce the quantity of credit. The first experiment is useful to assess how much of a difference does it make to allow for financial frictions and financial intermediation in the transmission of monetary policy, and how different our findings are from those of other papers that feature some of these mechanisms, such as Iacoviello (2005), Christiano *et al.* (2007) and Goodfriend and McCallum (2207). The second experiment will be used to simulate a “financial market turmoil” similar the one that hitted global markets in the summer of 2007.[10]

5.1 Monetary policy shock

The transmission of a monetary policy shock is first studied by analyzing the benchmark model impulse responses to an unanticipated increase of 25 basis points in the policy rate (R_t^{IB}; see Fig. 2). The transmission mechanism in our model is affected by the presence of a real rate effect (here working also through a change in the net present value of the collateral), of a financial accelerator effect (working through a change in asset prices), of a nominal debt effect (working through a wealth redistribution effect that originates from the presence of nominal contracts) and, finally, by the presence of monopolistic banks that set interest rates with adjustment costs. The first three factors have already been analyzed in the literature and they have been shown to contribute to amplify and propagate the initial impulse of a monetary policy restriction (Iacoviello, 2005; Calza *et al.*, 2007); the importance of banks' decisions has instead been almost ignored: our results suggest that the slow adjustment of retail interest rates attenuates the impact response of real variables to a monetary shock.

After an official rate rise, since prices are sticky, inflation does not rise on impact and thus real rates rise too. This triggers an interest rate channel modified by the presence of borrowing constraints: all agents would be induced to postpone consumption, but in the local equilibrium that we analyze constrained agents are eager for consuming more immediately if endowed with more resources, and therefore they do not respond by cutting current consumption as patient agents do instead. Entrepreneurs respond to the decrease in demand by cutting production and investment, which in turn depresses labor and capital income for households. House prices face a downward pressure from the fall in housing demand (supply is fixed); the value of installed capital (Tobin's q) falls, given the lower expected future production.

A second channel works through a debt-deflation effect. The contraction spurred by the increase in real rates induces a fall in the general price level and this puts additional strain on borrowers' balance-sheets by raising the real cost of current debt obligations (R_{t-1}^B/π_t). The opposite effect occurs on patient agents, since their real remuneration on savings rises. The net effect of this redistribution of wealth (from impatients and entrepreneurs to patients) is a further contraction in aggregate demand since impatients

[10] The assumption of independently distributed shocks allows simulating the 'financial market turmoil' scenario by adding the impulse responses to each of the shock.

and entrepreneurs have, by construction, a higher propensity to consume.

Moreover, a financial accelerator is at work in the model. On impact, the rise of real interest rates reduces the net present value of tomorrow's capital holdings, causing banks to cut the amount of loans they are willing to supply to impatients and entrepreneurs. As we see from Figure 2 (fifth and sixth subplots), both households and firms lending fall. The contraction in borrowing, by reducing resources available to constrained agents, puts additional downward pressure on aggregate demand. As a consequence, the fall in house and capital prices accentuates, triggering what can be seen as a 'second round' effect on impatients' and entrepreneurs' borrowing ability, stemming from the expected reduction in the price of their collateral.

Finally, the presence of banks creates a new effect in the model, a banking attenuator effect. When the official rate rises, banks increase the remuneration of deposits and the cost of loans only gradually and by a lower amount (overall bank rates, i.e. the rates which are relevant for agents' decisions, rise by around five times less than the policy rate; see Figure 2). Thus, compared to a model without banks, financial intermediation simply introduces a moderating effect on each of the channels listed above, and hence on the responses of real and financial variables after a monetary policy shock.

In order to assess the quantitative relevance of these different channels in altering the dynamic properties of the economy, we compare the impulses responses of the benchmark model after a monetary policy shock with those coming from three alternative models: one in which financial frictions are present (so that the borrowing constraint effect, the financial accelerator and the debt-deflation effect are still relevant) but credit is intermediated through a perfectly competitive banking sector that always sets active and passive rates equal to the monetary policy rate (we called this the 'perf. comp. banks' model); one in which the role of the borrowing constraint is minimized (the debt-deflation channel is muted by assuming that the yields on loans and deposits are index-linked; the financial accelerator effect is muted by assuming that the asset posted as collateral is evaluated at its steady-state price; in this model then the real values of loans and deposits are fixed to their respective steady-state levels) but banking rates are still set sluggishly (the 'no collateral effects' model); and one in which both these two financial frictions are simultaneously muted (a model closer to a standard new-keynesian model, identified as 'NK' in Figure 3). Let's focus first on the difference between the benchmark and the 'perf. comp. banks' model. To fix ideas, in the first model there is a wedge between active and passive rates (called the banking intermediation spread) that moves according to the cyclical conditions of the economy as well as the adjustment costs parameters. In the second model, this wedge is always zero. As we see from Figure 3, an unanticipated increase of 25 basis points in the policy rate in the benchmark model raises active bank rates by about 10 basis points on impact (the passive rate, not shown in the picture, raises by about 3) whereas in the 'perf. comp. banks' model all rates jump by exactly the full 25 basis points, i.e. almost three times more. This initial difference in responses vanishes quite rapidly, after about three quarters, after which active banking rates from the two models seem to overlap. But since the passive rates are slower to adjust the banking spread (the difference between active and passive rates) experiences more persistent fluctuations. Initially the spread increases, as active rates are assumed to react faster, but it rapidly returns to its steady-state level and actually undershoots it for several quarters starting from the fifth quarter after the shock. The initially smaller increase in active rates in the benchmark model is enough to induce a smaller reduction in loan demand, actually very persistent in the case of household loans (see Figure 3, sixth subplot). The implied reaction of the real economy is correspondingly attenuated. Consumption declines on impact by 0.10 percentage points instead of 0.15; investment drops by 0.14 percentage points, instead of 0.19, and this subdued reaction is quite persistent, vanishing only after more than two years. Inflation is only marginally altered. Comparing the responses of output, it can be seen that the banking attenuation effect reduces the contractionary effect of the monetary policy shock by about a third on impact. This dampened effect vanishes quite rapidly in about four quarters, after which output seems unaffected by further movements in the banking spread. Overall, the transmission of monetary policy shocks is not qualitatively altered by the presence of monopolistic banks that set rates sluggishly; from a quantitative point of view, the attenuator effect that results from their presence can be sizeable on impact.

A related question is whether (and how) this attenuator effect interacts with the presence (and/or strength) of credit frictions. Is the effect bigger when financial frictions (e.g., borrowing constraints) are more relevant in the economy? To understand this, we compared the responses coming from the two previous models with those coming from two models in which the role of the borrowing constraints has been muted (the 'no collateral effects' and the 'NK' models). As we see from Figure 3, the banking attenuator effect seem to be equally large on impact, but the extra-persistence on investment, inflation and output is gone. Now, after 3-4 quarters all responses overlap almost exactly in the two cases, indicating that banks play no role after that horizon.

Our results about the relative strengths of the effects coming from the financial frictions and the banking sector are in line with much of the available literature. Christensen *et al.* (2007) find that financial frictions boost the response of output after an increase in policy rates by about a third, mainly on account of a stronger response of both consumption and investment. As for the role of banks, Christiano *et al.* (2007) find that, in general, adding banks and financial frictions strengthen significantly the propagation mechanism of monetary policy: the output response is both bigger and more persistent compared to a model that does not feature these channels. Although their banks, compared to ours, are rather different intermediaries that operate under perfect competition providing mainly screening and financing services to firms, they also find that banks play a marginal role in propagating the monetary impulse while the financial accelerator has important effects on investment and the price of capital. An attenuation effect coming from banks similar to our has been found in Goodfriend and McCallum (2007) banking model. In their model, the effect occurs only when the monetary impulse is very volatile, since then marginal costs in the banking sector become procyclical (otherwise the effect is of opposite sign). The attenuation effect in our model is more general, as bank rates adjustment is sluggish irrespective of the persistence of monetary shocks.

A further sensitivity exercise is to check how the overall transmission mechanism of monetary policy is affected by different levels of collateral requirements (loan-to-value ratios) on either households or firms (see Figures 4 and 5). When households and firms can collateralize a low share of their housing or capital stock (low values for m^I and m^E), the monetary tightening has, in general, less severe consequences on real variables. The effectiveness of the rate hike seems particularly sensitive to the entrepreneurs' loan-to-value-ratio, which affects the response of both consumption and investment, while household LTV affects aggregate demand only via consumption expenditure. Low values of m^I and m^E imply low "leverage" on the part of households and firms, i.e. a low amount of borrowing compared to their own resources. As highlighted by Iacoviello and Neri (2008) and Calza *et al.* (2007), and as described in Section 3.1.2, in this case the absolute amount of borrowing is less sensitive to changes in the net present value of the collateral. Therefore, the amplifying role of the debt-deflation channel and of the financial accelerator is dampened. In the extreme case of non-collateralizable asset ($m^E, m^I = 0$), a monetary restriction would have no effect on the real economy via those financial channels.

5.2 The effects of a tightening of credit conditions

Starting in summer of 2007, financial markets in a number of industrialized countries fell under considerable strain. The initial deterioration in the US sub-prime mortgage market quickly spread across other financial markets, affecting the valuation of a number of assets. The general repricing of risk and the increased uncertainty over valuation of complex instruments invested various financial institutions; banks, in particular, suffered losses from significant write-offs and reported increasing funding difficulties, in connection with the persisting tensions in the interbank market and with the substantial hampering of securitization activity. Intermediaries reported that concerns over their liquidity and capital position induced them to tighten credit standards for the approval of loans to the private sector. In the euro area, since the October 2007 round, banks participating to the Eurosystem's quarterly Bank Lending Survey reported to have strongly increased the margins charged on average and riskier loans and to have implemented a restriction on collateral requirements both for households and firms; 25% of respondent banks reported to have also reduced the loan-to-value ratio for house purchase mortgages in the second half of 2007. Against this background, policymakers have been particulary concerned with the impact that a sufficient restriction in the availability and cost of credit might have on the real economy. The potential consequences on economic activity of the financial turmoil have been given considerable attention when evaluating the appropriateness of the monetary policy stance.[11]

Our model is well-suited to analyze the effects of a tightening in credit conditions on the real activity and to give indications (at least qualitatively) on the appropriate response of a central bank following a Taylor-type monetary policy rule. In this section, we outline a scenario which is qualitatively similar to that experimented in the aftermath of the recent financial turmoil, in which bank loans to both households and firms are interested unexpectedly and simultaneously by a restriction in supply and an increase in interest rates (independent of monetary policy). We do not attempt to outline a quantitatively realistic scenario; this would be indeed very difficult, given the conflicting indications coming from hard and survey evidence on the tightening od credit standards, in particular in the euro area, and the uncertainty on the effects that have already occurred and on those that might still be in the pipeline. Our experiment consists of a contemporaneous combination of two pairs of persistent shocks: an increase in banks collateral requirements for loans to both households and firms and, contemporaneously, one in banks degree of market power in these loan markets. Figure 6 shows the effect of this credit crunch experiment, with the overall response obtained by summing up the responses to the four shocks. The magnitude of loans restriction is calibrated so that the impact responses are around -1.0 per cent; the size of the shocks on interest rates on loans is instead calibrated according to indications from the small-scale VAR commented above. In particular, we calibrate it

[11] In the Introductory statement of November 2007 the Governing Council of the ECB acknowledged that risks to economic growth lied on the downside as the result of the negative impact of the ongoing reappraisal of risk in financial markets and that the high uncertainty warranted "a thorough examination of additional information before drawing further conclusions for monetary policy".

according to the average differential with the VAR of the responses obtained simulating over the period of the turmoil the behavior of banks rates once excluded the effect of shocks to the money market rate implied by estimation. The impact of shocks unrelated to those to the market rate over the period of the turmoil is equal on average to 17 basis points for rates on household loans and 19 for rates on loans to firms.

By construction, the credit tightening brings about an increase in bank rates, an increase in the effective net present value of collateral to borrowers and a reduction in the amount of borrowing from banks. Given nominal rigidities, the increase in the real interest rate causes a reduction in patients' consumption, which is smoothed over time. Aggregate demand and output fall. As expected returns from investing in physical capital also fall, investment and the price of capital drop, driving down the value of the collateral in the hands of entrepreneurs and thus reinforcing the leverage restriction. Limitations to access to credit put an additional burden on aggregate demand, which, impinging on the constrained part of the economy, is magnified as for the negative consequences on activity. More factors contribute to this result. As inflation falls following a decline in marginal costs, it induces an increase in the real cost of servicing debt and a negative wealth effect on the part of borrowers. Real ex-post return to lenders increases instead. Resources are redistributed from borrowers to lenders also through banks profits, which increase following the loans supply restriction and the rates hike. To patient agents, the increase in banks profits more than compensates the decrease in those accruing from the depressed final good sector. This gives a positive impulse to consumption of both goods and housing by patient agents.

Borrowers also reduce the demand for loans as they face higher rates. This adverse effect sum up to the unfavorable redistributions which affect them. Nevertheless, as reflected in the shadow values of borrowing, the restraints have more severe consequences for entrepreneurs: on the one hand, they cannot partially recover from the negative wealth effects by working more (as they are assumed not to work); on the other hand, their net worth gets reduced, limiting borrowing for either one of the two possible uses that they have at hand, consumption and production. Entrepreneurs' demand for goods and inputs harshly falls. Constrained households do instead become more willing to supply labor in order to offset, at least in part, the overall negative wealth effect and sustain consumption. Nevertheless, equilibrium labor and wages fall, as the decline in labor demand prevails. A positive support to consumption of impatients comes from dismissing some real estate, given that the price is somewhat pushed up by the higher demand by patients, but this further diminishes collateral value in the hands of impatients.

Taken in isolation, the effect of a tightening of credit to firms spills over to the household sector through a negative effect on labor income and a deflation-driven increase in the real value of households' debt. Spill-overs to firms from a credit crunch to households are, instead, minor.

A decomposition of the overall response of investment, consumption and output shows that the effect of the increase in collateral requirements is larger than the effect of the increase in interest rate on loans. Similarly the decline in loans to firms reflects primarily the negative shock to the loan-to-value ratio of entrepreneurs. The decline in loans to households, instead, is driven by the interest rate shock.

The reaction dictated by the Taylor rule to the central bank translates into a quite accommodative stance, yielding a virtually unchanged policy rate. It is perhaps worth noticing that such passive behavior actually resembles the one followed by the ECB during the entire financial turmoil crisis.

6 Concluding remarks

The paper has presented a model in which both entrepreneurs and impatients households face borrowing constraints and loans are supplied by imperfectly competitive banks intermediating funds from both patient households deposits. Bank interest rates on loans to firms, to households, and on deposits, adjust slowly to changes in the policy rate because of adjustment costs.

The presence of financial intermediaries exerts some attenuation of the negative effects of a monetary policy tightening on the real net present value of agents' collateral. A shock that reduces the availability of credit and increases the interest rates on loans ("credit crunch shock") can have significant effects on economic activity.

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Table 1A. Calibrated parameters

Parameter	Value	Parameter	Value
β^P	0.9953	a^P	0.6
β^I	0.975	a^I	0.6
β^E	0.975	a^E	0.6
ε^h	0.2	ϕ	1.5
α	0.25	ε_d	284
δ	0.025	ε_b^H	253
ε_y	6	ε_b^E	305
ε_l	5	κ_d	1800
κ_i	1	κ_h	500
κ_p	100	κ_e	375
κ_w	100	m^I	0.7
ζ	0.25	m^E	0.25
ρ_{m^I}	0.8	ρ^{IB}	0.75
ρ_{m^E}	0.8	ϕ_π	1.5
$\rho_{\varepsilon_b^E}$	0.8	ϕ_y	0.0
$\rho_{\varepsilon_b^H}$	0.8		

Table 1B. Steady state ratios

Variable	Interpretation	Value
c/y	Ratio consumption to GDP	0.88
i/y	Ratio business investment to GDP	0.12
k/y	Ratio business capital to GDP	4.4
B/y	Ratio of loans to GDP	2.1
B^H/B	Share of loans to households over total loans	0.49
B^E/B	Share of loans to firms over total loans	0.51
$4 \times (R^D - 1)$	Annualized bank rate on deposits (per cent)	1.8
$4 \times (R^{BH} - 1)$	Annualized bank rate on loans to households (per cent)	4.9
$4 \times (R^{BE} - 1)$	Annualized bank rate on loans to firms (per cent)	4.6

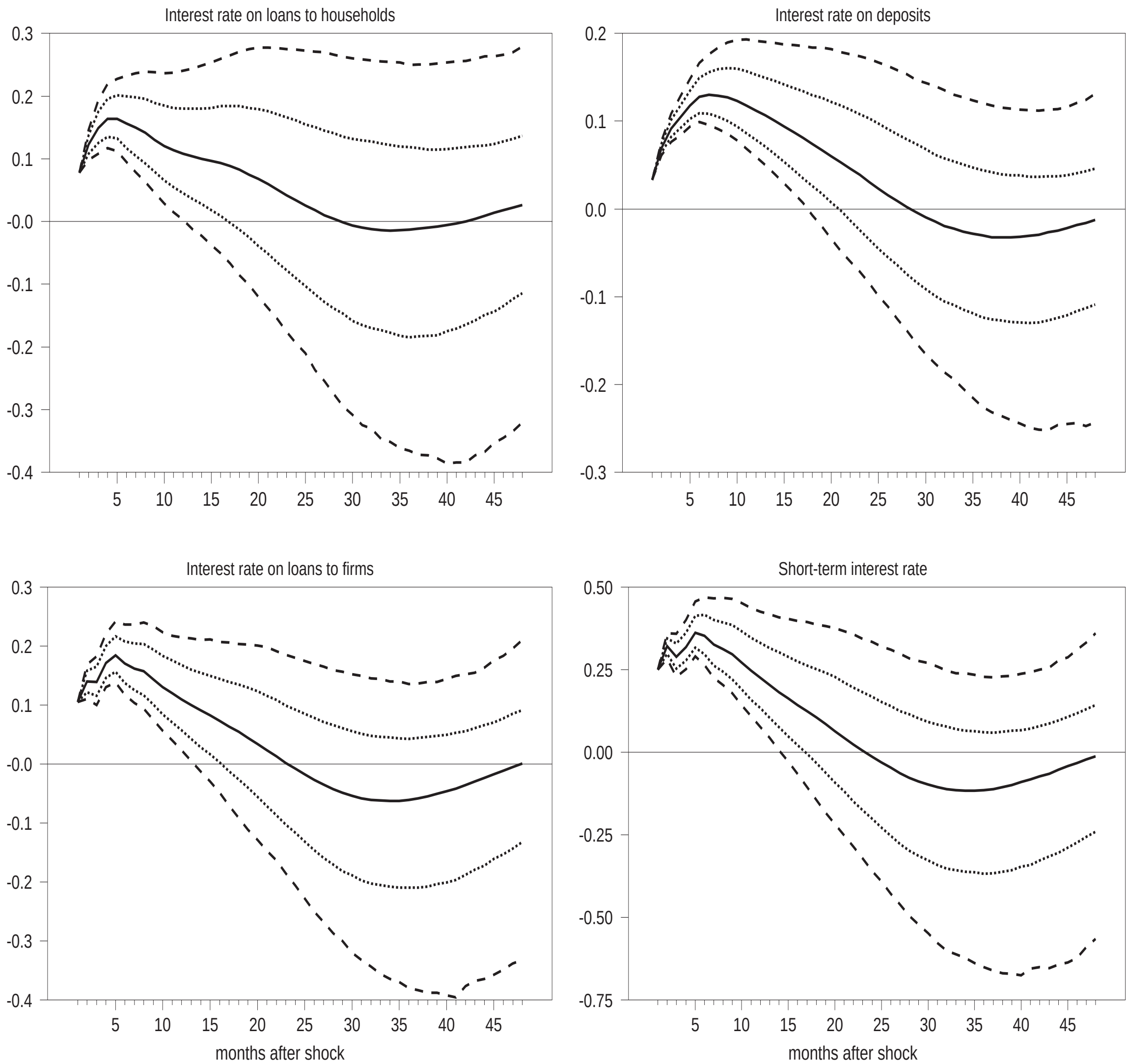

Figure 1: The effects of an exogenous change in the 3-month money market rate on banks rates on loans and deposits. Solid lines represent median values of the posterior distribution of the impulse responses. Dotted lines denote the 0.68 per cent probability intervals, while dashed lines represent the 0.90 per cent probability interval.

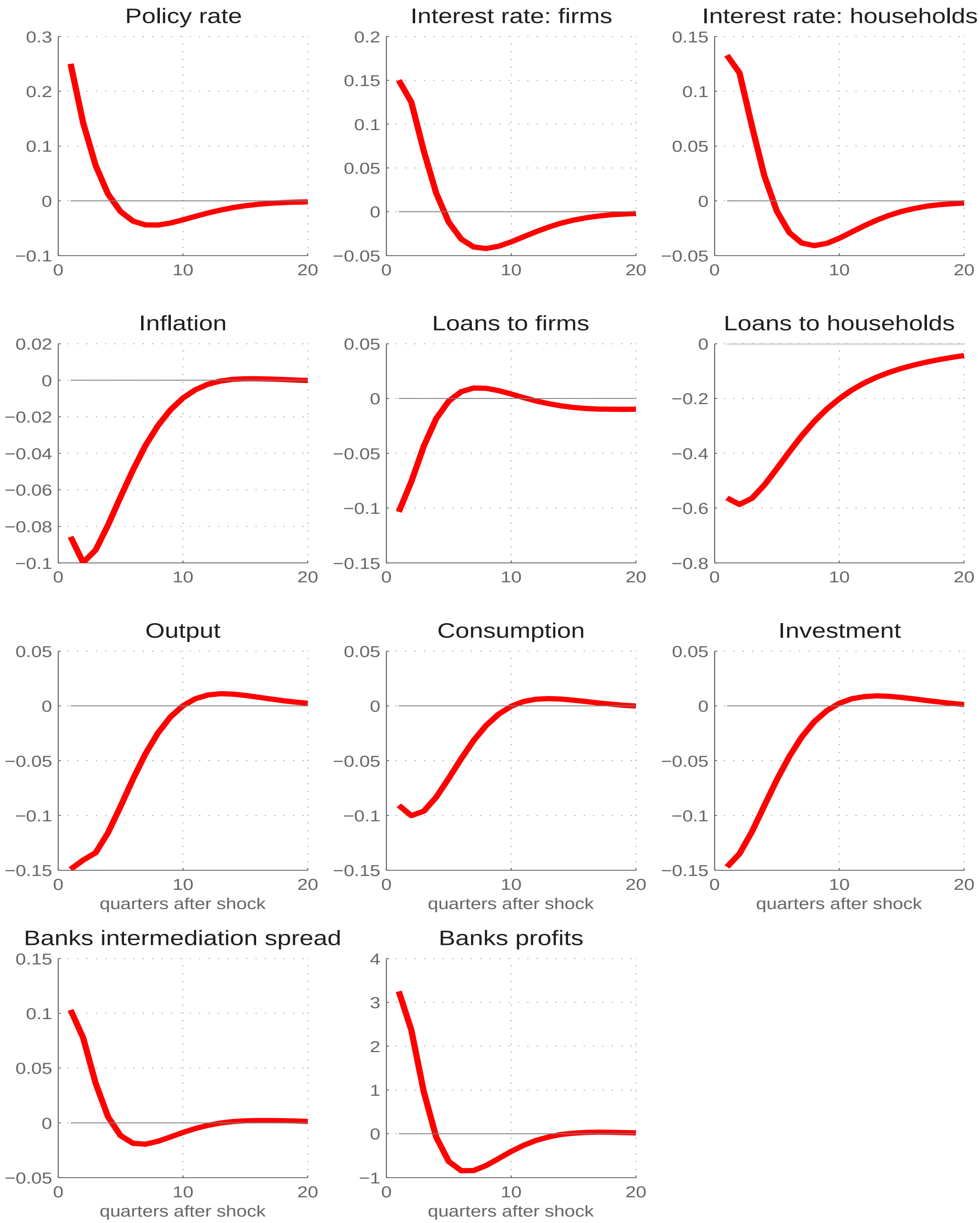

Figure 2: The effects of a contractionary monetary policy shock. Interest rates and banks spreads are shown as absolute deviations from steady state (expressed in percentage points). All others are percentage deviations from steady state.

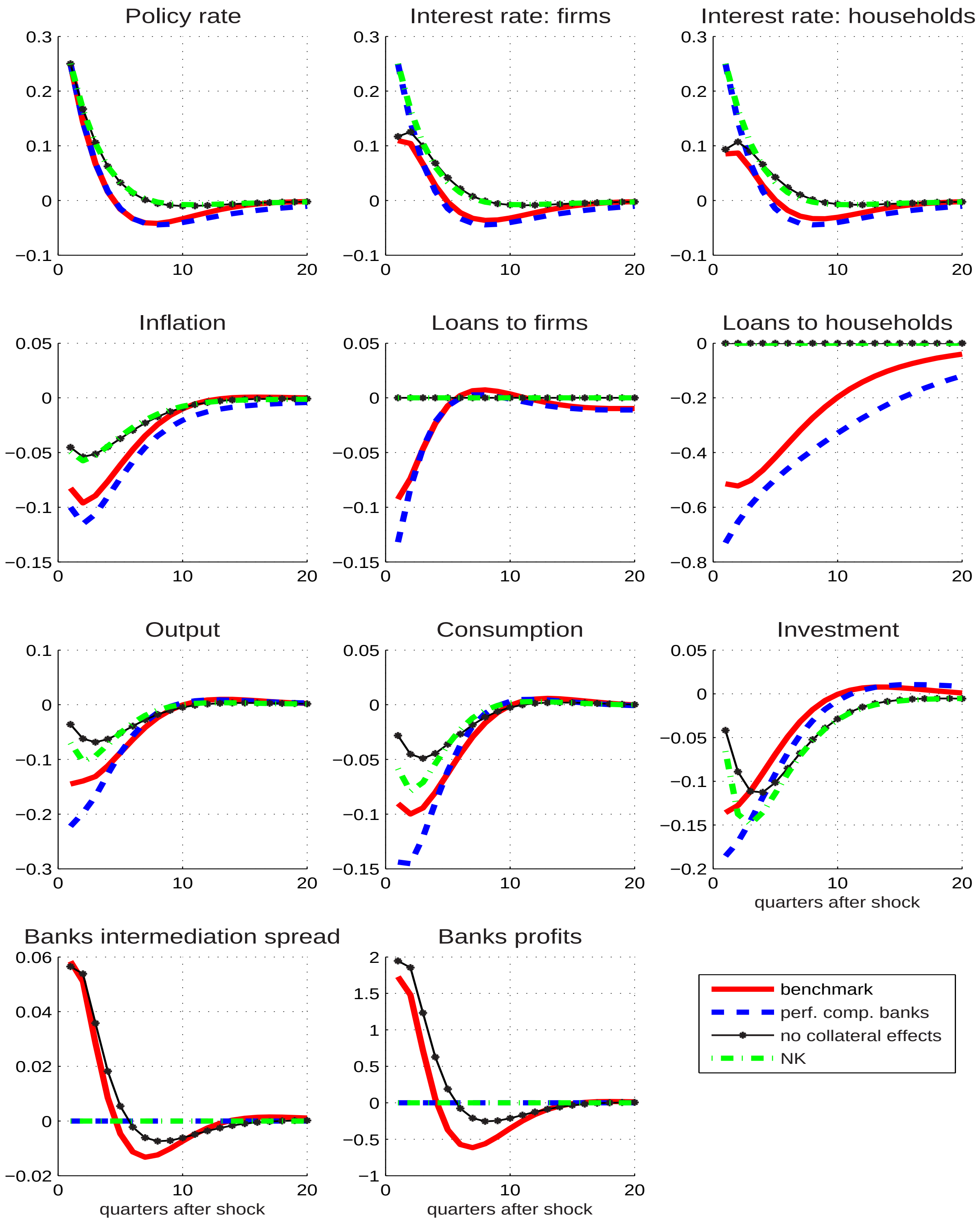

Figure 3: The role of banks and financial frictions after a monetary policy shock. The red solid line is the benchmark model. The blue dashed line is from a model with perfectly competitive banks but with collateral effects. The black starred line is from a model without collateral effects but with monopolistic banks. The green dash-dotted line is from a model without both.

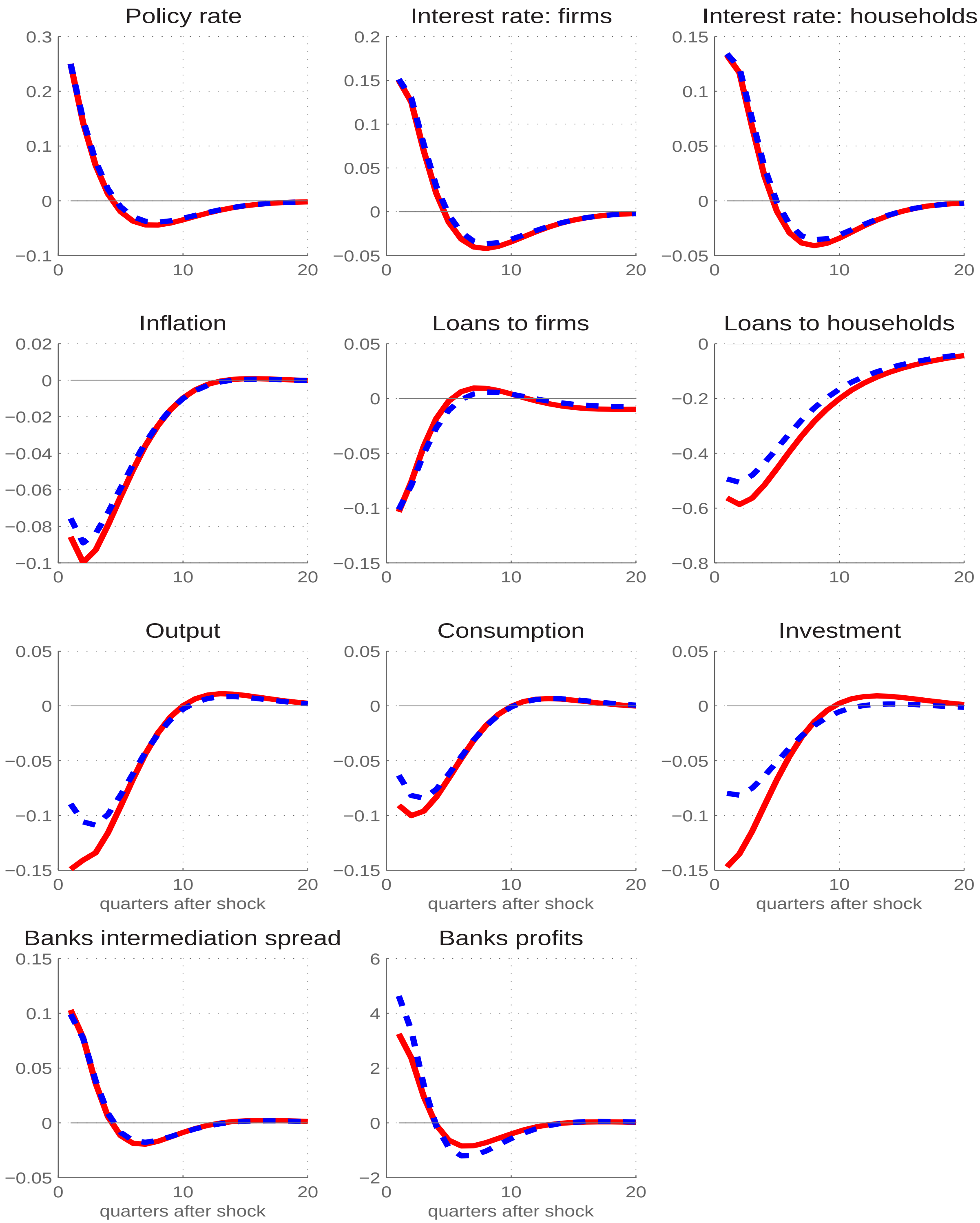

Figure 4: The effects of halfening entrepreneurs' loan-to-value ratio m^E (dashed blue line) against benchmark (red solid line). Interest rates and banks spreads are shown as absolute deviations from steady state (expressed in percentage points). All others are percentage deviations from steady state.

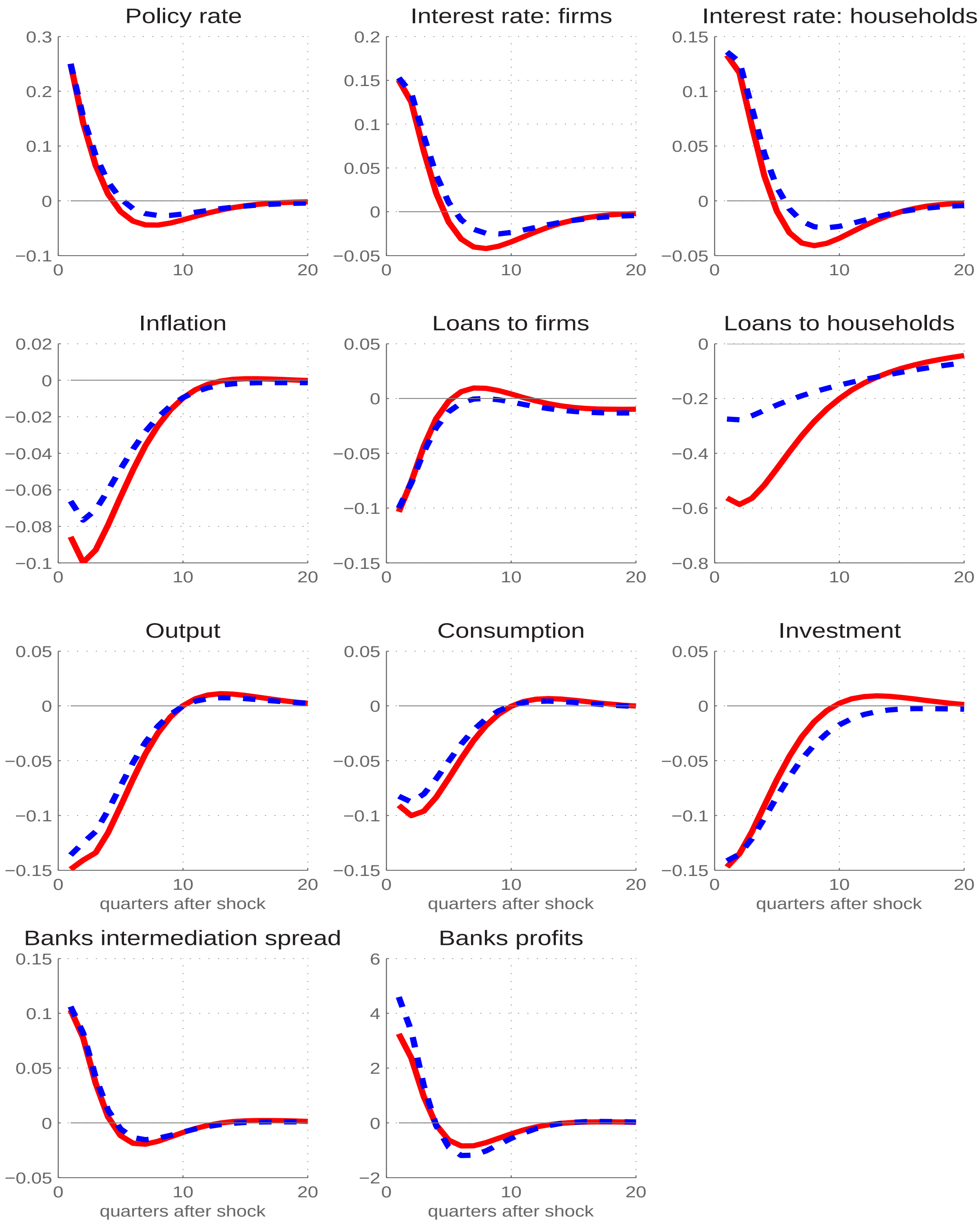

Figure 5: The effects of halfening households' loan-to-value ratio m^I (dashed blue line) against benchmark (red solid line). Interest rates and banks spreads are shown as absolute deviations from steady state (expressed in percentage points). All others are percentage deviations from steady state.

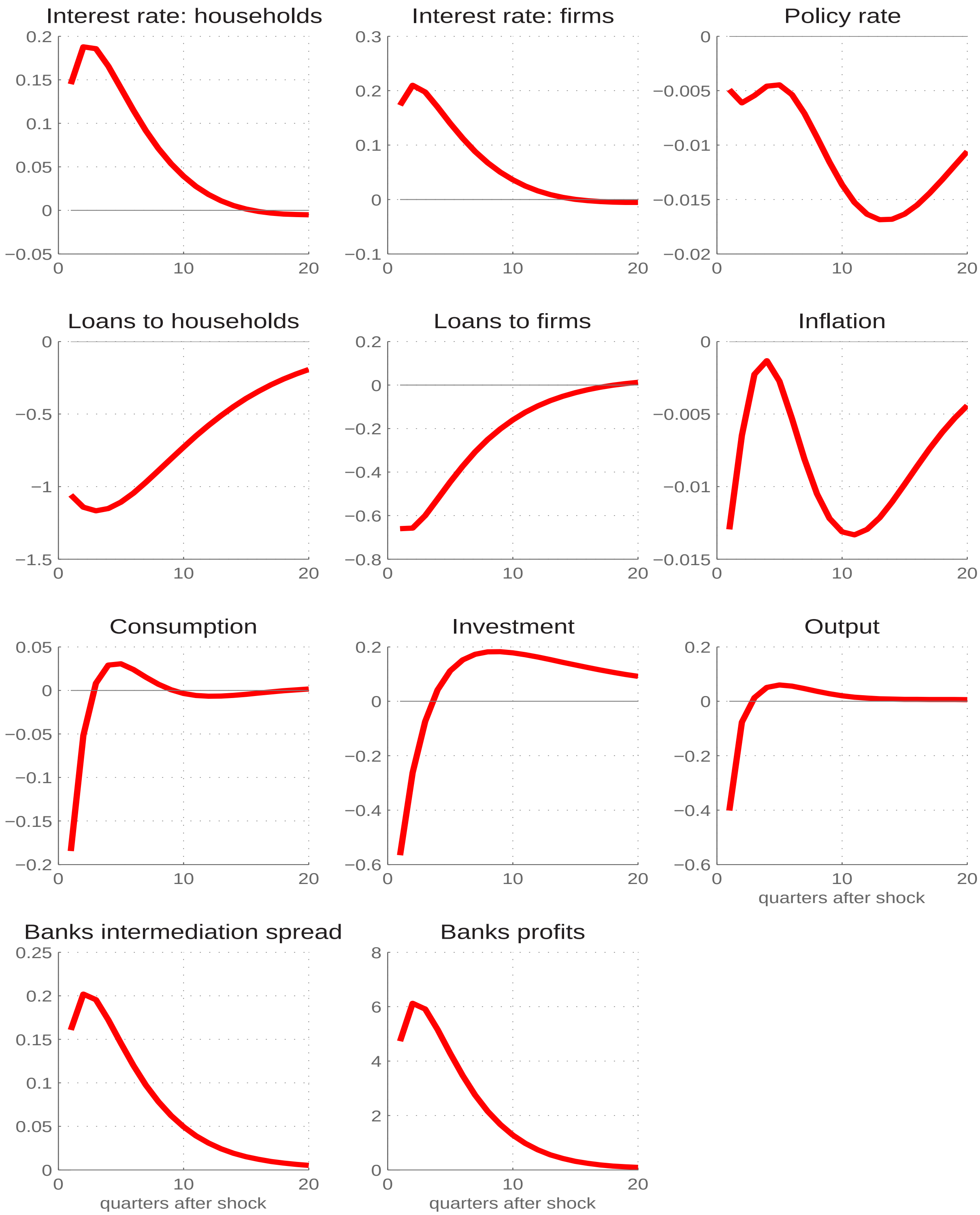

Figure 6: A credit crunch. Interest rates and banks spreads are shown as absolute deviations from steady state (expressed in percentage points). All others are percentage deviations from steady state.