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Credit and Banking in a DSGE Model of the Euro Area

This paper studies the role of credit supply factors in business cycle fluctuations using a dynamic stochastic general equilibrium (DSGE) model with financial frictions enriched with an imperfectly competitive banking sector. Banks issue collateralized loans to both households and firms, obtain funding via deposits, and accumulate capital out of retained earnings. Loan margins depend on the banks' capital-to-assets ratio and on the degree of interest rate stickiness. Balance-sheet constraints establish a link between the business cycle, which affects bank profits and thus capital, and the supply and cost of loans. The model is estimated with Bayesian techniques using data for the euro area. The analysis delivers the following results. First, the banking sector and, in particular, sticky rates attenuate the effects of monetary policy shocks, while financial intermediation increases the propagation of supply shocks. Second, shocks originating in the banking sector explain the largest share of the contraction of economic activity in 2008, while macroeconomic shocks played a limited role. Third, an unexpected destruction of bank capital may have substantial effects on the economy.

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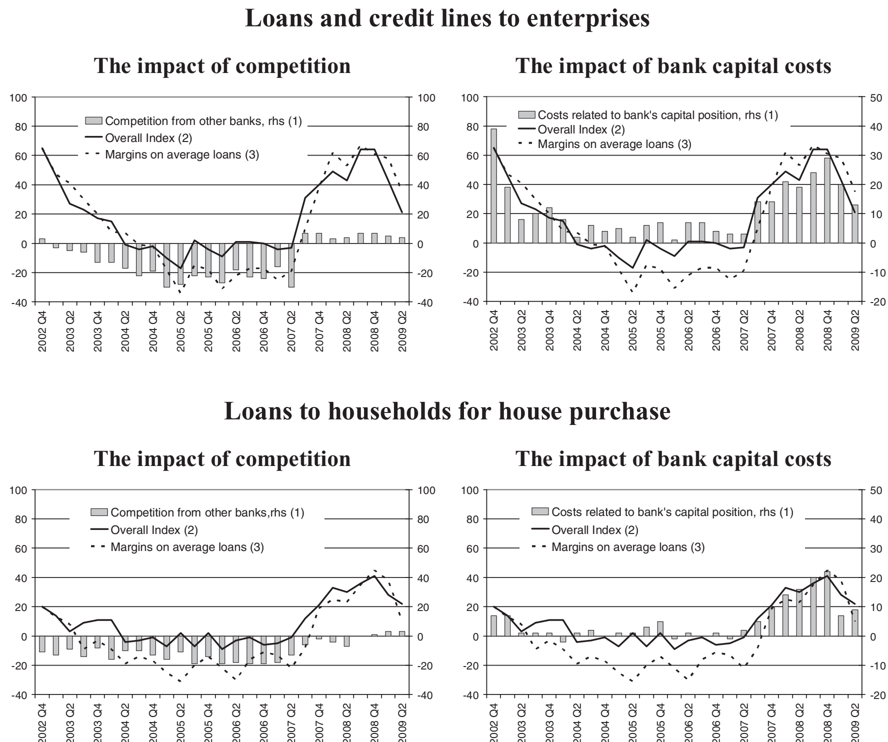
THIS PAPER SEEKS TO understand the role of financial frictions and banking intermediation in shaping the business cycle in the euro area. To this end, we set up and estimate a dynamic general equilibrium model incorporating a banking sector characterized by monopolistic competition where intermediaries accumulate capital subject to a capital adequacy requirement. We use the model to: (i) investigate how the transmission mechanisms of monetary and technology impulses are modified by the introduction of banking, (ii) study how shocks that destroy bank capital are transmitted to the real economy, and (iii) quantify the contribution of financial shocks to the 2008 slowdown in economic activity.

The financial crisis that started in 2007 has shown that the interaction between financial and credit markets and the rest of the economy is crucial for explaining macroeconomic fluctuations. While policymakers have traditionally highlighted the importance of these interactions, until recently most quantitative models used in academia as well as policy institutions either abstracted from them or approached the problem emphasizing only the *demand* side of credit: credit spreads in those models generally only reflect the riskiness of borrowers, while perfectly competitive banks accommodate the changing conditions on the demand side (e.g., Bernanke, Gertler, and Gilchrist 1999).

Conditions from the *supply* side of credit markets—such as the degree of competition in the banking sector, or banks' rate-setting strategies and financial soundness—are, instead, at least as important. Figure 1 reports evidence from the Bank Lending Survey of the Eurosystem suggesting how the interest rate margin on the average loan is affected by supply factors such as the degree of competition and the costs related to banks' capital position (in particular, since the onset of the financial crisis). We focus on banks as they represent by far the main funding source for households and firms in the euro area.

In modeling credit supply, we add a stylized banking sector to a model with credit frictions and borrowing constraints *à la* Iacoviello (2005). Banks have three distinctive features. *First*, they enjoy some degree of market power in loan and deposit markets and set different rates for households and firms. We do not try to pinpoint the source of market power, which the theoretical literature has typically linked to asymmetric information problems, long-term customer relationships, or the presence of switching costs; instead, we calibrate the average elasticities of loan and deposit demands to reproduce the degree of market power observed in the euro area. *Second*, banks face costs of adjusting retail rates and the pass-through on loan and deposit rates of changes in the policy rate is incomplete on impact. This is an important ingredient if the model is to capture the different speeds at which banks' rates react to changes in monetary conditions: the empirical evidence in favor of a partial and heterogenous adjustment of bank rates in the euro area is, indeed, overwhelming.



(1) Net percentage of banks reporting the factor as contributing to tightening of lending standards.
(2) Net percentage of banks reporting an overall tightening in lending standards.
(3) Net percentage of banks reporting to have increased margin.

FIG. 1. Bank Lending Survey of the Euro Area (Net Percentages).

NOTE: The figure reproduces, separately for entrepreneurs' and households' loans, the behavior of an indicator of credit tightness (i.e., the net percentage of responding banks indicating a tightening in lending standards in any given quarter), an indicator of interest rate margins (as reported by the responding banks), and indicators of the impact of, respectively, competitive pressure (left panels) and costs related to banks' capital position (right panels) on lending standards.

Third, banks accumulate capital out of retained earnings and aim at keeping their capital-to-assets ratio as close as possible to an exogenous target level. Banks' capital position affects the amount and price of loans, introducing a feedback loop between the real and the financial side of the economy.

These modeling choices allow us to introduce shocks that originate on the *supply* side of credit and to study their propagation to the real economy. In particular, we introduce shocks to the interest rate spreads charged on loans to households, loans to firms, and deposits that are meant to capture, for example, fluctuations in the price and amount of risk that could affect credit market spreads but are not explicitly accounted for in the model. We also introduce shocks to loan-to-value (LTV) ratios that are interpreted as disturbances that affect credit availability. Finally, we introduce a shock to bank capital to study the effects of a drastic weakening in the balance sheet of banks.

The model is estimated with Bayesian techniques using data for the euro area over the period 1998Q1–2009Q1. Three results emerge. *First*, banking attenuates the response of output to a monetary policy shock; this mainly reflects the presence of sticky bank rates, which moderate the impact of changes in the policy rate on both consumption and investment. Financial intermediation induces some attenuation on output after a technology shock too, due to the presence of monopolistic power; in this case, however, banking also enhances the endogenous propagation mechanism of the model. *Second*, we estimate that the largest contribution to the contraction of euro area economic activity in 2008 has come from shocks originating in the banking sector, that is, factors that either pushed up the cost of loans or reduced the amount of credit available to the private sector. *Finally*, we find that a credit crunch induced by an unexpected and persistent destruction of bank capital has substantial negative effects on real activity. The sudden fall in bank capital triggers an increase of lending margins and a contraction of credit volumes, as a consequence of banks' need to deleverage. The restriction on credit supply severely affects firms' investment; aggregate consumption is also hit, despite a temporary improvement in labor income.

Recently, a number of papers have developed models with financial intermediaries and a time-varying spread between deposits and lending rates (e.g., Goodfriend and McCallum 2007, Andrés and Arce 2008, Christiano, Motto, and Rostagno 2008, Cúrdia and Woodford 2009, Gilchrist, Ortiz, and Zakrajsek 2009). Other authors have studied the role of equity and bank capital for the transmission of macroeconomic shocks (de Walque, Pierrard, and Rouabah 2008, van den Heuvel 2008, Meh and Moran 2010). Our contribution is to combine the main insights from these strands of literature in a setting featuring stickiness in bank rates and to estimate the resulting model to assess its quantitative implications. Our analysis admittedly omits some elements of the 2007–08 financial crisis (e.g., the increase in risk in financial markets and the freezing up of money markets). However, we think it constitutes an important step in the direction of quantifying the effects of credit sector shocks on the business cycle.

The rest of the paper is organized as follows. Section 1 reviews theoretical arguments and empirical evidence supporting our key modeling choices. Section 2 describes the model. Section 3 presents the results of the estimation. Section 4 studies the propagation of shocks. Section 5 quantifies the role of financial shocks in the 2008 downturn of economic activity in the euro area and studies the effects of a credit crunch on the economy. Section 6 concludes.

1. MARKET POWER AND SLUGGISH RATES IN BANKING

In this section, we discuss the key modeling assumptions concerning the banking sector, namely, the presence of monopolistic power in the deposit and loan markets and the sticky adjustment of bank rates to movements in the corresponding market rates, reviewing both theoretical and empirical arguments in their support.

As regards *monopolistic competition*, microeconomic theory typically considers market power as a distinctive feature of the banking sector (Freixas and Rochet 1997). One often-cited reason is the presence of switching costs, for both customers and lenders, which generate a "lock-in" effect that gives banks market power. Switching costs might be the result of asymmetric information which typically leads to long-term relationships between banks and borrowers (see, e.g., Diamond 1984, Greenbaum, Kanatas, and Venezia 1989, Sharpe 1990); they could also arise due to the presence of pure "menu costs," like technical fees charged to close or to open a bank account, or fees incurred into when applying for a loan or renegotiating the terms of an outstanding debt (see, among others, Kim, Kliger, and Vale 2003, Von Thadden 2004). Another frequently cited source of bank rents is market structure. The traditional *structure-conduct-performance* approach links market concentration to market power and interest-rate-setting behavior (Berger et al. 2004); other approaches highlight the importance of market contestability and regulatory restrictions as a source of market power (Demirguc-Kunt, Laeven, and Levine 2004). Empirically, the presence of market power in the banking sector, as well as its determinants over the business cycle, are well documented. Berger et al. (2004) and Degryse and Ongena (2008) provide extensive surveys and conclude that the degree of competition does indeed influence interest rate spreads and banks' profitability.[1]

In the model, the measure of banks' market power is the interest rate elasticity of deposit and loan demand. We calibrate these elasticities at 1.5 for deposits and at about -3.0 for loans so that the steady state spreads in the model between the loan and the policy rate and between the policy and the deposit rate equal the average corresponding spreads in our sample (respectively, 1.7% and 1.2% on annual basis).[2]

The second unconventional assumption about the banking sector, namely, that interest rates are *sticky*, is also supported by theoretical and empirical findings. From a theoretical point of view, infrequent adjustment of bank rates may be optimal if customers' demand is inelastic in the short run due to switching costs (Calem, Gordy, and Mester 2006), if there are menu costs of adjusting rates (Berger and Hannan 1991) or if the importance of preserving customer relationships leads banks to smooth rates over the business cycle to shield borrowers from market rate fluctuations (Berger and Udell 1992). From an empirical standpoint, the evidence in favor of bank rate stickiness is overwhelming and does not seem to come solely from bankers' practice of indexing bank rates to market rates. For example, Kok Sørensen and Werner (2006) study the interest rate pass-through for various types of loans and deposits in euro

1. Among the paper included in the surveys, Claessens and Laeven (2004), using bank-level data for 50 countries for the period 1994–2001, show that most banking markets can be classified as monopolistically competitive. For the euro area, see De Bandt and Davis (2000).

2. These numbers are in line with the empirical evidence. On interest rate demand elasticities, see Dick (2002) for the United States and Neven and Röller (1999) for European countries; on loan-deposit margins in European countries, see Claeys and Van der Vennet (2008).

area countries and find that, even where the speed of adjustment is the highest, only 23% of the disequilibrium is adjusted in just one period.

We introduce sticky rates by assuming that banks face quadratic costs for adjusting retail rates. This assumption is a modeling shortcut and as such begs the question of its microfoundations. However, it captures a stylized fact in a tractable way, similarly to the assumption of costly price adjustment in goods markets, which has now become standard in New Keynesian models. In addition, we estimate the parameters pinning down the degree of stickiness for differentiated loans and deposits (see Section 3), thus letting the data tell us whether this is a reasonable assumption or not.[3] Our estimates suggest an incomplete short-run pass-through of policy rates to retail rates.

2. THE MODEL ECONOMY

The economy is populated by two groups of households (patient P and impatient I) and by entrepreneurs (E), each group having unit mass. Households consume, work, and accumulate housing (in fixed supply), while entrepreneurs produce homogenous intermediate goods using capital, bought from capital-good producers, and hired labor. One key difference among agent types is the degree of impatience: the discount factor of patient households (β_P) is higher than those of impatient households (β_I) and entrepreneurs (β_E).

Two types of one-period financial instruments, supplied by banks, are available: saving contracts (deposits) and borrowing contracts (loans). When taking out a bank loan, agents face a borrowing constraint, tied to the value of tomorrow's collateral holdings: households can borrow against the value of their stock of housing, while entrepreneurs against 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 households and entrepreneurs borrow a positive amount of loans. The banking sector is monopolistically competitive: banks set interest rates on deposits and on loans so as to maximize profits. The amount of loans issued by each intermediary can be financed through deposits and bank capital, which is accumulated out of profits.

On the production side, workers supply their differentiated labor services through unions, which set wages to maximize members' utility subject to adjustment costs. In addition to entrepreneurs, there are two other producing sectors: a monopolistically competitive retail sector and a capital goods producing sector. Retailers buy intermediate goods from entrepreneurs in a competitive market, differentiate and price them subject to nominal rigidities. Capital goods producers are introduced so to derive a market price for capital.

3. The estimated stickiness does not reflect compositional issues or the choice of a particular bank rate. As data refer to new-business coverage, they do *not* embed sluggishness by construction, as it would have been the case if we had used rates on outstanding amounts that are influenced by rates set in the past.

2.1 Patient Households

The representative patient household i maximizes the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1 - a^P)\varepsilon_t^z \log\left(c_t^P(i) - a^P c_{t-1}^P\right) + \varepsilon_t^h \log h_t^P(i) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right],$$

which depends on current individual (and lagged aggregate) consumption c_t^P, housing h_t^P, and hours worked l_t^P. There are external and group-specific habits in consumption; premultiplication by one minus the habit coefficient a^P offsets their impact on the steady-state marginal utility of consumption. Labor disutility is parameterized by ϕ. Preferences are subject to two disturbances: one affecting consumption (ε_t^z) and one housing demand (ε_t^h).[4] Household's choices must obey to the following budget constraint (in real terms)

$$c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) \leq w_t^P l_t^P(i) + \left(1 + r_{t-1}^d\right) d_{t-1}^P(i)/\pi_t + t_t^P(i). \quad (1)$$

The flow of expenses includes current consumption, accumulation of housing (with real house price q_t^h), and real deposits to be made in the period d_t^P. Resources consist of wage earnings $w_t^P l_t^P$ (where w_t^P is the real wage rate for the labor input of each patient household), gross interest income on last period deposits $(1 + r_{t-1}^d)d_{t-1}^P/\pi_t$ (where $\pi_t \equiv P_t/P_{t-1}$ is gross inflation), and lump-sum transfers t_t^P that include a labor union membership net fee and dividends from firms and banks (of which patient households are the only owners).

2.2 Impatient Households

The representative impatient household i maximizes the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_I^t \left[(1 - a^I)\varepsilon_t^z \log\left(c_t^I(i) - a^I c_{t-1}^I\right) + \varepsilon_t^h \log h_t^I(i) - \frac{l_t^I(i)^{1+\phi}}{1+\phi} \right],$$

which depends on consumption c_t^I, housing services h_t^I, and hours worked l_t^I. The parameter a^I measures consumption habits; ε_t^h and ε_t^z are the same shocks that affect the utility of patient households. Household decisions have to match the budget constraint

$$c_t^I(i) + q_t^h \Delta h_t^I(i) + \left(1 + r_{t-1}^{bH}\right) b_{t-1}^I(i)/\pi_t \leq w_t^I l_t^I(i) + b_t^I(i) + t_t^I(i),$$

in which resources spent for consumption, housing, and gross reimbursement of borrowing b_{t-1}^I (with a net interest rate of r_{t-1}^{bH}) have to be financed with labor income

4. With the exception of a noise shock for monetary policy, we assume that any generic shock ε_t in the model follows a stochastic AR(1) process of the type $\varepsilon_t = (1 - \rho_\varepsilon)\bar{\varepsilon} + \rho_\varepsilon \varepsilon_{t-1} + \eta_t^\varepsilon$, where ρ_ε is the autoregressive coefficient, $\bar{\varepsilon}$ is the steady-state value, and η_t^ε follows a normal i.i.d. process with zero mean and standard deviation σ_ε.

(w_t^I is the wage of impatient households) and new loans b_t^I (t_t^I only includes net union fees).

In addition, impatient households face a borrowing constraint: the expected value of their housing stock must guarantee repayment of debt and interests,

$$\left(1 + r_t^{bH}\right) b_t^I(i) \leq m_t^I E_t \left[q_{t+1}^h h_t^I(i) \pi_{t+1}\right] \tag{2}$$

where m_t^I is the (stochastic) LTV ratio for mortgages. From a microeconomic point of view, (1-m_t^I) can be interpreted as the proportional cost of collateral repossession for banks in case of default. At a macro level, the value of m_t^I determines the amount of credit that banks can provide to households, for a given (discounted) value of their housing stock. We assume that LTV ratios follow exogenous stochastic processes.

2.3 *Entrepreneurs*

Each entrepreneur i only cares about deviations of his own consumption $c_t^E(i)$ from aggregate lagged group habits (parameterized by a^E) and maximizes the utility function

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

by choosing consumption, physical capital k_t^E, loans from banks b_t^E, the degree of capacity utilization u_t, and the labor inputs $l_t^{E,P}$ and $l_t^{E,I}$, for patient and impatient households, respectively. His decisions are subject to the budget constraint

$$c_t^E(i) + w_t^P l_t^{E,P}(i) + w_t^I l_t^{E,I}(i) + \frac{1 + r_{t-1}^{bE}}{\pi_t} b_{t-1}^E(i) + q_t^k k_t^E(i) + \psi(u_t(i)) k_{t-1}^E(i)$$
$$= \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta) k_{t-1}^E(i)$$

where δ is the depreciation rate of capital, q_t^k is the price of capital in terms of consumption, $\psi(u_t)k_{t-1}^E$ is the real cost of setting a level u_t of utilization rate and $P_t^W/P_t = 1/x_t$ is the relative competitive price of the wholesale good y_t^E produced according to the technology

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

with a_t^E being stochastic total factor productivity. Aggregate labor l_t^E combines inputs from patient and impatient households according to $l_t^E = (l_t^{E,P})^{\mu}(l_t^{E,I})^{1-\mu}$, where μ measures the labor income share of patient households (see Iacoviello and Neri 2010).

The amount of resources that banks are willing to lend to entrepreneurs is constrained by the value of the collateral, which is given by entrepreneurs' holdings of capital. This assumption, which differs from Iacoviello (2005) where entrepreneurs borrow against housing (commercial real estate), seems a more realistic choice, as overall balance-sheet conditions give the soundness and creditworthiness of a firm. The borrowing constraint is thus

$$\left(1 + r_t^{bE}\right) b_t^E(i) \leq m_t^E \mathrm{E}_t\left[q_{t+1}^k \pi_{t+1} (1-\delta) k_t^E(i)\right], \tag{3}$$

where m_t^E is the stochastic LTV ratio for type *E*. Our assumption on discount factors is such that, absent uncertainty, households' and entrepreneurs' borrowing constraints would bind in a neighborhood of the steady state. As in Iacoviello (2005), we take the size of the shocks to be "sufficiently small" so that these constraints always bind in that neighborhood.

2.4 *Loan and Deposit Demand*

We model market power in the banking industry assuming a Dixit–Stiglitz framework for the retail credit and deposit markets.[5] In particular, we assume that units of loan and deposit contracts bought by households and entrepreneurs are a composite constant elasticity of substitution basket of slightly differentiated financial products—each supplied by a branch of a bank *j*—with elasticity terms equal to $\varepsilon_t^{bH}\ (>1)$, $\varepsilon_t^{bE}\ (>1)$, and $\varepsilon_t^d\ (<-1)$, respectively. These terms will be a major determinant of spreads between bank rates and the policy rate. We introduce an exogenous component in credit market spreads by assuming that each of these elasticity terms is stochastic. Innovations to interest rate elasticities of loans and deposits can be interpreted as innovations to bank spreads arising independently of monetary policy.

Demand by household *i* seeking an amount of real loans equal to $\bar{b}_t^I(i)$ can be derived from minimizing over $b_t^I(i, j)$ the total repayment due to the continuum of banks j, $\int_0^1 r_t^{bH}(j) b_t^I(i, j)\, dj$, subject to $[\int_0^1 b_t^I(i, j)^{(\varepsilon_t^{bH}-1)/\varepsilon_t^{bH}} dj]^{\varepsilon_t^{bH}/(\varepsilon_t^{bH}-1)} \geq \bar{b}_t^I(i)$. Aggregating over symmetric households, aggregate demand for loans at bank *j* by impatient households, $b_t^I(j)$, turns out to depend on the overall volume of loans to households b_t^I and on the interest rate charged on loans to households by bank *j* relative to the rate index for that kind of loans $r_t^{bH} = [\int_0^1 r_t^{bH}(j)^{1-\varepsilon_t^{bH}}\, dj]^{\frac{1}{1-\varepsilon_t^{bH}}}$. Applying the same reasoning to loans to entrepreneurs results in the following demand schedules:

$$b_t^I(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^I \qquad\qquad b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_t^{bE}}\right)^{-\varepsilon_t^{bE}} b_t^E. \tag{4}$$

Demand for deposits of patient household *i*, seeking an overall amount of real savings $\bar{d}_t^P(i)$, is obtained by maximizing over $d_t^P(i, j)$ the revenue of total savings, $\int_0^1 r_t^d(j)\, d_t^P(i, j)\, dj$, subject to $[\int_0^1 d_t^P(i, j)^{(\varepsilon_t^d-1)/\varepsilon_t^d} dj]^{\varepsilon_t^d/(\varepsilon_t^d-1)} \leq \bar{d}_t^P(i)$. Combining first-order conditions, aggregate households' demand for deposits at bank j, $d_t^P(j)$,

5. Benes and Lees (2007) take a similar shortcut. In Andrés and Arce (2008), imperfectly competitive banks are finite in number and customers buy a bank service at a higher cost the farther they are from that bank.

is given by

$$d_t^P(j) = \left(\frac{r_t^d(j)}{r_t^d}\right)^{-\varepsilon_t^d} d_t, \tag{5}$$

where d_t are the aggregate deposits in the economy and $r_t^d = [\int_0^1 r_t^d(j)^{1-\varepsilon_t^d}\, dj]^{\frac{1}{1-\varepsilon_t^d}}$ is the deposit rate index.

2.5 *The Labor Market*

We assume that workers provide differentiated labor types, sold by unions to perfectly competitive labor packers who assemble them in a CES aggregator with stochastic parameter ε_t^l and sell the homogeneous labor to entrepreneurs. For each labor type m there are two unions, one for patient households and one for impatient households (indexed by s). Each union (s, m) sets nominal wages $W_t^s(m)$ for its members by maximizing their utility subject to a downward sloping demand and to quadratic adjustment costs (parameterized by κ_w), with indexation to a weighted average of lagged (weight ι_w) and steady-state inflation (weight $1 - \iota_w$). The union, which charges each member household lump-sum fees to cover adjustment costs, maximizes

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left\{ U_{c_t^s(i,m)} \left[\frac{W_t^s(m)}{P_t} l_t^s(i,m) - \frac{\kappa_w}{2} \left(\frac{W_t^s(m)}{W_{t-1}^s(m)} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right)^2 \frac{W_t^s}{P_t} \right] - \frac{l_t^s(i,m)^{1+\phi}}{1+\phi} \right\}$$

subject to demand from labor packers $l_t^s(i,m) = l_t^s(m) = (\frac{W_t^s(m)}{W_t^s})^{-\varepsilon_t^l} l_t^s$. In a symmetric equilibrium, labor supply for a household of type s is given by

$$\kappa_w \left(\pi_t^{w^s} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \pi_t^{w^s} = \beta_s E_t \left[\frac{\lambda_{t+1}^s}{\lambda_t^s} \kappa_w \left(\pi_{t+1}^{w^s} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^s\,2}}{\pi_{t+1}} \right] + \left(1 - \varepsilon_t^l\right) l_t^s + \frac{\varepsilon_t^l l_t^{s\,1+\phi}}{\omega^s{}_t \lambda_t^s},$$

where, for each type, ω_t^s is the real wage and $\pi_t^{w^s}$ is the nominal wage inflation.

2.6 *Banks*

Banks enjoy market power in conducting their intermediation activity, which allows them to adjust rates on loans and deposits in response to shocks or to the cyclical conditions of the economy, and have to obey a balance-sheet identity of the form *loans* $=$ *deposits* $+$ *capital*.[6] Bank capital is almost fixed in the short run; it is adjusted

6. When estimating the model, we add a shock ε_t^{kb} to liabilities to avoid near stochastic singularity.

only slowly through accumulation of retained earnings.[7] Furthermore, we assume that banks have an "optimal" exogenous target for their capital-to-assets ratio (i.e., the inverse of leverage), deviations from which imply a quadratic cost. The optimal leverage ratio in this context can be thought of as capturing the trade-offs that would arise in the decision of how much own resources to hold, or alternatively as a simple shortcut for studying the implications and costs of regulatory capital requirements. Given these assumptions, bank capital will have a key role in determining credit supply, since it potentially generates a feedback loop between the real and the financial side of the economy. As macroeconomic conditions deteriorate, banks profits and capital might be negatively hit; depending on the nature of the shock hitting the economy, banks might respond to the ensuing weakening of their financial position by reducing lending, hence exacerbating the original contraction. The model might thus potentially account for the type of "credit cycle" observed in the 2008 recession, with a weakening real economy, a reduction of bank profits and capital and the ensuing credit restriction.

Modeling banks' leverage position and interest rate setting subject to collateral requirements allows us to introduce a number of shocks that originate from the *supply side of credit* and to study their effects on the real economy. In particular, we introduce shocks to the LTV ratios that capture an exogenous decrease in loans availability and shocks to the demand elasticities for loans and deposits that might be used to simulate an exogenous increase in loan and deposit rates.[8] In Section 5.2, we will also introduce a shock to bank capital to simulate an unexpected destruction of bank equity.

To highlight more clearly the distinctive features of the banking sector and to facilitate exposition, we can think of each bank $j \in [0, 1]$ in the model as actually composed of two "retail" branches and one "wholesale" unit. The first retail branch is responsible for giving out differentiated loans to households and to entrepreneurs; the second for raising differentiated deposits. These branches set rates in a monopolistically competitive fashion, subject to adjustment costs. The wholesale unit manages the capital position of the group.[9]

Wholesale branch. Each wholesale branch operates under perfect competition: on the liability side, it combines net worth, or bank capital (K_t^b), and wholesale deposits (D_t), while on the asset side, it issues wholesale loans (B_t) (all in real terms). We impose a cost on this wholesale activity, related to the capital position of the bank. In particular, the bank pays a quadratic cost (parameterized by a coefficient κ_{Kb} and

7. In the benchmark calibration, all the profits are retained and used to accumulate bank capital (zero-dividend policy). Assuming positive dividends does not change the properties of the model.

8. See Cúrdia and Woodford (2009) for similar interpretations of "financial" shocks that affect bank rates.

9. An alternative setup where the two retail branches are not distinct would produce identical results. However, the role of bank capital in the market for loanable funds is best outlined by keeping the wholesale unit separated from the retail branches (see equation (6) below).

proportional to outstanding bank capital) whenever the capital-to-assets ratio K_t^b/B_t moves away from the target value ν^b.

Bank capital is accumulated out of retained earnings:

$$\pi_t K_t^b = (1-\delta^b)K_{t-1}^b + j_{t-1}^b,$$

where j_t^b are overall real profits made by the three branches of each bank, and δ^b measures resources used up in managing bank capital. The problem for the wholesale bank is to choose loans and deposits so to maximize the discounted sum of (real) cash flows:

$$\max_{\{B_t, D_t\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \Bigg[\left(1+R_t^b\right) B_t - B_{t+1}\pi_{t+1} + D_{t+1}\pi_{t+1} - \left(1+R_t^d\right) D_t + \left(K_{t+1}^b \pi_{t+1} - K_t^b\right) - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b \Bigg]$$

subject to the balance-sheet constraint $\left(B_t = D_t + K_t^b\right)$ and taking R_t^b (the net wholesale loan rate) and R_t^d (the net wholesale deposit rate) as given.[10] Using the constraint twice (at date t and $t+1$), the objective boils down to

$$\max_{\{B_t, D_t\}} R_t^b B_t - R_t^d D_t - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - \nu^b\right)^2 K_t^b.$$

The first-order conditions deliver a condition linking the spread between wholesale rates on loans and on deposits to the degree of leverage B_t/K_t^b, that is,

$$R_t^b = R_t^d - \kappa_{Kb}\left(\frac{K_t^b}{B_t} - \nu^b\right)\left(\frac{K_t^b}{B_t}\right)^2 .$$

To close the model, we assume that banks have access to unlimited finance at the policy rate r_t from a lending facility at the central bank; hence, by arbitrage the wholesale deposit rate is equal to the policy rate ($R_t^d = r_t$) and the above equation becomes

$$S_t^W \equiv R_t^b - r_t = -\kappa_{Kb}\left(\frac{K_t^b}{B_t} - \nu^b\right)\left(\frac{K_t^b}{B_t}\right)^2, \tag{6}$$

where S_t^W is the spread prevailing at the wholesale level. The left-hand side of the equation represents the marginal benefit from increasing lending (an increase in profits equal to the spread); the right-hand side is the marginal cost from doing so (an increase in the costs for deviating from ν^b). Therefore, banks choose a level of loans that at the margin equalizes costs and benefits of reducing the capital-to-assets ratio.

10. Since banks are owned by patient households, they value future profits using the discount factor $\Lambda_{0,t}^P$.

Retail banking. Retail banks are monopolistic competitors on both the loan and the deposit markets.

Loan Branch. The retail loan branch of bank j obtains wholesale loans $B_t(j)$, in real terms, from the wholesale unit at rate R_t^b, differentiates them at no cost and resells them to households and firms applying two different markups. In doing so, each retail bank faces quadratic adjustment costs for changing over time the rates it charges on loans; these costs are parameterized by κ_{bE} and κ_{bH} and are proportional to aggregate returns on loans. Retail loan bank j maximizes, over $\{r_t^{bH}(j), r_t^{bE}(j)\}$, the objective

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t^{bH}(j) b_t^I(j) + r_t^{bE}(j) b_t^E(j) - R_t^b B_t(j) \right.$$
$$\left. - \frac{\kappa_{bH}}{2} \left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1 \right)^2 r_t^{bH} b_t^I - \frac{\kappa_{bE}}{2} \left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1 \right)^2 r_t^{bE} b_t^E \right]$$

subject to demands (4) and with $B_t(j) = b_t(j) = b_t^I(j) + b_t^E(j)$. First-order conditions for interest rates to households and firms (indexed by s) yield (after imposing a symmetric equilibrium)

$$1 - \varepsilon_t^{bs} + \varepsilon_t^{bs} \frac{R_t^b}{r_t^{bs}} - \kappa_{bs} \left(\frac{r_t^{bs}}{r_{t-1}^{bs}} - 1 \right) \frac{r_t^{bs}}{r_{t-1}^{bs}}$$
$$+ \beta_P E_t \left\{ \frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_{bs} \left(\frac{r_{t+1}^{bs}}{r_t^{bs}} - 1 \right) \left(\frac{r_{t+1}^{bs}}{r_t^{bs}} \right)^2 \frac{b_{t+1}^s}{b_t^s} \right\} = 0\,, \tag{7}$$

where λ_t^P is the multiplier on the budget constraint (1). The log-linearized version of (7) is

$$\hat{r}_t^{bs} = \frac{\kappa_{bs} \hat{r}_{t-1}^{bs}}{\varepsilon^{bs} - 1 + (1 + \beta_P)\kappa_{bs}} + \frac{\beta_P \kappa_{bs} E_t \hat{r}_{t+1}^{bs}}{\varepsilon^{bs} - 1 + (1 + \beta_P)\kappa_{bs}}$$
$$+ \frac{\left(\varepsilon^{bs} - 1\right) \hat{R}_t^b}{\varepsilon^{bs} - 1 + (1 + \beta_P)\kappa_{bs}} - \frac{\hat{\varepsilon}_t^{bs}}{\varepsilon^{bs} - 1 + (1 + \beta_P)\kappa_{bs}}.$$

Solving forward, this equation highlights how loan rates are set based on current and expected future values of the shock to the markup and of the wholesale rate, the relevant measure of marginal cost for this type of bank, which in turn depends on the policy rate and the capital position of the bank, as highlighted in the previous section. The adjustment to changes in the wholesale rate depends inversely on the intensity of the adjustment costs κ_{bs} and positively on the steady-state degree of competition in the bank loans sector (measured by $1/\varepsilon^{bs}$). Under flexible rates, the spread between the loan and the policy rate is

$$S_t^{bs} \equiv r_t^{bs} - r_t = \frac{\varepsilon_t^{bs}}{\varepsilon_t^{bs} - 1} S_t^W + \frac{1}{\varepsilon_t^{bs} - 1} r_t,$$

which is obtained combining the flexible rate $r_t^{bs} = \frac{\varepsilon_t^{bs}}{\varepsilon_t^{bs}-1} R_t^b$ with the expression for S_t^W in (6). The spread on retail loans is thus increasing in the policy rate, and is proportional to the wholesale spread S_t^W, determined by the bank's capital position. In addition, the degree of monopolistic competition also plays a role; an increase in market power (i.e., a reduction in ε_t^{bs}) determines—*ceteris paribus*—a wider absolute spread.

Deposit Branch. Similarly, the retail deposit branch of bank j collects deposits $d_t^P(j)$ from households and passes the raised funds on to the wholesale unit, which remunerates them at rate r_t. The problem for the deposit branch is

$$\max_{\{r_t^d(j)\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t D_t(j) - r_t^d(j) d_t^P(j) - \frac{\kappa_d}{2} \left(\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right)^2 r_t^d d_t \right]$$

subject to demand (5) and with $D_t(j) = d_t^P(j)$. Quadratic adjustment costs for changing the deposit rate are parameterized by κ_d and are proportional to aggregate interest paid on deposits. After imposing symmetry, the first-order condition for deposit interest rate setting reads

$$\begin{aligned} &-1 + \varepsilon_t^d - \varepsilon_t^d \frac{r_t}{r_t^d} - \kappa_d \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right) \frac{r_t^d}{r_{t-1}^d} \\ &\quad + \beta_P E_t \left\{ \frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_d \left(\frac{r_{t+1}^d}{r_t^d} - 1 \right) \left(\frac{r_{t+1}^d}{r_t^d} \right)^2 \frac{d_{t+1}}{d_t} \right\} = 0 \end{aligned} \tag{8}$$

yielding a log-linearized version similar to that for loan rate setting. Solving forward one could see that banks set the deposit rate taking into account expected future levels of the policy rate. Adjustments to changes in the policy rate depend inversely on how important adjustment costs are (i.e., on κ_d) and positively on the steady-state degree of competition in banks fund raising (as measured by the inverse of ε^d). With fully flexible rates, r_t^d is just a markdown over the policy rate, that is, $r_t^d = \frac{\varepsilon_t^d}{\varepsilon_t^d - 1} r_t$.

Bank Profits. Overall bank profits are the sum of net earnings from the wholesale unit and the two retail branches. Deleting intragroup transactions yields (in real terms)

$$j_t^b = r_t^{bH} b_t^H + r_t^{bE} b_t^E - r_t^d d_t - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - \nu^b \right)^2 K_t^b - Adj_t^B, \tag{9}$$

where Adj_t^B indicates adjustment costs for changing interest rates on loans and deposits. Note that equation (9) implies that our definition of profits is a narrow one as it coincides (net of adjustment costs) with the interest rate margin and does not include other items of the income statement.

2.7 *Capital and Final Goods Producers*

Perfectly competitive firms buy last-period undepreciated capital $(1-\delta)k_{t-1}$ at price Q_t^k from entrepreneurs (owners of these firms) and i_t units of final goods from retailers at price P_t. With these inputs, firms' flow output $\Delta\bar{x}_t = k_t - (1-\delta)k_{t-1}$ increases the stock of effective capital $\bar{x}_t$, which is then sold back to entrepreneurs at the price Q_t^k. The transformation of the final good into new capital is subject to adjustment costs. Firms choose $\bar{x}_t$ and i_t so as to maximize $E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E (q_t^k \Delta\bar{x}_t - i_t)$ subject to $\bar{x}_t = \bar{x}_{t-1} + [1 - \frac{\kappa_i}{2}(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1)^2] i_t$ where κ_i denotes the cost for adjusting investment, ε_t^{qk} is a shock to the efficiency of investment, and $q_t^k \equiv \frac{Q_t^k}{P_t}$ is the real price of capital.

The retail goods market is assumed to be monopolistically competitive as in Bernanke, Gertler, and Gilchrist (1999). Retailers' prices are sticky and are indexed to a combination of past and steady-state inflation, with relative weights parameterized by ι_p; if retailers want to change their price beyond what indexation allows, they face a quadratic adjustment cost parameterized by κ_p. They choose $\{P_t(j)\}$ so as to maximize $E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P [P_t(j) y_t(j) - P_t^W y_t(j) - \frac{\kappa_p}{2}(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p})^2 P_t y_t]$, subject to the demand derived from consumers' maximization, $y_t(j) = (\frac{P_t(j)}{P_t})^{-\varepsilon_t^y} y_t$, where ε_t^y is the stochastic demand price elasticity.

2.8 *Monetary Policy and Market Clearing*

The central bank sets the policy rate r_t according to

$$(1+r_t) = (1+r)^{(1-\phi_R)} (1+r_{t-1})^{\phi_R} \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi (1-\phi_R)} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y (1-\phi_R)} \varepsilon_t^r,$$

where ϕ_π is the weight assigned to inflation and ϕ_y to output growth, r is the steady-state policy rate, and ε_t^r is a white noise monetary policy shock with standard deviation σ_r.

The market clearing condition in goods market is

$$y_t = c_t + q_t^k [k_t - (1-\delta)k_{t-1}] + k_{t-1}\psi(u_t) + \delta^b \frac{K_{t-1}^b}{\pi_t} + Adj_t,$$

where $c_t \equiv c_t^P + c_t^I + c_t^E$ is aggregate consumption, k_t is aggregate physical capital, and K_t^b aggregate bank capital. The term Adj_t includes all adjustment costs. In the housing market, equilibrium is given by $\bar{h} = h_t^P(i) + h_t^I(i)$, where $\bar{h}$ is the fixed housing stock.

2.9 Log-Linearization and Model Solution

The model is log-linearized around the steady state. This means that we cannot capture precautionary or buffer-stock behaviors or other nonlinearities. Furthermore, perturbation methods are valid only in a neighborhood of the steady state: as we move away from it not only the quality of the linear approximation deteriorates but also the conditions that ensure that the borrowing constraints bind in the steady state might not hold.

3. ESTIMATION

The model is estimated with Bayesian methods. In this section, we first discuss the data, the calibrated parameters and the priors, and then we report the parameter estimates and some robustness checks. We estimate the parameters driving the model dynamics, while we calibrate those determining the steady state so as to match key statistics in the data.

3.1 Data

We use 12 observables for the euro area: real consumption, real investment, real house prices, real deposits, real loans to households and firms, the overnight rate, interest rates on deposits, loans to firms and households, quarter-on-quarter nominal wage, and consumer price inflation rates. For a description of the data, see the Appendix. The sample period is 1998Q1–2009Q1. Data with a trend are made stationary using the HP filter (smoothing parameter equal to 1,600), while all interest and inflation rates are demeaned. Figure 2 plots the transformed data.

3.2 Calibrated Parameters and Prior Distributions

Calibrated parameters. Table 1 reports the values of the calibrated parameters. We set the discount factor of patient households at 0.9943 in order to match the average monthly rate on M2 deposits in our sample. As for impatient households' and entrepreneurs' discount factors β_I and β_E, we set them at 0.975 as in Iacoviello (2005). The weight of housing in households' utility function ε^h is set at 0.2, close to the value in Iacoviello and Neri (2010). As for the LTV steady-state ratios, for households we set m^I at 0.7, in line with evidence in Calza, Monacelli, and Stracca (2009). For entrepreneurs, the calibration of m^E is somewhat more problematic. Christensen et al. (2007) estimate a much lower value (0.32) in a model for Canada, in which firms can borrow against capital. We computed, for the euro area, an average ratio of long-term loans to the value of shares and other equities for the nonfinancial corporations sector of 0.40. Based on this evidence, we set m^E at 0.35. The capital share α is set at 0.25 and the depreciation rate of capital δ at 0.025. In the labor market, we assume a markup of 25% and set ε^l at 5. In the goods market, a value of 6 for ε^y delivers a markup of 20%, a value commonly used in the literature. We

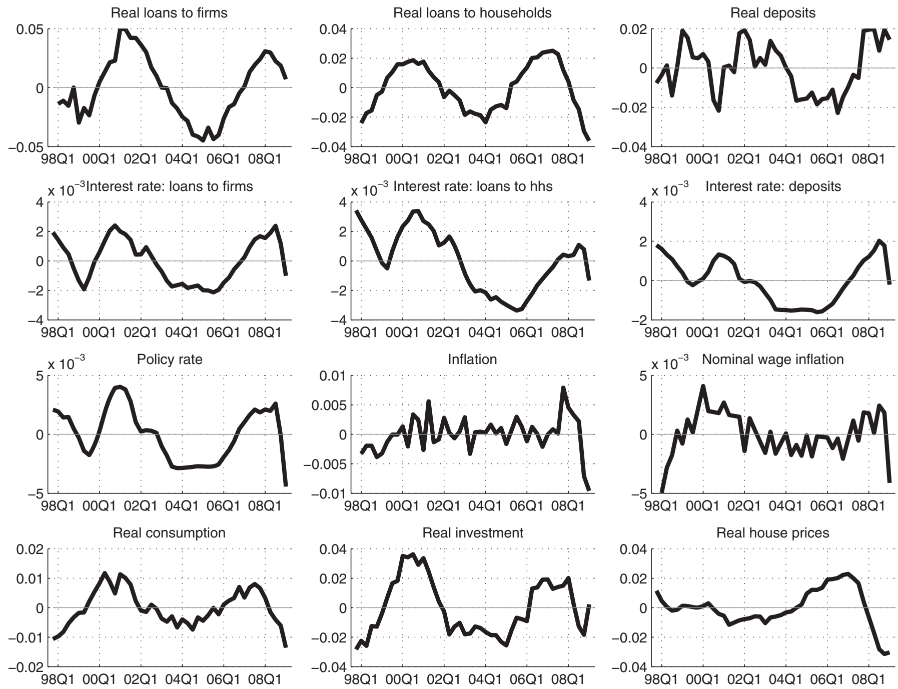


FIG. 2. Euro Area Observable Variables Used in Estimation.

NOTE: Real variables (loans to firms and households, consumption, investment and house prices) are expressed as log deviations from the HP-filter trend. Interest rates and inflation rates are net rates expressed on a quarterly basis and in absolute deviations from the sample mean.

specify $\psi(u_t)$ as in Schmitt-Grohé and Uribe (2006). The patient households' labor income share μ is calibrated at 0.8 in line with the findings in Iacoviello and Neri (2010).

We calibrate the banking parameters so as to replicate sample averages of bank interest rates and spreads. For the deposit rate, the steady-state markdown on the policy rate is given by $\frac{\varepsilon^d}{\varepsilon^d - 1}$; given an average spread between retail deposit rates and the Eonia of about 125 basis points in annualized terms in our sample, we calibrate ε^d at -1.46. Similarly, for loan rates we calibrate ε^{bH} and ε^{bE} to 2.79 and 3.12, exploiting the steady-state expressions for the markups over the policy rate $\frac{\varepsilon^{bs}}{\varepsilon_t^{bs} - 1}$. The steady-state ratio ν^b of bank capital to total loans $(B^H + B^E)$ is set at 9%. The parameter δ^b is set at the value (0.1049) which ensures that the ratio of bank capital to total loans is exactly 0.09.

Prior distributions. Our priors are listed in Tables 2A and 2B. Overall, they are either consistent with the previous literature or relatively uninformative. As for the parameters governing interest rates adjustment costs, their prior means are set at values between 3 and 10, chosen so that the coefficients in the log-linearized

TABLE 1

Calibrated Parameters

Parameter	Description	Value
β_P	Patient households' discount factor	0.9943
β_I	Impatient households' discount factor	0.975
β_E	Entrepreneurs' discount factor	0.975
ϕ	Inverse of the Frisch elasticity	1.0
μ	Share of unconstrained households	0.8
ε^h	Weight of housing in households' utility function	0.2
α	Capital share in the production function	0.25
δ	Depreciation rate of physical capital	0.025
ε^y	$\frac{\varepsilon^y}{\varepsilon^y-1}$ is the markup in the goods market	6
ε^l	$\frac{\varepsilon^l}{\varepsilon^l-1}$ is the markup in the labor market	5
m^I	Households' LTV ratio	0.7
m^E	Entrepreneurs' LTV ratio	0.35
ν^b	Target capital-to-loans ratio	0.09
ε^d	$\frac{\varepsilon^d}{\varepsilon^d-1}$ is the markdown on deposit rate	-1.46
ε^{bH}	$\frac{\varepsilon^{bH}}{\varepsilon^{bH}-1}$ is the markup on rate on loans to households	2.79
ε^{bE}	$\frac{\varepsilon^{bE}}{\varepsilon^{bE}-1}$ is the markup on rate on loans to firms	3.12
δ^b	Cost for managing the bank's capital position	0.1049
ξ_1	Parameter of adjustment cost for capacity utilization	0.0478
ξ_2	Parameter of adjustment cost for capacity utilization	0.00478

Note: The adjustment cost for capacity utilization is specified as $\psi(u_t) = \xi_1(u_t - 1) + \frac{\xi_2}{2}(u_t - 1)^2$ (see Schmitt-Grohé and Uribe 2006).

TABLE 2A

Prior and Posterior Distribution of the Structural Parameters

	Parameter	Prior distribution			Posterior distribution			
		Distrib.	Mean	Std.dev.	Mean	2.5%	Median	97.5%
κ_p	p stickiness	Gamma	50.0	20.0	30.57	10.68	28.65	49.89
κ_w	w stickiness	Gamma	50.0	20.0	102.35	70.29	99.90	133.81
κ_i	Invest. adj. cost	Gamma	2.5	1.0	10.26	7.57	10.18	12.81
κ_d	Dep. rate adj. cost	Gamma	10.0	2.5	3.63	2.28	3.50	4.96
κ_{bE}	Firms rate adj. cost	Gamma	3.0	2.5	9.51	6.60	9.36	12.31
κ_{bH}	HHs rate adj. cost	Gamma	6.0	2.5	10.22	7.47	10.09	12.88
κ_{Kb}	Leverage dev. cost	Gamma	10.0	5.0	11.49	4.03	11.07	18.27
ϕ_π	T.R. coeff. on π	Gamma	2.0	0.5	2.01	1.72	1.98	2.30
ϕ_R	T.R. coeff. on R	Beta	0.75	0.10	0.77	0.72	0.77	0.81
ϕ_y	T.R. coeff. on y	Normal	0.10	0.15	0.35	0.15	0.35	0.55
ι_p	p indexation	Beta	0.50	0.15	0.17	0.06	0.16	0.28
ι_w	w indexation	Beta	0.50	0.15	0.28	0.16	0.28	0.39
a^h	Habit coefficient	Beta	0.50	0.10	0.85	0.81	0.86	0.90

Note: Results based on 10 chains, each with 100,000 draws based on the Metropolis algorithm.

rate-setting equations imply immediate pass-through of the magnitude documented in European Central Bank (ECB) (2009). The prior on the parameter governing the adjustment costs in banking (κ_{Kb}) is harder to set. We assume a rather widespread distribution, with a mean of 10 and a standard deviation of 5.

TABLE 2B

PRIOR AND POSTERIOR DISTRIBUTION OF THE STRUCTURAL PARAMETERS—EXOGENOUS PROCESSES

		Prior distribution			Posterior distribution			
	Parameter	Distribution	Mean	Std.dev.	Mean	2.5%	Median	97.5%
AR coefficients								
ρ_z	Consumpt. prefer.	Beta	0.8	0.10	0.396	0.260	0.394	0.531
ρ_h	Housing prefer.	Beta	0.8	0.10	0.917	0.858	0.921	0.975
ρ_{mE}	Firms' LTV	Beta	0.8	0.10	0.892	0.839	0.894	0.945
ρ_{mI}	HHs' LTV	Beta	0.8	0.10	0.925	0.875	0.929	0.979
ρ_d	Dep. markdown	Beta	0.8	0.10	0.830	0.739	0.838	0.917
ρ_{bH}	HHs loans markup	Beta	0.8	0.10	0.808	0.675	0.820	0.949
ρ_{bE}	Firms loans markup	Beta	0.8	0.10	0.820	0.688	0.834	0.956
ρ_a	Technology	Beta	0.8	0.10	0.936	0.899	0.939	0.975
ρ_{qk}	Invest. efficiency	Beta	0.8	0.10	0.543	0.396	0.548	0.694
ρ_y	p mark-up	Beta	0.8	0.10	0.306	0.205	0.305	0.411
ρ_l	w mark-up	Beta	0.8	0.10	0.636	0.511	0.640	0.769
ρ_{Kb}	Balance sheet	Beta	0.8	0.10	0.810	0.717	0.813	0.906
Standard deviations								
σ_z	Consumpt. prefer.	Inv. Gamma	0.01	0.05	0.027	0.019	0.027	0.035
σ_h	Housing prefer.	Inv. Gamma	0.01	0.05	0.076	0.022	0.071	0.129
σ_{mE}	Firms' LTV	Inv. Gamma	0.01	0.05	0.007	0.005	0.007	0.009
σ_{mI}	HHs' LTV	Inv. Gamma	0.01	0.05	0.003	0.003	0.003	0.004
σ_d	Dep. markdown	Inv. Gamma	0.01	0.05	0.033	0.024	0.032	0.043
σ_{bH}	HHs loans markup	Inv. Gamma	0.01	0.05	0.067	0.035	0.066	0.115
σ_{bE}	Firms loans markup	Inv. Gamma	0.01	0.05	0.063	0.034	0.063	0.096
σ_a	Technology	Inv. Gamma	0.01	0.05	0.006	0.004	0.006	0.007
σ_{qk}	Invest. efficiency	Inv. Gamma	0.01	0.05	0.019	0.013	0.019	0.025
σ_R	Monetary policy	Inv. Gamma	0.01	0.05	0.002	0.001	0.002	0.002
σ_y	p mark-up	Inv. Gamma	0.01	0.05	0.634	0.274	0.598	0.985
σ_l	w mark-up	Inv. Gamma	0.01	0.05	0.577	0.378	0.561	0.761
σ_{Kb}	Balance-sheet	Inv. Gamma	0.01	0.05	0.031	0.026	0.031	0.037

NOTE: Results based on 10 chains, each with 100,000 draws based on the Metropolis algorithm.

3.3 Posterior Estimates

Tables 2A and 2B also report summary statistics of the posterior distribution of the parameters. Draws from the posterior distribution of the parameters were obtained using the Metropolis algorithm. We ran 10 chains, each of 100,000 draws. Convergence was assessed both by means of the convergence statistics proposed by Brooks and Gelman (1998) and by computing recursive means of the parameters.[11] Figure 3 reports the prior and posterior marginal densities of the structural parameters of the model.[12]

All shocks are quite persistent with the only exception of the price markup shock ε_t^y. The posterior median of the parameter measuring the degree of consumption habits a^h is estimated to be high, at 0.86. The median of the investment adjustment

11. Assessment of convergence is reported in the technical appendix available upon request.

12. We interpret a substantial difference between the prior and the posterior means as an indication that parameters are identified. However, we acknowledge that this is not a sufficient criterion since the mapping between the parameters and the solution of the model is nonlinear.

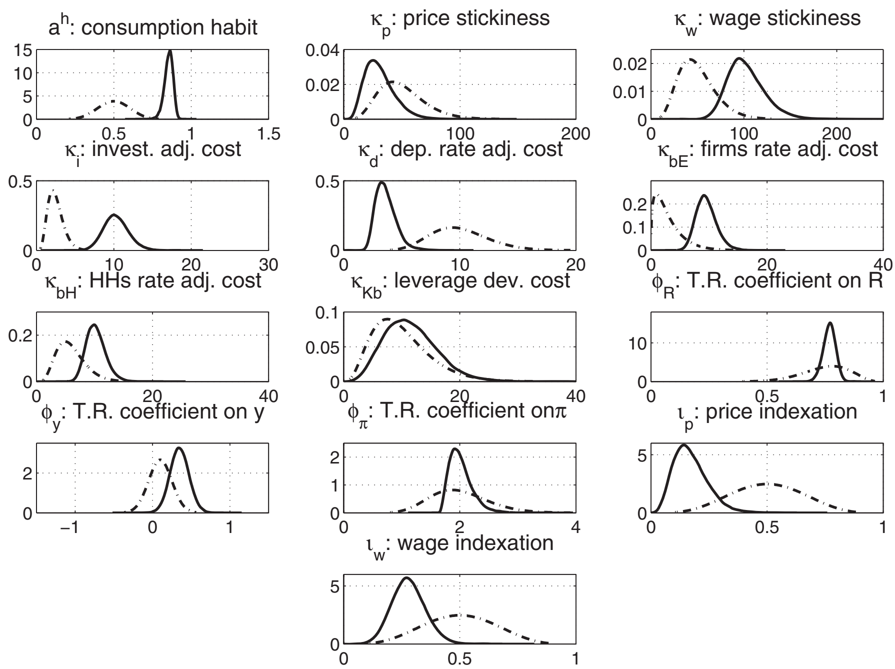


FIG. 3. Prior and Posterior Marginal Distributions.

NOTE: The marginal posterior densities are based on 10 chains, each with 100,000 draws based on the Metropolis algorithm. Solid lines denote the posterior distribution, dashed lines the prior distribution.

cost κ_i is around 10, slightly above the estimate in Smets and Wouters (2003). For monetary policy, our estimation confirms the weak identification of the response to inflation ϕ_π and the relatively high degree of policy rate inertia ϕ_R; the posterior median of the coefficient measuring the response to output growth ϕ_y is more than three times the prior mean. Concerning nominal rigidities, in line with previous studies we find that wage stickiness is stronger than price stickiness. Concerning the parameters measuring the degree of stickiness in bank rates, we find that deposit rates adjust more rapidly than the rates on loans to changes in the policy rate. This result is not surprising given that our measure of deposits include time deposits, whose interest rates are typically highly reactive to changes in money market rates. Finally, the posterior distribution for the coefficient measuring the cost of deviating from targeted leverage, κ_{Kb}, stays very close to the prior, which might be a signal of weak identification. However, experimenting with larger and smaller values for the prior mean, the posterior distribution moves away from the prior one and toward our estimated median, suggesting that the data do have some informative content for this parameter.

3.4 *Robustness*

The ability of the model to fit the data depends on the shocks and frictions that are considered. Moreover, the posterior distribution of the structural parameters may depend on the type of transformation used to make the data stationary. In this section, we report the results of a series of robustness checks that are meant to shed light on the role of financial shocks, sticky rates, bank capital, and detrending of the data.[13]

To highlight the importance of including financial shocks, we have estimated the model shutting off these shocks, while adding i.i.d. measurement errors to all banking sector observables so to be able to bring the model to the data with the same set of variables used in the estimation of the benchmark model. This version of the model has a very hard time explaining the dynamics of loans to firms, households' deposits and bank rates; the marginal data density of this model (which is commonly used to compare estimated models) falls to 2,018 (log points) from 2,311 of the benchmark model. In terms of storytelling (see Section 5.1), the model without financial shocks explains the 2008 downturn as the result of unfavorable technology and cost-push shocks.

The importance of sticky rates is assessed by estimating a version of the model with flexible bank rates (i.e., setting κ_d, κ_{bE}, and κ_{bH} to zero). The marginal density of this model falls to 2,262 (compared to 2,311), thus suggesting the importance of this feature. The other structural parameters are hardly affected by removing stickiness in rates. The main difference is in the persistence of the shocks to bank rates, which increases from 0.83, on average across the three rates, to 0.91, and in the degree of price stickiness, which more than doubles. Removing bank capital results in a reduction of the marginal density from 2,311 to 2,307, suggesting that this feature plays a more limited role compared to the stickiness in bank rates in accounting for the data. However, bank capital does play an important role, for example, in propagating supply shocks (see Section 4.2).

Finally, we have estimated the benchmark model using linearly detrended data (with a different trend for each variable) and found no major difference in the posterior distribution of the structural parameters but only an increase in the persistence of almost all the shocks. Imposing a *common* linear trend on all the nonstationary time series would result in unreasonable dynamics of loans to firms, loans to households, and real house prices. These financial variables have indeed been growing at rates significantly higher than those of consumption and investment in our sample period, fueled by financial innovations and the waves of mergers and acquisitions of the 1990s and early 2000s.

4. PROPERTIES OF THE ESTIMATED MODEL

In this section, we study how the transmission mechanism of monetary and technology shocks is affected by the presence of financial frictions and financial

13. Detailed results of the experiments discussed here are reported in the technical appendix.

intermediation. The interest-rate-setting behavior of banks introduces an additional layer of complexity on top of the already nonstandard transmission channels usually at work in models with heterogeneous agents and borrowing constraints. In order to highlight the contribution of each feature of banking, we compare the benchmark model (BK model, for bank capital) with a number of models where we progressively shut down (in order):[14] (i) bank capital (yielding a sticky rates model, or SR), (ii) stickiness in bank rates setting (yielding a flexible rates, or FR, model), (iii) imperfect competition in banking (yielding a financial frictions, or FF, model similar to Iacoviello 2005), and (iv) the collateral and debt-deflation channels (yielding a quasi-New Keynesian, or QNK, model).[15]

4.1 Monetary Policy Shock

Figure 4 shows the impulse responses from an unanticipated 50 basis points increase in the policy rate (r_t). Parameter values are set at the estimated posterior median. The responses of the BK model (in circled gray) are qualitatively very standard. Output and inflation fall; real interest rates for households and entrepreneurs go up, reflecting the increase in bank interest rates, and asset prices decline, determining a reduction in the present discounted value of the collateral. As a consequence, loans to both households and firms decline.[16] On impact, bank profits get pushed up by the increase in banks' intermediation spread, which more than offsets the reduction in the amount of intermediated funds; after a few quarters, however, profits turn negative as the increase in bank margins unwinds while loans and deposits remain negative for longer.[17] Following profits, bank capital initially increases but it then turns negative after about 10 quarters.

The introduction of banking attenuates the impact of the policy tightening. This is mainly due to sticky rates, which dampen the response of retail loan rates, thus reducing the contraction in loans, consumption and investment (see the difference between the SR and the FR lines in Figure 4). The impact of market power in banking (i.e., the difference between the FR and FF lines) on output is rather limited,

14. We do not reestimate each model since doing so would make it impossible to attribute any change in the propagation mechanism of shocks to a specific feature of the model since all the parameters may change.

15. In the QNK model, agents are still credit constrained but there is no effect of asset prices on the collateral value (fixed at the steady state level), and loans and deposits (plus interests) are repaid in real terms.

16. This contradicts some empirical VAR-based evidence, which has shown that lending to firms tends to increase after a monetary tightening (e.g., Giannone, Lenza, and Reichlin 2009 for the euro area). The explanations rely on factors outside of our model such as banks' tendency to increase the supply of short-term less risky loans (Den Haan, Sumner, and Yamashiro 2007), firms' need to keep financing production and inventories (Gertler and Gilchrist 1994), or firms' attempts to exhaust favorable precommitted credit lines.

17. The initial rise of bank profits is a counterfactual implication of the model and is due to the fact that profits almost coincide with the interest rate margin, for which price effects outweigh movements in intermediated funds. Despite some empirical evidence supports countercyclicality of interest rate margins (e.g., Olivero 2010), overall bank profits have been shown to be procyclical (Albertazzi and Gambacorta 2008).

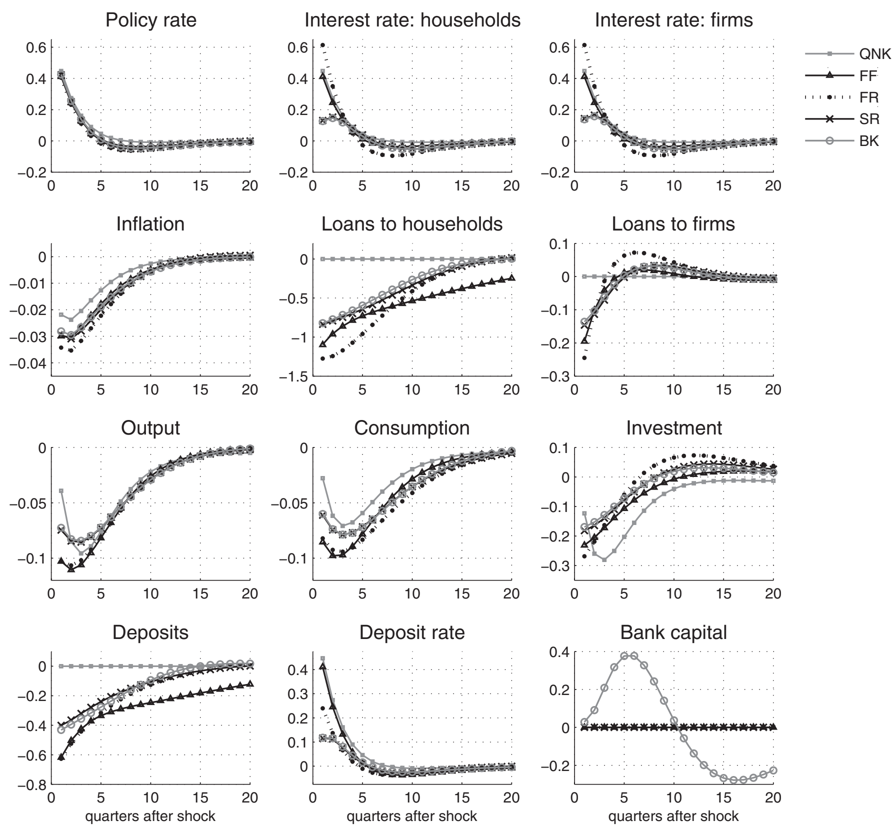


FIG. 4. The Role of Banks and Financial Frictions in the Transmission of a Contractionary Monetary Policy Shock.

NOTE: All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state. The gray circled line is from the benchmark model (BK). The gray line with squares is from the quasi-NK model (QNK). The black line with triangles is from the model with financial frictions but without banks (FF). The black dotted line is from the model with banks, but with flexible rates and without bank capital (FR). The black crossed line is from the model without bank capital but with sticky rates (SR). Baseline parameters are set at the median of the posterior distribution of the benchmark model.

reflecting the opposite and mutually offsetting effects on borrowers and lenders: the markup on loan rates determines a bigger increase of the relevant rates for impatient households and entrepreneurs, while the markdown on the deposit rate attenuates the restriction for patient households. Finally, the introduction of bank capital has virtually no effect on the dynamics of the real variables (i.e., the difference between the BK and the SR lines is small); this mainly reflects the small median value of κ_{Kb}.[18]

18. Our parameters imply that a reduction of the capital-to-assets ratio by half (from 9% to 4.5%) would increase the spread between the wholesale loan rate and the policy rate by only 10 basis points.

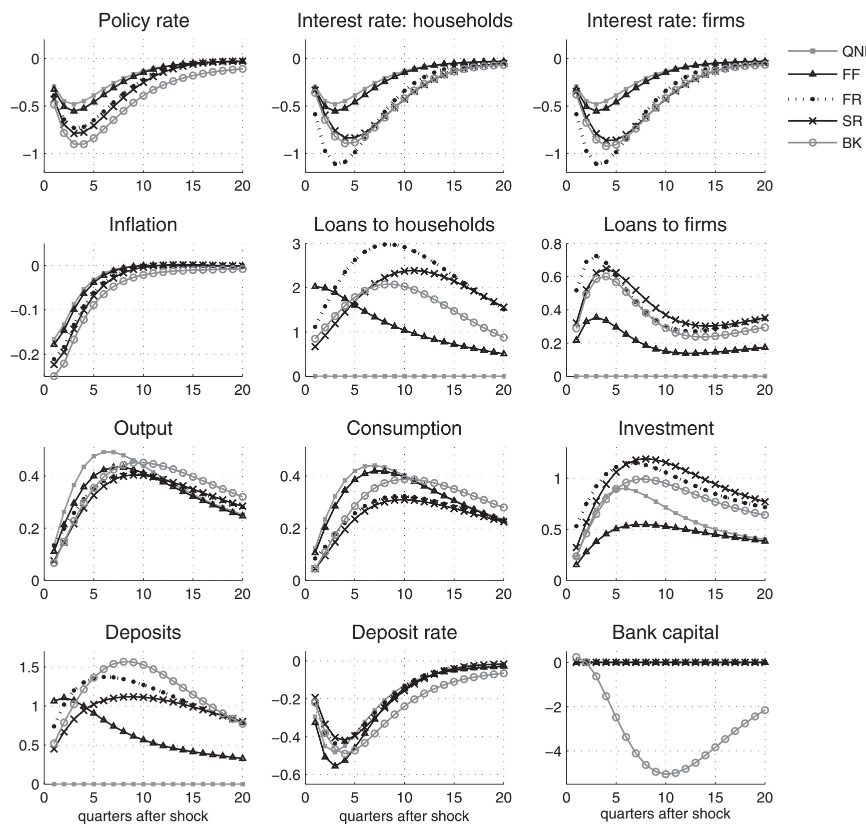


FIG. 5. The Role of Banks and Financial Frictions in the Transmission of a Positive Technology Shock.

NOTE: All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state. The gray circled line is from the benchmark model (BK). The gray line with squares is from the quasi-NK model (QNK). The black line with triangles is from the model with financial frictions but without banks (FF). The black dotted line is from the model with banks, but with flexible rates and without bank capital (FR). The black crossed line is from the model without bank capital but with sticky rates (SR). Baseline parameters are set at the median of the posterior distribution of the benchmark model.

Our findings of an attenuating effect of banking after a monetary policy shock are in line with the results in Goodfriend and McCallum (2007). In their model, the attenuation effect stems from the presence of procyclical marginal costs and occurs only when the monetary impulse is very persistent. Andrés and Arce (2008) find an attenuation effect in a model with imperfectly competitive banks and flexible rate setting.

4.2 Technology Shock

Figure 5 shows the responses to a positive one standard deviation shock to a_t^E. Overall, in the three models with banking (FR, SR, BK), the response of consumption and output is attenuated compared to the FF model, while the response of investment is amplified. Banking also seems to enhance the endogenous propagation of the shock as all real variables display a higher persistence: output peaks after about 10 quarters, compared to seven in the FF model. To understand these results, it is useful to discuss how the assumption of monopolistic markups in banking modifies the transmission channels usually at work in models with financial frictions.

As for the collateral channel, the presence of markups amplifies and propagates the expansion. With imperfectly competitive banking, the decline in the policy rate triggers a larger fall in loan rates. Investment is boosted both by the technology improvement and by the easier access to credit; the increased demand for capital by entrepreneurs and for housing by impatient households pushes asset prices up, so that borrowers also benefit from the wider access to credit that higher collateral values afford. The debt deflation channel yields a somewhat opposite result, as the existence of markups on loan rates raises the cost of debt servicing and exacerbates the already dampening effect of debt deflation, resulting in a smaller expansion after a technology shock. A given deflation leaves debtors with a higher burden of real obligations which weighs more on their resources and spending, so that the dampening of the supply shock due to debt being nominal is initially stronger.

Overall, the debt-deflation attenuating effect prevails on impact; over a longer horizon, however, collateral-channel effects prevail, inducing higher persistence in real variables. Adding stickiness in bank rates limits their fall and hence the expansion of lending, but overall it only marginally affects the dynamics of real variables.

Finally, the introduction of bank capital affects mainly investment, which peaks almost 30% below what it does in the SR model. In the BK model, bank profits fall after a positive technology shock, mainly because the bank interest rates spread falls.[19] This adverse financial sector development spills over to the real sector because fewer bank profits means lower bank capital and, *ceteris paribus*, a higher bank leverage ratio. Banks react to the increased leverage costs by reducing lending, in particular to entrepreneurs.

5. APPLICATIONS

Once the model has been estimated and its propagation mechanism studied, we can use it to address two issues raised in the introduction: What role did the shocks to the banking sector play in the 2008 downturn in euro area economic activity? What are the effects of a credit crunch originating from a fall in bank capital?

19. Bank profits display a countercyclical behavior also conditional on technology shocks. After the initial fall in inflation, and due to market power in banking, the cut in the policy rate triggers a reduction of the banking rate spread; this effect outweighs the increase in intermediated funds, generating a fall in profits.

5.1 The Role of Financial Shocks in the Business Cycle

In order to quantify the relative importance of each shock in the model we perform a historical decomposition of the dynamics of the main macroeconomic and financial variables. The decomposition is obtained by fixing the parameters of the model at the posterior median and using the Kalman smoother to recover the innovations that replicate exactly our observables. The aim of the exercise is to investigate how our financially rich model interprets both the expansion of 2006–07 and the ensuing slowdown in 2008.

We divide the shocks into three groups. First, there is a "macroeconomic" group, which pools shocks to production technology, to intertemporal preferences, to housing demand, to the investment-specific technology, and to price and wage markups. The "monetary policy" group isolates the contribution of the nonsystematic monetary policy. The "financial" group consists of shocks to the LTV ratios on loans to firms and households, shocks to the markup on bank interest rates and shock to banks' balance sheet.

Figure 6 shows the results of the exercise for some key macro variables since 2004. Concerning output (defined as the sum of consumption and investment) the model interprets the rise of 2006–07 as initially fueled by positive financial and monetary policy shocks (up until 2006Q4), while the favorable macroeconomic conditions started to play a significant role only in 2007. The sharp contraction started in 2008 was instead almost entirely caused by adverse financial shocks and, to a smaller extent, by the simultaneous retreat of the positive stimulus coming from macroeconomic shocks. A closer inspection of macroeconomic shocks reveals that price markup shocks were an important contributor; these shocks likely capture the effects of the sharp increase in commodity prices in the first half of 2008. This hypothesis is confirmed by their large contribution to inflation.[20] Less obvious is the finding that financial shocks explain also much of the boom phase of 2006–07. This should not come as a complete surprise, given the available evidence coming from surveys (see Figure 1) that points to a loosening of bank lending standards during 2006 and 2007.[21] The model also predicts that the link between financial shocks and the real economy operates mainly via aggregate investment. The decomposition of this variable confirms how unusually large (positive) financial shocks, mainly related to firms' LTV ratios, were responsible for the expansion of investment in 2006 and 2007 and how these same shocks turned negative in 2008, accounting for the fall in investment.

The historical decomposition of the policy rate shows a significant positive contribution of macroeconomic shocks until the third quarter of 2008; this again reflects the strong inflationary pressures coming from commodity prices. At the same time, in 2008 monetary policy appears to have been looser than what a strict adherence to the

20. We obtain quite similar results using linearly detrended data. In this case, only the last two quarters of the sample show a significant contribution of financial shocks to the downturn in economic activity.

21. When we shut down financial shocks altogether (see Section 3.4), the story is less palatable as the boom phase is mainly the result of positive technology and preference shocks.

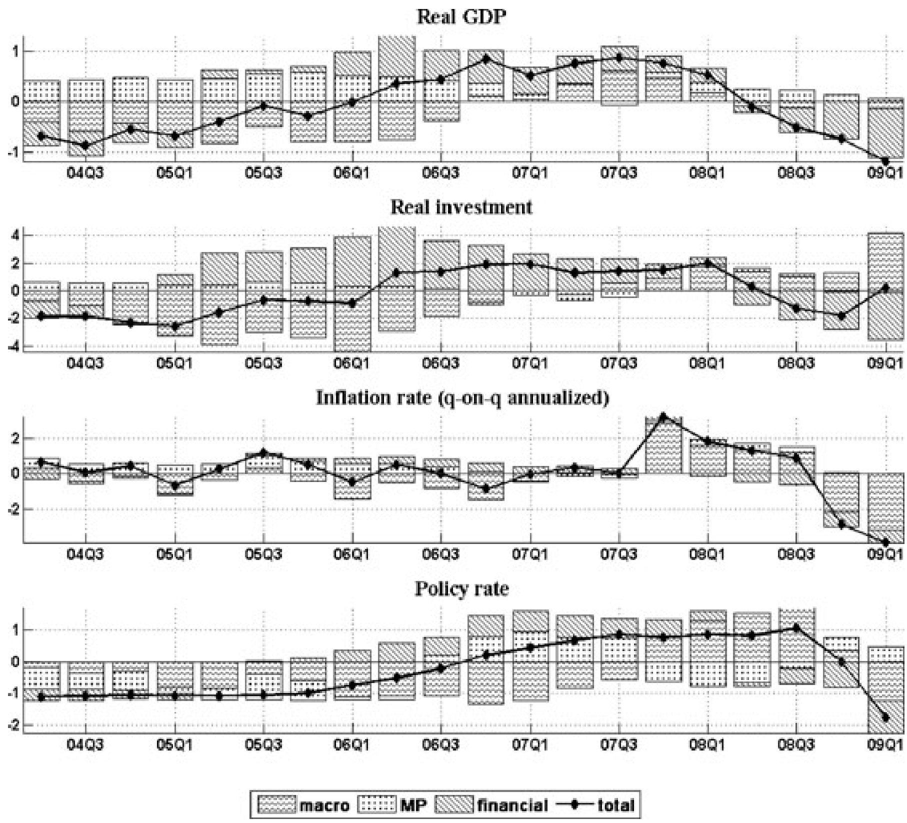


FIG. 6. Historical Decomposition of the Main Macro Variables: 2004Q1–2009Q1.

NOTE: The figure shows as various shocks contribute to the percentage deviations from steady state of real GDP and investment, and to the absolute deviations from steady state (expressed in percentage points) of inflation and the policy rate. The decomposition is computed using the median of the posterior distribution of the benchmark model. Macro shocks include shocks to: price and wage markups, technology, consumption preferences, housing demand, and investment-specific technology. MP refers to monetary policy shocks. Financial shocks include shocks to the LTV ratios on loans to firms and households, shocks to the markup on bank interest rates, and balance-sheet shocks.

policy rule would have implied; this could reflect the impact of increasing uncertainty regarding the economic outlook on the ECB's assessment of the policy stance. Since the third quarter of 2008, when the policy rate was rapidly cut by more than 300 basis points, the contribution of financial shocks gradually increased, accounting for the bulk of the reduction of the policy rate.

Figure 7 reports the historical decomposition of loans to households and firms and the corresponding bank rates. In this case it is convenient to divide the "financial" group in three subcategories: shocks directly related to loans to households (i.e., shocks to households' LTV ratios and to interest rate markups on their loans), shocks directly related to loans to firms, and other financial shocks (deposit rate markup

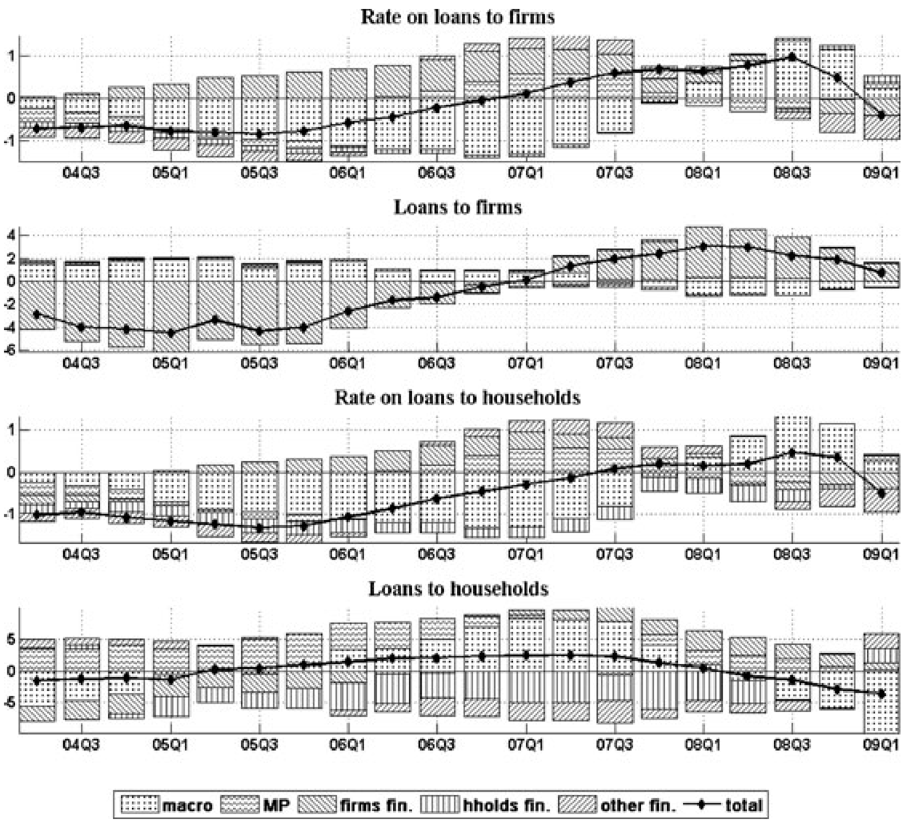


FIG. 7. Historical Decomposition of the Main Financial Variables: 2004Q1–2009Q1.

NOTE: The figure shows as various shocks contribute to the percentage deviations from steady state of loans to firms and to households, and to the absolute deviations from steady state (expressed in percentage points) of the respective interest rates. The decomposition is computed using the median of the posterior distribution of the benchmark model. Macro shocks include shocks to: price and wage markups, technology, consumption preferences, housing demand, and investment-specific technology. MP refers to monetary policy shocks. The firms' financial category includes shocks to LTV ratios for loans to firms and shocks to the interest rate markup on their loans. The households financial category includes shocks to LTV ratios for loans to households and shocks to the interest rate markup on their loans. Finally, other financial shocks include shocks to the interest rate markdown on deposits and shocks to banks' balance sheets.

and bank balance-sheet shocks). As regards interest rates on loans to both firms and households, they basically mirrored what observed for the policy rate and were mainly driven by macroeconomic shocks; for firms' loan rate, however, a significant contribution appears to have come also from sector-specific credit shocks. As for lending, loans to firms were mainly driven by sector-specific credit shocks, while the main driver for households' loans turns out to be housing demand shocks, which explain most of the strong rise in 2006 and, at a decreasing pace, in 2007, as well as the subsequent decline in 2008, tracking the house price cycle.

5.2 The Effects of a Bank Capital Loss

In this section, we simulate an exogenous and unexpected destruction of bank capital—taking an agnostic approach on the causes behind it—and study its transmission mechanism to the real variables.[22] We calibrate the shock so as to obtain, on impact, a fall of bank capital equal to 5%. We focus on the qualitative results of the experiment and we do not attempt to construct a quantitatively realistic scenario; although our model is a useful instrument to analyze how shocks affecting bank capital affect the real economy, it falls short of addressing most of the mechanisms that were behind the origination of the crisis.

To better highlight the role of bank capital, we also analyze an alternative calibration where we increase (by a factor of 10) the parameter κ_{Kb} measuring the cost for banks to deviate from the targeted capital-to-assets ratio. This amplifies the effects of the shock on the profitability of our banks (see equation (9)) and makes the adjustment of the balance sheet harder. We interpret this alternative calibration as mimicking a "stress" scenario in which banks are poorly capitalized (so that they have strong difficulties in reducing further, even temporarily, their capital-to-assets ratio) and cannot easily raise new capital in the market.

Figure 8 reports the simulation. After the shock, banks are too leveraged and face high costs related to their capital position. In an attempt to rebalance assets and liabilities, they increase loan rates, which weakens loan demand. The contraction in lending induces entrepreneurs to cut investment substantially and to increase capital utilization, given that its relative cost has decreased and that capital is less useful as collateral; at the same time, entrepreneurs increase labor demand, pushing up wages, which sustains consumption and restrains the fall in output. Over a longer horizon, however, the persistently tighter financing conditions for borrowers drag real activity further down and output reaches a trough (−0.3%) in the third year. The central bank increases only slightly the policy rate to counteract the increase in inflation that follows higher wages and financing costs.

In the "stress" scenario in which we increase the cost of deviating from the target capital-to-assets ratio, all the responses are harshened as banks can no longer afford a prolonged period of undercapitalization and instead are forced to quickly close the gap between their capital-to-assets ratio and the target level. Such harsh deleveraging in the financial sector results in a stronger contraction of investment and more severe and prolonged falls in consumption and in output, which reaches a trough (−0.5%) after 5 years.

The scenario we have considered has a hard time to account for the magnitudes recorded during the financial crisis and the sharp fall in the policy rate. There are two main reasons behind these results. First, the calibration of the fall in bank capital is likely to underestimate actual losses incurred by euro area banks since the beginning

22. We modify the model introducing, in the corresponding accumulation equation, the possibility of an unexpected contraction in bank capital K_t^b. The persistence of the shock is 0.95; the other parameters are set at the median of their posterior distribution.

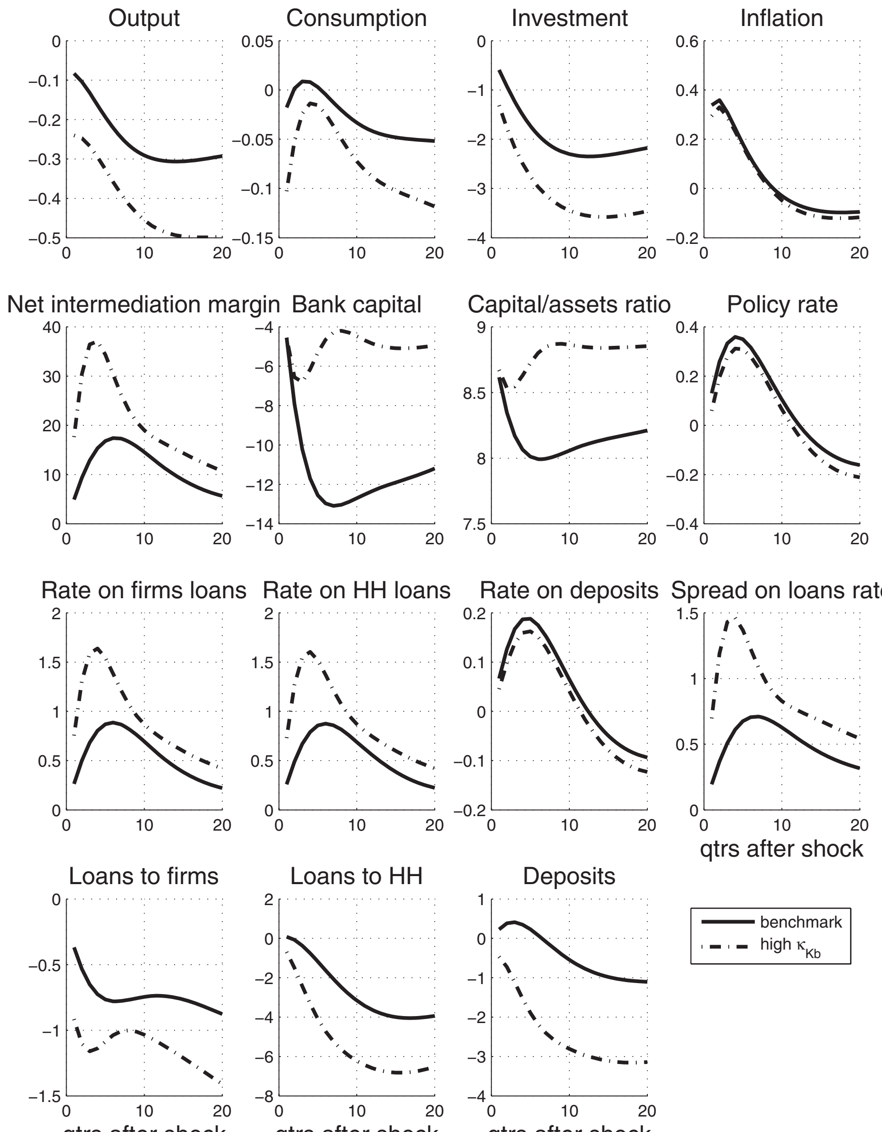


FIG. 8. Impulse Responses to a Negative Shock to Capital.

NOTE: The impulse responses are computed using the median of the posterior distribution of the benchmark model (solid lines) and replacing $\kappa_{Kb} = 100$ (dashed lines), respectively. All rates are shown as absolute deviations from steady state, expressed in percentage points. The capital-to-assets ratio is expressed in percentage points. All other variables are percentage deviations from steady state.

of the crisis.[23] Second, our simulation considers only one shock and disregards others that could be used to capture the surge and fall in commodity prices and the fall in aggregate demand in 2008.[24]

6. CONCLUDING REMARKS

This paper has presented a model with financial frictions and a role for credit-supply factors in the business cycle. Imperfectly competitive banks supply loans to households and firms, obtain funding through deposits and own capital. Margins on loans depend on the interest rate elasticities of demand, on the degree of interest rate stickiness, and on the banks' capital-to-assets ratio. Banks' balance-sheet constraints establish a link between the business cycle, which affects bank profits and capital, and the supply and the cost of loans. Shocks in the credit sector are used to capture changes in lending supply conditions due to factors that are outside the model.

The model has been estimated using Bayesian techniques and data for the euro area over the period 1998Q1–2009Q1. The analysis suggests that the model can rationalize two alternative points of view on the role of banks in the business cycle. On the one hand, financial intermediation can shield—at least to some extent—economic agents from fluctuations in market rates; in this sense, banks may contribute to stabilizing business cycle fluctuations, reducing the potentially disruptive consequences that nonfinancial shocks have in other models with financial frictions. In the model, this is reflected in an attenuation of the effects of monetary and technology shocks on output. On the other hand, banking may introduce additional volatility to the business cycle; this is the consequence of shocks originating in credit markets and of procyclical loan supply, which is linked to asset prices and borrowers' balance-sheet conditions, via the collateral constraint, and to banks' balance-sheet conditions, via the link between loan margins and the capital-to-assets ratio.

The model presented is a first attempt to incorporate credit supply factors in a dynamic general equilibrium framework and, as such, it suffers from a number of limitations. The model depends heavily on large financial shocks to explain the data. A more satisfactory framework, in which movements in credit spreads and lending arise endogenously due to financial frictions, would be one where uncertainty and risk matter. In addition, the only source of profits for banks is the intermediation margin. This has two main consequences: first, the cyclical properties of bank profits are counterfactual because countercyclical movements in the spread outweigh fluctuations in intermediated funds; second, the model cannot capture fluctuations in profits

23. International Monetary Fund (2009) estimates that actual and potential write-downs on loans by euro area banks between 2007 and 2010 amount to 480 billion dollars, corresponding to around 20% of their equity.

24. In a scenario—that we do not report—in which we jointly consider a shock to bank capital, to consumption preference and to the efficiency of investment, we are able to generate a much larger contraction of output and a sharp reduction in the policy rate with no increase in inflation.

stemming from asset-valuation effects, the evolution of trading fees, or other items that have assumed a growing relevance in a bank's income statement. Moreover, the mechanisms behind the sluggish adjustment of bank rates and the existence of a target leverage ratio for financial intermediaries are somewhat *ad hoc*. Finally, a crucial challenge for future research will be to address credit market facts, which were of particular relevance for the 2007–08 financial crisis, like the dry-up of funding liquidity or the strong increase in the uncertainty surrounding asset valuation, and the policy responses by governments and central banks.

APPENDIX: DATA AND SOURCES

Real consumption: Consumption of households and nonprofit institutions serving households (NPISH), constant prices, seasonally adjusted, not working day adjusted, euro area 15 (Eurostat).
Real investment: Gross fixed capital formation, constant prices, seasonally adjusted, not working day adjusted, euro area 15 (Eurostat).
Real house prices: Nominal residential property prices deflated with the harmonized index of consumer prices (ECB and Eurostat).
Wages: Hourly labor cost index—wages and salaries, whole economy excluding agriculture, fishing and government sectors, seasonally and working day adjusted (Eurostat).
Inflation: HICP overall index, quarterly changes, seasonally adjusted, not working day adjusted, euro area 15 (ECB).
Nominal interest rate (policy): Eonia rate (ECB).
Interest rate on loans to households: Annualized agreed rate (AAR) on loans for house purchases, total maturity, new business coverage (ECB).
Interest rate on loans to firms: AAR on loans other than bank overdrafts to nonfinancial corporations with maturity of over 1 year, new business coverage (ECB).
Interest rate on deposits: Weighted average (with weights proportional to outstanding amounts) of AARs on overnight deposits (total maturity), on deposits with agreed maturity of up to 2 years, and on deposits redeemable at notice of up to 3 months, households and nonprofit institutions serving households, new business coverage (ECB).
Loans to households: Outstanding amounts of loans to households for house purchasing, total maturity, neither seasonally nor working day adjusted (ECB).
Loans to firms: Outstanding amounts of loans to nonfinancial corporations, total maturity, neither seasonally nor working day adjusted (ECB).
Deposits: Overnight, with agreed maturity up to 2 years, redeemable at notice up to 3 months; outstanding amounts; households and NPISH (ECB).

For bank rates, we merged two ECB data sets. From 2003M1, we use harmonized monthly data from the MFI Interest Rate (MIR) statistics in new business coverage. Data from MIR are extended back to 1998M1 using euro area Retail Interest Rate

(RIR) data, compiled by the ECB until 2003M9. Since original national data in RIR are neither harmonized in coverage nor in nature, we check the stability of the relation between comparable MIR-RIR rates series over the overlapping period before using variations in RIR rates to backcast MIR rates. Volumes of loans and deposits refer to outstanding amounts: if data on new businesses were used (available from 2003Q1) their high volatility would not allow a safe backcasting of stocks and would induce instability when aggregating bank rates.

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