EUROPEAN CENTRAL BANK

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Abstract

The financial crisis clearly illuminated the potential amplifying role of financial factors on macroeconomic developments. Indeed, the heavy impairments of banks' balance sheets brought to the fore the banking sector's ability to provide a smooth flow of credit to the real economy. However, most existing structural macroeconomic models fail to take into account the crucial role of banks' balance sheet adjustment in the propagation of shocks to the economy. This paper contributes to fill this gap, analyzing the role of credit market frictions in business cycle fluctuations and in the transmission of monetary policy. We estimate a closed-economy dynamic stochastic general equilibrium (DSGE) model for the euro area with financially-constrained households and firms and embedding an oligopolistic banking sector facing capital constraints. Using this setup we examine the macroeconomic implications of various financial frictions on the supply and demand of credit, and in particular we assess the effects of introducing risk-sensitive and more stringent capital requirements. Finally, we explore the scope for counter-cyclical bank capital rules and the strategic complementarities between macro-prudential tools and monetary policy.

Keywords: DSGE models, Bayesian estimation, Banking, Financial regulation.

JEL classification: E4, E5, F4.

1 Non-technical summary

This paper analyzes the role of credit market frictions in business cycle fluctuations and in the transmission of monetary policy. We estimate a closed-economy dynamic stochastic general equilibrium (DSGE) model for the euro area with financially-constrained households and firms and embedding an oligopolistic banking sector facing capital constraints. Using this setup we examine the monetary policy implications of the various financial frictions to credit supply and demand and furthermore examine the real economic implications of increasing capital requirements and of introducing risk-sensitive capital requirements. Moreover, the potential for introducing counter-cyclical bank capital rules and aligning macro-prudential tools with standard monetary policy tools is examined.

The financial crisis which started in 2007 brought to the fore the importance of the financial sector and its potential amplifying effects on business cycle fluctuations. The massive write-downs and losses that banks had to incur over this period significantly impaired their liquidity and capital positions, which in turn forced many banks to cut back on activities and to shed assets. This deleveraging process in the banking sector may have hampered the access to financing for some bank-dependent borrowers and thereby reduced their ability to consume and invest, potentially reinforcing the economic downturn. Whereas in the macroeconomic literature it has long been recognized that financial intermediation may play a role in economic fluctuations through the financial accelerator mechanism relating to the banks' borrowers, the possible amplifying impact on the business cycle of shocks directly hitting the financial intermediaries has only recently been taken up by the literature.

The importance of the banks' balance sheet situation in transmitting shocks to monetary policy (and other types of shocks) has, however, long been recognized in the empirical literature. For example, it has been pointed out that more liquid and well-capitalized banks are better able to absorb shocks hitting the macroeconomic environment (including changes in monetary policy) than more capital and liquidity-constrained banks. Furthermore, the financial crisis has reinforced interest in macro-prudential tools and policies that might be applied by policy makers to reduce the risks of financial boom and bust cycles and thereby lead to a more stable path of real economic growth.

In addition to the attention on the role of financial intermediaries brought forward by the financial crisis, the introduction of more risk-sensitive capital requirements (i.e. the Basel II capital adequacy framework; see BCBS [2006]) has reinforced the concerns that financial intermediation by itself might have substantial feedback effects on the real economy. In particular, it has been argued that by introducing capital requirements that are sensitive to the state of the economy, the inherent cyclicality in banks' lending behaviour is likely to be reinforced. Hence, as bank capital requirements will be less strict when risks are perceived to be benign and, vice versa, will be tighter when the quality of the assets is deteriorating, banks are likely to engage in riskier lending during economic upturns and to contract credit supply during economic downturns. To the extent that some firms and households are dependent on having access to bank financing in their investment and spending decisions, more cyclical capital requirements would be expected to reinforce the propagation mechanism between the financial system and the real economy. In other words, ceteris paribus, a risk-sensitive capital requirements regime is expected to have pro-cyclical effects. It has, however, been argued that by inducing a more forward-looking behaviour in banks' risk-taking, a risk-sensitive capital adequacy framework may also include some mitigating elements with respect to its overall pro-cyclical effects. While the extent to which a risk-sensitive capital adequacy framework introduces amplifying pro-cyclical effects is ultimately an empirical question, the analysis of such effects needs to be placed in a broader context whereby the feedback mechanism between the financial and the real sector as well as the forward-looking, strategic behaviour of financial intermediaries are properly taken into account. In other words, a general equilibrium framework is needed to appropriately account for the interlinkages between financial and real economic factors. Moreover, as a consequence of the financial crisis, the Basel Committee on Banking Supervision (BCBS) has already proposed amendments to the bank regulatory framework (i.e. Basel III) with the aim of strengthening capital requirements. Our model is also well-suited for analyzing the potential costs (and benefits) of moving towards higher capital ratio targets and the role of monetary policy during such a transition. Finally, a general equilibrium framework is also useful for analyzing the potential for macro-prudential tools and their interaction with other macroeconomic and monetary policy instruments.

Using our model setup we document the role of financial frictions in amplifying shocks to the economy. For example, via the collateral channel housing-specific shocks generate sizeable effects on non-residential consumption and investment. Moreover, it is shown that the specification where borrowing constraints are always binding produces more pronounced propagation than benchmark model with endogenous defaults. Furthermore, capital constraints and costs related to capital adjustments are shown to amplify the macroeconomic propagation of exogenous shocks. In addition, it is shown that risk-sensitive capital requirements imply marginally more volatility in the economy than a fixed-rate capital requirement regime. However, the degree of macroeconomic volatility varies with types of shocks, with especially risk shocks and financial shocks are found to have amplifying impact when capital requirements are risk sensitive. At the same time, banks are found to actively reshuffle their portfolios when faced with credit risk shocks which somewhat mitigates the pro-cyclical implications. As regards the introduction of more stringent capital requirements (as proposed under Basel III), we show that it would lead to a transitory negative impact on output. The costs related to introducing the new capital requirements are, however, reduced the later the implementation date and may furthermore be mitigated by monetary policy accommodation. Finally, we illustrate the potentially complementary roles of monetary macro-prudential policies in supporting macroeconomic stabilisation, but also emphasize that the design and magnitude of macro-prudential policy rules and its interaction with monetary policy need careful consideration.

2 Introduction

This paper analyzes the role of credit market frictions in business cycle fluctuations and in the transmission of monetary policy. We estimate a closed-economy dynamic stochastic general equilibrium (DSGE) model for the euro area with financially constrained households and firms and embedding an oligopolistic banking sector facing capital constraints. Using this setup we examine the monetary policy implications of the various financial frictions to credit supply and demand and furthermore examine the real economic implications of increasing capital requirements and of introducing risk-sensitive capital requirements. Moreover, the potential for introducing counter-cyclical bank capital rules and aligning macro-prudential tools with standard monetary policy tools is examined.

The financial crisis which started in 2007 brought to the fore the importance of the financial sector and its potential amplifying effects on business cycle fluctuations. The massive write-downs and losses that banks had to incur over this period significantly impaired their liquidity and capital positions, which in turn forced many banks to cut back on activities and to shed assets. This deleveraging process in the banking sector may have hampered the access to financing for some bank-dependent borrowers and thereby reduced their ability to consume and invest, potentially reinforcing the economic downturn. Whereas in the macroeconomic literature it has long been recognized that financial intermediation may play a role in economic fluctuations through the financial accelerator mechanism relating to the banks' borrowers [1], the possible amplifying impact on the business cycle of shocks directly hitting the financial intermediaries has only recently been taken up by the literature. [2] The importance of the banks' balance sheet situation in transmitting shocks to monetary policy (and other types of shocks) has, however, long been recognized in the empirical literature. For example, it has been pointed out that more liquid and well-capitalized banks are better able to absorb shocks hitting the macroeconomic environment (including changes in monetary policy) than more capital and liquidity-constrained banks. [3] Furthermore, the financial crisis has reinforced interest in macroprudential tools and policies that might be applied by policy makers to reduce the risks of financial boom and bust cycles and thereby lead to a more stable path of real economic growth.

In addition to the attention on the role of financial intermediaries brought forward by the financial crisis, the introduction of more risk-sensitive capital requirements (i.e. the Basel II capital adequacy framework; see BCBS [2006]) has reinforced the concerns that financial intermediation by itself might have substantial feedback effects on the real economy. In particular, it has been argued that by introducing capital requirements that are sensitive to the state of the economy, the inherent cyclicality in banks' lending behaviour is likely to be reinforced. Hence, as bank capital requirements will be less strict when

[1]Financing frictions arising in the context of asymmetric information between borrowers and lenders are often suggested as a prime candidate for endogenously amplifying and increasing the persistence of even small transitory exogenous shocks. The basic idea, often called the financial accelerator, is that in the presence of credit constraints exogenous shocks can generate a positive feedback effect between the financial health of borrowing firms or households and output; See e.g. Carlstrom and Fuerst [1997], Kiyotaki and Moore [1997] and Bernanke et al. [1999] (BGG hereafter). Recent work by Christiano et al. [2007], Christensen and Dib [2008] and Liu et al. [2009] quantifies the interlinkages between the financial and real sectors using a financial accelerator mechanism.

[2]For some recent studies modelling the banking sector in a DSGE modelling framework, see e.g. Van den Heuvel [2008], Meh and Moren [2008], De Walque et al. [2009], Dib [2009], Gerali et al. [2009], Aguiar and Drumond [2009], Agenor and Pereira da Silva [2009], Agenor and Alper [2009], Gertler and Karadi [2009], Covas and Fujita [2009], Angeloni and Faia [2009] and Christiano et al. [2010].

[3]See e.g. Bernanke and Lown [1991], Peek and Rosengren [1995], Kashyap and Stein [2000], Van den Heuvel [2002], Gambacorta and Mistrulli [2004], and Kishan and Opiela [2006].

risks are perceived to be benign and, vice versa, will be tighter when the quality of the assets is deteriorating, banks are likely to engage in riskier lending during economic upturns and to contract credit supply during economic downturns. To the extent that some firms and households are dependent on having access to bank financing in their investment and spending decisions, more cyclical capital requirements would be expected to reinforce the propagation mechanism between the financial system and the real economy. In other words, ceteris paribus, a risk-sensitive capital requirements regime is expected to have pro-cyclical effects. [4] It has, however, been argued that by inducing a more forward-looking behaviour in banks' risk-taking, a risk-sensitive capital adequacy framework may also include some mitigating elements with respect to its overall pro-cyclical effects. [5] While the extent to which a risk-sensitive capital adequacy framework introduces amplifying pro-cyclical effects is ultimately an empirical question, the analysis of such effects needs to be placed in a broader context whereby the feedback mechanism between the financial and the real sector as well as the forward-looking, strategic behaviour of financial intermediaries are properly taken into account. In other words, a general equilibrium framework is needed to appropriately account for the interlinkages between financial and real economic factors. Moreover, as a consequence of the financial crisis, the Basel Committee on Banking Supervision (BCBS) has already proposed amendments to the bank regulatory framework (i.e. Basel III) with the aim of strengthening capital requirements.[6] Our model is also well-suited for analyzing the potential costs (and benefits) of moving towards higher capital ratio targets and the role of monetary policy during such a transition. Finally, a general equilibrium framework is also useful for analyzing the potential for macro-prudential tools and their interaction with other macroeconomic and monetary policy instruments.

Against this background, in this paper we propose a closed-economy DSGE model with financial frictions including a banking sector which faces monopolistic competition and is subject to capital constraints. The latter may owe both to market disciplining forces (i.e. banks operate with a capital buffer) and to regulatory capital adequacy rules (which can be either risk-insensitive or risk-sensitive). Furthermore, the presence of monopolistic competition in the banking sector gives rise to some degree of stickiness in banks' adjustment of lending and deposit rates to changes in monetary policy rates. From a theoretical viewpoint a sluggish pass-through of bank loan and deposit rates to policy rate changes is based on the notion of banks having some degree of market power, which may derive from banks being "special" in the sense of being able to reduce (by acting as "delegated monitors") the information gap between savers and borrowers of funds.[7] In general, banks' interest rate setting behaviour can be expected to depend on the degree of bank competition (or market power of banks) and on factors related to the costs of financial intermediation (such as interest rate and credit risk, menu costs and other operational costs, banks' degree of risk aversion and the cost of non-deposit funding sources).[8] Hence, by exploiting their market power banks are able to generate profits and thus to replenish their capital

[4]On the procyclicality of risk-sensitive requirements, see e.g. Danielsson et al. [2001], Catarineau-Rabell et al. [2005], Kashyap and Stein [2004], Gordy and Howells [2006], and Brunnermeier et al. [2009]. See also Drumond [2008] for an overview of the literature.

[5]See e.g. Borio and Zhu [2008], Zhu [2008], Repullo and Suarez [2009], Jokivuolle et al. [2009], and Boissay and Kok Sørensen [2009].

[6]See BCBS (2009), "Strengthening the resilience of the banking sector - consultative document", December and BCBS (2010), "The Group of Governors and Heads of Supervision announces higher global minimum capital standards", September.

[7]see e.g. Diamond and Dybvig [1983], Diamond [1984] and Diamond and Rajan [2001].

[8]There is ample empirical evidence for the existence of a sluggish bank interest rate pass-through in the euro area (see e.g. Mojon [2001], De Bondt [2005], Sander and Kleimeier [2006], Kok Sørensen and Werner [2006] and Gropp et al. [2007].

buffers following shocks to their liquidity and capital positions.[9] Under risk-sensitive capital requirements banks' capital positions are affected by changes in the risk profile of their borrowers over the business cycle and the time-varying nature of bank borrower risk profiles is therefore also considered in our modelling of firms and households.

On the real side of the economy we assume that households and firms are financially constrained in their spending and investment decisions and we furthermore incorporate some degree of heterogeneity in the household sector. The model has a subset of firms that are financially constrained and can only borrow by using revenue and capital as collateral, and a subset of financially-constrained households that use debt collateralized by housing and part of their wage income. Both firms and households are affected by idiosyncratic shocks to their collateral values. Firms and households default on their loans when the value of their collateral is below the repayment promised to the lender. In order to keep the model tractable we follow other DSGE models of financial frictions in using differences in the level of impatience of agents to generate equilibrium borrowing and lending (e.g. Iacoviello [2005]). In equilibrium, more impatient agents (borrowers and entrepreneurs) will borrow from patient savers. We assume that borrowers of each type (households and firms) belong to a large family, as in Shi [1997]. While this allows them to diversify their idiosyncratic risk each period after all debt contracts are settled, they cannot commit to sharing the proceeds of this insurance with the banks and hence the latter cannot seize the proceeds of the insurance payments when the borrower defaults. The combination of the large family insurance and limited liability allows us to partially preserve the effects of risk averse, consumption-smoothing behaviour of agents despite the ex-ante heterogeneity among agents and the nonlinear default decision.

More specifically, as regards the household sector, we follow a recent strand of literature which - like Kiyotaki and Moore [1997] - considers a dual structure, with agents belonging to two different groups according to their intertemporal discount factor. Households' heterogeneity generates equilibrium debt as the result of intertemporal borrowing between more and less impatient agents. Building on Iacoviello and Neri [2009] and Notarpietro [2007], we define a two-agent, two-sector economy, where the impatient agents face collateral requirements when asking for mortgages or loans. Firms produce nondurable consumption goods and residential goods. The latter serve two purposes: they can be directly consumed, thus providing utility services as any durable good, or they can be used as collateral in the credit market, to obtain extra funds for financing consumption. The role of collateral constraints in closed economies has been estimated in DSGE models by Iacoviello and Neri [2009] and Notarpietro [2007], who report the relevance of housing market shocks in shaping consumption dynamics in the US. Most existing models of household borrowing in a DSGE framework follow Iacoviello [2005] and Kiyotaki and Moore [1997] in using a hard borrowing constraint and assuming it always binds. The Kiyotaki-Moore model of credit constraints can be seen as a special case of the current model in which there is no uncertainty about the future value of the collateral when the loan is made. The assumption that the constraint always binds makes the leverage ratio in their model constant. Furthermore, they ignore any difference between borrowing rates and the risk free rate. The model proposed here can at least qualitatively match the typically observed countercyclical leverage ratio of households[10] The assumption of an al-

[9] There are a few recent studies that embed features of an incomplete bank interest rate pass-through into a DSGE model framework, see e.g. Kobayashi [2008], Agenor and Alper [2009], Hülsewig et al. [2009] and Gerali et al. [2009].

[10] For instance, as found for the US by Adrian and Shin [2009].

ways binding borrowing constraint is questionable for large shocks that may be of particular interest to policymakers, and it may severely distort the dynamics of borrowers and the rest of the economy in those circumstances. The soft borrowing constraint in our model (with interest rates rising smoothly as a function of borrowing) will always bind as long as it can be satisfied.

For what concerns the non-financial corporate sector we broadly follow Bernanke et al. [1999] and Carlstrom and Fuerst [1997] who introduced equilibrium default of firms into DSGE models. To facilitate aggregation, they assumed risk-neutral entrepreneurs, and constant-returns-to-scale production. Using a setup with equilibrium default, as in those earlier models, allows us to examine the impact of time-varying interest rate spreads and leverage ratios. At the same time, in contrast to the previous literature, we consider a more standard formulation of entrepreneur balance sheets than the less conventional balance sheet used by BGG. In particular, in our setup entrepreneurs own their capital stock, as in more sophisticated heterogeneous agent models of financing constraints, and do not have to repurchase it or rent it each period as in BGG or Carlstrom and Fuerst [1997]. Furthermore, entrepreneurs are risk averse and make a meaningful consumption-saving choice. In contrast, BGG assume an exogenously fixed constant savings rate for entrepreneurs, while Carlstrom and Fuerst [1997] assume that they are risk neutral. Finally, our specification of the non-financial corporate sector allows considering other non-linearities in the budget constraint of financially-constrained entrepreneurs, such as decreasing returns to scale, imperfect competition or labor adjustment costs.

The only other papers that have allowed for financing frictions affecting both households and firms are Iacoviello [2005] and Gerali et al. [2009]. Both of these papers rely on hard borrowing constraints, as in Kiyotaki and Moore [1997], to model credit frictions and assume the borrowing constraints always bind. Our model setup provides an alternative perspective by including costs of default and positive lending spreads.

By allowing for frictions concerning both credit demand and supply, the contributions of this paper cover several dimensions. First, we examine to what extent such frictions amplify shocks to the economy and how they affect the monetary policy transmission mechanism. Apart from encompassing the traditional financial accelerator mechanism arising in the context of financially-constrained borrowers, our model allows for assessing the impact of frictions within the banking sector, such as its price-setting behavior and constraints to its capital management. In particular, we assess the extent to which the presence of bank loan and deposit rate sluggishness affect monetary policy optimization. Moreover, our setup allows for examining the macroeconomic implications of shocks to bank capital (as those observed during the 2007-10 financial crisis as well as reflected in the proposal to introduce stronger capital requirements under the Basel III agreement) and the implications of introducing risk-sensitive capital requirements or the transitional effects of higher capital requirements. Furthermore, our model can also shed some light on the potential effects of active macro-prudential policies over the cycle and their interaction with monetary policy.

At the same time, our current model setup is less suited for analyzing the issues of liquidity and wholesale funding vulnerabilities, which arguably were other main contributing factors to the severity and propagation of the financial crisis. The macroeconomic implications of money market disruptions and the potential role of unconventional monetary policies have been addressed in other recent papers (see e.g. Gertler and Kiyotaki [2009] and also Christiano et al. [2010])

The rest of the paper is organized as follows. Section 2 describes the main decision problems of the structural model. Section 3 presents the results of the Bayesian estimation. Section 4 explores in turn the propagation of housing-related and productivity shocks in the estimated model. Furthermore, the business cycle implications of the imperfect bank interest rate pass-through and bank capital constraints are highlighted. In section 5 we investigate the optimal monetary policy responses under different regulatory frameworks focusing in particular on the introduction of risk-based capital requirements and macro-prudential rules. Section 6 concludes.

3 Theoretical model

The economy is modeled as a three-agent, two-sector economy, producing residential and non-residential goods. Residential goods are treated here as *durable* goods. A continuum of entrepreneurs, with unit mass, produce non-residential and residential intermediate goods under perfect competition and face financing constraints. Then retailers differentiate the intermediate goods under imperfect competition and staggered price setting, while competitive distribution sectors serve final non-residential consumption as well as residential and non-residential investments. A continuum of infinitely-lived households, with unit mass, is composed of two types, differing in their relative intertemporal discount factor. A fraction $(1-\omega)$ of households are relatively *patient*, the remaining fraction ω being *impatient*. Households receive utility from consuming both non-residential and residential goods, and disutility from labor. Impatient households are financially constrained.
The banking sector collects deposit from patient households and provides funds to entrepreneurs and impatient households. Three layers of frictions affect financial intermediaries. First, wholesales banking branches face capital requirements (which can be risk-insensitive or risk-sensitive) as well as adjustment costs related to their capital structure. Second, some degree of nominal stickiness generates some imperfect pass-through of market rates to bank deposit and lending rates. Finally, due to asymmetric information and monitoring cost in the presence of idiosyncratic shocks, the credit contracts proposed to entrepreneurs and impatient households factor in external financing premia which depend indirectly on the borrower's leverage.

3.1 Households

3.1.1 The saver's program

The patient agents, $s \in [\omega, 1]$, are characterized by a higher intertemporal discount factor than the borrowers, and thus act as net lenders in equilibrium. They own the productive capacities of the economy. Each patient agent receives instantaneous utility from the following instantaneous utility function:

$$\mathcal{W}_t^s = \mathbb{E}_t \left\{ \sum_{j \geq 0} \gamma^j \left[\begin{array}{c} \frac{1}{1-\sigma_X} \left(X_{t+j}^s \right)^{1-\sigma_X} - \frac{\varepsilon_{t+j}^L \overline{L}_{S,C}}{1+\sigma_{LC}} \left(N_{Ct+j}^s \right)^{1+\sigma_{LC}} \\ - \frac{\varepsilon_{t+j}^L \overline{L}_{S,D}}{1+\sigma_{LD}} \left(N_{Dt+j}^s \right)^{1+\sigma_{LD}} \end{array} \right] \varepsilon_{t+j}^\beta \right\}$$

where X_t^s is an index of consumption services derived from non-residential final goods (C^s) and residential stock (D^s), respectively.

$$X_t^s \equiv \left[\left(1-\varepsilon_t^D \omega_D\right)^{\frac{1}{\eta_D}} \left(C_t^s - h_S C_{t-1}^s \right)^{\frac{\eta_D - 1}{\eta_D}} + \varepsilon_t^D \omega_D^{\frac{1}{\eta_D}} \left(D_t^s \right)^{\frac{\eta_D-1}{\eta_D}} \right]^{\frac{\eta_D}{\eta_D - 1}}$$

with the parameter h_S capturing habit formation in consumption of non-residential goods. We introduce three stochastic terms in the utility function: a preference shock ε_t^{β}, a labor supply shock ε_t^L (common across sectors) and a housing preference shock, ε_t^D. The latter affects the relative share of residential stock, ω_D, and modifies the marginal rate of substitution between non-residential and residential goods consumption. All the shocks are assumed to follow stationary AR(1) processes.

Households receive disutility from their supply of homogenous labor services to each sector, $N_{C,t}^s$ and $N_{D,t}^s$. The real compensation of hours worked in each sector are denoted $w_{C,t}^s$ and $w_{D,t}^s$. The specification of labor supply assumes that households have preferences over providing labor services across different sectors. In particular, the specific functional form adopted implies that hours worked are perfectly substitutable across sectors. $\overline{L}_C$ and $\overline{L}_D$ are level-shift terms needed to ensure that the patient's labor supply is equal to one in steady state.

The saver maximizes its utility function subject to an infinite sequence of the following budget constraint:

$$\begin{aligned} & C_t^s + Q_{D,t}T_{D,t}\left(D_t^s - (1-\delta)\,D_{t-1}^s\right) + Dep_t^s \\ = \quad & \frac{(1+R_{D,t-1})}{(1+\pi_t)} Dep_{t-1}^s + (1-\tau_{w,t})\left(w_{C,t}^s N_{C,t}^s + w_{D,t}^s N_{D,t}^s\right) + \Pi_t^s + TT_t^s \end{aligned}$$

where $Q_{D,t}T_{D,t}$ is real price of housing stock in terms of non-residential goods, TT_t^s are real government transfers and Π_t^s are real distributed profits. $\delta \in (0,1)$ is the residential good depreciation rate. π_t is the non-residential good inflation rate. $R_{D,t-1}$ is the nominal interest rate paid on the one-period real deposits Dep_t^s.

In equilibrium, all savers have identical consumption plans. Therefore, we can drop superscripts s. We also allow for a time-varying labor income tax, given by $1-\tau_{w,t} = \left(1-\overline{\overline{\tau}}_w\right)\varepsilon_t^W$.

The optimality conditions characterizing the solution of the saver's problem are reported in the Appendix.

3.1.2 The borrower's program

Each impatient agent $b \in [0,\omega]$ receives utility from the same type of function as in the case of patient households but with a lower discount factor $\beta < \gamma$[11]:

$$\mathcal{W}_t^b = \mathbb{E}_t \left\{ \sum_{j\geq 0} \beta^j \left[\begin{array}{c} \frac{1}{1-\sigma_X}\left(\widetilde{X}_{t+j}^b\right)^{1-\sigma_X} - \frac{\varepsilon_{t+j}^L \overline{L}_{B,C}}{1+\sigma_{LC}}\left(N_{C,t+j}^b\right)^{1+\sigma_{LC}} \\ -\frac{\varepsilon_{t+j}^L \overline{L}_{B,D}}{1+\sigma_{LD}}\left(N_{D,t+j}^b\right)^{1+\sigma_{LD}} \end{array} \right] \varepsilon_{t+j}^{\beta} \right\}$$

where $\widetilde{X}_t^b$ is given by :

$$\widetilde{X}_t^b \equiv \left[\left(1-\varepsilon_t^D\omega_D\right)^{\frac{1}{\eta_D}} \left(\widetilde{C}_t^b - h_B \widetilde{C}_{t-1}^b\right)^{\frac{\eta_D-1}{\eta_D}} + \varepsilon_t^D \omega_D^{\frac{1}{\eta_D}} \left(\widetilde{D}_t^b\right)^{\frac{\eta_D-1}{\eta_D}} \right]^{\frac{\eta_D}{\eta_D-1}}$$

As regards savers, $\overline{L}_{B,C}$ and $\overline{L}_{B,D}$ are level-shift terms needed to ensure that the impatient's labor supply equals one in steady state.

[11]Variables related to the saver are denoted with a superscript b, as opposed to s, used for the savers.

Borrowers' incomes and housing stock values are subject to common idiosyncratic shocks $\varpi_{HH,t}$ that are i.i.d across borrowers and across time. $\varpi_{HH,t}$ has a lognormal CDF $F(\varpi)$ with $F'(\varpi) = f(\varpi)$, and a mean of $E(\varpi) = 1$. The variance of the idiosyncratic shock $\sigma_{HH,t}$ is time-varying. The value of the borrower's house is given by

$$\varpi_{HH,t}\widetilde{Q}_{D,t}T_{D,t}(1-\delta)\widetilde{D}^b_{t-1}.$$

Lending in this economy is only possible through 1-period state-contingent debt contracts that require a constant repayment of $\frac{(1+R^L_{HH,t})}{1+\pi_t}B_{HH,t-1}$ independent of $\varpi_{HH,t}$ if the borrower is to avoid costly loan monitoring or enforcement, where $R^L_{HH,t}$ is the nominal lending rate.

The borrower can default and refuse to repay the debt. Savers cannot force borrowers to repay. Instead lending must be intermediated by commercial banks that have a loan enforcement technology allowing them to seize collateral expressed in real terms

$$\varpi_{HH,t}\tilde{A}^b_{HH,t} = (1-\chi_{HH})\varpi_{HH,t}\widetilde{Q}_{D,t}T_{D,t}(1-\delta)\widetilde{D}^b_{t-1}$$

at a proportional cost $\mu_{HH}\varpi_{HH,t}\tilde{A}_{HH,t}$ when the borrower defaults.

$\mu_{HH} \in (0,1)$ determines the deadweight cost of default, $0 < \chi_{HH} \leq 1$ represents housing exemptions. It defines the maximum loan to collateral ratio (often called the Loan-to-Value Ratio) that the bank is willing to grant against each component of the collateral . Conditional on enforcement, the law cannot prevent the bank from seizing $\varpi_{HH,t}\tilde{A}_{HH,t}$. Suppose first that the borrower does not have access to any insurance against the $\varpi_{HH,t}$ shock. Whenever $\varpi_{HH,t} < \overline{\varpi}_{HH,t}$ the borrower prefers to default and lose

$$\varpi_{HH,t}\tilde{A}^b_{HH,t} < \frac{(1+R^L_{HH,t})}{1+\pi_t}B_{HH,t-1} = \overline{\varpi}_{HH,t}\tilde{A}^b_{HH,t}$$

when the bank enforces the contract. On the other hand when $\varpi_{HH,t} \geq \overline{\varpi}_{HH,t}$ the borrower prefers to pay $\frac{(1+R^L_{HH,t})}{1+\pi_t}B_{HH,t-1}$ rather than lose $\varpi_{HH,t}\tilde{A}_{HH,t} \geq \frac{(1+R^L_{HH,t})}{1+\pi_t}B_{HH,t-1}$.

To be able to use a representative agent framework while maintaining the intuition of the default rule above, we assume that borrowers belong to a large family that can pool their assets and diversify away the risk related to $\varpi_{HH,t}$ after loan repayments are made. As in Lucas [1990] and Shi [1997], The family maximizes the expected lifetime utility of borrowers with an equal welfare weight for each borrower. The payments from the insurance scheme cannot be seized by the bank. As a result, despite the insurance the bank cannot force the borrower to repay $\frac{(1+R^L_{HH,t})}{1+\pi_t}B_{HH,t-1}$ when $\varpi_{HH,t} < \overline{\varpi}_{HH,t}$. Like the individual borrowers, the family cannot commit to always repay the loan (or make up for any lack of payment by a borrower), even though from an ex-ante perspective it is optimal to do so. Ex-post, from the perspective of maximizing the expected welfare of the borrowers, for any given $R^L_{HH,t}$ it is optimal to have borrowers with $\varpi_{HH,t} < \overline{\varpi}_{HH,t}$ default and borrowers with $\varpi_{HH,t} \geq \overline{\varpi}_{HH,t}$ repay $\frac{(1+R^L_{HH,t})}{1+\pi_t}B_{HH,t-1}$.

Given the large family assumption in particular, households decisions are the same in equilibrium. Therefore, we can drop the superscript b.

By pooling the borrowers' resources, the representative family has the following aggregate repayments and defaults on its outstanding loan:

$$H(\overline{\varpi}_{HH,t})\tilde{A}_{HH,t} = [(1-F_t(\overline{\varpi}_{HH,t}))\overline{\varpi}_{HH,t} + \int_0^{\overline{\varpi}_{HH,t}} \varpi dF_t]\tilde{A}_{HH,t}.$$

On the commercial lending bank side, the profit made on the credit allocation is given by

$$G(\varpi_{HH,t})\tilde{A}_{HH,t} - \frac{(1+R_{HH,t-1})}{1+\pi_t}B_{HH,t-1} \geq 0$$

with

$$G(\varpi_{HH,t}) = (1-F_t(\varpi_{HH,t}))\varpi_{HH,t} + (1-\mu_{HH})\int_0^{\varpi_{HH,t}} \varpi dF_t$$

$R_{HH,t-1}$ is the interest rate at which the commercial lending bank gets financing every period while $R^L_{HH,t}$ is the state-contingent lending rate. Competition among banks will ensure that profits are null in equilibrium. The zero profit condition could also be seen as the borrowing constraint in this model. Notice that this constraint always binds as long as it can be satisfied.[12] In contrast, the hard borrowing constraint in Kiyotaki and Moore [1997] or Iacoviello [2005] may not bind, even though authors using that framework assume it always binds to allow the use of perturbation methods.[13] The caveat, is that if a new shock significantly lowers the value of $\tilde{A}_{HH,t}$ it may be impossible to find a default threshold that allows the bank to break even on the loan with the risk free rate. This should not be a major concern except for very low aggregate shock values.[14]

With the assumption of perfectly competitive banks we can represent the problem of borrowers as if they choose default thresholds as a function of the aggregate states directly, subject to the bank's participation constraints.

Each borrower maximizes utility function with respect to $(\widetilde{C}_t, \widetilde{D}_t, B_{HH,t}\varpi_{HH,t}, N_{C,t}, N_{D,t})$ subject to an infinite sequence of real budget constraints[15]:

$$\begin{aligned} \widetilde{C}_t + \widetilde{Q}_{D,t}T_{D,t}\left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}\right) + H(\varpi_{HH,t})\tilde{A}_{HH,t} \quad &= \quad B_{HH,t} + \widetilde{TT}_t \\ &\quad + \widetilde{w}_{C,t}\widetilde{N}_{C,t} + \widetilde{w}_{D,t}\widetilde{N}_{D,t} \end{aligned}$$

and the zero profit condition for the commercial lending banks.

We report the first order conditions for this problem in the Appendix.

3.2 Labor supply and wage setting

The labor market structure is modeled following Schmitt-Grohe and Uribe [2006]. In both countries, households of each type (patient, impatient) provide homogeneous labor services, which are transformed by monopolistically competitive unions into differentiated labor inputs. As a result, all household of the same type supply the same amount of hours worked in each sector, in equilibrium.

We assume that in each sector $j \in \{C, D\}$ there exist monopolistically competitive labor unions indexed representing the patient and impatient households. Unions differentiate the homogeneous labor provided by households, N_{jt} from savers and $\widetilde{N}_{jt}$ from borrowers, creating a continuum of measure one of labor services (indexed by $z \in [0,1]$) which are sold to labor packers.

[12] If the constraint were slack, the lender could always reduce the borrower's expected repayments while still respecting the constraint by reducing $\varpi_{HH,t}$

[13] This may be a reasonable assumption for small shocks, but it can be a bad approximation for larger shocks that may be of concern to policymakers.

[14] In our calibrations, the balanced growth path value of the Loan to Value ratio (LTV) $G(\varpi_{HH,t})$ is around 0.5. This suggests that we would need shocks that cause extremely large movements in the LTV on impact before we violate the upper bound on the LTV. See the appendix in Bernanke et al. [1999] for a discussion of the same issue in their model.

[15] We use the non-residential goods price level as a deflator.

Then perfectly competitive labor packers buy the differentiated labor input and aggregate them through a CES technology into one labor input per sector and households type. Finally the labor inputs are further combined using a Cobb-Douglas technology to produce the aggregate labor resource $L_{C,t}$ and $L_{D,t}$ that enter the production functions of entrepreneurs (see later). We specify the details of the labor packers profit-maximization problem below.
For $i \in \{B, S\}$, $L_{j,i,t}$ measures aggregate labor input for household type i and sector j,

$$L_{j,i,t} = \left[\int_0^1 L_{j,i,t}(z)^{\frac{1}{\mu_w}} \mathrm{d}z \right]^{\mu_w}$$

while $W_{j,i,t}$ denotes the aggregate nominal wage for type i and sector j :

$$W_{j,i,t} = \left[\int_0^1 W_{j,i,t}(z)^{\frac{1}{1-\mu_w}} \mathrm{d}z \right]^{1-\mu_w}$$

Each union thus faces the following labor demand (originating from sector-specific labor packers):

$$L_{j,i,t}(z) = \left(\frac{W_{j,i,t}(z)}{W_{j,i,t}} \right)^{-\frac{\mu_w}{\mu_w - 1}} L_{j,i,t}$$

where $z \in [0,1]$, $\mu_w = \frac{\theta_w}{\theta_w - 1}$ and $\theta_w > 1$ is the elasticity of substitution between differentiated labor services, which we assume to be constant across types and sectors. Clearly, our structure gives rise to four different wages in equilibrium, each corresponding to a specific worker type (patient, impatient) in a specific sector (C, D). Unions set wages on a staggered basis. Every period, each union faces a constant probability $1 - \alpha_{wji}$ of being able to adjust its nominal wage. If the union is not allowed to re-optimize, wages are indexed to past and steady-state inflation according to the following rule:

$$W_{j,i,t}(z) = [\Pi_{t-1}]^{\gamma_w^{j,i}} \left[\overline{\Pi} \right]^{1-\gamma_w^{j,i}} W_{j,i,t-1}(z)$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ and $\gamma_w^{j,i}$ denotes the degree of indexation in each sector, for each type. Taking into account that unions might not be able to choose their nominal wage optimally in the future, the optimal nominal wage $\widehat{W}_{j,i,t}(z)$ is chosen to maximize intertemporal utility under the budget constraint and the labor demand function. The Appendix reports the first order conditions for this program written in a recursive form, and an expression for the aggregate wage dynamics.
Market clearing conditions between household supply of homogenous labor services and unions differentiated labor input imply for $j \in \{C, D\}$:

$$\omega \widetilde{N}_{j,t} \equiv \int_0^1 L_{j,B,t}(z) dz = \Delta_{j,B,t}^w L_{j,B,t}$$

and

$$(1-\omega) N_{j,t} \equiv \int_0^1 L_{j,S,t}(z) dz = \Delta_{j,S,t}^w L_{j,S,t}$$

The final aggregate by labor packers uses a Cobb-Douglas production function as follows:

$$L_j \equiv \omega^{\omega} (1-\omega)^{(1-\omega)} \left(\frac{N_{j,t}}{\Delta_{j,S,t}^w} \right)^{(1-\omega)} \left(\frac{\widetilde{N}_{j,t}}{\Delta_{j,B,t}^w} \right)^{\omega}$$

where cost minimization implies

$$\frac{N^B_{j,t}}{\Delta^w_{j,B,t}} W_{j,B,t} = \frac{N^S_{j,t}}{\Delta^w_{j,S,t}} W_{j,S,t}$$

and leads to the following aggregate wage per sector

$$W_{j,t} = \frac{\left(W_{j,S,t}\right)^{1-\omega} \left(W_{j,B,t}\right)^{\omega}}{\omega^{\omega}(1-\omega)^{1-\omega}}$$

The term $\Delta^w_{j,i,t}$ denotes wage dispersion in sector j, related to agent i. Notice that wage dispersion is inefficient, as all job varieties are ex-ante identical [16].

3.3 Non-financial corporate sectors

3.3.1 Entrepreneurs

Entrepreneurs are also more impatient than household savers and have a discount factor $\beta_E < \beta$. They receive utility from their consumption of non-residential goods. They are in charge of the production of intermediate residential and non-residential goods, and operate in a perfectly competitive environment. They do not supply labor services. Their intertemporal utility function is given by

$$\mathcal{W}^E_t = \mathbb{E}_t \left\{ \sum_{j \geq 0} (\beta_E)^j \frac{\left(C^E_{t+j} - h_E C^E_{t+j-1}\right)^{1-\sigma_{CE}}}{1-\sigma_{CE}} \varepsilon^{\beta}_{t+j} \right\}$$

Non-residential intermediate goods are produced with capital and labor while residential intermediate goods combine capital, labor and land. In every period of time, savers are endowed with a given amount of land, which they sell to the entrepreneurs in a fixed quantity. We assume that the supply of land is exogenously fixed and that each entrepreneur takes the price of land as given in its decision problem. Entrepreneurs make use of Cobb-Douglas technology as follows:

$$\begin{aligned} Z_t(e) &= \varepsilon^A_t \left(u^C_t(e) K^C_{t-1}(e)\right)^{\alpha_C} L^C_t(e)^{1-\alpha_C} - \Omega_C \qquad \forall e \in [0,1] \\ Z_{D,t}(e) &= \varepsilon^{A_D}_t \left(u^D_t(e) K^D_{t-1}(e)\right)^{\alpha_D} L^D_t(e)^{1-\alpha_D-\alpha_{\mathcal{L}}} \mathcal{L}_t(e)^{\alpha_{\mathcal{L}}} - \Omega_D \end{aligned}$$

where ε^A_t and $\varepsilon^{A_D}_t$ are an exogenous technology shocks and $\mathcal{L}_t(e)$ denotes the endowment of land used by entrepreneur e at time t. Capital is sector specific and is augmented by a variable capacity utilization rate u_t. MC_t and $MC_{D,t}$ denote the selling prices for intermediate non-residential and residential products.

Entrepreneurs' fixed capital are subject to common multiplicative idiosyncratic shocks $\varpi_{E,t}$. As for households, these shocks are independent and identically distributed across time and across entrepreneurs with $E(\varpi_{E,t}) = 1$, and a lognormal CDF $F^E(\varpi_{E,t})$. Here again, the variance of the idiosyncratic shock $\sigma_{E,t}$ is time-varying.

As for borrowers, entrepreneurs only use debt contracts in which the loan rates can be made contingent on aggregate shocks but not on the idiosyncratic shock $\varpi_{E,t}$. Entrepreneurs belong to a large family that can diversify the idiosyncratic risk after loan contracts are settled, but cannot commit to sharing

[16] see Schmitt-Grohe and Uribe [2006]

the proceeds of this insurance with banks. Banks can seize collateral $\varpi_{E,t}\tilde{A}_{E,t}$ when the entrepreneur refuses to pay at a cost of $\mu_E\varpi_{E,t}\tilde{A}_{E,t}$. The value of the collateral that the bank can seize is

$$\varpi_{E,t}\tilde{A}_{E,t} = \varpi_{E,t}(1-\chi_E)(1-\delta_K)(Q_t^C K_{t-1}^C + Q_t^D K_{t-1}^D)$$

We assume that the capital utilization rate is predetermined with respect to the idiosyncratic shock to facilitate aggregation. χ_E reflect the ability to collateralize capital This specification relates to models where only capital serves as collateral as in Gerali et al. [2009] or Kobayashi et al. [2007].
Aggregate repayments or defaults on outstanding loan to entrepreneurs are:

$$H^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} = [(1-F_t^E(\overline{\varpi}_{E,t}))\overline{\varpi}_{E,t} + \int_0^{\overline{\varpi}_{E,t}} \varpi dF_t^E]\tilde{A}_{E,t}.$$

On the commercial lending bank side, the profit made on the credit allocation is given by

$$G^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} - \frac{(1+R_{E,t-1})}{1+\pi_t}B_{E,t-1} \geq 0$$

with

$$G^E(\overline{\varpi}_{E,t}) = (1-F_t^E(\overline{\varpi}_{E,t}))\overline{\varpi}_{E,t} + (1-\mu_E)\int_0^{\overline{\varpi}_{E,t}} \varpi dF_t^E$$

$R_{E,t-1}$ is the interest rate at which the commercial lending bank gets financing every period while $R_{E,t}^L$ is the state-contingent lending rate to entrepreneurs.
Overall, each entrepreneur maximizes its utility function with respect to $(C_t^E, K_t^C, K_t^D, u_t^C, u_t^D, B_t^E, \overline{\varpi}_{E,t}, L$ subject to an infinite sequence of real budget constraints

$$\begin{aligned} & C_t^E + Q_t^C(K_t^C - (1-\delta_K)K_{t-1}^C) + Q_t^D(K_t^D - (1-\delta_K)K_{t-1}^D) + H^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} \\ = \; & B_{E,t} + MC_t Z_t + MC_{D,t}Z_{D,t} - W_{C,t}^r L_{C,t} - W_{D,t}^r L_{D,t} - p_{lt}\mathcal{L}_t \\ & -\Phi\left(u_t^C\right)K_{t-1}^C - \Phi\left(u_t^D\right)K_{t-1}^D + TT_t^E \end{aligned}$$

together with the participation constraints for the banks.We assume the following functional form for the adjustment costs on capacity utilization: $\Phi(X) = \frac{\overline{\overline{R^k}}(1-\varphi)}{\varphi}\left(\exp\left[\frac{\varphi}{1-\varphi}(X-1)\right]-1\right)$. Following Smets and Wouters [2007], the cost of capacity utilization is zero when capacity is fully used ($\Phi(1)=0$). p_{lt} denotes the relative price of land deflated by non-residential goods price.
We report the first order conditions for this problem in the Appendix.

3.3.2 Retailers and distribution sectors

Retailers differentiate the residential and non-residential goods produced by the entrepreneurs and operate under monopolistic competition. They sell their output to the perfectly competitive distribution sectors which aggregate the continuum of differentiated goods. The elementary differentiated goods are imperfect substitutes with elasticity of substitution denoted $\frac{\mu_D}{\mu_D-1}$ and $\frac{\mu}{\mu-1}$ for the residential and the non-residential sectors respectively. The distributed goods are then produced with the following technology $Y_D = \left[\int_0^1 Z_D(d)^{\frac{1}{\mu_D}}\mathrm{d}d\right]^{\mu_D}$ and $Y = \left[\int_0^1 Z(c)^{\frac{1}{\mu}}\mathrm{d}c\right]^{\mu}$. The corresponding aggregate price indexes are defined as $P_D = \left[\int_0^1 p_D(d)^{\frac{1}{1-\mu_D}}\mathrm{d}d\right]^{1-\mu_D}$ for the residential sector and $P = \left[\int_0^1 p(c)^{\frac{1}{1-\mu}}\mathrm{d}c\right]^{1-\mu}$ for the non-residential sector. The distribution goods serve as final consumption goods for households and are used by capital and housing stock producers.

Retailers are monopolistic competitors which buy and the homogenous intermediate products of the entrepreneurs at prices MC_t for the non-residential intermediate goods and $MC_{D,t}$ for the residential intermediate goods. The intermediate products are then differentiated and sold back to the distributors. Retailers set their prices on a staggered basis *à la* Calvo [1983]. In each period, a retailer in the non-residential sector faces a constant probability $1-\xi_C$ (resp. $1-\xi_D$ in the residential sector) of being able to re-optimize its nominal price. If they cannot re-optimize their price, the price evolves according to the following simple rule in each sector:

$$\begin{aligned} p_t(c) &= \Pi_{t-1}^{\gamma_C}\overline{\Pi}^{1-\gamma_C}p_{t-1}(c) \\ p_{D,t}(d) &= \Pi_{D,t-1}^{\gamma_D}\overline{\Pi}^{1-\gamma_D}p_{D,t-1}(d) \end{aligned}$$

with γ_C and γ_D denoting price indexation. The demand curves that retailers face in each sector follow $Z_D(d) = \left(\frac{p_D(d)}{P_D}\right)^{-\frac{\mu_D}{\mu_D-1}} Y_D$ and $Z(c) = \left(\frac{p(c)}{P}\right)^{-\frac{\mu}{\mu-1}} Y$.

3.3.3 Capital and housing stock producers

Using distributed residential and non-residential goods, a segment of perfectly competitive firms, owned by the patient households, produce a stock of housing and fixed capital. At the beginning of period t, those firms buy back the depreciated housing stocks from both households types $(1-\delta)D_{t-1}$ and $(1-\delta)\widetilde{D}_{t-1}$ as well as the depreciated capital stocks $(1-\delta_K)K_{t-1}^C$, $(1-\delta_K)K_{t-1}^D$ at real prices (in terms of consumption goods) $Q_{D,t}T_{D,t}$, $\widetilde{Q}_{D,t}T_{D,t}$, Q_t^D, Q_t^C respectively. Then they augment the various stocks using distributed goods and facing adjustment costs. The augmented stocks are sold back to entrepreneurs and households at the end of the period at the same prices. The decision problem of capital and housing stock producers is given by

$$\max_{\{K_t^C, K_t^D, I_t^C, I_t^D, D_t, \widetilde{D}_t, I_{D,t}, \widetilde{I}_{D,t}\}} \mathbb{E}_t \sum_{t=0}^{\infty} \left\{ \begin{array}{c} Q_t^C(K_t^C - (1-\delta_K)K_{t-1}^C) - I_t^C \\ Q_t^D(K_t^D - (1-\delta_K)K_{t-1}^D) - I_t^D \\ Q_{D,t}T_{D,t}(D_t - (1-\delta)D_{t-1}) - I_{D,t} \\ \widetilde{Q}_{D,t}T_{D,t}(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}) - \widetilde{I}_{D,t} \end{array} \right\}$$

subject to the constraints

$$\begin{aligned} K_t^C &= (1-\delta_K)K_{t-1}^C + \left[1 - S\left(\frac{I_t^C\varepsilon_t^I}{I_{t-1}^C}\right)\right] I_t^C \\ K_t^D &= (1-\delta_K)K_{t-1}^D + \left[1 - S\left(\frac{I_t^D\varepsilon_t^I}{I_{t-1}^D}\right)\right] I_t^D \\ D_t &= (1-\delta)D_{t-1} + \left[1 - S_D\left(\frac{I_{D,t}}{I_{D,t-1}}\right)\right] I_{D,t} \\ \widetilde{D}_t &= (1-\delta)\widetilde{D}_{t-1} + \left[1 - S_D\left(\frac{\widetilde{I}_{D,t}}{\widetilde{I}_{D,t-1}}\right)\right] \widetilde{I}_{D,t} \end{aligned}$$

S and S_D are non-negative adjustment cost functions formulated in terms of the gross rate of change in investment and ε_t^I is an efficiency shock to the technology of fixed capital accumulation, common to both sectors. The functional forms adopted are $S(x) = \phi/2\ (x-1)^2$ for fixed capital stocks and $S_D(x) = \phi_D/2\ (x-1)^2$ for housing stocks.

3.4 The Banking sector

The banking sector is owned by the patient households and is segmented in three parts. Following Gerali et al. [2009], each banking group is first composed of a wholesale branch which gets financing in the money market and allocates funds to the rest of the group, facing an adjustment cost on the overall capital ratio of the group. The wholesale branch takes the bank capital and the dividend policy as given in its decision problem and operates under perfect competition. The second segment of the banking group comprises a deposit branch which collects savings from the patient households and place them in the money markets as well as two loan book financing branches which receive funding from the wholesale branch and allocate them to the commercial lending branches. In this second segment, banks operate under monopolistic competition and face nominal rigidity in their interest rate settings. The third segment of the banking group is formed by two commercial lending branches which provide loan contracts to impatient households and entrepreneurs. The commercial lending branches are zero profit competitive firms.

3.4.1 Wholesale branch

The perfectly competitive wholesale branches receives deposits Dep_t^{wb}, from the retail deposit banks, with an interest rate set at the policy rate R_t. Taking as given the bank capital $Bankcap_t$ in real terms, they provide loans $B_{E,t}^{wb}$ and $B_{HH,t}^{wb}$ at interest rates $R_{E,t}^{wb}$ and $R_{HH,t}^{wb}$to the loan book financing branches for lending to entrepreneurs and households respectively. When deciding on deposits and loans, the wholesale banks are constrained by an adjustment cost on bank's leverage. This friction is meant to capture the capital requirement pressures on the banks behavior. For this reason, we assume that wholesale banks target a capital ratio of 11% and the quadratic cost is supposed to illustrate the various interactions between banks' balance sheet structure, market disciplining forces and the regulatory framework.[17] On the one hand, this reflects that owing to pecuniary and reputational costs banks are keen to avoid getting too close to the regulatory minimum capital requirement and hence tend to operate with a substantial buffer over that minimum capital ratio.[18] On the other hand, bank capital is costly relative to other sources of financing (like deposits and bond issuance) implying that banks tend to economize on the amount of capital they hold.[19]

Under the Basel I-like capital requirement regime, the bank's static profit maximization problem can be formulated as follows where all quantities are expressed in real terms

$$\max_{B_t^w, Dep_t^w} R_{HH,t}^{wb} B_{HH,t}^{wb} + R_{E,t}^{wb} B_{E,t}^{wb} - R_t Dep_t^{wb} - \frac{\chi_{wb}}{2} \left(\frac{Bankcap_t}{0.5 B_{HH,t}^{wb} + B_{E,t}^{wb}} - 0.11 \right)^2 Bankcap_t$$

subject to the balance sheet identity

$$B_{HH,t}^{wb} + B_{E,t}^{wb} = Dep_t^{wb} + Bankcap_t$$

[17] The 11% capital ratio target corresponds to the average (risk-adjusted) total capital ratio of the around 100 largest euro area banks for the period 1999-2008; according to Datastream (Worldscope).

[18] There is a rich literature providing evidence that banks' operate with substantial capital buffers; for some recent studies see e.g. Ayuso et al. [2004], Bikker and Metzemakers [2004], Berger et al. [2008], Gropp and Heider [2009], and Stolz and Wedow [2005].

[19] For example, ECB estimates of the cost of equity, cost of market-based debt (i.e. bond issuance) and the cost of deposits for euro area banks show that the former was on average around 6.7% in the period 2003-2009. During the same period, banks' cost of raising debt in the capital markets was around 5%, while their average cost of deposit funding was close to 2%.

As in Gerali et al. (2009) the derived lending spreads emphasize "the role of bank capital in determining loan supply conditions". Hence, on the one hand, if the spread between the lending rate and the policy rate is positive, the bank would have an incentive to increase profits by raising loan volumes. This, on the other hand, would increase its leverage, which is however penalized by regulatory rules and market disciplining forces; as the capital ratio moves away from its target, which poses a cost to the bank. The bank's decision problem is therefore finely balanced between boosting its profits via increased leverage and retaining control of its capital structure. Moreover, a key point to notice for our Basel I-type specification is that the bank's target capital ratio is insensitive to changes in borrower risk over time. In addition, reflecting the risk weighting of the Basel I regulatory framework, household loans are given a (fixed) risk weight of 50% whereas the risk weight attached to corporate loans is 100%.
The decision problem of the wholesale bank leads to the following condition on the spread between the lending rate and the policy rate

$$\begin{aligned} R^{wb}_{HH,t} - R_t &= -\chi_{wb}\left(\frac{Bankcap_t}{0.5B^{wb}_{HH,t} + B^{wb}_{E,t}} - 0.11\right)\left(\frac{Bankcap_t}{0.5B^{wb}_{HH,t} + B^{wb}_{E,t}}\right)^2 0.5 \\ R^{wb}_{E,t} - R_t &= -\chi_{wb}\left(\frac{Bankcap_t}{0.5B^{wb}_{HH,t} + B^{wb}_{E,t}} - 0.11\right)\left(\frac{Bankcap_t}{0.5B^{wb}_{HH,t} + B^{wb}_{E,t}}\right)^2 \end{aligned}$$

When the leverage of the bank increases beyond the targeted level, banks increase their loan-deposit margins.
The capital base of the wholesale branch is accumulated out of retained earnings form the bank group profits

$$Bankcap_t = (1 - \delta^{wb})Bankcap_{t-1} + \nu^b \Pi^b_t$$

where δ^{wb} represents the resources used in managing bank capital, Π^b_t is the overall profit of the bank group and ν^b is the share of profits not distributed to the patient households.

3.4.2 Imperfect pass-through of policy rate on bank lending rates

The retail deposit branch and the loan book financing branches are monopolistic competitors and set their interest rates on a staggered basis with some degree of nominal rigidity *à la Calvo*.

Retail deposit branch The deposits offered to patient households are a CES aggregation of the differentiated deposits provided by the retail deposit branches: $Dep = \left[\int_0^1 Dep(j)^{\frac{1}{\mu^R_D}} \mathrm{d}j\right]^{\mu^R_D}$, expressed in real terms. Retail deposits are imperfect substitute with elasticity of substitution $\frac{\mu^R_D}{\mu^R_D - 1} < -1$. The corresponding average interest rate offered on deposits is $R_D = \left[\int_0^1 R_D(j)^{\frac{1}{1-\mu^R_D}} \mathrm{d}j\right]^{1-\mu^R_D}$.
Retail deposit branches are monopolistic competitors which collect deposit from savers and place them in the money market. Deposit branches set interest rates on a staggered basis *à la* Calvo (1983), facing each period a constant probability $1 - \xi^R_D$ of being able to re-optimize their nominal interest rate. When a retail deposit branch cannot re-optimize its interest rate, the interest rate is left at its previous period level:

$$R_{D,t}(j) = R_{D,t-1}(j)$$

The retail deposit branch j chooses $\hat{R}_{D,t}(j)$ to maximize its intertemporal profit.

$$\mathbb{E}_t \left[\sum_{k=0}^{\infty} \left(\gamma \xi_D^R\right)^k \frac{\Lambda_{t+k}}{\Lambda_t} \left(R_{t+k} Dep_{t+k}(j) - \hat{R}_{t,D}(j) Dep_{t+k}(j) \right) \right]$$

where $Dep_{t+k}(j) = \left(\frac{\hat{R}_{D,t}(j)}{R_{D,t}}\right)^{-\frac{\mu_D^R}{\mu_D^R-1}} \left(\frac{R_{D,t}}{R_{D,t+k}}\right)^{-\frac{\mu_D^R}{\mu_D^R-1}} Dep_{t+k}$ and Λ_t is the marginal value of non-residential consumption for the households savers.
A markup shock $\varepsilon_{D,t}^R$ is introduced on the interest rate setting.

Loan book financing branches As for the retail deposit branches, loan book financing branches provide funds to the commercial lending branches which obtain overall financing through a CES aggregation of the differentiated loans: $B_{E,t} = \left[\int_0^1 B_{E,t}(j)^{\frac{1}{\mu_E^R}} \mathrm{d}j\right]^{\mu_E^R}$ as regards commercial loans to entrepreneurs and $B_{HH,t} = \left[\int_0^1 B_{HH,t}(j)^{\frac{1}{\mu_{HH}^R}} \mathrm{d}j\right]^{\mu_{HH}^R}$ as regards commercial loans to households. Loans from loan book financing branches are imperfect substitute with elasticity of substitution $\frac{\mu_E^R}{\mu_E^R-1}$ and $\frac{\mu_{HH}^R}{\mu_{HH}^R-1} >$ 1. The corresponding average lending rate is

$$R_E = \left[\int_0^1 R_E(j)^{\frac{1}{1-\mu_E^R}} \mathrm{d}j\right]^{1-\mu_E^R} \text{ and } R_{HH} = \left[\int_0^1 R_{HH}(j)^{\frac{1}{1-\mu_{HH}^R}} \mathrm{d}j\right]^{1-\mu_{HH}^R}$$

Loan book financing branches for each segment of the credit market are monopolistic competitors which levy funds from the wholesale branches and set interest rates on a staggered basis *à la* Calvo (1983), facing each period a constant probability $1 - \xi_E^R$ and $1 - \xi_{HH}^R$ of being able to re-optimize their nominal interest rate. If a loan book financing branch cannot re-optimize its interest rate, the interest rate is left at its previous period level:

$$\begin{aligned} R_{HH,t}(j) &= R_{HH,t-1}(j) \\ R_{E,t}(j) &= R_{E,t-1}(j) \end{aligned}$$

In each sector $i \in \{E, HH\}$, the loan book financing branch j chooses $\hat{R}_{i,t}(j)$ to maximize its intertemporal profit.

$$\mathbb{E}_t \left[\sum_{k=0}^{\infty} \left(\gamma \xi_i^R\right)^k \frac{\Lambda_{t+k}}{\Lambda_t} \left(\hat{R}_{i,t}(j) B_{i,t+k}(j) - R_{i,t}^{wb}(j) B_{i,t+k}(j) \right) \right]$$

where $B_{i,t+k}(j) = \left(\frac{\hat{R}_{i,t}(j)}{R_{i,t}}\right)^{-\frac{\mu_i^R}{\mu_i^R-1}} \left(\frac{R_{i,t}}{R_{i,t+k}}\right)^{-\frac{\mu_i^R}{\mu_i^R-1}} B_{i,t+k}$.
As for deposit rates, we add markup shocks $\varepsilon_{HH,t}^R$ and $\varepsilon_{E,t}^R$ to the staggered nominal lending rate settings.

Commercial lending branches Commercial lending branches are delivering credit contracts for entrepreneurs and household borrowers. Those branches are perfectly competitive and in equilibrium have zero profits. Details on the credit contract and the decision problems for the commercial lending branches are provided in the sections on entrepreneurs and household borrowers.

3.5 Government and monetary authority

Public expenditures $\overline{\overline{G}}$ are subject to random shocks ε_t^G. The government finances public spending with lump-sum transfers.
Monetary policy is specified in terms of an interest rate rule targeting inflation, output and their first difference as well as changes in the relative price of housing. Written in deviation from the steady state, the interest rate rule used has the following form:

$$r_t = \rho r_{t-1} + (1-\rho)\left(r_\pi \pi_{t-1} + r_y y_{t-1}\right) + r_{\Delta\pi}\Delta\pi_t + r_{\Delta y}\Delta y_t + r_{T_D}\Delta t_{D,t} + \log\left(\varepsilon_t^R\right)$$

where lower case letters denote log-deviations of a variable from its deterministic steady-state.

3.6 Market clearing conditions

Aggregate domestic demands for non-residential goods are given by:

$$Y_t = \omega\widetilde{C}_t + (1-\omega)C_t + I_t^C + I_t^D + \overline{\overline{G}}\varepsilon_t^G + \Phi\left(u_t^C\right)K_{t-1}^C + \Phi\left(u_t^D\right)K_{t-1}^D$$

Aggregate non-residential productions satisfy:

$$Z_t = \varepsilon_t^A\left(u_t^C K_{t-1}^C\right)^{\alpha_C}\left(L_t^C\right)^{1-\alpha_C} - \Omega_C$$

Market clearing condition in the non-residential goods markets leads to the following relations:

$$Z_t = \Delta_t Y_t$$

where $\Delta_t = \int_0^1 \left(\frac{p_t(c)}{P_t}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}c$ measures price dispersion among intermediate products.
Similarly, aggregate production of residential goods reads:

$$Z_{D,t} = \varepsilon_t^{A_D}\left(u_t^D K_{t-1}^D\right)^{\alpha_D}\left(L_t^D\right)_t^{1-\alpha_D-\alpha_{\mathcal{L}}}\mathcal{L}_t^{\alpha_{\mathcal{L}}} - \Omega_D$$

Market clearing condition for the residential markets is

$$Z_{D,t} = \Delta_{D,t}\left[\omega\left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}\right) + (1-\omega)\left(D_t - (1-\delta)D_{t-1}\right)\right]$$

where $\Delta_{D,t} = \int_0^1 \left(\frac{p_{D,t}(d)}{P_{D,t}}\right)^{-\frac{\mu_D}{\mu_D-1}} \mathrm{d}d$ measures price dispersions among non-residential intermediate goods.
On the credit market, due to nominal rigidity in the setting of interest rate by retail banking branches, the following conditions holds

$$\begin{aligned} B_{HH,t}^{wb} &= \omega\Delta_{HH,t}^R B_{HH,t} \\ B_{E,t}^{wb} &= \Delta_{E,t}^R B_{E,t} \\ Dep_t^{wb} &= (1-\omega)\Delta_{D,t}^R Dep_t \end{aligned}$$

where $\Delta_{i,t}^R = \int_0^1 \left(\frac{R_{i,t}(j)}{R_{i,t}}\right)^{-\frac{\mu_i^R}{\mu_i^R-1}} \mathrm{d}j$ $i \in \{E, HH, D\}$ are dispersion indexes among retail bank interest rates.
Aggregate bank profit is given by

$$\Pi_t^b = \omega R_{HH,t}B_{HH,t} + R_{E,t}B_{E,t} - (1-\omega)R_{D,t}Dep_t - \frac{\chi_{wb}}{2}\left(\frac{Bankcap_t}{.0.5B_{HH,t}^{wb} + B_{E,t}^{wb}} - 0.11\right)^2 Bankcap_t$$

3.7 Alternative commercial lending contracts

Compared with the benchmark model presented above, we consider two additional variants for the credit contracts proposed to households and firms.
First, we assume now that the commercial lending branches propose credit contracts where the lending rate is not contingent on the realization of aggregate uncertainty.
Second, we consider a specification of the credit frictions which does not allow for strategic default and which consists in constraining the amount of new loans by the value of the available collateral. The modeling strategy using binding collateral constraints is similar to Gerali et al. [2009].

4 Bayesian Estimation

The model is estimated euro area data using Bayesian likelihood methods. We consider 15 key macroeconomic quarterly time series from 1986q1 to 2008q2: output, consumption, non-residential fixed investment, hours worked, real wages, CPI inflation rate, 3 month short-term interest rate, residential investment, real house prices, household loans, non-financial corporation loans, households deposits, bank lending rates on household loans, on non-financial corporation loans and on household deposits. All real variables and real house prices are linearly detrended prior to estimation. Inflation and nominal interest rates are mean-adjusted (see the calibration section for more details). Full description of the dataset is provided in the Appendix.
We summarize here the exogenous stochastic shocks that we introduce:

- Efficient shocks: AR(1) technology (ε_t^A (common to both sectors), AR(1) housing-specific technology $\varepsilon_t^{A_D}$), AR(1) non-residential investment specific productivity (ε_t^I), AR(1) labor supply (ε_t^L), AR(1) public expenditure (ε_t^G), AR(1) consumption preferences (ε_t^B), AR(1) housing preferences (ε_t^D)
- Inefficient shocks: i.i.d price markup (ε_t^P), AR(1) interest rate markups on deposits and loans ($\varepsilon_{D,t}^R$, $\varepsilon_{HH,t}^R$, $\varepsilon_{E,t}^R$).
- Riskiness shocks: the standard deviation of the idiosyncratic risk for impatient households and entrepreneurs is subject to AR(1) shocks ($\varepsilon_{HH,t}^\sigma$, $\varepsilon_{E,t}^\sigma$)
- AR(1) bank capital shock ($\varepsilon_t^{Bankcap}$)
- Monetary policy shock (ε_t^R).

As regards behavioral parameters, we chose to limit the number of estimated coefficients by bringing some symmetry across sectors and agents.We estimate the parameters driving the adjustment costs on residential and non-residential investment, ϕ_D, ϕ, which are the same across household types and sectors respectively. The parameter on capacity utilization adjustment cost φ is also the same for both sectors. Concerning preference parameters, the intertemporal elasticity of substitution, σ_X, is similar for the two household types, the labor supply elasticity, σ_L, is the same across household types and sector-specific labor service, whereas the habit parameter, h, is equalized across all agents. The Calvo parameters on nominal wage rigidity, α_{wC}, α_{wD}, are the same for both household types while we introduce a single indexation parameter γ_w. The Calvo parameter on non-residential retail goods price setting, ξ_C, and the associated indexation coefficients, γ_C, are estimated while in the residential goods sector, we estimate the Calvo parameter, ξ_D, and set the indexation parameter, γ_D, to zero. On the imperfect interest rate pass-through, we draw some inference on the three coefficients driving the staggered rate setting on deposits and loans, ξ_D^R, ξ_{HH}^R, ξ_E^R. The adjustment cost on banks' capital structure, χ_{wb}, is also estimated. Finally the parameters in the Taylor rule are ρ, r_π, r_y, $r_{\Delta\pi}$, $r_{\Delta y}$, r_{T_D}.

In the benchmark estimation, we do not introduce the share of households borrowers. As argued later on, given the weak identification of the parameter and the lack of observable data on households heterogenous features, we calibrated this parameter to achieve realistic debt structure in the steady state. At the same, some inference and sensitivity analysis on this coefficient is presented thereafter. Calibrating the share of borrowers is also symmetric to our assumption that all firms are financially constrained.

4.1 Calibrated parameters and steady state

Some parameters are excluded from the estimation and have to be calibrated. These are typically parameters driving the steady state values of the state variables, for which the econometric model based on detrended data is almost noninformative.

The discount factors are calibrated to 0.995 for the patient agents and 0.96 for the impatient agents and entrepreneurs [20]. The implied equilibrium real deposit interest rate is 2% in annual terms[21]. The depreciation rate for housing, δ, is equal to 0.01, corresponding to an annual rate of 4%, whereas the depreciation rate of capital, δ_X, is set to 0.1. Markups are equal to 1.3 in the goods markets (for both nonresidential and residential goods) and 1.5 in the labor market (in each sector). The relative share of residential goods in the utility function, ω_D, is set to 0.1 for both household types. The value is chosen to pin down the steady state ratio of residential investment to GDP. The intratemporal elasticity of substitution, η_D, is equal to 1. The intertemporal elasticity of substitution of entrepreneurs is set to 1 (σ_{CE}). The relative shares of inputs in production are 0.3 for capital (α) and 0.7 for labor in the nonresidential goods sector, while in the residential sector we assign a weight equal to 0.1 to land ($\alpha_{\mathcal{L}}$), and reduce the share of capital to 0.2 (α_D), in order to maintain the level of labor intensity unchanged.

The markups on loan and deposit rates are calibrated so that the margin between the loan rate and the deposit rate is 100 bps in annual terms, while the annual spreads on lending rates to households and entrepreneurs are 200 bps and 120 bps, respectively. Those numbers are very close to the historical averages from 1999Q1 to 2008Q2.[22] Given the discount factors and the markups on retail interest rates, the steady state value for the default cut-off points $\overline{\varpi}_E$, $\overline{\varpi}_{HH}$ are numerically determined by the modified Euler equations of borrowers and entrepreneurs. Once those cut-off points are computed and assuming monitoring costs of 0.2 for non-financial corporations, μ_E, and 0.15 for households, μ_{HH}, the standard deviations of the idiosyncratic shocks are adjusted to reproduce default frequencies for impatient house-

[20] See e.g. Iacoviello [2005] and Iacoviello and Neri [2009] and Monacelli [2009] for a thorough discussion of the calibration of the discount factors in a similar setup.

[21] The steady-state level of the interest rate is pinned down by the savers' intertemporal discount factor.

[22] We confine the calibration of the loan-deposit margin and the lending spreads to the period starting in 1999Q1, as due to the convergence of interest rates prior to the introduction of the euro there was a gradual downward level shift in loan and deposit rates in the years preceding 1999. Because of this structural shift in the level of rates, for the steady state calibration we apply the pattern of loan and deposit rates for the euro-period only.

holds and firms of 0.3% and 0.7% respectively.[23]

Finally, we set in the benchmark estimation the share of borrowers ω at 0.25. The loan-to-value ratio (determined by the terms $(1-\chi_E)$ for non-financial corporations and $(1-\chi_{HH})$ for impatient households) are then determined to ensure plausible debt to GDP ratio in the steady state. With $(1-\chi_E)$ at 0.6 and $(1-\chi_{HH})$ at 0.2, the share of corporate loans to annual GDP is around 33% while the share of household housing loans to annual GDP is around 25%. This calibration is close to the levels recorded in the euro area around the year 2000 as well as to their historical average levels since 1980. Besides, the loan-to-value (LTV) ratio are consistent with the available range of estimates.[24]

4.2 Prior distributions

The standard errors of the structural shocks are assumed to follow a Uniform distribution, while the persistence parameters follow a Beta distribution with mean 0.5 and standard deviation 0.2.

About the parameters of the monetary policy reaction function, we follow Smets and Wouters [2005] quite closely. The interest rate smoothing parameter follows a Beta distribution with parameters 0.75 and 0.1. The parameters capturing the response to changes in inflation and output gap follow a Gamma distribution with parameters 0.3 and 0.1, and 0.12 and 0.05, respectively. Concerning the response to inflation and output gap, the prior distributions are a Normal with mean 2.5 and standard deviation 0.25, and a Gamma with parameters 0.12 and 0.05, respectively. The prior on the level inflation terms has been increased compared with the empirical DSGE literature as the determinacy region in the two-sector economy considered in this paper requires stronger reaction to price pressures.

About preference parameters, the intertemporal elasticity of substitution, which is common to both household types, follows a Gamma distribution with mean 1.2 and standard deviation 0.2. The habit formation parameter is also the same savers, borrowers and entrepreneurs, following a Beta distribution with parameters 0.75 and 0.1. The elasticity of labor supply is the same for both household types and sectors, and has a Gamma(1.5, 0.1) prior distribution. On the production side, the adjustment cost parameters for fixed investment and the capacity utilization elasticity, which are common to both sectors, follow respectively a Normal(4, 1.5) and a Beta(0.5, 0.15) prior distributions. The prior distribution regarding the adjustment cost parameter for residential investments of savers and borrowers is a Gamma(1,0.5). About nominal rigidities, the Calvo parameters for price setting in the non-residential sector and wage settings in each sector are distributed according to a Beta distribution with mean 0.75 and standard deviation 0.05[25]. The indexation parameters are instead centered around 0.5, with a standard deviation of 0.15. In the residential sector, we set lower priors for the nominal price rigidities, with a Beta(0.2,0.1) given assumptions made in the literature on the flexibility of housing prices (see Iacoviello

[23]This is consistent with corporate default statistics from Moody's, the rating agency, which show an average default rate on (non-US) non-financial corporate bonds of 0.75% for the period 1989-2009. Household default rates can be approximately derived using the loan write-off data in the ECB's MFI balance sheet statistics. Computing the ratio of average write-offs on mortgage loans to corporate loans for the period of available data (2001-2009) it is found that the share of defaulting mortgage loans to corporate loans is c. 45%. Hence, using the non-financial corporate default rate derived from Moody's implies an approximate mortgage default rate of 0.34%; i.e. close to our steady state calibrated value.

[24]LTV ratios for euro area housing loans differ across countries, but tend on average to lie in the range of 0.7-0.8%; see ECB (2009), "Housing Finance in the Euro Area", Occasional Paper no. 101. LTV ratios can be approximated by the debt-to-financial asset ratio of the non-financial corporate sector, which on average between 1999-2009 was around 0.45.; sources: ECB and Eurostat and ECB calculations.

[25]In the estimation exercise we impose that the same level of nominal rigidity applies to the saver's and borrower's wages in a given sector. Such restriction is motivated by the availability of sector-specific, as opposed to individual-specific data on wages.

and Neri [2009] for example). We do not introduce indexation on past inflation in the residential sector price setting.
Turning to the Calvo parameters driving the imperfect pass-through of policy rate on lending rates, we choose fairly uninformative priors with Beta(0.5,0.2). The sensitivity of bank spreads on bank capital ratio inadequacy has relative tight priors, with a Gamma(20,2.5), as in Gerali et al. [2009]. Finally, in the benchmark model, the share of borrowers is not estimated but in alternative specifications we introduce priors following Beta distribution, with mean 0.35 and standard deviation 0.05. This choice is similar to the one of Iacoviello and Neri [2009]. The model is still well-defined when the share of borrowers goes to zero so that the estimation of the parameters is not affected by a singular point in zero.

4.3 Posterior distributions

We performed Bayesian estimations on various specifications of the theoretical model described previously. Thereafter we call benchmark specification the version of the model where commercial lending rates are state-contingent. We also consider the estimation of models with pre-determined lending rates or with binding collateral constraints. Regarding the range of free parameters for the estimation, the inclusion on the share of borrowers as well as some correlations between structural shocks will be considered.
Tables 1 and 2 report the mode, the mean and the 10th and 90th percentiles of the posterior distribution of the structural parameters for the benchmark model and the pre-determined lending rate specification. Table 3 presents the estimation results for the model specification assuming always binding collateral constraints. When comparing the marginal data density of the three model specifications, it clearly appears that the benchmark version delivers the best statistical performance with a log data density of -432.1. The model with binding collateral constraints, which should be seen as relatively close to Gerali et al. [2009], has the lowest log data density, at -650, while the model with predetermined lending rates leads to intermediate level, at - 579.3.
Thereafter, we concentrate on the parameter estimates, emphasizing those features that are more closely related to our expanded modeling framework with respect to the sectoral structure of the economy and financial frictions. Among the stochastic exogenous disturbances, the posterior distributions for autoregressive coefficients turned out to be very close to unity for several shocks, notably those related to the housing sector, housing preference and productivity shocks, and to loan dynamics, risk shocks on households and entrepreneurs (or alternatively loan-to-value ratio shocks for the model with binding collateral constraints). Visual inspection of de-trended real house prices and loan data over the sample indeed suggest very high degrees of persistence which are not well captured by the internal propagation of the model. The mark-up shocks on bank interest rates also display high autoregressive coefficients with the notable exception of lending rates to households for which lower inertia seems to compensate for higher nominal rigidity (see thereafter).
Turning to behavioral parameters, qualitative similarities appear across model specifications. This concerns first the real rigidities on non-residential investment and capacity utilization as well as the nominal rigidities wage setting and on price setting in the non-residential sector. In all estimations, the labor supply elasticity as well as the inflation term in level in the monetary policy rule are weakly identified. The various estimations do not support the evidence of meaningful specific reaction of monetary policy to

house prices.

Then the Calvo parameters on the imperfect adjustment of lending rates are estimated to be the lowest for deposit rates, at around 0.3 in the benchmark estimation, the highest for lending rates to households, at around 0.9 in the benchmark estimation, and somewhat in between for lending rates to entrepreneurs, at around 0.75 in the benchmark estimation. The higher flexibility of deposit rates is also found by Gerali et al. [2009] and is most likely due to differences in the maturity structures of the various composite rates which cannot be accounted for by the one-period loans considered in the DSGE model.

Finally, the posterior distribution for the adjustment cost on banks' capital structure, χ_{wb}, stays very close to its prior distribution in all model specifications. At the same time, having experimented with alternative priors, the posterior distribution could eventually depart significantly from the prior one, therefore suggesting that data are somewhat informative about this parameter.

The main difference in the estimation results of the three model specifications relates to the real and nominal rigidities for the residential sector. The benchmark estimation leads to an adjustment cost parameter for residential investment, ϕ_D, of around 0.2 at the mode. The degree of nominal rigidity is then quite elevated with a posterior mode for the Calvo parameter on residential prices of 0.81. By contrast, the estimation of the models with pre-determined lending rate or binding collateral constraints points to low nominal rigidities and no adjustment cost on residential investment. As we will see later, the real rigidities in the residential sector have compounded effects on macroeconomic propagation through households' borrowing constraint and consequently households' consumption expenditures. Compared with the benchmark specification, the response of consumption to economic disturbances under binding collateral constraints is very sensitive to adjustment costs on residential investment. Overall, it seems that data call for some degree of real rigidity in the residential markets. Everything else being equal, this implies that relative prices would react more to economic shocks. In order to limit the volatility of residential prices in the presence of adjustment costs on residential investment, staggered housing price setting is needed. However, this combination of real and nominal rigidity which improves the performance of the model in the benchmark specification, interferes with binding collateral constraints in particular.

Tables 4 and 5 show the posterior parameter distributions for the benchmark model and the pre-determined lending rate specification, introducing correlations between the consumption preference shock and the housing preference shock on the one hand, and between the housing preference shocks and the household risk shock on the other hand. These experiments were guided by the correlations of structural shocks obtained in the benchmark estimations.

The innovation on the consumption preference shock, ε_t^B, has been introduced in the AR(1) process of the housing preference shock. Such a positive correlation between both exogenous disturbances is partly correcting for the sharp negative co-movement after a consumption preference shock between consumption and residential investment, which may not be supported by data given the positive unconditional correlation observed in our sample. The introduction of the innovation on the housing preference shock in the AR(1) process of the risk shock on housing loans is limiting the negative co-movement between residential price and residential investment on the one hand and lending rate spreads to households on the other hand. The presence of such correlations is affecting the inference on behavioral parameters. In particular, the estimated real and nominal rigidities for the residential sector become much higher in the pre-determined lending rate specification, at levels close to the ones obtained in the benchmark specification.

In the results reported in tables 4 and 5, we also let the share of household borrowers, ω, free in the estimation procedure. The prior distribution for this parameter was set with a relatively elevated mean and small variance. For the benchmark model, the posterior distribution for the household borrowers' share reaches 28% at the mode. The posterior mode is lower in the pre-determined lending rate specification. Overall, ω does not seem to be strongly identified. This confirms the results of Darracq Pariès and Notarpietro [2008]. The presence of borrowers is not rejected by the data, as all specifications lead to strictly positive values for such shares, but model comparison based on marginal data density would favor lower shares than in the benchmark estimation.

4.4 Forecast errors decomposition

We also analyze the role of credit market frictions and financial shocks in economic fluctuations. Table 6 and 7 report unconditional variance decomposition of HP-filtered variables, for the three model specifications, emphasizing the contribution of housing-related structural shocks and shocks to the banking sector. For each model, the variance decomposition is computed using the posterior modes of their respective estimation. Therefore results across models reflect both differences in behavioral specifications as well as in parameter estimates.

We will comment first on the variance decomposition of the benchmark model. More than 50% of unconditional variance of loans to households and entrepreneurs are explained by their respective risk shock. Indeed, looking at zero profit condition for household loans for example

$$G(\varpi_{HH,t})\tilde{A}_{HH,t} - \frac{(1+R_{HH,t-1})}{1+\pi_t}B_{HH,t-1} \geq 0$$

we see that the term $G(\varpi_{HH,t})$ could be interpreted as a time-varying loan-to-value ratio and is directly related to the risk shock on household borrowers. In the empirical exercise, this shock is therefore partly capturing the gap between the dynamics of loans and the dynamics of its collateral value. Household deposits are mainly driven by risk shocks on households and entrepreneurs as well as by bank capital shocks, with a respective contribution or around 20%. Those disturbances have a strong impact on bank assets and capital, thereby mechanically affecting bank liabilities. Overall, approximately 20% of the unconditional volatility of loans and deposits are driven by disturbances not related to the financial or housing blocks.

On bank lending rates, for each sector, the risk shock and the interest rate markup shock have strong contributions, explaining jointly more than 50% of variance. By contrast, the role of financial shocks is more limited as regards the volatility of deposit rates.

Turning to the residential sector, the housing preference shock explains a large part of price and quantity in this sector. The housing-specific productivity shock contributes mainly to residential investment volatility. On balance, 40% of residential investment and 60% of real housing prices are driven by non housing-specific disturbances.

For the non-residential sector, the corporate-risk shock has a large contribution to non-residential investment fluctuations, whereas the household-risk shock contributes significantly to consumption volatility, albeit to a lesser extent. The housing preference shock as well as the interest rate markup shock on deposits are non-negligible sources of consumption unconditional variance. For GDP, consumption and non-residential investment, roughly 50% of unconditional variances are not explained by financial and housing-specific shocks.

Finally, on consumer prices, the risk shocks and the interest rate shock on deposits have some meaningful contributions but almost 80% of variance is driven by disturbances not related to the financial or the housing blocks.

The decomposition of variance in the benchmark model is substantially modified when considering the estimated models with the alternative specifications for the credit contracts. Certainly, in the pre-determined lending rate and binding collateral constraint models, the credit market shocks also account for most of the unconditional variance of loans, deposit and bank interest rates. However, the difference in the estimation of real and nominal rigidities in the residential sector seems to strongly affect the contribution of the housing preference shock. Presumably, the presence of relatively high real and nominal frictions in the benchmark estimation increases the internal persistence of this shock. Moreover, the relative flexibility of housing prices in the two alternative specifications may explain the lower contribution of financial shocks to consumption price inflation. A singularity in the pre-determined lending rate model regards the role of corporate-risk shock which contributes to GDP volatility by around 25%, against 4% in the benchmark model.

5 The role of credit frictions in macroeconomic propagation

In this section we consider the macroeconomic implications of the various types of credit frictions embedded in our model, illustrating how the presence of credit market frictions affect the macroeconomic propagation of shocks to real economic activity.

5.1 Transmission of non-financial economic disturbances through demand and supply credit frictions

In terms of shock transmission, focussing first on the benchmark model, Figures 1-15 show the impulse response functions to the various shocks identified in Section 3. Overall, the presence of demand and supply credit frictions tends to amplify the macroeconomic propagation of economic shocks.

Focusing first on supply shocks, a positive shock to housing preferences, (ε_t^D), via its positive effect on housing collateral values leads to lower credit spreads on housing loans, which in turn positively affects consumption and increases household loan growth (see Fig. 7). As a reaction, monetary policy is tightened which leads to a negative spill-over effect on the corporate sector in the form of somewhat higher corporate lending rates, a decline in corporate loan growth and lower investment growth. Deposit rates respond quicker to the monetary policy tightening relative to in particular household loan rates, which leads to an initial reduction of bank capital accumulation. Bank capital, however, increases subsequently as the monetary policy impact on deposit rates fades out quicker than its impact on lending rates. Finally, there is an initial positive impact on real GDP and inflation, which over the longer term is counterbalanced by the monetary policy-induced negative spill-over effect on corporate investment. By contrast, a positive demand shock leading to higher consumption, (ε_t^B), has a negative impact on residential investment and hence collateral values thereby increasing the credit risk premium on household loans, which in turn also slows down household lending (see Fig. 5). The rise in inflation following the shock to consumption induces the central bank to raise its policy rate. As a result, deposit and lending rates increase. The latter implies a slump in investment and a fading out of the positive consumption shock. All in all, the negative spill-over to investment results in a muted effect on real activity. The overall effect on bank capital is rather modest though positive in the long run, which seems to be driven particularly by a decline in bank deposits and lower bank leverage.

Other efficiency shocks, such as technology shocks (ε_t^A), shocks to labor supply (ε_t^L) and investment (ε_t^I), in the baseline have the usual positive impact on real activity and the amplification impact of financial intermediation is broadly similar to the findings of Gerali et al. [2009] as the policy-induced reduction in lending rates increases loan demand. The greater availability of credit amplifies the initial impact on spending and investment. Overall, bank profitability is broadly unaffected by these shocks due to the counterbalancing effects on both the asset and liability sides of the bank balance sheets (i.e. higher lending and higher deposits and a muted impact on bank leverage).

In terms of the shock to monetary policy, (ε_t^R), as illustrated in Figure 15 the rise in the policy rate lowers output and inflation. This fuels a decline in asset prices and hence collateral values, which in turn lowers the credit available to households and firms and hence leads to a propagation of the initial shock via the presence of financial intermediation. Somewhat puzzling, however, we observe an initial positive reaction of loans to households and, in particular, firms.[26] Notably, the transitory shock to monetary policy is only to a limited extent passed on to bank lending rates. This largely reflects the forward-looking, but staggered, price-setting behavior of the imperfectly competitive banks whereby lending rates are set according to expected future configurations of the yield curve. A transitory shock to short-term (policy) rates therefore does not have a significant impact on lending rates predominantly referring to the longer end of the yield curve, such as mortgage loans. The fact that monetary policy accommodates the initial negative impact on output and inflation results in only transitory negative real economic implications from the policy shock. Finally, bank capital is overall affected only to a limited extent.

5.2 Risk shocks on households and entrepreneurs

Via the financial accelerator mechanism, changes in borrower creditworthiness is propagated throughout the economy in the presence of credit market frictions.

Hence, shocks to borrower riskiness, ($\varepsilon_{HH,t}^{\sigma}$ and $\varepsilon_{E,t}^{\sigma}$) respectively, by raising default probabilities reduces lending to and spending by the affected sector (see Fig. 12 and 13). The resulting monetary policy accommodation in turn has moderate positive spill-over effects on the other borrowing sector, which over time somewhat helps attenuate the immediate slowdown of GDP growth. Bank profitability is overall negatively affected by lower lending rates and the broad decline in lending activity.

This underlines the importance of banks' risk perception in guiding their lending behavior and stresses its potential amplifying effect on economic fluctuations. Sharp deteriorations in the creditworthiness of households and firms, as for example observed during the 2007-9 financial crisis, [27] are therefore likely

[26]Similar evidence for the euro area is found in Christiano et al. [2010]. Likewise, in an empirical paper Giannoni et al. [2009] provide evidence of an increase of non-financial corporate loan growth in response to a monetary policy shock. Similar findings have previously been found for the US; see e.g. Bernanke and Gertler [1995] and Christiano et al. [1996]. Among other reasons, this pattern could be due to an increase in demand to finance increased inventories, a reduced utilization of the workforce or a drawing down of pre-committed credit lines.

[27]For example, expected default frequencies of euro area non-financial corporations (which is a measure of corporate default

to produce reverberating feedback effects on real economic activity.

5.3 Interest rate markup shocks and bank interest rate pass-through

A common finding in the empirical literature is that banks only gradually pass on the changes in monetary policy rates to the rates offered to their retail customers. This sluggishness may thus affect the speed and effectiveness of the monetary policy transmission via the interest rate channel. The frictions are furthermore often found to be asymmetric in the sense that bank lending rates tend to adjust quicker as a response to policy rate increases than to policy rate decreases.[28]

The magnitude and speed of bank lending rate pass-through are often associated with the degree of imperfect competition in the banking sector and the presence of nominal adjustment ("menu") costs. These frictions may deter banks from reacting on a regular basis to changes in policy and market rates, and banks may instead choose to delay the adjustment of their lending rates until the change in market rates exceeds a certain threshold. Beyond this, other factors related to financial intermediation may affect the developments in the spreads between bank lending rates and market rates, such as costs related to interest rate and credit risk, the banks' degree of risk aversion, unit operating costs, bank liquidity and product diversification. Also the conduct of monetary policy may impact on how quickly banks respond to policy rate changes.[29]

Another common observation is that there are differences across retail bank products in terms of the speed and degree with which banks pass-through changes in policy rates facing their borrowers and depositors. These differences can, among other things, be assumed to hinge on the degree of market power the bank has in particular segments. For instance, it can be assumed that large firms are in a better bargaining position vis-à-vis the bank than are its retail customers. Accordingly, it is often found that corporate loan rates (and certain deposit rates) adjust to policy rate changes in a speedier and sometimes more complete way than rates on loans to households. Indeed, this is the pattern we observe when running an error-correction model relating our composite loan and deposit rates to changes in the policy rate. Whereas corporate loan rates are relatively quick to adjust to monetary policy changes, the adjustment is somewhat slower in the case of mortgage rates (and to a certain extent also deposit rates). The sluggishness of retail bank interest rates is another friction affecting the way shocks are propagated to the real economy. As an illustration, the amplifications caused by shocks to the interest rate markups are shown in Figures 9-11. A positive shock to deposit rates, ($\varepsilon^{R}_{D,t}$), has a positive effect on both consumption, residential investment and property prices. The latter improves housing collateral values and hence lower the spread on loans to households. The increase in demand results in positive effects on real activity and inflation forcing the central bank to tighten monetary policy, which in turn causes negative spill-over effects on corporate investment (owing to higher lending rates). Accordingly, the positive impact on real GDP turns out to be relatively short-lived and it fades away over the longer term. Finally, the combination of lower bank rates and a decline in deposit taking as well as lower bank

risk produced by Moody's KMV) increased six-fold between June 2007 and December 2009. Likewise, according to the ECB Bank Lending Survey, the net percentage of banks reporting that risk perceptions contributed to a tightening of credit standards increased from 9% in Q2 2007 to 46% in Q4 2008 with respect to mortgage loans. and from -4% in Q2 2007 to 64% in Q4 2008 with respect to loans to enterprizes.

[28] See e.g. Mester and Saunders [1995], Mojon [2001] and Gropp et al. [2007].

[29] For instance Sander and Kleimeier [2006] argue that better anticipated monetary policy implies a quicker response of retail bank interest rates.

leverage implies a positive impact on banks' capital accumulation over the horizon. A lower credit risk premium on loans to households, ($\varepsilon^R_{HH,t}$), by boosting household borrowers' access to loan financing positively impacts on consumption and residential investment. As a response to the ensuing inflationary pressures, the central bank raises its policy rate, which in turn leads to a lagged response on bank loan and deposit rates. The higher cost of financing for entrepreneurs negatively impacts investment and gradually also the initial impact on consumption and residential investment diminishes. Similarly, the immediate positive impact on GDP growth fades away over time. Moreover, the combination of the fall in corporate lending and the higher deposit funding costs as well as increasing bank leverage results in a lasting decline in bank capital. A similar pattern is observed in the case of a negative shock to corporate credit spreads, ($\varepsilon^R_{E,t}$), although in this case investment is temporarily positively affected while there are negative spill over effects on consumption and housing activity. The initial impact on GDP is more muted relative to the household loan markup shock, but it remains positive also in the long run.
The importance of retail bank interest rate rigidities is furthermore highlighted in Figures 1-8 and Figures 12-15, which show impulse response functions for the case where banks have no market power when setting rates and where consequently the pass-through of policy rates to bank interest rates is immediate and complete are shown (green dotted lines). Overall, this implies that monetary policy accommodation to the various shocks hitting the economy is transmitted fully and more quickly to the interest rates facing savers and borrowers. Hence, the counterbalancing impact of monetary policy is more powerful in this case. In other words, the common finding that the bank interest rate pass-through is sluggish implies a somewhat attenuated impact of the policy rate changes through the interest rate channel of monetary policy transmission.

5.4 Bank capital shocks and bank capital channel

The recent financial crisis led banks to incur substantial losses on their trading and loan books, which in turn put severe pressure on their capital positions. In order to return to a more stable capital situation and possibly responding to pressures from regulators and market participants to operate with more solid capital buffers, banks have been faced with a trade-off of either raising new capital or adjusting their asset side, or (more likely) a combination of the two. Our model specification can be used to assess the macroeconomic implications of such shocks to bank capital, which in our case will lead banks to replenish their capital position by boosting their retained earnings. This is illustrated in Figure 14, which shows the implications of an adverse shock to bank capital, ($\varepsilon^{Bankcap}_t$). The bank capital shock results in an increase in bank leverage which in order for banks to reestablish their target leverage ratio leads to an increase in banks' loan-deposit margins. This is driven mainly by higher lending rates, which in turn lowers loan demand.[30] Real activity falls somewhat and the impact of the bank capital shock is protracted, despite diminishing slightly over time in response to the monetary policy accommodation. The negative impact on output of the bank capital shock in the benchmark model is relatively modest but persistent.[31]

[30] This mechanism is corroborated by empirical findings for the US, which suggests that pressure on bank capital positions induce banks to apply higher lending rates (in particular vis-à-vis their riskier borrowers); see Santos and Winton [2009].

[31] Recent empirical studies suggests an approximate effect of a one percentage point shock to bank capital positions (or loan supply shocks more generally) in the range of an approx. 0.1-1.0 percentage point impact on real economic activity; see e.g. Cappiello et al. [2010], Ciccarelli et al. [2009], Francis and Osborne [2009] and Van den Heuvel [2008]. Our baseline estimates are at the lower end of this range.

The specific role of the bank capital channel in the propagation of economic shocks via the financial sector can be further analyzed by increasing banks' adjustment cost on their leverage (setting $\chi_{wb} = 50$). This is illustrated by the blue dotted lines with circles in Figures 1-15. Focusing first on a shock to bank capital itself (Figure 14), it is clear that a more pronounced bank capital channel results in a much stronger propagation of shocks from the banking sector to the real economy. Consequently, the monetary policy response is also more forceful than in the benchmark case, which allows for output to rebound back towards the baseline over time. The immediate effect on output from the bank capital shock is considerably more pronounced than in the baseline case and corresponds well with evidence from the empirical literature.

The role of bank capital constraints can also be illustrated in the case of a negative shock to corporate loan spreads (Figure 11). It is observed that the short-lived boost to investment is muted somewhat in the presence of a strong bank capital channel, as banks react to the increase in leverage by raising their loan-deposit margin. Interestingly, also the negative spill-over to investment arising in the context of a negative shock to mortgage loan spreads (Figure 10) is reinforced when it is more costly for banks to adjust their capital ratio.

5.5 Comparison with pre-determined lending rates and binding collateral constraint specification

If the lending rates offered by banks are not contingent on the ex post realization of aggregate uncertainty (i.e. "pre-determined lending rates"; red dashed lines in Fig. 1-15), shocks hitting the economy tend to have a more muted effect relative to the benchmark scenario. This reflects the, in this case, less pronounced interactive effects between macroeconomic developments (e.g. the accelerator effects on borrower net worth) and the credit market. This mitigates somewhat the macroeconomic amplification implied by the existence of credit frictions observed in the benchmark case.

Finally, turning to the specification with binding collateral constraints (Fig. 16-19; blue dashed lines) we observe that owing to the resulting more limited borrower access to credit markets the immediate macroeconomic impact of, for example, adverse shocks to borrower riskiness (($\varepsilon^R_{HH,t}$) and ($\varepsilon^R_{E,t}$), respectively) is more pronounced than when collateral constraints are not binding in the strict sense. This comes about mainly via the more restrictive lending implied by borrowers being bound by their collateral values.

6 Monetary policy stabilization under different regulatory frameworks

6.1 Macroeconomic propagation under risk-sensitive capital requirements

Under the risk-sensitive Basel II-like capital requirement regime the static profit maximization problem of the bank is as follows

$$\max_{B^w_t, Dep^w_t} R^{wb}_{HH,t} B^{wb}_{HH,t} + R^{wb}_{E,t} B^{wb}_{E,t} - R_t Dep^{wb}_t - \frac{\chi_{wb}}{2}(RWCap_t - 0.11)^2 Bankcap_t$$

where

$$RWCap_t = \frac{Bankcap_t}{(a_0^E + a_1^E LEV_{E,t}^{wb} + b^E \varepsilon_{E,t}^{\sigma}) B_{E,t}^{wb} + (a_0^{HH} + a_1^{HH} LEV_{HH,t}^{wb} + b^{HH} \varepsilon_{HH,t}^{\sigma}) B_{HH,t}^{wb}}$$

and subject to the balance sheet identity

$$B_{HH,t}^{wb} + B_{E,t}^{wb} = Dep_t^{wb} + Bankcap_t$$

$LEV_{E,t}^{wb}$ and $LEV_{HH,t}^{wb}$ are leverage ratios for the corporate and household sectors defined as debt over collateralized assets. a_0^E, a_1^E, b^E and $a_0^{HH}, a_1^{HH}, b^{HH}$ represent coefficients in the linearized version of the Basel II formula (see below for details). This formulation leads to the following lending spreads conditioned on the risk-sensitive capital requirements.

$$\begin{aligned} R_{HH,t}^{wb} - R_t &= -\chi_{wb}(RWCap_t - 0.11)\, RWCap_t^2(a_0^{HH} + 2a_1^{HH} LEV_{HH,t}^{wb}) \\ R_{E,t}^{wb} - R_t &= -\chi_{wb}(RWCap_t - 0.11)\, RWCap_t^2(a_0^{E} + 2a_1^{E} LEV_{E,t}^{wb}) \end{aligned}$$

In contrast to the lending spreads derived under the Basel I regulatory regime, the target capital ratio is now dependent on the riskiness of the banks' borrowers, which is dependent on the state of the economy impinging on borrower net worth (via income and housing wealth on the side of households and via the value of the capital stock on the side of corporations).

For calculating the steady state linear relationship between Basel II risk weights and leverage we take as a starting point the Basel II risk-weight formulas and subsequently linearize the resulting risk curves for entrepreneurs and households around their respective steady state leverage ratios.

As a first step, under the Basel II capital adequacy framework the risk weighted assets are derived using the following formulas.[32] The capital requirement formula for the corporate exposures is given by

$$CR^E = LGD^E \Phi \left[\left(1 - \tau^E\right)^{-0.5} \Phi^{-1} PD^E + \left(\frac{\tau^E}{1 - \tau^E} \right)^{0.5} \Phi^{-1}(0.999) \right] - PD^E LGD^E$$

where PD^E and LGD^E refer to probability of default and loss-given-default on corporate exposures, respectively. Φ denotes the cumulative distribution function for a standard normal random variable. τ^E denotes the asset-value correlation which parameterizes cross-borrower dependencies and being a decreasing function of PD is equal to

$$\tau^E = 0.12 \left[\frac{(1 - \exp(-50 PD^E))}{(1 - \exp(-50))} \right] + 0.24 \left[1 - \frac{(1 - \exp(-50 PD^E))}{(1 - \exp(-50))} \right]$$

As we assume a fixed LGD (equal to 0.45), the only time-varying component in the risk weighting is the PD and the resulting risk curve has a concave nature.

For household exposures, we apply the following derivation of the capital requirement

$$CR^{HH} = LGD^{HH} \Phi \left[\left(1 - \tau^{HH}\right)^{-0.5} \Phi^{-1} PD^{HH} + \left(\frac{\tau^{HH}}{1 - \tau^{HH}} \right)^{0.5} \Phi^{-1}(0.999) \right] - PD^{HH} LGD^{HH}$$

[32] We focus here on the Foundation Internal Ratings Based approach and assume fixed LGD values provided by the supervisory authority. For corporate exposures (i.e. entrepreneurs) we assume an LGD value of 0.45 and for household exposures we assume an LGD value of 0.35 (retail mortgage exposures are presumably better collateralized, hence the lower LGD). We furthermore, for simplicity, assume a one-year maturity. For more details on the Basel II formulas, see on Banking Supervision [2004].

where τ^{HH} equals 0.15. Also in the case of household exposures the time-variation of the risk curve is a function of PDs only (as LGD^{HH} is fixed at 0.35). The risk-weighted assets are subsequently derived as $RWA^E = CR^E * 12.5 * 1.06 * EAD^E$ and $RWA^{HH} = CR^{HH} * 12.5 * EAD^{HH}$, where EAD denotes exposure-at-default (i.e. $B^{wb}_{E,t}$ and $B^{wb}_{HH,t}$ for corporate exposures and household exposures, respectively).[33] The time-varying correlation adjustment parameter and the assumed higher LGD for corporate exposures results in higher risk weights and an initially steeper risk curve relative to the risk function with respect to household exposures.

In the next step, the Basel II-based risk weight functions can be expressed in terms of borrower leverage, $(G(\varpi))$ for households and $(G_E(\varpi_E))$ for entrepreneurs. As can be seen from Figure 30 there is a positive and concave relationship between required capital and the leverage of borrowers, which in turn is a positive function of the probability of default, $(\overline{\varpi}_{HH,t})$ and $(\overline{\varpi}_{E,t})$ for households and entrepreneurs, respectively.

Mechanically, owing to the risk weight functions it can be conjectured that shocks to borrower credit risk would give rise to higher capital requirements. As credit risk often deteriorates in economic downturns and improves in upturns, it has been argued that the regulatory risk curves as formulated in Basel II could have amplifying pro-cyclical effects on the business cycle (to the extent that bank capital constrains bank lending which in turn may be an imperfect substitute to other financing sources).[34]

At the same time, if banks engage in active management of their loan portfolio, either as a response to or in anticipation of cyclical requirements to their minimum capital levels, the overall effect on the business cycle may not be as mechanical as what the simple transposition of the risk weighting to capital requirements and lending would prescribe.[35] In this respect, the first tentative evidence as to the cyclicality of minimum required capital in the first $1\frac{1}{2}$ years of Basel II provides some interesting, if still preliminary, insights. Hence, whereas there does indeed seems to be some degree of cyclicality in the underlying risk parameters (in the sense of higher PDs, and to a lesser extent higher LGDs, in situations with relatively low economic activity), the impact is so far rather muted. Moreover, despite this observed cyclicality in risk parameters the resulting minimum required capital until now has remained broadly unaffected by the period's economic slowdown. The main reason for the stability of minimum required capital appears to be that banks have actively engaged in reshuffling their portfolios towards less risky exposures, which has mitigated the effect of the somewhat higher PDs[36]

Keeping these caveats in mind, we first conduct a simple counterfactual exercise. The DSGE model has been estimated on euro area data, assuming constant capital requirements over the cycle, which is interpreted as consistent with Basel I regulatory framework. Given the estimated sources of business cycle fluctuations, we simulate a counterfactual economy where capital requirements are risk-sensitive according to the Basel II risk weights formula. The model considers two types of risky assets: loans to households for house purchase and loans to non-financial corporations. The counterfactual economy under Basel II turns out to be marginally more volatile overall, with unchanged monetary policy rule. Compared with economic fluctuations under Basel I, risk-sensitive capital requirements imply 5%

[33] The scaling factor of 1.06 in the calculation of the risk weight function for corporate exposures aims at compensating for the expected overall decline in capital requirements caused by the transition from Basel I to Basel II.

[34] See e.g. Danielsson et al. [2001], Catarineau-Rabell et al. [2005], Kashyap and Stein [2004].

[35] See e.g. Gordy and Howells [2006], **?**, Jokivuolle et al. [2009] and Boissay and Kok Sørensen [2009].

[36] Apart from the portfolio reshuffling impact, a number of other factors may also have contributed to the relative stability of capital requirements, such as infrequent recalibration of banks' internal PD estimates, the fact that banks already operate with so-called "stressed" LGDs and decreases in outstanding credit line commitments reducing the size of exposure at default.

higher volatility in real GDP growth and 4% higher volatility in inflation.

This relatively limited impact on macroeconomic volatility masks more pronounced amplification mechanisms for specific sources of economic disturbances, and notably financial shocks. Figures 20-24 illustrate the impact of more risk-sensitive capital requirements on real and financial variables. Focusing on the different shock amplifications in the benchmark model (i.e. Basel I; black plain lines) and the Basel II-based benchmark model (blue dashed lines), we observe that for example a shock to borrower riskiness (Fig. 21-22) has a more pronounced impact on lending spreads when banks are subject to risk-sensitive capital requirements. In contrast to the benchmark case, bank lending rates increase allowing banks to rebuild their capital in response to the higher (risk-weighted) leverage. In the case of a negative shock to corporate riskiness, investment is more adversely affected under the Basel II framework and the positive spill-over impact on consumption is more muted relative to the baseline (Basel I). Likewise, in the case of an adverse shock to household default risk the need for banks to accumulate more capital results in a negative spill-over effect on the corporate sector (via higher corporate lending spreads). Overall, we observe that changes in credit risk across time, especially in the case of a shock to corporate creditworthiness, amplifies the impact on output compared to the situation with flat-rate capital requirements. This notwithstanding, it is notable that under risk-sensitive capital requirements banks are found to more actively reshuffle their loan portfolio in response to credit risk shocks, as for example illustrated by the stronger reaction of the volumes of corporate loans and mortgage loans to a shock to household and corporate creditworthiness, respectively. This might hence exert a mitigating impact on the pro-cyclical nature of the risk-sensitive capital requirements, although in our specification it is not enough to completely eliminate the cyclical propagation mechanism of the Basel II framework.

The negative shock to bank capital (Figure 23) is furthermore found to be amplified with the introduction of Basel II rules. Its adverse impact on bank leverage and in turn on bank margins is amplified by the reinforced negative feedback effect via time-varying risk weights. This induces banks to raise lending spreads by more than in the benchmark case and to more aggressively lower their leverage. Overall, the bank deleveraging needs are found to have a more substantial amplifying impact on the macroeconomic variables under the Basel II framework relative to the benchmark case. A similar pattern is found with respect to the monetary policy shock (Figure 29), although in this case the amplifying real economic effects from the introduction of Basel II is much less pronounced. A similar observation can be made with respect to most of the other efficiency and markup shocks. Whereas lending spreads and banks' profit accumulation appear to react stronger to such shocks, the overall effects on the real side of the economy is typically less severe.

6.2 Transitional dynamics towards higher capital requirements

Our model is also well-suited to investigate the macroeconomic implications of such changes to the regulatory framework. The reform of the financial regulatory landscape acted in end-2010 (so-called "Basel III"), following the proposal of the Basel Committee on Banking Supervision (BCBS), will lead to higher required capital for the banking sector.[37]. The simulations presented thereafter remain illustrative of the transitional costs of introducing higher capital requirements but should not be interpreted as a quantitative economic assessment of the introduction of Basel III. Indeed, the magnitude of the shock is not

[37] See BCBS (20010)

related to the exact calibration of the reform and to the balance sheet structure of the euro area system. Moreover, the more is silent on the steady-state and cyclical benefits of higher capital requirements.

The first set of simulations is conducted using the version of the model with endogenous defaults of households and firms (Chart 31) whereas a second set of simulations is based on the model with binding collateral constraints (see Chart 32). Note that both models share to a large extent some common specifications but they have been estimated on euro area data separately and therefore have different deep parameter values. As regards the timing of the introduction of the higher capital requirements, the experiments assume the implementation of higher capital requirements at different horizons (i.e. immediate implementation, after two, four and six years, respectively). The model is run under perfect foresight and with endogenous monetary policy, following the estimated Taylor rule. Given the specification of the bank capital frictions and the calibration strategy for the steady state, capital requirements have no tangible impact on the real allocation over the long term. As described above, the required bank balance sheet adjustments take place through higher loan-deposit margins, which curb loan demand and support the internal capital accumulation through higher retained earnings.

The parameter driving the bank capital channel has been set at its highest value found across the various estimation exercises ($\chi_{wb} = 50$). We also experimented with simulations through unexpected capital requirement shocks. This led to somewhat stronger effects which could even be more pronounced by assuming unchanged monetary policy. On balance, the perfect foresight simulations presented below may be seen as the mid-range effects given possible assumptions on expectations and monetary policy reaction.

We analyze first the simulations from the model with endogenous defaults. In the case of immediate implementation of higher capital requirements (blue lines in Chart 31), the maximum impact on real GDP is obtained after several quarters. A 2 p.p. increase in capital requirements leads to a peak decline in real GDP of 0.3 p.p., the negative effects being rapidly re-absorbed over the medium term. The downward pressures on inflation are relatively short-lived, reaching -0.05 p.p. of quarterly inflation after few quarters then reverting back to positive territory. As mentioned before, in the long-term, the transition towards higher capital requirements leave the real economy and the outstanding amount of loans unchanged since the adjustment will be fully reflected in higher bank capital. The required increase in bank profits depends on the magnitude of loan-deposit margins' increase compared with loan volume contraction. Chart 13 shows the hump-shaped responses of spreads and loans with opposite signs. Given the more gradual interest rate pass-through on mortgage lending rates, the price and volume adjustments of household credit are more sluggish than in the case of non-financial corporations.

Considering now the announcement of higher capital requirements at distant horizons (other lines in Charts 31), it turns out that the output cost of bank balance sheet consolidation becomes smaller, the later the implementation date. For implementation in 2012, the peak negative impact on GDP is much more moderate and materializes later than in the previous case. The transition path of GDP even turns positive when higher capital requirements are expected to be implemented in 2014. In the latter case, GDP only falls below baseline around the year of the implementation. The expansion of GDP in the first years is notably supported by lower bank lending rate spreads. The more benign impact on activity the further into the future the actual implementation of the new requirements is moved can be interpreted as a "smoothing out" of the negative implications of the capital shock. If banks have more time to adjust their activities and balance sheets to the new environment they will tend to smooth the impact of the shock. In other words, the tighter the implementation schedule, the more important will non-linearities in credit frictions be.

The simulations conducted using the model with binding collateral constraints share some qualitative similarities with the previous experiments. First, assuming an immediate implementation of higher capital requirements (blue lines in Chart 32), the contraction of output reaches a peak effect of 0.35 p.p. after more than one year. Compared with the model with endogenous defaults, the adverse impact on activity is more persistent as GDP remains 0.15 p.p. below baseline at the end of the simulation horizon. The negative effect on inflation peaks at less than 0.05 p.p. in the first year. Turning now to the delayed implementation period (other lines in Chart 32), which is perfectly anticipated by all agents, the simulations show that the adverse implications for the economy would be limited by putting forward by few years and credibly communicating future regulatory changes. This result is common to both model specifications.

Nonetheless, in the model with binding collateral constraints, the mitigation of the adverse transitional effects due to the implementation delay is weaker than in the model with endogenous defaults. In particular, the announcement of higher capital requirements in 2012 still implies a decline in real GDP of around 0.25 p.p. at the peak in 2013. Another difference with the previous model regards the price and volume adjustments in credit markets. The model with binding collateral constraints leads to a more pronounced contraction in loans and to higher lending rates.

6.3 Accounting for counter cyclical macroprudential policies

A final application of the model is devoted to the interactions between monetary policy and macro-prudential policy. In particular, we want to assess whether a counter-cyclical regulatory regime would support macroeconomic stabilization. Recent papers like Kannan et al. [2009] or Angeloni and Faia [2009] have investigated this issue with different formulation of the strategic interactions between monetary policy and macro-prudential policy. Here we focus on the joint determination of the two policy rules as to maximize an *ad hoc* loss function under credible commitment.

The intertemporal quadratic loss function penalizes deviations from steady state for consumer price inflation, output growth and policy rate. Monetary policy conduct is described as an interest rate rule while macro-prudential policy is assumed to follow a capital requirement rule. Both rules feature policy inertia and respond to level and first difference of consumer inflation, detrended output, and first difference of loans to households, loans to entrepreneurs, real housing prices and real equity prices [38]. We chose to limit the analysis to a stylized loss function instead of a welfare-based objective as the "reduced-form" nature of the bank capital friction considered in this paper would weakly portray the welfare trade-offs faced by macro-prudential policy in particular. Consequently, we preferred to abstract from welfare calculations and gear the policy discussion towards general macroeconomic stabilization without investigating how the micro-foundations of the model influence the policy objectives.

The loss function considered can be written as follows:

$$\mathcal{L}_t = \lambda_\pi \pi_t^2 + \lambda_z \left[\Delta z_t\right]^2 + \lambda_r r_t^2 + \lambda_{lev} [Leverage_t]^2 + \beta \mathbb{E}_t \mathcal{L}_{t+1}$$

where λ_π, λ_z and λ_r are the coefficients weighting the respective costs of volatility in CPI inflation,

[38] real equity prices are defined as the average real price of fixed capital in the economy

changes in output and nominal interest rate. Later on, we would consider introducing a penalty for bank leverage volatility.

The weights in the loss function are selected in the following way. The monetary policy rule has the same form as the estimated one. The exogenous processes for the structural shocks are taken from the benchmark estimation. Then we search for the weighting scheme which delivers at the optimal rule, the same volatility for inflation and policy rate as under the estimated rule. The optimal weights we obtain are $\lambda_\pi = 1$, $\lambda_z = 4$ and $\lambda_r = 0.75$. Such a loss function constitutes an intuitive benchmark. Another possibility would have been to consider the full efficiency curve in the inflation, output growth space. But, for the sake of clarity, we kept only one specific loss function. The essence of the results presented thereafter holds for any point of this efficiency curve.

A first exercise consists in optimizing the parameters of the monetary policy rule augmented with asset prices and credit variables, keeping capital requirements constant. We concentrate on the following formulation of the monetary policy rule.

$$\begin{aligned} r_t &= \rho r_{t-1} + (1-\rho)\left(r_\pi \pi_{t-1} + r_y y_{t-1}\right) + r_{\Delta\pi}\Delta\pi_t + r_{\Delta y}\Delta y_t \\ &\quad + r_{T_D}\Delta t_{D,t} + r_Q \Delta q_t + r_h \Delta b_{HH,t} + r_e \Delta b_{E,t} \end{aligned}$$

We only consider financial shocks, as provided by the benchmark estimation: those disturbances relate to interest rate markups, borrowers ' risk, bank capital and housing preference (also introduced its contribution to housing prices). Focusing on economic disturbances at the core of credit intermediation enables us to present more striking results on the role of credit and asset prices for monetary policy conduct in interaction with a counter-cyclical regulatory framework. As sensitivity analysis (not presented here), we verified that the findings exposed thereafter were still holding when all shocks were introduced.

Table 8 presents the macroeconomic volatilities associated with various optimized rules in the presence of financial shocks (except for the first column). In the first two columns, the monetary policy rule is specified as in the estimation and optimized under constant capital requirements. For the sake of completeness, the exercise is conducted either with financial shocks or with the overall set of economic disturbances. In both cases, the optimized monetary policy rule features a high level of interest rate inertia, a strong long-term response to inflation, stronger reaction to changes in output than in its level, and a specific role for housing prices. The restriction to financial shocks seems to increase the coefficient on housing prices and output growth but does not change qualitatively the main properties on the monetary policy rule. The macroeconomic variances generated by this monetary policy rule are taken as benchmark to normalize the moments obtained with the other policy regimes in Table 8.

In the third column, we allow for monetary policy reaction to credit and equity prices. The augmented optimal rule improves upon the previous one, reducing the loss function from 0.34 to 0.23. However, the lower volatility obtained for output growth and the interest rate is counterbalanced by a higher standard deviation for inflation. This optimal rule still displays a high degree of interest rate inertia, a strong reaction to inflation and some specific role for housing prices. But in addition, the rule include some positive response to household loans whereas the coefficients on loans to entrepreneurs and real equity prices are close to zero. Even without introducing asset prices or credit in the objective function, it turns out that the financial frictions on the household side vindicate some specific monetary policy focus on credit and asset prices.

With the augmented monetary policy rule specification, we also investigated the implications of risk-sensitive capital requirements. In this case, the optimized coefficients remain very close to the ones obtained with constant capital requirements (see column 4 in Table 8). At the margin, the monetary policy response to housing prices and household loans turns out to be stronger.

In the last two columns of Table 8, we allow for time-varying capital requirements. We assume that the target bank capital ratio follows a log-linear rule of the form

$$\begin{aligned} cap_t &= \rho^{bc} cap_{t-1} + r_y^{bc} y_t + r_{\Delta y}^{bc} \Delta y_t \\ &+ r_{\Delta h}^{bc} \Delta b_{HH,t} + r_{\Delta e}^{bc} \Delta b_{E,t} + r_{T_D}^{bc} \Delta t_{D,t} + r_Q^{bc} \Delta q_t \end{aligned}$$

Keeping the same loss function as in the previous experiments, the joint optimal determination of policy rules suggests that counter-cyclical regulation could provide a strong support to macroeconomic stabilization. The optimized capital requirement rule features some inertia and a very high positive response to output while the role for credit variables and asset prices seems negligible. The optimized monetary policy rule is very much affected by the introduction of counter-cyclical regulation: in particular, all coefficients on credit and asset prices become insignificant. Acting at the core of the financial system, regulatory policy seems to be relatively more effective than monetary policy in addressing destabilizing fluctuations in credit markets and intratemporal wedges between financial costs, therefore alleviating somehow the need for monetary policy to "lean against the wind". The jointly determined policy rules deliver a superior macroeconomic outcome. The loss function gets close to zero, with output growth volatility at 16.5% of the benchmark, inflation volatility at 70% and interest rate at 30%. However, in the model, the main transmission channel of regulatory policy on the economy works through the adjustment of bank balance sheets and its impact on bank lending rates. Consequently, the macroeconomic stabilization support from the optimized capital requirement rule implies an almost fivefold increase in bank leverage volatility. Such a degree of counter-cyclical capital requirements would therefore be difficult to implement and lead to excessive volatility in bank balance sheets. As shown in the last column of Table 8, if we constrain the regulatory framework by introducing a relatively small penalty for leverage volatility in the loss function, then the optimized capital requirement rule becomes only moderately time-varying and the monetary policy rule is very similar to the one obtained under constant capital requirements.

Overall, while some counter-cyclical regulation seems suitable as far as macroeconomic stabilization is concerned, its design and magnitude should be carefully considered. The analysis presented here remains illustrative and subject to clear limitations. Notably, a structural interpretation of systemic risk (and in particular its cross-sectional dimension) is absent from the model. Such a concept is essential to define a meaningful objective for macro-prudential policy.

7 Conclusions

The recent years' dramatic events which brought financial markets into turmoil highlighted the crucial role of credit market frictions in the propagation of economic and financial shocks. However, the nature of banking and the role of banks in amplifying macroeconomic fluctuations are elements have hitherto been largely neglected in the macroeconomic literature and, in particular, in the design of general equilibrium models. To reflect this, a number of recent papers try to correct this void by incorporating banking sectors and other financial frictions into DSGE modeling frameworks. The model presented in this paper contributes to this research by incorporating a number of demand and supply credit frictions into an estimated DSGE model of the euro area.

Apart from documenting the potential amplifying effects of credit frictions, this setup allows us to analyze changes in the regulatory regimes facing the financial sector, such as the introduction of risk sensitive capital requirements or the transition towards more stringent regulatory regimes. Moreover, reflecting the renewed focus on the nexus between monetary policy and macro-prudential (or financial stability-oriented) policies, our results point to important complementarities.

Finally, a few caveats and directions for further research should be mentioned. First of all, the banking sector in our setup is of a reduced form nature and can be further improved. For example, a more complete description of the balance sheet composition of the banks taking into account issues such as liquidity, wholesale funding and trading book valuations would enhance the specification and also allow for analyzing the macroeconomic impact of money market disruptions, bank liquidity positions and unconventional monetary policies. Likewise, a more micro-founded optimization of the policy rule to study the interactions between macro-prudential and monetary policies could be pursued.

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A Supplementary model description

A.1 The borrower's program

Let us define

$$\begin{aligned} H(\varpi) &= (1-\mathcal{N}_{cdf}(\log(\varpi)/\sigma_{HH}+0.5\sigma_{HH}))\varpi+\mathcal{N}_{cdf}(\log(\varpi)/\sigma_{HH}-0.5\sigma_{HH}) &(1)\\ G(\varpi) &= (1-\mathcal{N}_{cdf}(\log(\varpi)/\sigma_{HH}+0.5\sigma_{HH}))\varpi+(1-\mu_{HH})\mathcal{N}_{cdf}(\log(\varpi)/\sigma_{HH}-0.5\sigma_{HH}) &(2)\\ \mathcal{Y}(\varpi) &= (1-\mathcal{N}_{cdf}(\log(\varpi)/\sigma_{HH}+0.5\sigma_{HH}))/(1-\mathcal{N}_{cdf}(\log(\varpi)/\sigma_{HH}+0.5\sigma_{HH})-\mu_{HH}\varpi f(\varpi)) &(3)\end{aligned}$$

where $\mathcal{N}_{cdf}$ is the normal cumulative distribution, centered and standardized.
We denote $\widetilde{\Lambda}_t$ and $\widetilde{\Lambda}_t\Psi_t$ the lagrange multipliers associated with the budget constraint of impatient households and the participation constraints for the commercial lending branches

$$\begin{aligned} &\widetilde{C}_t+\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_t+H(\overline{\varpi}_{HH,t})(1-\chi_{HH})Q_{D,t}T_{D,t}(1-\delta)\widetilde{D}^b_{t-1}\\ =\ &(1-\delta)\,\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1}+B_{HH,t}+\widetilde{TT}_t+W_{C,t}N_{C,t}+W_{D,t}N_{D,t} \qquad (4)\end{aligned}$$

$$G(\overline{\varpi}_{HH,t})(1-\chi_{HH})\widetilde{Q}_{D,t}T_{D,t}(1-\delta)\widetilde{D}_{t-1}=\frac{(1+R_{HH,t-1})}{1+\pi_t}B_{HH,t-1} \qquad (5)$$

We also define

$$\widetilde{\mathcal{U}\prime}_{X,t}=\varepsilon^{\beta}_t\widetilde{X}_t^{-\sigma_C} \qquad (6)$$

$$\begin{aligned}\widetilde{\mathcal{U}\prime}_{C,t}=&\left(1-\varepsilon^D_t\omega_D\right)^{\frac{1}{\eta_D}}\left(\widetilde{C}_t-h_B\widetilde{C}_{t-1}\right)^{-\frac{1}{\eta_D}}\widetilde{X}_t^{\frac{1}{\eta_D}}\widetilde{\mathcal{U}\prime}_{X,t}\\ &-\beta h_B\left(1-\varepsilon^D_t\omega_D\right)^{\frac{1}{\eta_D}}\left(\frac{\widetilde{C}_t}{\widetilde{X}_t}\right)^{-\frac{1}{\eta_D}}\mathbb{E}_t\left\{\begin{array}{c}\left(1-\varepsilon^D_{t+1}\omega_D\right)^{\frac{1}{\eta_D}}\\ \left(\widetilde{C}_{t+1}-h_B\widetilde{C}_t\right)^{-\frac{1}{\eta_D}}\widetilde{X}_{t+1}^{\frac{1}{\eta_D}}\widetilde{\mathcal{U}\prime}_{X,t+1}\end{array}\right\} \qquad (7)\end{aligned}$$

$$\widetilde{\mathcal{U}\prime}_{D,t}=\varepsilon^D_t\omega_D^{\frac{1}{\eta_D}}\left(\frac{\widetilde{D}_t}{\widetilde{X}_t}\right)^{-\frac{1}{\eta_D}}\widetilde{\mathcal{U}\prime}_{X,t} \qquad (8)$$

The maximization of household welfare with respect to the default threshold $\overline{\varpi}_{HH,t}$ implies after some manipulations

$$\Psi_t=\mathcal{Y}(\overline{\varpi}_{HH,t}) \qquad (9)$$

The first order condition related to non-residential consumption and residential stock are respectively,

$$\widetilde{\Lambda}_t=\widetilde{\mathcal{U}\prime}_{C,t} \qquad (10)$$

and

$$\begin{aligned}&\widetilde{\Lambda}_t\widetilde{Q}_{D,t}T_{D,t}-\widetilde{\mathcal{U}\prime}_{D,t}-\beta\,(1-\delta)\,\mathbb{E}_t\left\{\widetilde{\Lambda}_{t+1}\widetilde{Q}_{D,t+1}T_{D,t+1}\right\}\\ =\ &\beta\,(1-\delta)\,\mathbb{E}_t\left\{\widetilde{\Lambda}_{t+1}\widetilde{Q}_{D,t+1}T_{D,t+1}\,(1-\chi)\,(G(\overline{\varpi}_{HH,t+1})\Psi_{t+1}-H(\overline{\varpi}_{HH,t+1}))\right\} \qquad (11)\end{aligned}$$

Finally, the optimality condition regarding the loan decision gives a "modified" version of the standard Euler equation

$$\widetilde{\Lambda}_t=\beta\mathbb{E}_t\left\{\widetilde{\Lambda}_{t+1}\frac{(1+R_{HH,t})}{1+\pi_{t+1}}\mathcal{Y}(\overline{\varpi}_{HH,t+1})\right\} \qquad (12)$$

Note that $\mathcal{Y}(\overline{\varpi}_{HH,t+1})$ plays the role of spread on the real interest rate which drives the intertemporal consumption smoothing. The spread between the lending rate in the optimal credit contract and the financing rate for the commercial lending banks is then given by

$$\frac{1+R^{L}_{HH,t}}{1+R_{HH,t-1}}=\frac{\overline{\varpi}_{HH,t}}{G(\overline{\varpi}_{HH,t})}>1 \tag{13}$$

As regards the supply of labour services,

$$\frac{\mu_w}{(1\text{-}\tau_{w,t})}\varepsilon^{\beta}_{t}L_{B,i}N^{\sigma_{L_i}}_{i,t}=\left(\omega_r\Lambda^{r}_{t}+(1-\omega_r)\,\Lambda^{o}_{t}\right)w_t$$

A.2 The saver's program

Let us denote

$$\mathcal{U}\prime_{X,t}=\varepsilon^{\beta}_{t}X_t{}^{-\sigma_C} \tag{14}$$

$$\begin{aligned}\mathcal{U}\prime_{C,t}=&\left(1-\varepsilon^{D}_{t}\omega_D\right)^{\frac{1}{\eta_D}}\left(C_t-hC_{t-1}\right)^{-\frac{1}{\eta_D}}X_t^{\frac{1}{\eta_D}}\mathcal{U}\prime_{X,t}\\&-\gamma h\left(1-\varepsilon^{D}_{t}\omega_D\right)^{\frac{1}{\eta_D}}\left(\frac{C_t}{X_t}\right)^{-\frac{1}{\eta_D}}\mathbb{E}_t\left\{\begin{array}{c}\left(1-\varepsilon^{D}_{t+1}\omega_D\right)^{\frac{1}{\eta_D}}\left(X_{t+1}\right)^{\frac{1}{\eta_D}}\\\left(C_{t+1}-hC_t\right)^{-\frac{1}{\eta_D}}\mathcal{U}\prime_{X,t+1}\end{array}\right\}\end{aligned} \tag{15}$$

$$\mathcal{U}\prime_{D,t}=\varepsilon^{D}_{t}\omega_D^{\frac{1}{\eta_D}}\left(\frac{D_t}{X_t}\right)^{-\frac{1}{\eta_D}}\mathcal{U}\prime_{X,t} \tag{16}$$

The first order condition related to non-residential consumption and residential stock are respectively,

$$\Lambda_t=\mathcal{U}\prime_{C,t} \tag{17}$$

and

$$\Lambda_tQ_{D,t}T_{D,t}=\mathcal{U}\prime_{D,t}+\gamma\left(1-\delta\right)\mathbb{E}_t\left\{\Lambda_{t+1}Q_{D,t+1}T_{D,t+1}\right\} \tag{18}$$

where Λ_t is the multiplier associated with the budget constraint.

A.3 Labor supply and wage setting

The first-order condition for the wage setting program of agent i in sector j can be written recursively as follows:

$$\frac{\widehat{W}_{j,i,t}}{P_t}=\left(\mu_w\frac{\mathcal{H}^{wji}_{1,t}}{\mathcal{H}^{wji}_{2,t}}\right)^{\frac{\mu_w-1}{\mu_w-1}}$$

The resulting aggregate real wage dynamics for each type in each sector is:

$$\begin{aligned}\left(W^{r}_{j,i,t}\right)^{\frac{1}{1-\mu_w}}=&\left(1-\alpha_{wji}\right)\left(\mu_w\frac{\mathcal{H}^{wji}_{1,t}}{\mathcal{H}^{wji}_{2,t}}\right)^{-\frac{1}{\mu_w-1}}\\&+\alpha_{wji}\left(W^{r}_{j,i,t-1}\right)^{\frac{1}{1-\mu_w}}\left(\frac{\Pi_t}{\Pi^{\xi_{wji}}_{t-1}\overline{\Pi}^{1-\xi_{wji}}}\right)^{\frac{-1}{1-\mu_w}}\end{aligned} \tag{19}$$

where

$$\mathcal{H}_{1,t}^{wji} = \overline{L}_{j,i}\left(N_{j,t}^{i}\right)^{1+\sigma_{Lj,i}}\left(W_{j,i,t}^{r}\right)^{\frac{\mu_w}{\mu_w-1}} + \alpha_{wji}\beta_i\mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_{wj,i}}\left[\overline{\Pi}\right]^{1-\xi_{wj,i}}}\right)^{\frac{\mu_w}{\mu_w-1}}\mathcal{H}_{1,t+1}^{wji}\right] \tag{20}$$

and

$$\mathcal{H}_{2,t}^{wji} = \Lambda_{it}N_{j,t}^{i}\left(W_{j,i,t}^{r}\right)^{\frac{\mu_w}{\mu_w-1}} + \alpha_{wji}\beta_i\mathbb{E}_t\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_{wj,i}}\left[\overline{\Pi}\right]^{1-\xi_{wj,i}}}\right)^{\frac{1}{\mu_w-1}}\mathcal{H}_{2,t+1}^{wji} \tag{21}$$

with $\beta_i = \beta$ if $i = S$ and $\beta_i = \gamma$ if $i = B$. Also, $W_{j,i,t}^{r}$ denotes the real wage of type i in sector j and Λ_{it} is the marginal utility of consumption of type i.
The dynamics of wage dispersion per sector j and per household type i can be written as:

$$\begin{aligned}\Delta_{j,i,t}^{w} &= (1-\alpha_{wji})\left(W_{j,i,t}^{r}\right)^{\frac{\mu_w}{\mu_w-1}}\left(\mu_w\frac{\mathcal{H}_{1,t}^{wji}}{\mathcal{H}_{2,t}^{wji}}\right)^{-\frac{\mu_w}{\mu_w-1}} \\ &\quad +\alpha_{wji}\Delta_{j,i,t-1}^{w}\left(\frac{W_{j,i,t}^{r}}{W_{j,i,t-1}^{r}}\right)^{\frac{\mu_w}{\mu_w-1}}\left(\frac{\Pi_t}{\Pi_{t-1}^{\xi_{wj,i}}\left[\overline{\Pi}\right]^{1-\xi_{wj,i}}}\right)^{\frac{\mu_w}{\mu_w-1}}\end{aligned} \tag{22}$$

A.4 Entrepreneurs

Let us denote

$$H_E(\varpi_E) = (1-\mathcal{N}_{cdf}(\log(\varpi_E)/\sigma_E + 0.5\sigma_E))\varpi_E + \mathcal{N}_{cdf}(\log(\varpi_E)/\sigma_E - 0.5\sigma_E) \tag{23}$$

$$G_E(\varpi_E) = (1-\mathcal{N}_{cdf}(\log(\varpi_E)/\sigma_E + 0.5\sigma_E))\varpi_E + (1-\mu_E)\mathcal{N}_{cdf}(\log(\varpi_E)/\sigma_E - 0.5\sigma_E) \tag{24}$$

$$\mathcal{Y}_E(\varpi_E) = (1-\mathcal{N}_{cdf}(\log(\varpi_E)/\sigma_E + 0.5\sigma_E))/(1-\mathcal{N}_{cdf}(\log(\varpi_E)/\sigma_E + 0.5\sigma_E) - \mu_E\varpi f(\varpi_E)) \tag{25}$$

where $\mathcal{N}_{cdf}$ is the normal cumulative distribution, centered and standardized.
We denote $\Lambda_{E,t}$ and $\Lambda_{E,t}\Psi_{E,t}$ the lagrange multipliers associated with the budget constraint of entrepreneurs and the participation constraints for the commercial lending branches

$$\begin{aligned}& C_t^E + Q_t^C(K_t^C - (1-\delta_K)K_{t-1}^C) + Q_t^D(K_t^D - (1-\delta_K)K_{t-1}^D) + H^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} \\ = \; & B_{E,t} + MC_tZ_t + MC_{D,t}Z_{D,t} - W_{C,t}^r L_{C,t} - W_{D,t}^r L_{D,t} - p_{lt}\mathcal{L}_t \\ & -\Phi\left(u_t^C\right)K_{t-1}^C - \Phi\left(u_t^D\right)K_{t-1}^D + TT_t^E\end{aligned} \tag{26}$$

and

$$G^E(\overline{\varpi}_{E,t})(1-\chi_E)(1-\delta_K)(Q_t^C K_{t-1}^C + Q_t^D K_{t-1}^D) = \frac{(1+R_{E,t-1})}{1+\pi_t}B_{E,t-1} \tag{27}$$

The choice of capacity utilization rates lead to

$$\alpha_C\varepsilon_t^A\left(\frac{L_t^C}{u_t^C K_{t-1}^C}\right)^{1-\alpha_C} = \Phi'(u_t^C) \equiv R_t^{k,C} \tag{28}$$

$$\alpha_D\varepsilon_t^{A_D}\frac{\left(L_t^D\right)^{1-\alpha_D-\alpha_{\mathcal{L}}}\mathcal{L}_t^{\alpha_{\mathcal{L}}}}{\left(u_t^D K_{t-1}^D\right)^{1-\alpha_D}} = \Phi'(u_t^D) \equiv R_t^{k,D} \tag{29}$$

We define $R_t^{k,C}$ and $R_t^{k,D}$ as the apparent return on fixed capital for sector C and D.

Cost minimizations implicit in the productive decisions would lead to the following input demand relations:

$$\frac{W^r_{C,t}L^C_t}{R^{k,C}_t u^C_t K^C_{t-1}} = \frac{1-\alpha_C}{\alpha_C} \tag{30}$$

$$\frac{W^r_{D,t}L^D_t}{R^{k,D}_t u^D_t K^D_{t-1}} = \frac{1-\alpha_D-\alpha_{\mathcal{L}}}{\alpha_D} \tag{31}$$

$$\frac{p_{lt}\mathcal{L}_t}{W^r_{D,t}L^D_t} = \frac{\alpha_{\mathcal{L}}}{1-\alpha_D-\alpha_{\mathcal{L}}} \tag{32}$$

In addition, the factor-price frontiers are given by

$$MC_t = \frac{W^{r(1-\alpha_C)}_{C,t}\left[R^{k,C}_t\right]^{\alpha_C}}{\varepsilon^A_t \alpha^{\alpha_C}_C (1-\alpha_C)^{(1-\alpha_C)}} \tag{33}$$

$$MC_{D,t} = \frac{W^{r(1-\alpha_D-\alpha_{\mathcal{L}})}_{D,t}\left[R^{k,D}_t\right]^{\alpha_D}[p_{lt}]^{\alpha_{\mathcal{L}}}}{\varepsilon^{A_D}_t \alpha^{\alpha_D}_D (1-\alpha_D-\alpha_{\mathcal{L}})^{(1-\alpha_D-\alpha_{LAND})}(\alpha_{\mathcal{L}})^{\alpha_{\mathcal{L}}} T_{D,t}} \tag{34}$$

We also define

$$\widetilde{\mathcal{U}\prime}_{E,t} = \varepsilon^\beta_t \left(C^E_t - h_E C^E_{t-1}\right)^{-\sigma_{CE}} - \beta_E h_E \mathbb{E}_t\left\{\varepsilon^\beta_{t+1}\left(C^E_{t+1} - h_E C^E_t\right)^{-\sigma_{CE}}\right\} \tag{35}$$

The first order condition related to non-residential consumption gives,

$$\Lambda_{E,t} = \widetilde{\mathcal{U}\prime}_{C,t} \tag{36}$$

The maximization of entrepreneur welfare with respect to the default threshold $\overline{\varpi}_{E,t}$ implies after some manipulations

$$\Psi_{E,t} = \mathcal{Y}_E(\overline{\varpi}_{E,t}) \tag{37}$$

The optimality condition regarding the loan decision implies another "modified" version of the standard Euler equation

$$\Lambda_{E,t} = \beta_E \mathbb{E}_t\left\{\Lambda_{E,t+1}\frac{(1+R_{E,t})}{1+\pi_{t+1}}\mathcal{Y}_E(\overline{\varpi}_{E,t+1})\right\} \tag{38}$$

Note that $\mathcal{Y}_E(\overline{\varpi}_{E,t+1})$ plays the role of spread on the real interest rate which drives the intertemporal consumption smoothing of entrepreneurs. The spread between the lending rate in the optimal credit contract and the financing rate for the commercial lending banks is then given by

$$\frac{1+R^L_{E,t}}{1+R_{E,t-1}} = \frac{\overline{\varpi}_{E,t}}{G_E(\overline{\varpi}_{E,t})} > 1 \tag{39}$$

Finally, the choice of fixed capital stock for the sector C and D implies

$$Q^C_t = \mathbb{E}_t\left[\beta_E\frac{\Lambda_{E,t+1}}{\Lambda_{E,t}}\left(\frac{Q^C_{t+1}(1-\delta_K) + R^{k,C}_{t+1}u^C_{t+1} - \Phi\left(u^C_{t+1}\right)}{Q^C_{t+1}(1-\delta_K)(1-\chi_E)(G_E(\overline{\varpi}_{E,t+1})\Psi_{E,t+1} - H_E(\overline{\varpi}_{E,t+1}))}\right)\right] \tag{40}$$

$$Q^D_t = \mathbb{E}_t\left[\beta_E\frac{\Lambda_{E,t+1}}{\Lambda_{E,t}}\left(\frac{Q^D_{t+1}(1-\delta_K) + R^{k,D}_{t+1}u^D_{t+1} - \Phi\left(u^D_{t+1}\right)}{Q^D_{t+1}(1-\delta_K)(1-\chi_E)(G_E(\overline{\varpi}_{E,t+1})\Psi_{E,t+1} - H_E(\overline{\varpi}_{E,t+1}))}\right)\right] \tag{41}$$

A.5 Bank lending rate setting

The imperfect pass-through of market interest rates on bank lending and deposit rates is described in the recursive formulation of the staggered interest rate setting on savers ′ deposits and on funding costs of the commercial lending banks.

The following equations determines the average interest rate $R_{HH,t}$ applied to funds provided by the wholesale branches to the commercial lending branches, specialized in household loans for house purchase.

$$\mathcal{Z}^R_{HH1,t} = \frac{R^{wb}_t}{R_{HH,t}} \Lambda_t \widetilde{B}_{HH,t} + \xi^R_{HH} \gamma \mathbb{E}_t \left[\left(\frac{R_{HH,t+1}}{R_{HH,t}} \right)^{\frac{\mu^R_{HH}}{\mu^R_{HH}-1}+1} \mathcal{Z}^R_{HH1,t+1} \right] \tag{42}$$

$$\mathcal{Z}^R_{HH2,t} = \varepsilon^R_{HH,t} \Lambda_t \widetilde{B}_{HH,t} + \xi^R_{HH} \gamma \mathbb{E}_t \left[\left(\frac{R_{HH,t+1}}{R_{HH,t}} \right)^{\frac{\mu^R_{HH}}{\mu^R_{HH}-1}} \mathcal{Z}^R_{HH2,t+1} \right] \tag{43}$$

$$1 = \xi^R_{HH} \left(\frac{R_{HH,t}}{R_{HH,t-1}} \right)^{\frac{1}{\mu^R_{HH}-1}} + (1 - \xi^R_{HH}) \left(\mu^R_{HH} \frac{\mathcal{Z}^R_{HH1,t}}{\mathcal{Z}^R_{HH2,t}} \right)^{\frac{1}{1-\mu^R_{HH}}} \tag{44}$$

Similarly, the average interest rate charged to the commercial lending branches specialized in loans to entrepreneurs $R_{E,t}$ is given by the following set of equations.

$$\mathcal{Z}^R_{E1,t} = \frac{R^{wb}_t}{R_{E,t}} \Lambda_t B_{E,t} + \xi^R_E \gamma \mathbb{E}_t \left[\left(\frac{R_{E,t+1}}{R_{E,t}} \right)^{\frac{\mu^R_E}{\mu^R_E-1}+1} \mathcal{Z}^R_{E1,t+1} \right] \tag{45}$$

$$\mathcal{Z}^R_{E2,t} = \varepsilon^R_{E,t} \Lambda_t B_{E,t} + \xi^R_E \gamma \mathbb{E}_t \left[\left(\frac{R_{E,t+1}}{R_{E,t}} \right)^{\frac{\mu^R_E}{\mu^R_E-1}} \mathcal{Z}^R_{E2,t+1} \right] \tag{46}$$

$$1 = \xi^R_E \left(\frac{R_{E,t}}{R_{E,t-1}} \right)^{\frac{1}{\mu^R_E-1}} + (1 - \xi^R_E) \left(\mu^R_E \frac{\mathcal{Z}^R_{E1,t}}{\mathcal{Z}^R_{E2,t}} \right)^{\frac{1}{1-\mu^R_E}} \tag{47}$$

Finally, the average deposit rate offered to patient households $R_{D,t}$ is derived from

$$\mathcal{Z}^R_{D1,t} = \frac{R_t}{R_{D,t}} \Lambda_t Dep_t + \xi^R_D \gamma \mathbb{E}_t \left[\left(\frac{R_{D,t+1}}{R_{D,t}} \right)^{\frac{\mu^R_D}{\mu^R_D-1}+1} \mathcal{Z}^R_{D1,t+1} \right] \tag{48}$$

$$\mathcal{Z}^R_{D2,t} = \varepsilon^R_{D,t} \Lambda_t Dep_t + \xi^R_D \gamma \mathbb{E}_t \left[\left(\frac{R_{D,t+1}}{R_{D,t}} \right)^{\frac{\mu^R_D}{\mu^R_D-1}} \mathcal{Z}^R_{D2,t+1} \right] \tag{49}$$

$$1 = \xi^R_D \left(\frac{R_{D,t}}{R_{D,t-1}} \right)^{\frac{1}{\mu^R_D-1}} + (1 - \xi^R_D) \left(\mu^R_D \frac{\mathcal{Z}^R_{D1,t}}{\mathcal{Z}^R_{D2,t}} \right)^{\frac{1}{1-\mu^R_D}} \tag{50}$$

Lending rate dispersion indexes are then given by

$$\Delta^R_{HH,t} = (1-\xi^R_{HH})\left(\mu^R_{HH}\frac{\mathcal{Z}^R_{HH1,t}}{\mathcal{Z}^R_{HH2,t}}\right)^{-\frac{\mu^R_{HH}}{\mu^R_{HH}-1}} + \xi^R_{HH}\Delta^R_{HH,t-1}\left(\frac{R^b_{HH,t}}{R^b_{HH,t-1}}\right)^{\frac{\mu^R_{HH}}{\mu^R_{HH}-1}} \tag{51}$$

$$\Delta^R_{E,t} = (1-\xi^R_{E})\left(\mu^R_{E}\frac{\mathcal{Z}^R_{E1,t}}{\mathcal{Z}^R_{E2,t}}\right)^{-\frac{\mu^R_{E}}{\mu^R_{E}-1}} + \xi^R_{E}\Delta^R_{E,t-1}\left(\frac{R^b_{E,t}}{R^b_{E,t-1}}\right)^{\frac{\mu^R_{E}}{\mu^R_{E}-1}} \tag{52}$$

$$\Delta^R_{D,t} = (1-\xi^R_{D})\left(\mu^R_{D}\frac{\mathcal{Z}^R_{D1,t}}{\mathcal{Z}^R_{D2,t}}\right)^{-\frac{\mu^R_{D}}{\mu^R_{D}-1}} + \xi^R_{D}\Delta^R_{D,t-1}\left(\frac{R^D_{t}}{R^D_{t-1}}\right)^{\frac{\mu^R_{D}}{\mu^R_{D}-1}} \tag{53}$$

A.6 Price setting in the retail and distribution sector

The price setting in the retail and distribution non-residential sector leads to the following recursive formulation which implicitly determines the inflation rate Π_t:

$$\mathcal{Z}_{1,t} = \Lambda_t MC_t Y_t + \xi_C \gamma \mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_C}\overline{\Pi}^{1-\gamma_C}}\right)^{\frac{\mu}{\mu-1}} \mathcal{Z}_{1,t+1}\right] \tag{54}$$

$$\mathcal{Z}_{2,t} = \varepsilon^P_t \Lambda_t Y_t + \xi_C \gamma \mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi_{C,t}^{\gamma_C}\overline{\Pi}^{1-\gamma_C}}\right)^{\frac{1}{\mu-1}} \mathcal{Z}_{2,t+1}\right] \tag{55}$$

and

$$1 = \xi_C\left(\frac{\Pi_{C,t}}{\Pi_{t-1}^{\gamma_C}\overline{\Pi}^{1-\gamma_C}}\right)^{\frac{1}{\mu-1}} + (1-\xi_C)\left(\mu\frac{\mathcal{Z}_{1,t}}{\mathcal{Z}_{2,t}}\right)^{\frac{1}{1-\mu}} \tag{56}$$

where ε^P_t represents a stationary cost-push shock.
Similarly the recursive form related the price setting in the residential sectors follows

$$\mathcal{Z}_{D1,t} = \Lambda_t MC_{D,t} Y_{D,t} T_{D,t} + \xi_D \gamma \mathbb{E}_t\left[\left(\frac{\Pi_{D,t+1}}{\Pi_{D,t}^{\gamma_D}\overline{\Pi}^{1-\gamma_D}}\right)^{\frac{\mu_D}{\mu_D-1}} \mathcal{Z}_{D1,t+1}\right] \tag{57}$$

$$\mathcal{Z}_{D2,t} = \Lambda_t Y_{D,t} T_{D,t} + \xi_C \gamma \mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi_{C,t}^{\gamma_C}\overline{\Pi}^{1-\gamma_C}}\right)^{\frac{1}{\mu_D-1}} \mathcal{Z}_{D2,t+1}\right] \tag{58}$$

and

$$1 = \xi_D\left(\frac{\Pi_{D,t}}{\Pi_{D,t-1}^{\gamma_D}\overline{\Pi}^{1-\gamma_D}}\right)^{\frac{1}{\mu_D-1}} + (1-\xi_D)\left(\mu_D\frac{\mathcal{Z}_{D1,t}}{\mathcal{Z}_{D2,t}}\right)^{\frac{1}{1-\mu_D}} \tag{59}$$

Price dispersion indexes are then given by

$$\Delta_t = (1-\xi_C)\left(\mu\frac{\mathcal{Z}_{1,t}}{\mathcal{Z}_{2,t}}\right)^{-\frac{\mu}{\mu-1}} + \xi_C\Delta_{t-1}\left(\frac{\Pi_t}{\Pi_{t-1}^{\gamma_C}\overline{\Pi}^{1-\gamma_C}}\right)^{\frac{\mu}{\mu-1}} \tag{60}$$

$$\Delta_{D,t} = (1-\xi_D)\left(\mu_D\frac{\mathcal{Z}_{D1,t}}{\mathcal{Z}_{D2,t}}\right)^{-\frac{\mu_D}{\mu_D-1}} + \xi_D\Delta_{D,t-1}\left(\frac{\Pi_{D,t}}{\Pi_{D,t-1}^{\gamma_D}\overline{\Pi}^{1-\gamma_D}}\right)^{\frac{\mu_D}{\mu_D-1}} \tag{61}$$

A.7 Capital and Housing stock producers

Given the accumulation processes

$$\begin{aligned}
K_t^C &= (1-\delta_K)K_{t-1}^C + \left[1 - S\left(\frac{I_t^C \varepsilon_t^I}{I_{t-1}^C}\right)\right] I_t^C \\
K_t^D &= (1-\delta_K)K_{t-1}^D + \left[1 - S\left(\frac{I_t^D \varepsilon_t^I}{I_{t-1}^D}\right)\right] I_t^D \\
D_t &= (1-\delta)D_{t-1} + \left[1 - S_D\left(\frac{I_{D,t}}{I_{D,t-1}}\right)\right] I_{D,t} \\
\widetilde{D}_t &= (1-\delta)\widetilde{D}_{t-1} + \left[1 - S_D\left(\frac{\widetilde{I}_{D,t}}{\widetilde{I}_{D,t-1}}\right)\right] \widetilde{I}_{D,t}
\end{aligned} \tag{62}$$

the first order conditions for the capital and housing stock producers are
The resulting first order conditions read

$$\begin{aligned}
Q_t^C\left[1 - S\left(\frac{I_t^C\varepsilon_t^I}{I_{t-1}^C}\right) - \frac{I_t^C\varepsilon_t^I}{I_{t-1}^C}S'\left(\frac{I_t^C\varepsilon_t^I}{I_{t-1}^C}\right)\right] + \gamma\mathbb{E}_t\left[Q_{t+1}^C\frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{I_{t+1}^C\varepsilon_{t+1}^I}{I_t^C}\right)^2 S'\left(\frac{I_{t+1}^C\varepsilon_{t+1}^I}{I_t^C}\right)\right] &= 1 \\
Q_t^D\left[1 - S\left(\frac{I_t^D\varepsilon_t^I}{I_{t-1}^D}\right) - \frac{I_t^D\varepsilon_t^I}{I_{t-1}^D}S'\left(\frac{I_t^D\varepsilon_t^I}{I_{t-1}^D}\right)\right] + \gamma\mathbb{E}_t\left[Q_{t+1}^D\frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{I_{t+1}^D\varepsilon_{t+1}^I}{I_t^D}\right)^2 S'\left(\frac{I_{t+1}^D\varepsilon_{t+1}^I}{I_t^D}\right)\right] &= 1 \\
Q_{D,t}\left[1 - S_D\left(\frac{I_{D,t}}{I_{D,t-1}}\right) - \frac{I_{D,t}}{I_{D,t-1}}S_D'\left(\frac{I_{D,t}}{I_{D,t-1}}\right)\right] + \gamma\mathbb{E}_t\left[Q_{D,t+1}\frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{I_{D,t+1}}{I_{D,t}}\right)^2 S'\left(\frac{I_{D,t+1}}{I_{D,t}}\right)\right] &= 1 \\
\widetilde{Q}_{D,t}\left[1 - S_D\left(\frac{\widetilde{I}_{D,t}}{\widetilde{I}_{D,t-1}}\right) - \frac{\widetilde{I}_{D,t}}{\widetilde{I}_{D,t-1}}S_D'\left(\frac{\widetilde{I}_{D,t}}{\widetilde{I}_{D,t-1}}\right)\right] + \gamma\mathbb{E}_t\left[\widetilde{Q}_{D,t+1}\frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{\widetilde{I}_{D,t+1}}{\widetilde{I}_{D,t}}\right)^2 S'\left(\frac{\widetilde{I}_{D,t+1}}{\widetilde{I}_{D,t}}\right)\right] &= 1
\end{aligned} \tag{63}$$

B Predetermined lending rates

We assume now that the commercial lending branches propose credit contract where the lending rate is not contingent on the realization of aggregate uncertainty.

B.1 Entrepreneurs

As in the benchmark case, entrepreneurs' fixed capital are subject to common multiplicative idiosyncratic shocks $\varpi_{E,t}$. As for households, these shocks are independent and identically distributed across time and across entrepreneurs with $E(\varpi_{E,t}) = 1$, and a lognormal CDF $F^E(\varpi_{E,t})$. Here again, the variance of the idiosyncratic shock $\sigma_{E,t}$ is time-varying.
As for borrowers, entrepreneurs only use debt contracts in which the loan rates can be made contingent on aggregate shocks but not on the idiosyncratic shock $\varpi_{E,t}$. Entrepreneurs belong to a large family that can diversify the idiosyncratic risk after loan contracts are settled, but cannot commit to sharing the proceeds of this insurance with banks. Banks can seize collateral $\varpi_{E,t}\tilde{A}_{E,t}$ when the entrepreneur refuses to pay at a cost of $\mu_E\varpi_{E,t}\tilde{A}_{E,t}$. The value of the collateral that the bank can seize is

$$\varpi_{E,t}\tilde{A}_{E,t} = \varpi_{E,t}(1-\chi_E)(1-\delta_K)(Q_t^C K_{t-1}^C + Q_t^D K_{t-1}^D)$$

Before the realization of aggregate uncertainty in period , there exists a cut-off point $\overline{\varpi}_{E,t}$ on the realization of the idiosyncratic shock below which the entrepreneur chooses to default. This threshold verifies that the debt repayment is equal to the expected value of the collateral

$$\left(1 + R_{E,t}^L\right) B_{E,t} = \overline{\varpi}_{E,t}\mathbb{E}_t\left\{\left(Q_{t+1}^C K_t^C + Q_{t+1}^D K_t^D\right)(1+\pi_{t+1})\right\}$$

For the bank to participate in the credit contract, the ex ante profit must be positive

$$G^E(\overline{\varpi}_{E,t})(1-\chi_E)(1-\delta_K)\mathbb{E}_t\left\{\left(Q^C_{t+1}K^C_t+Q^D_{t+1}K^D_t\right)(1+\pi_{t+1})\right\}\geq(1+R_{E,t})\,B_{E,t}$$

with

$$G^E(\overline{\varpi}_{E,t})=(1-F^E_t(\overline{\varpi}_{E,t}))\overline{\varpi}_{E,t}+(1-\mu_E)\int_0^{\overline{\varpi}_{E,t}}\overline{\varpi}dF^E_t$$

Once the aggregate uncertainty resolves, the ex post cut-off point $\overline{\varpi}^B_{E,t}$ changes so that

$$\left(1+R^L_{E,t-1}\right)B_{E,t-1}=\overline{\varpi}^B_{E,t}(1-\chi_E)(1-\delta_K)\left(Q^C_tK^C_{t-1}+Q^D_tK^D_{t-1}\right)(1+\pi_t)$$

The spread between the lending rate and the financing rate for the commercial lending bank is

$$\frac{1+R^L_{E,t}}{1+R_{E,t}}=\frac{\overline{\varpi}_{E,t}}{G_E(\overline{\varpi}_{E,t})}\tag{64}$$

Let us denote

$$\begin{aligned}\widetilde{H}^K_E(\overline{\varpi}_{E,t-1},\overline{\varpi}^B_{E,t})&=(1-\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}+0.5\sigma_{E,t-1}\right))\overline{\varpi}_{E,t-1}\\&\quad\frac{\mathbb{E}_{t-1}\left\{\left(Q^C_tK^C_{t-1}+Q^D_tK^D_{t-1}\right)(1+\pi_t)\right\}}{(1+\pi_t)}\\&\quad+\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}-0.5\sigma_{E,t-1}\right)\left(Q^C_tK^C_{t-1}+Q^D_tK^D_{t-1}\right)\end{aligned}\tag{65}$$

$$\begin{aligned}\widetilde{H}_E(\overline{\varpi}_{E,t-1},\overline{\varpi}^B_{E,t})&=(1-\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}+0.5\sigma_{E,t-1}\right))\overline{\varpi}_{E,t-1}\\&\quad+\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}-0.5\sigma_{E,t-1}\right)\end{aligned}\tag{66}$$

$$\begin{aligned}G_E(\overline{\varpi}_{E,t})&=(1-\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}+0.5\sigma_{E,t-1}\right))\overline{\varpi}_{E,t}\\&\quad+(1-\mu_E)\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}-0.5\sigma_{E,t-1}\right)\end{aligned}\tag{67}$$

$$\widetilde{\mathcal{Y}}_E(\overline{\varpi}_{E,t-1},\overline{\varpi}^B_{E,t})=\frac{1-\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}+0.5\sigma_{E,t-1}\right)}{1-\mathcal{N}_{cdf}\left(\frac{\log(\overline{\varpi}^B_{E,t})}{\sigma_{E,t-1}}+0.5\sigma_{E,t-1}\right)-\mu_E\overline{\varpi}f(\overline{\varpi}_{E,t-1})}\tag{68}$$

Each entrepreneur maximizes its utility function with respect to $(C^E_t,K^C_t,K^D_t,u^C_t,u^D_t,B^E_t,\overline{\varpi}_{E,t},L_{C,t},L_{D,t})$ subject to an infinite sequence of budget constraints and participation constraints for the commercial lending branches. We denote $\Lambda_{E,t}$ and $\beta_E\Lambda_{E,t}\widetilde{\Psi}_{E,t}$ the lagrange multipliers associated with the respective constraints

$$\begin{aligned}&C^E_t+Q^C_t(K^C_t-(1-\delta_K)K^C_{t-1})+Q^D_t(K^D_t-(1-\delta_K)K^D_{t-1})+(1-\chi_E)(1-\delta_K)\widetilde{H}^K_E(\varpi_{E,t-1},\varpi^B_{E,t})\\=\;&B_{E,t}+MC_tZ_t+MC_{D,t}Z_{D,t}-W^r_{C,t}L_{C,t}-W^r_{D,t}L_{D,t}-p_{lt}\mathcal{L}_t\\&-\Phi\left(u^C_t\right)K^C_{t-1}-\Phi\left(u^D_t\right)K^D_{t-1}+TT^E_t\end{aligned}\tag{69}$$

$$G^E(\overline{\varpi}_{E,t})(1-\chi_E)(1-\delta_K)\mathbb{E}_t\left\{\left(Q^C_{t+1}K^C_t+Q^D_{t+1}K^D_t\right)(1+\pi_{t+1})\right\}=(1+R_{E,t})\,B_{E,t} \quad (70)$$

substituting out for the ex post default threshold using

$$\varpi^B_{E,t}\left(Q^C_tK^C_{t-1}+Q^D_tK^D_{t-1}\right)=\varpi_{E,t-1}\frac{\mathbb{E}_{t-1}\left\{\left(Q^C_tK^C_{t-1}+Q^D_tK^D_{t-1}\right)(1+\pi_t)\right\}}{(1+\pi_t)}$$

We focus thereafter on the first order conditions changing with respect to the benchmark case.
The maximization of entrepreneur welfare with respect to the default threshold $\overline{\varpi}_{E,t}$ implies after some manipulations

$$\widetilde{\Psi}_{E,t}\mathbb{E}_t\left\{\left(Q^C_{t+1}K^C_t+Q^D_{t+1}K^D_t\right)(1+\pi_{t+1})\right\}=\mathbb{E}_t\left\{\widetilde{\mathcal{Y}}_E(\overline{\varpi}_{E,t},\overline{\varpi}^B_{E,t+1})\frac{\Lambda_{E,t+1}}{\Lambda_{E,t}}\left(Q^C_{t+1}K^C_t+Q^D_{t+1}K^D_t\right)\right\} \quad (71)$$

The optimality condition regarding the loan decision implies

$$1=\beta_E\widetilde{\Psi}_{E,t}\,(1+R_{E,t}) \quad (72)$$

Finally, the choice of fixed capital stock for the sector C and D implies

$$Q^C_t = \mathbb{E}_t\beta_E\left[\begin{array}{c}\frac{\Lambda_{E,t+1}}{\Lambda_{E,t}}\left(\begin{array}{c}Q^C_{t+1}(1-\delta_K)+R^{k,C}_{t+1}u^C_{t+1}-\Phi\left(u^C_{t+1}\right)\\-Q^C_{t+1}(1-\delta_K)(1-\chi_E)\widetilde{H}_E(\overline{\varpi}_{E,t},\overline{\varpi}^B_{E,t+1}))\end{array}\right)\\Q^C_{t+1}(1-\delta_K)(1-\chi_E)G_E(\overline{\varpi}_{E,t})\widetilde{\Psi}_{E,t}\,(1+\pi_{t+1})\end{array}\right] \quad (73)$$

$$Q^D_t = \mathbb{E}_t\beta_E\left[\begin{array}{c}\frac{\Lambda_{E,t+1}}{\Lambda_{E,t}}\left(\begin{array}{c}Q^D_{t+1}(1-\delta_K)+R^{k,D}_{t+1}u^D_{t+1}-\Phi\left(u^D_{t+1}\right)\\-Q^D_{t+1}(1-\delta_K)(1-\chi_E)\widetilde{H}_E(\overline{\varpi}_{E,t},\overline{\varpi}^B_{E,t+1}))\end{array}\right)\\Q^D_{t+1}(1-\delta_K)(1-\chi_E)G_E(\overline{\varpi}_{E,t})\widetilde{\Psi}_{E,t}\,(1+\pi_{t+1})\end{array}\right] \quad (74)$$

B.2 Impatient Households

Let us denote

$$\widetilde{H}^{D}(\varpi_{HH,t-1},\varpi^{B}_{HH,t}) = (1-\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}+0.5\sigma_{HH,t-1}\right))\varpi_{HH,t-1} \quad (75)$$

$$\frac{\mathbb{E}_{t-1}\left\{\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1}\left(1+\pi_{t+1}\right)\right\}}{(1+\pi_t)}$$

$$+\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}-0.5\sigma_{E,t-1}\right)\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1}$$

$$\widetilde{H}(\varpi_{HH,t-1},\varpi^{B}_{HH,t}) = (1-\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}+0.5\sigma_{HH,t-1}\right))\varpi_{HH,t-1} \quad (76)$$

$$+\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}-0.5\sigma_{HH,t-1}\right)$$

$$G(\varpi_{HH,t}) = (1-\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}+0.5\sigma_{HH,t}\right))\varpi_{HH,t} \quad (77)$$

$$+(1-\mu_{HH})\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}-0.5\sigma_{HH,t}\right)$$

$$\widetilde{\mathcal{Y}}(\varpi_{HH,t-1},\varpi^{B}_{HH,t}) = \frac{1-\mathcal{N}_{cdf}\left(\frac{\log(\varpi^{B}_{HH,t})}{\sigma_{HH,t-1}}+0.5\sigma_{HH,t-1}\right)}{1-\mathcal{N}_{cdf}\left(\frac{\log(\varpi_{HH,t-1})}{\sigma_{HH,t-1}}+0.5\sigma_{HH,t-1}\right)-\mu_{HH}\varpi_{HH,t-1}f(\varpi_{HH,t-1})} \quad (78)$$

Each borrower maximizes its utility function with respect to $(\widetilde{C}_t,\widetilde{D}_t,B_{HH,t},\varpi_{HH,t},N_{C,t},N_{D,t})$ under the infinite sequence of budget constraint for impatient households and the participation constraints for the commercial lending branches. We denote $\widetilde{\Lambda}_t$ and $\beta\widetilde{\Lambda}_t\widetilde{\Psi}_t$ the lagrange multipliers associated with the respective constraints

$$\begin{aligned} & \widetilde{C}_t+\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_t+(1-\chi_{HH})(1-\delta)\widetilde{H}^{D}(\varpi_{HH,t-1},\varpi^{B}_{HH,t}) \\ = \; & (1-\delta)\,\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1}+B_{HH,t}+\widetilde{TT}_t+W_{C,t}N_{C,t}+W_{D,t}N_{D,t} \end{aligned} \quad (79)$$

$$G(\varpi_{HH,t})(1-\chi_{HH})(1-\delta)\mathbb{E}_t\left\{\widetilde{Q}_{D,t+1}T_{D,t+1}\widetilde{D}_t\left(1+\pi_{t+1}\right)\right\} = \left(1+R_{HH,t}\right)B_{HH,t} \quad (80)$$

substituting out for the ex post default threshold using

$$\varpi^{B}_{HH,t}\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1} = \varpi_{HH,t-1}\frac{\mathbb{E}_{t-1}\left\{\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1}\left(1+\pi_t\right)\right\}}{(1+\pi_t)} \quad (81)$$

We focus thereafter on the first order conditions changing with respect to the benchmark case.
The maximization of entrepreneur welfare with respect to the default threshold $\varpi_{HH,t}$ implies after some manipulations

$$\widetilde{\Psi}_t\mathbb{E}_t\left\{\widetilde{Q}_{D,t+1}T_{D,t+1}\left(1+\pi_{t+1}\right)\right\} = \mathbb{E}_t\left\{\widetilde{\mathcal{Y}}(\varpi_{HH,t},\varpi^{B}_{HH,t+1})\frac{\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t}\widetilde{Q}_{D,t+1}T_{D,t+1}\right\} \quad (82)$$

The optimality condition regarding the loan decision implies

$$1 = \beta \widetilde{\Psi}_t \left(1 + R_{HH,t}\right) \tag{83}$$

The first order condition related to non-residential consumption and residential stock are respectively,

$$\widetilde{\Lambda}_t = \widetilde{\mathcal{U}\prime}_{C,t} \tag{84}$$

and

$$\begin{aligned} & \widetilde{\Lambda}_t \widetilde{Q}_{D,t} T_{D,t} - \widetilde{\mathcal{U}\prime}_{D,t} - \beta\left(1-\delta\right)\mathbb{E}_t\left\{\widetilde{\Lambda}_{t+1}\widetilde{Q}_{D,t+1}T_{D,t+1}\right\} \\ = \quad & \beta\left(1-\delta\right)\left(1-\chi\right)\mathbb{E}_t\left\{\begin{array}{c} \widetilde{\Lambda}_t\widetilde{Q}_{D,t+1}T_{D,t+1}G(\varpi_{HH,t+1})\widetilde{\Psi}_t\left(1+\pi_{t+1}\right) \\ -\widetilde{\Lambda}_{t+1}\widetilde{Q}_{D,t+1}T_{D,t+1}\widetilde{H}(\varpi_{HH,t},\varpi^B_{HH,t+1}) \end{array}\right\} \end{aligned} \tag{85}$$

The spread between the lending rate and the financing rate for the commercial lending bank is

$$\frac{1+R^L_{HH,t}}{1+R_{HH,t}} = \frac{\varpi_{HH,t}}{G_E(\varpi_{HH,t})}$$

B.3 Profit accumulation in the banking system

With pre-determined lending rates, the difference between *ex ante* and *ex post* default rates has an impact on the profits generated by the banking group as follows

$$\begin{aligned} \Pi^b_t \quad = \quad & \omega R_{HH,t}B_{HH,t} + R_{E,t}B_{E,t} - (1-\omega)R_{D,t}Dep_t - \frac{\chi_{wb}}{2}\left(\frac{Bankcap_t}{.0.5B^{wb}_{HH,t}+B^{wb}_{E,t}} - 0.11\right)^2 Bankcap_t \\ & +\omega G(\varpi^B_{HH,t})(1-\chi_{HH})(1-\delta)\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_t\left(1+\pi_t\right) \\ & -\omega G(\varpi_{HH,t-1})(1-\chi_{HH})(1-\delta)\mathbb{E}_{t-1}\left\{\widetilde{Q}_{D,t}T_{D,t}\widetilde{D}_{t-1}\left(1+\pi_t\right)\right\} \\ & +G^E(\varpi^B_{E,t})(1-\chi_E)(1-\delta_K)(Q^C_{t+1}K^C_t + Q^D_{t+1}K^D_t)\left(1+\pi_{t+1}\right) \\ & -G^E(\varpi_{E,t-1})(1-\chi_E)(1-\delta_K)\mathbb{E}_{t-1}\left\{(Q^C_t K^C_{t-1} + Q^D_t K^D_{t-1})\left(1+\pi_t\right)\right\} \end{aligned}$$

C Binding collateral constraints

We consider a specification of the credit frictions which does not allow for strategic default and which consists in constraining the amount of new loans by the value of the available collateral. The modelling strategy using collateral constraints is similar to Gerali et al. [2009].

C.1 Entrepreneurs

We remove the presence of idiosyncratic risk on the assets of entrepreneurs and therefore we do not consider the possibility of strategic default. Instead, we assume that all the entrepreneurs have limited access to credit markets, as summarized by the following (nominal) collateral constraint:

$$B_{E,t} \leq (1-\chi_E)(1-\delta_K)\mathbb{E}_t\left\{(Q^C_{t+1}K^C_t + Q^D_{t+1}K^D_t)\,\frac{(1+\pi_{t+1})}{(1+R_{E,t})}\right\}$$

Entrepreneurs do not default on their loans and in equilibrium the collateral constraint is binding.

Compared with the benchmark case, there is no spread between the lending rate and the financing rate for the commercial lending bank

$$R^L_{E,t} = R_{E,t} \tag{86}$$

Each entrepreneur maximizes its utility function with respect to $(C^E_t, K^C_t, K^D_t, u^C_t, u^D_t, B^E_t, L_{C,t}, L_{D,t})$ subject to an infinite sequence of budget constraints and collateral constraints. We denote $\Lambda_{E,t}$ and $\beta_E \Lambda_{E,t} \widetilde{\Psi}_{E,t}$ the lagrange multipliers associated with the respective constraints

$$\begin{aligned} & C^E_t + Q^C_t(K^C_t - (1-\delta_K)K^C_{t-1}) + Q^D_t(K^D_t - (1-\delta_K)K^D_{t-1}) + \frac{(1+R_{E,t-1})}{(1+\pi_t)} B_{E,t-1} \\ = \; & B_{E,t} + MC_t Z_t + MC_{D,t} Z_{D,t} - W^r_{C,t} L_{C,t} - W^r_{D,t} L_{D,t} - p_{lt}\mathcal{L}_t \\ & -\Phi\left(u^C_t\right) K^C_{t-1} - \Phi\left(u^D_t\right) K^D_{t-1} + TT^E_t \end{aligned} \tag{87}$$

$$B_{E,t} = (1-\chi_E)(1-\delta_K)\mathbb{E}_t \left\{ \left(Q^C_{t+1} K^C_t + Q^D_{t+1} K^D_t\right) \frac{(1+\pi_{t+1})}{\left(1+R^L_{E,t}\right)} \right\} \tag{88}$$

We focus thereafter on the first order conditions changing with respect to the benchmark case.
The optimality condition regarding the loan decision implies

$$\widetilde{\Psi}_{E,t} = 1 - \beta_E \mathbb{E}_t \left\{ \frac{\Lambda_{E,t+1}}{\Lambda_{E,t}} \frac{(1+R_{E,t})}{(1+\pi_{t+1})} \right\} \tag{89}$$

The choice of fixed capital stock for the sector C and D implies

$$Q^C_t = \mathbb{E}_t \beta_E \left[\begin{array}{c} \frac{\Lambda_{E,t+1}}{\Lambda_{E,t}} \left(Q^C_{t+1}(1-\delta_K) + R^{k,C}_{t+1} u^C_{t+1} - \Phi\left(u^C_{t+1}\right)\right) \\ Q^C_{t+1}(1-\delta_K)(1-\chi_E)\widetilde{\Psi}_{E,t+1} \frac{(1+\pi_{t+1})}{(1+R_{E,t})} \end{array} \right] \tag{90}$$

$$Q^D_t = \mathbb{E}_t \beta_E \left[\begin{array}{c} \frac{\Lambda_{E,t+1}}{\Lambda_{E,t}} \left(Q^D_{t+1}(1-\delta_K) + R^{k,D}_{t+1} u^D_{t+1} - \Phi\left(u^D_{t+1}\right)\right) \\ Q^D_{t+1}(1-\delta_K)(1-\chi_E)\widetilde{\Psi}_{E,t+1} \frac{(1+\pi_{t+1})}{(1+R_{E,t})} \end{array} \right] \tag{91}$$

C.2 Impatient Households

Given the absence of idiosyncratic risks and defaults, each borrower maximizes its utility function with respect to $(\widetilde{C}_t, \widetilde{D}_t, B_{HH,t}, N_{C,t}, N_{D,t})$ under the infinite sequence of budget constraint for impatient households and the participation constraints for the commercial lending branches. We denote $\widetilde{\Lambda}_t$ and $\beta \widetilde{\Lambda}_t \widetilde{\Psi}_t$ the lagrange multipliers associated with the respective constraints

$$\begin{aligned} & \widetilde{C}_t + \widetilde{Q}_{D,t} T_{D,t} \left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}\right) + \frac{(1+R_{E,t-1})}{(1+\pi_t)} B_{HH,t-1} \\ = \; & B_{HH,t} + \widetilde{TT}_t + W_{C,t} N_{C,t} + W_{D,t} N_{D,t} \end{aligned} \tag{92}$$

$$B_{HH,t} = (1-\chi_{HH})(1-\delta)\mathbb{E}_t \left\{ \widetilde{Q}_{D,t+1} T_{D,t+1} \widetilde{D}_t \frac{(1+\pi_{t+1})}{(1+R_{HH,t})} \right\} \tag{93}$$

Here again, there is no spread between the lending rate and the financing rate for the commercial lending bank

$$R^L_{HH,t} = R_{HH,t} \tag{94}$$

We focus thereafter on the first order conditions changing with respect to the benchmark case. The optimality condition regarding the loan decision implies

$$\widetilde{\Psi}_t = 1 - \beta \mathbb{E}_t \left\{ \frac{\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t} \frac{(1 + R_{HH,t})}{(1 + \pi_{t+1})} \right\} \tag{95}$$

The first order condition related to residential stock is,

$$\begin{aligned} & \widetilde{\Lambda}_t \widetilde{Q}_{D,t} T_{D,t} - \widetilde{\mathcal{U}\prime}_{D,t} - \beta (1-\delta) \mathbb{E}_t \left\{ \widetilde{\Lambda}_{t+1} \widetilde{Q}_{D,t+1} T_{D,t+1} \right\} \\ = \quad & \beta (1-\delta)(1-\chi) \widetilde{\Psi}_t \mathbb{E}_t \left\{ \widetilde{Q}_{D,t+1} T_{D,t+1} (1 + \pi_{t+1}) \right\} \end{aligned} \tag{96}$$

D Data

Data for GDP, consumption, investment, employment, wages and consumption-deflator are taken from Fagan et al (2001) and Eurostat. Employment numbers replace hours. Consequently, as in Smets and Wouters [2005], hours are linked to the number of people employed e_t^* with the following dynamics:

$$e_t^* = \beta \mathbb{E}_t e_{t+1}^* + \frac{(1 - \beta \lambda_e)(1 - \lambda_e)}{\lambda_e} (l_t^* - e_t^*)$$

House prices for the euro area are based on national sources and taken from the ECB website[39]. Residential investment is taken from Eurostat national accounts and is backdated using national sources. Households' debt for the euro area also comes from the ECB and Eurostat[40] The 3-month money market rate is the 3-month Euribor taken from the ECB website and we use backdated series for the period prior to 1999 based on national data sources. Household deposits are proxied using a backdated series of M2 which is available from the ECB website and which represent the main part of deposits held with MFIs by euro area non-financial private sector residents (households primarily). Data on MFI loans to households and non-financial corporations are likewise taken from the ECB website. Data prior to September 1997 have been backdated based on national sources. Meanwhile, data on retail bank loan and deposit rates are based on official ECB statistics from January 2003 onwards and on ECB internal estimates based on national sources in the period before. The lending rates refer to new business rates on loans to households for house purchase and new business rates on loans to non-financial corporations, excluding bank overdrafts. For the period prior to January 2003 the euro area aggregate series have been weighted using corresponding loan volumes (outstanding amounts) by country. Deposit rates refer to MFI interest rates on time deposits with agreed maturity taken from households. Similar to the derivation of the loan rates, from January 2003 deposit rates are based on official ECB statistics and prior to this period are based on a volume-weighted average of country-based rates.

[39] we applied some statistical interpolation methods to generate quarterly series
[40] See ECB Monthly Bulletin, October 2007, for the description of the data used

Tab. 1: PARAMETER ESTIMATES 1

Param	*A priori* beliefs			State-contingent lending rates *A posteriori* beliefs				pre-determined lending rates *A posteriori* beliefs			
	Dist.	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ε_t^A	unif	5	2.89	0.49	0.50	0.42	0.58	0.51	0.54	0.44	0.64
ε_t^I	unif	5	2.89	0.26	0.27	0.20	0.34	0.29	0.30	0.20	0.40
ε_t^L	unif	5	2.89	0.17	0.18	0.13	0.23	0.19	0.19	0.16	0.22
ε_t^G	unif	5	2.89	1.85	1.87	1.64	2.12	1.93	1.96	1.72	2.20
ε_t^B	unif	5	2.89	1.44	1.50	1.24	1.77	1.54	1.77	1.31	2.21
$\varepsilon_t^{A_D}$	unif	5	2.89	2.09	2.15	1.52	2.75	0.80	0.83	0.71	0.95
ε_t^D	unif	5	2.89	2.04	2.47	1.21	3.72	0.95	1.00	0.73	1.27
ε_t^P	unif	5	2.89	0.28	0.30	0.25	0.35	0.23	0.24	0.20	0.27
$\varepsilon_{D,t}^R$	unif	5	2.89	0.06	0.06	0.04	0.08	0.07	0.07	0.04	0.09
$\varepsilon_{HH,t}^R$	unif	5	2.89	0.06	0.06	0.05	0.07	0.07	0.08	0.06	0.09
$\varepsilon_{E,t}^R$	unif	5	2.89	0.12	0.13	0.11	0.15	0.23	0.24	0.20	0.28
$\varepsilon_{HH,t}^\sigma$	unif	5	2.89	0.08	0.08	0.07	0.09	0.07	0.08	0.06	0.09
$\varepsilon_{E,t}^\sigma$	unif	5	2.89	0.06	0.06	0.05	0.07	0.08	0.08	0.07	0.10
$\varepsilon_t^{Bankcap}$	unif	5	2.89	2.32	2.37	2.06	2.66	2.44	2.51	2.18	2.83
ε_t^R	unif	5	2.89	0.10	0.11	0.09	0.12	0.12	0.13	0.10	0.16
ρ_A	beta	0.5	0.2	0.92	0.90	0.85	0.95	0.90	0.88	0.84	0.92
ρ_I	beta	0.5	0.2	0.68	0.68	0.58	0.78	0.75	0.72	0.60	0.84
ρ_l	beta	0.5	0.2	0.85	0.83	0.73	0.93	0.06	0.08	0.01	0.15
ρ_G	beta	0.5	0.2	0.91	0.88	0.79	0.97	0.99	0.98	0.96	0.99
ρ_B	beta	0.5	0.2	0.95	0.94	0.91	0.97	0.98	0.98	0.97	0.99
ρ_{A_D}	beta	0.5	0.2	0.89	0.88	0.83	0.94	0.98	0.94	0.90	0.99
ρ_D	beta	0.5	0.2	0.99	0.98	0.97	0.99	0.99	0.99	0.98	0.99
$\rho_{D,t}^R$	beta	0.5	0.2	0.97	0.96	0.93	0.99	0.94	0.94	0.91	0.96
$\rho_{HH,t}^R$	beta	0.5	0.2	0.26	0.26	0.13	0.38	0.17	0.17	0.06	0.28
$\rho_{E,t}^R$	beta	0.5	0.2	0.40	0.41	0.23	0.57	0.06	0.09	0.01	0.16
$\rho_{HH,t}^\sigma$	beta	0.5	0.2	0.98	0.98	0.97	0.99	0.95	0.95	0.92	0.98
$\rho_{E,t}^\sigma$	beta	0.5	0.2	0.98	0.98	0.96	0.99	0.98	0.98	0.96	0.99
$\rho_t^{Bankcap}$	beta	0.5	0.2	0.71	0.70	0.61	0.79	0.60	0.58	0.49	0.68

Tab. 2: PARAMETER ESTIMATES 2

Param	A priori beliefs			State-contingent lending rates *A posteriori* beliefs				pre-determined lending rates *A posteriori* beliefs			
	Dist.	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ_D	gamm	1	0.5	0.23	0.23	0.15	0.31	0.01	0.01	0.01	0.01
ϕ	norm	4	1.5	7.72	7.71	5.63	9.74	7.89	7.92	5.73	9.91
φ	beta	0.5	0.15	0.75	0.76	0.63	0.89	0.84	0.84	0.75	0.94
σ_X	gamm	1.5	0.20	0.63	0.65	0.56	0.73	1.29	1.26	1.03	1.48
h	beta	0.75	0.1	0.59	0.58	0.54	0.62	0.37	0.37	0.28	0.46
σ_L	gamm	1.5	0.1	1.32	1.33	1.18	1.47	1.48	1.48	1.32	1.64
α_{wC}	beta	0.85	0.05	0.73	0.73	0.67	0.80	0.94	0.93	0.92	0.95
α_{wD}	beta	0.85	0.05	0.87	0.85	0.79	0.92	0.93	0.92	0.89	0.94
γ_w	beta	0.5	0.15	0.24	0.28	0.10	0.44	0.17	0.20	0.07	0.33
ξ_C	beta	0.75	0.05	0.83	0.83	0.79	0.86	0.90	0.90	0.87	0.92
γ_C	beta	0.5	0.15	0.58	0.61	0.45	0.78	0.06	0.07	0.02	0.12
ξ_D	beta	0.2	0.1	0.81	0.81	0.76	0.86	0.17	0.25	0.06	0.43
ξ_D^R	beta	0.5	0.2	0.32	0.31	0.26	0.37	0.28	0.29	0.22	0.35
ξ_{HH}^R	beta	0.5	0.2	0.92	0.92	0.88	0.95	0.93	0.92	0.90	0.95
ξ_E^R	beta	0.5	0.2	0.76	0.75	0.69	0.82	0.80	0.78	0.72	0.84
χ_{wb}	gamm	20	2.5	18.58	18.54	15.08	22.03	17.91	17.90	14.34	21.34
ρ	beta	0.75	0.1	0.84	0.84	0.82	0.87	0.89	0.90	0.87	0.93
r_π	gamm	2.5	0.25	2.37	2.38	2.17	2.59	1.80	1.85	1.68	2.02
r_y	gamm	0.2	0.1	0.03	0.03	0.01	0.05	0.05	0.07	0.02	0.12
$r_{\Delta\pi}$	gamm	0.30	0.10	0.24	0.24	0.18	0.31	0.21	0.20	0.14	0.27
$r_{\Delta y}$	gamm	0.12	0.05	0.07	0.08	0.05	0.11	0.17	0.17	0.13	0.21
r_{T_D}	norm	0.00	1.00	0.03	0.03	0.00	0.06	0.09	0.10	0.05	0.15
λ_e	beta	0.75	0.05	0.65	0.65	0.61	0.69	0.69	0.69	0.64	0.73
$P_\lambda(\mathcal{Y})$				-432.1				-579.3			

Tab. 3: PARAMETER ESTIMATES: DSGE WITH BINDING COLLATERAL CONSTRAINTS

Param	*A priori* beliefs			*A posteriori* beliefs				*A priori* beliefs			*A posteriori* beliefs		
	Mean	Dist.	Std.	Mode	$\mathcal{I}_1$	$\mathcal{I}_2$		Mean	Dist.	Std.	Mode	$\mathcal{I}_1$	$\mathcal{I}_2$
ε_t^A	unif	5	2.89	0.42	0.37	0.51	ϕ_D	-	-	-	-	-	-
ε_t^I	invg	5	2.89	0.19	0.17	0.24	ϕ	norm	4	1.5	6.18	4.72	7.89
ε_t^L	unif	5	2.89	0.18	0.11	0.25	φ	beta	0.5	0.15	0.83	0.76	0.95
ε_t^G	unif	5	2.89	1.95	1.69	2.17	σ_X	gamm	1.5	0.20	0.85	0.57	0.92
ε_t^B	invg	5	2.89	1.12	0.83	1.48	h	beta	0.7	0.05	0.44	0.40	0.52
$\varepsilon_t^{A_D}$	unif	5	2.89	0.82	0.71	0.96	σ_L	gamm	1.5	0.1	1.40	1.25	1.56
ε_t^D	invg	5	2.89	0.96	0.84	1.68	α_{wC}	beta	0.85	0.05	0.70	0.63	0.91
ε_t^P	unif	5	2.89	0.25	0.23	0.32	α_{wD}	beta	0.85	0.05	0.87	0.74	0.93
$\varepsilon_{D,t}^R$	invg	5	2.89	0.06	0.04	0.08	γ_w	beta	0.5	0.15	0.19	0.08	0.41
$\varepsilon_{HH,t}^R$	invg	5	2.89	0.05	0.04	0.06	ξ_C	beta	0.75	0.05	0.85	0.81	0.88
$\varepsilon_{E,t}^R$	invg	5	2.89	0.06	0.05	0.08	γ_C	beta	0.5	0.15	0.39	0.31	0.62
$\varepsilon_{HH,t}^{LTV}$	invg	5	2.89	0.87	0.78	1.04	ξ_D	beta	0.2	0.1	0.13	0.04	0.29
$\varepsilon_{E,t}^{LTV}$	invg	5	2.89	0.12	0.10	0.14	ξ_D^R	beta	0.5	0.1	0.30	0.26	0.36
$\varepsilon_t^{Bankcap}$	unif	5	2.89	2.49	2.23	2.87	ξ_{HH}^R	beta	0.5	0.1	0.91	0.88	0.93
ε_t^R	unif	5	2.89	0.11	0.10	0.13	ξ_E^R	beta	0.5	0.1	0.53	0.47	0.62
							χ_{wb}	gamm	20	2.5	11.94	9.69	14.27
							ρ	beta	0.75	0.1	0.82	0.79	0.85
ρ_A	beta	0.5	0.2	0.95	0.90	0.97	r_π	gamm	2.5	0.25	2.08	1.95	2.37
ρ_I	beta	0.5	0.2	0.39	0.32	0.57	r_y	-	-	-	-	-	-
ρ_l	beta	0.5	0.2	0.93	0.38	0.98	$r_{\Delta\pi}$	gamm	0.3	0.10	0.29	0.22	0.37
ρ_G	beta	0.5	0.2	0.99	0.92	1.00	$r_{\Delta y}$	gamm	0.12	0.05	0.14	0.10	0.18
ρ_B	beta	0.5	0.2	0.96	0.93	0.97	r_{T_D}	-	-	-	-	-	-
ρ_{A_D}	beta	0.5	0.2	0.98	0.90	0.99	λ_e	beta	0.75	0.05	0.65	0.60	0.70
ρ_D	beta	0.5	0.175	0.99	0.98	0.99							
$\rho_{D,t}^R$	beta	0.5	0.2	0.94	0.90	0.52							
$\rho_{HH,t}^R$	beta	0.5	0.2	0.40	0.28	0.52							
$\rho_{E,t}^R$	beta	0.5	0.2	0.94	0.88	0.97							
$\rho_{HH,t}^{LTV}$	beta	0.5	0.2	0.99	0.98	0.99							
$\rho_{E,t}^{LTV}$	beta	0.5	0.2	0.99	0.98	0.99							
$\rho_t^{Bankcap}$	beta	0.5	0.2	0.65	0.55	0.97							
$P_\lambda(\mathcal{Y})$				-650.0									

Tab. 4: Parameter Estimates: introducing correlations with the housing shock 1

Param	A priori beliefs			State-contingent lending rates A posteriori beliefs				pre-determined lending rates A posteriori beliefs			
	Dist.	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ε_t^A	unif	5	2.89	0.45	0.46	0.39	0.53	0.60	0.60	0.48	0.73
ε_t^I	unif	5	2.89	0.26	0.28	0.20	0.35	0.28	0.29	0.21	0.37
ε_t^L	unif	5	2.89	0.18	0.19	0.15	0.24	0.16	0.17	0.14	0.20
ε_t^G	unif	5	2.89	1.88	1.92	1.68	2.16	1.97	1.97	1.71	2.21
ε_t^B	unif	5	2.89	2.05	2.02	1.57	2.45	2.51	2.51	1.60	3.45
$\varepsilon_t^{A_D}$	unif	5	2.89	2.08	2.10	1.50	2.65	1.63	1.63	1.02	2.24
ε_t^D	unif	5	2.89	2.77	2.95	1.72	4.10	1.79	1.79	0.88	2.74
ε_t^P	unif	5	2.89	0.28	0.29	0.25	0.34	0.22	0.23	0.20	0.26
$\varepsilon_{D,t}^R$	unif	5	2.89	0.07	0.07	0.05	0.09	0.04	0.04	0.03	0.05
$\varepsilon_{HH,t}^R$	unif	5	2.89	0.06	0.06	0.05	0.07	0.09	0.09	0.07	0.10
$\varepsilon_{E,t}^R$	unif	5	2.89	0.12	0.13	0.11	0.15	0.24	0.25	0.21	0.29
$\varepsilon_{HH,t}^\sigma$	unif	5	2.89	0.03	0.03	0.02	0.04	0.09	0.09	0.08	0.11
$\varepsilon_{E,t}^\sigma$	unif	5	2.89	0.06	0.06	0.05	0.07	0.08	0.09	0.07	0.10
$\varepsilon_t^{Bankcap}$	unif	5	2.89	2.30	2.35	2.06	2.65	2.64	2.64	2.29	2.98
ε_t^R	unif	5	2.89	0.11	0.11	0.10	0.13	0.10	0.10	0.09	0.12
ρ_A	beta	0.5	0.2	0.97	0.96	0.93	0.98	0.87	0.86	0.82	0.90
ρ_I	beta	0.5	0.2	0.69	0.68	0.58	0.79	0.69	0.69	0.57	0.80
ρ_l	beta	0.5	0.2	0.79	0.60	0.27	0.89	0.08	0.09	0.01	0.16
ρ_G	beta	0.5	0.2	0.99	0.98	0.97	0.99	0.97	0.95	0.90	0.99
ρ_B	beta	0.5	0.2	0.97	0.97	0.96	0.98	0.98	0.97	0.96	0.99
ρ_{A_D}	beta	0.5	0.2	0.90	0.89	0.84	0.93	0.87	0.88	0.81	0.94
ρ_D	beta	0.5	0.2	0.97	0.97	0.96	0.99	0.98	0.98	0.96	0.99
$\rho_{D,t}^R$	beta	0.5	0.2	0.95	0.95	0.92	0.97	0.95	0.94	0.90	0.98
$\rho_{HH,t}^R$	beta	0.5	0.2	0.25	0.25	0.14	0.37	0.11	0.11	0.02	0.19
$\rho_{E,t}^R$	beta	0.5	0.2	0.37	0.37	0.22	0.52	0.08	0.09	0.01	0.16
$\rho_{HH,t}^\sigma$	beta	0.5	0.2	0.99	0.99	0.98	0.99	0.98	0.98	0.96	0.99
$\rho_{E,t}^\sigma$	beta	0.5	0.2	0.98	0.97	0.96	0.99	0.97	0.97	0.96	0.99
$\rho_t^{Bankcap}$	beta	0.5	0.2	0.72	0.71	0.62	0.80	0.57	0.57	0.47	0.67

Tab. 5: PARAMETER ESTIMATES: INTRODUCING CORRELATIONS WITH THE HOUSING SHOCK 2

Param	*A priori* beliefs			State-contingent lending rates *A posteriori* beliefs				pre-determined lending rates *A posteriori* beliefs			
	Dist.	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ_D	gamm	1	0.5	0.23	0.22	0.15	0.30	0.14	0.11	0.05	0.17
ϕ	norm	4	1.5	7.52	7.66	5.54	9.79	7.73	7.73	5.73	9.74
φ	beta	0.5	0.15	0.77	0.76	0.64	0.89	0.79	0.79	0.67	0.91
σ_X	gamm	1.5	0.20	0.71	0.72	0.66	0.79	0.94	0.94	0.78	1.10
h	beta	0.75	0.1	0.53	0.51	0.45	0.58	0.17	0.18	0.11	0.24
σ_L	gamm	1.5	0.1	1.32	1.32	1.18	1.46	1.48	1.48	1.33	1.64
α_{wC}	beta	0.85	0.05	0.83	0.79	0.68	0.89	0.94	0.94	0.92	0.95
α_{wD}	beta	0.85	0.05	0.88	0.86	0.81	0.92	0.89	0.88	0.84	0.93
γ_w	beta	0.5	0.15	0.19	0.26	0.09	0.43	0.20	0.21	0.07	0.33
ξ_C	beta	0.75	0.05	0.84	0.85	0.81	0.88	0.91	0.91	0.89	0.93
γ_C	beta	0.5	0.15	0.55	0.58	0.43	0.73	0.04	0.05	0.02	0.09
ξ_D	beta	0.2	0.1	0.81	0.79	0.75	0.84	0.76	0.74	0.62	0.86
ξ_D^R	beta	0.5	0.2	0.28	0.28	0.23	0.33	0.39	0.38	0.31	0.44
ξ_{HH}^R	beta	0.5	0.2	0.90	0.90	0.88	0.92	0.92	0.91	0.89	0.94
ξ_E^R	beta	0.5	0.2	0.77	0.76	0.70	0.82	0.78	0.78	0.72	0.83
χ_{wb}	gamm	20	2.5	19.07	19.34	15.90	22.56	18.38	18.38	15.02	21.93
ρ	beta	0.75	0.1	0.81	0.81	0.78	0.84	0.92	0.91	0.88	0.95
r_π	gamm	2.5	0.25	2.36	2.41	2.22	2.60	2.23	2.23	1.88	2.55
r_y	gamm	0.2	0.1	0.04	0.04	0.02	0.06	0.23	0.24	0.10	0.38
$r_{\Delta\pi}$	gamm	0.30	0.10	0.31	0.31	0.24	0.38	0.15	0.16	0.10	0.22
$r_{\Delta y}$	gamm	0.12	0.05	0.09	0.10	0.06	0.13	0.13	0.13	0.09	0.17
r_{T_D}	norm	0.00	1.00	0.01	0.01	-0.02	0.04	0.02	0.03	0.00	0.07
λ_e	beta	0.75	0.05	0.64	0.63	0.58	0.67	0.73	0.72	0.68	0.76
ω	beta	0.45	0.05	0.28	0.27	0.22	0.31	0.17	0.18	0.17	0.19
$\rho_{B,D}$	unif	0.00	2.89	0.89	0.91	0.53	1.26	0.93	0.93	0.31	1.51
$\rho_{D,\sigma_{HH}}$	gamm	1.00	0.50	1.78	1.76	1.20	2.33	1.13	1.13	0.32	1.89
$P_\lambda(\mathcal{Y})$				-387.2				-553.1			

Tab. 6: SHOCKS DECOMPOSITION OF UNCONDITIONAL VARIANCES 1: *HP Filtering*

	$\varepsilon_t^{A_D}$	ε_t^{D}	$\varepsilon_{HH,t}^{\sigma}$	$\varepsilon_{E,t}^{\sigma}$	$\varepsilon_{HH,t}^{R}$	$\varepsilon_{E,t}^{R}$	$\varepsilon_{D,t}^{R}$	$\varepsilon_t^{Bankcap}$	others
Estimation with state-contingent lending rates									
Z_t	3.1	19.1	14.9	3.5	1.2	0.1	8.2	0.7	49.1
C_t^{tot}	0.7	7.8	26.8	1.8	1.8	0.1	8.0	0.6	52.6
I_t	0.1	0.8	0.4	40.4	0.4	1.9	0.4	6.3	49.1
$Z_{D,t}$	23.3	42.9	1.4	0.8	0.4	0.1	5.0	0.1	26.1
$T_{D,t}$	3.6	36.5	1.3	3.0	0.0	0.1	1.2	0.5	53.9
L_t^{tot}	2.5	17.6	13.2	3.7	1.1	0.1	7.2	0.8	53.9
W_t^{tot}	0.5	4.3	16.0	1.2	1.1	0.0	6.9	0.4	69.7
Π_t	0.2	1.2	7.6	3.6	0.4	0.1	8.3	0.8	77.9
R_t	0.1	10.9	12.6	8.5	0.9	0.2	13.4	1.8	51.7
$R_{E,t}$	0.0	3.0	4.4	19.6	0.6	35.8	6.6	7.1	23.0
$R_{HH,t}$	0.2	8.5	24.6	2.7	42.9	0.8	5.9	2.6	11.9
$R_{D,t}$	0.1	11.6	14.4	10.5	0.9	0.3	4.7	2.2	55.4
$B_{E,t}$	0.0	1.5	6.3	61.1	0.8	1.0	3.5	3.1	22.7
$B_{HH,t}$	0.3	17.9	53.9	0.9	3.9	0.3	1.1	3.2	18.7
Dep_t	0.1	6.9	18.4	22.4	2.2	1.1	2.0	23.3	23.6
Estimation with pre-determined lending rates									
Z_t	1.9	1.9	1.7	26.8	0.2	0.8	7.1	0.7	58.9
C_t^{tot}	0.6	2.1	3.9	3.0	0.1	0.1	11.1	0.5	78.6
I_t	0.0	0.6	0.0	55.6	0.3	1.6	0.0	2.3	39.7
$Z_{D,t}$	40.9	13.5	0.2	2.5	0.2	0.2	4.0	0.2	38.3
$T_{D,t}$	5.2	36.5	0.3	4.5	0.4	0.3	9.0	0.3	43.5
L_t^{tot}	0.1	1.2	1.1	16.3	0.1	0.5	4.4	0.4	75.9
W_t^{tot}	0.0	0.4	0.1	2.4	0.0	0.0	1.1	0.1	96.0
Π_t	0.0	0.8	0.0	0.7	0.0	0.0	2.5	0.0	95.9
R_t	0.0	12.6	2.8	24.9	0.3	0.5	23.1	0.5	35.3
$R_{E,t}$	0.0	1.1	0.2	32.8	0.3	48.8	1.8	5.1	9.9
$R_{HH,t}$	0.1	2.0	7.3	4.7	73.0	1.1	1.4	2.6	7.8
$R_{D,t}$	0.0	12.2	2.4	35.3	0.3	0.6	1.4	0.7	47.0
$B_{E,t}$	0.0	0.1	0.1	92.2	0.2	0.6	0.2	1.7	5.0
$B_{HH,t}$	0.8	11.9	62.2	2.8	10.2	0.2	1.6	1.7	8.6
Dep_t	0.4	5.8	27.9	39.6	6.5	1.3	0.6	10.8	7.1

Tab. 7: SHOCKS DECOMPOSITION OF UNCONDITIONAL VARIANCES 2: *HP Filtering*

	$\varepsilon_t^{A_D}$	ε_t^{D}	$\varepsilon_{HH,t}^{LTV}$	$\varepsilon_{E,t}^{LTV}$	$\varepsilon_{HH,t}^{R}$	$\varepsilon_{E,t}^{R}$	$\varepsilon_{D,t}^{R}$	$\varepsilon_t^{Bankcap}$	others
Estimation with binding collateral constraints									
Z_t	1.5	1.3	0.2	4.3	0.5	0.7	6.6	0.4	84.5
C_t^{tot}	0.6	0.3	0.5	0.1	1.0	0.4	7.7	0.9	88.5
I_t	0.2	0.3	0.1	23.5	0.3	8.5	1.4	8.2	57.7
$Z_{D,t}$	41.0	20.3	0.0	0.0	0.1	0.4	3.2	0.1	35.1
$T_{D,t}$	5.2	45.0	0.0	0.0	0.3	1.1	4.4	0.1	43.8
L_t^{tot}	0.1	1.2	0.2	4.4	0.5	0.7	5.6	0.4	87.0
W_t^{tot}	0.3	0.6	0.3	0.8	0.7	0.1	5.9	0.1	91.3
Π_t	0.2	0.1	0.2	0.6	0.5	0.8	7.6	0.1	89.9
R_t	0.5	0.8	0.6	3.6	1.5	2.9	18.0	0.9	71.3
$R_{E,t}$	0.1	1.0	1.1	3.1	1.0	15.9	15.4	14.5	48.1
$R_{HH,t}$	0.0	0.1	0.1	0.3	78.9	4.1	3.1	2.0	11.5
$R_{D,t}$	0.4	0.8	0.7	3.7	2.0	4.1	4.5	1.2	82.6
$B_{E,t}$	0.0	0.1	0.1	65.7	0.1	4.8	0.9	4.1	24.2
$B_{HH,t}$	3.8	32.2	36.9	0.6	3.9	0.2	5.8	1.1	15.6
Dep_t	2.6	20.7	24.2	12.1	4.8	1.4	5.3	12.4	16.5

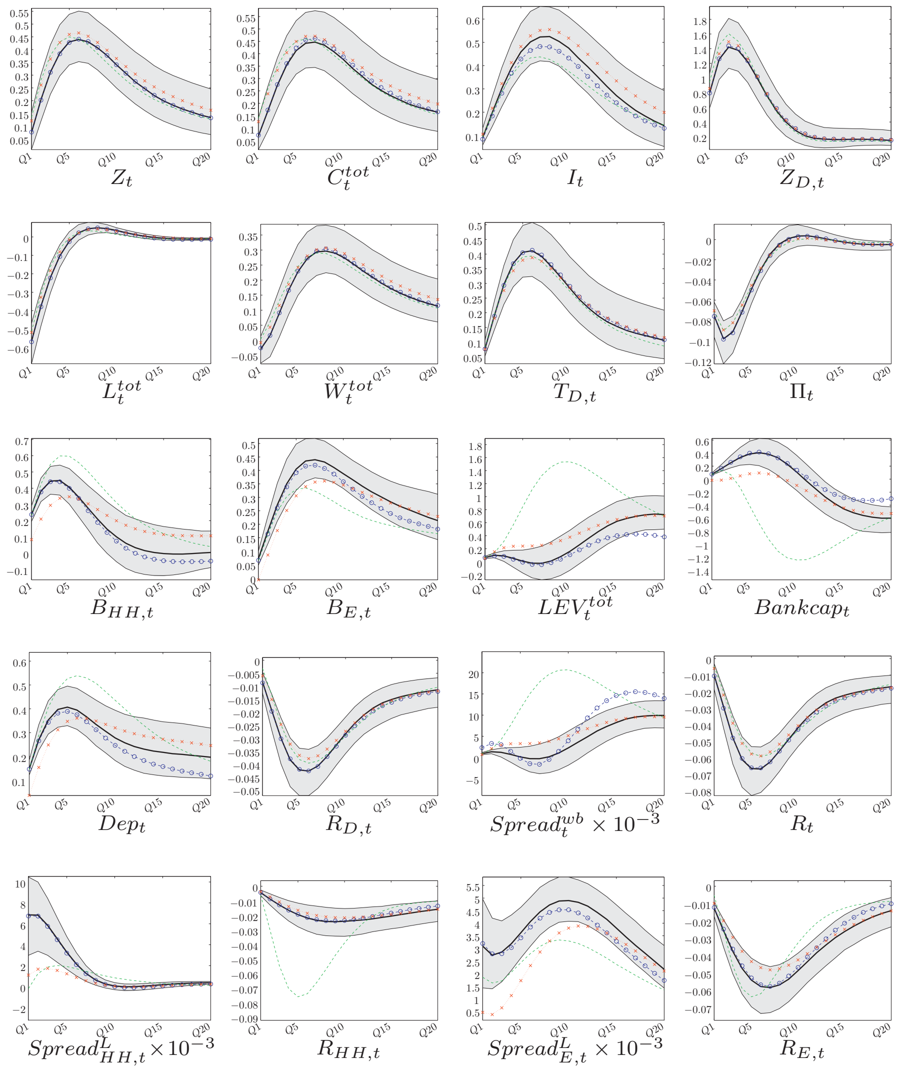


Fig. 1: Impulse Response Functions associated to a shock on ε_t^A. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

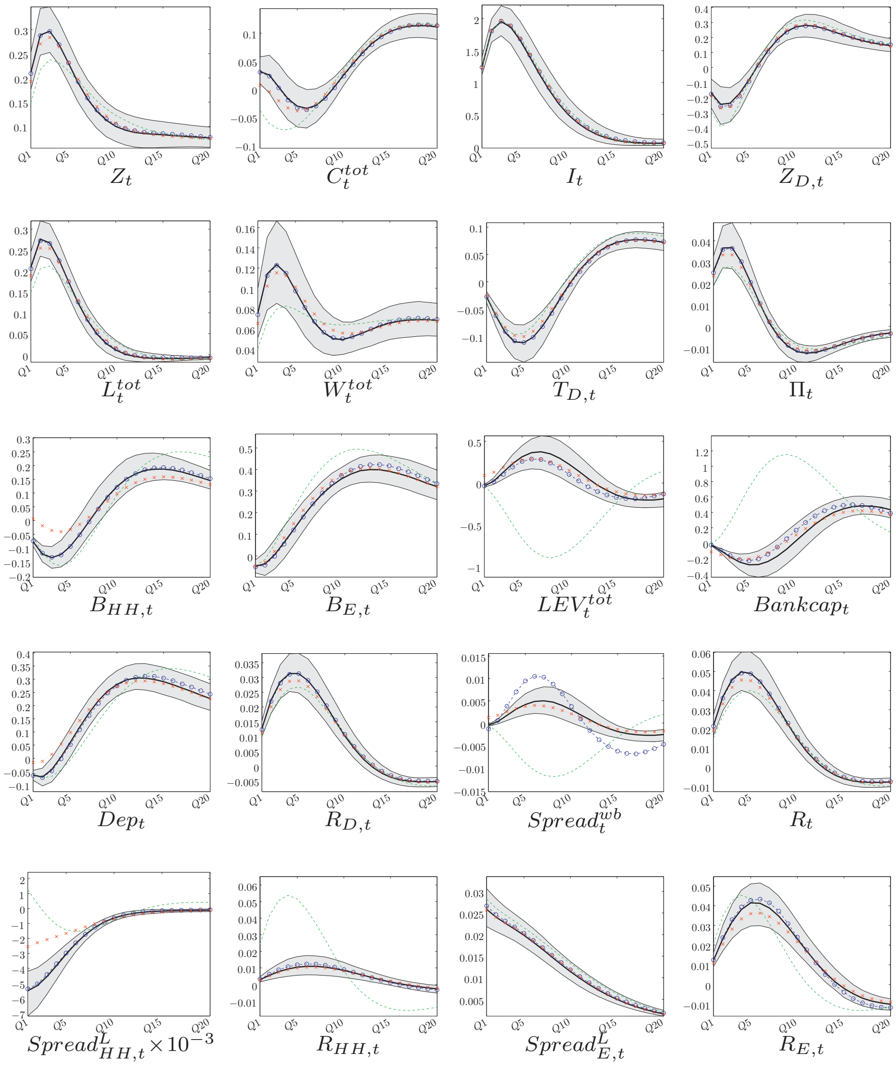


Fig. 2: Impulse Response Functions associated to a shock on ε_t^I. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

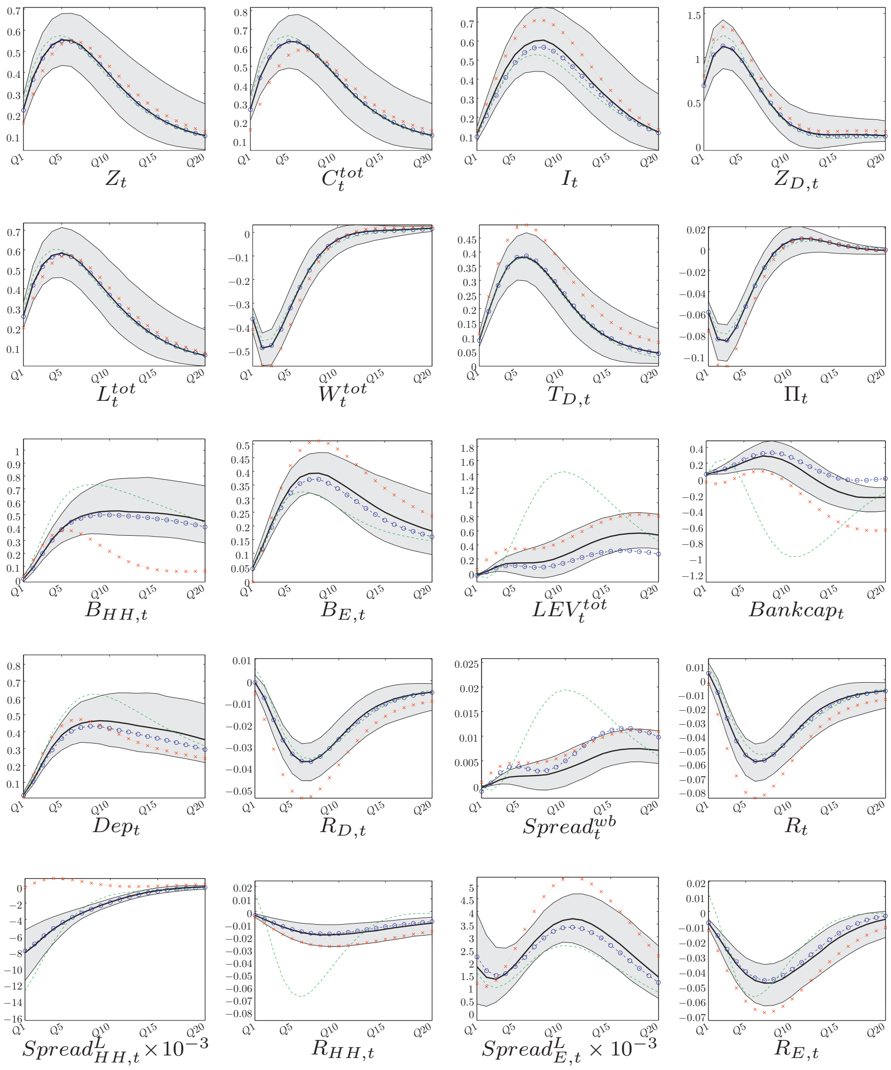


Fig. 3: Impulse Response Functions associated to a shock on ε_t^L. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

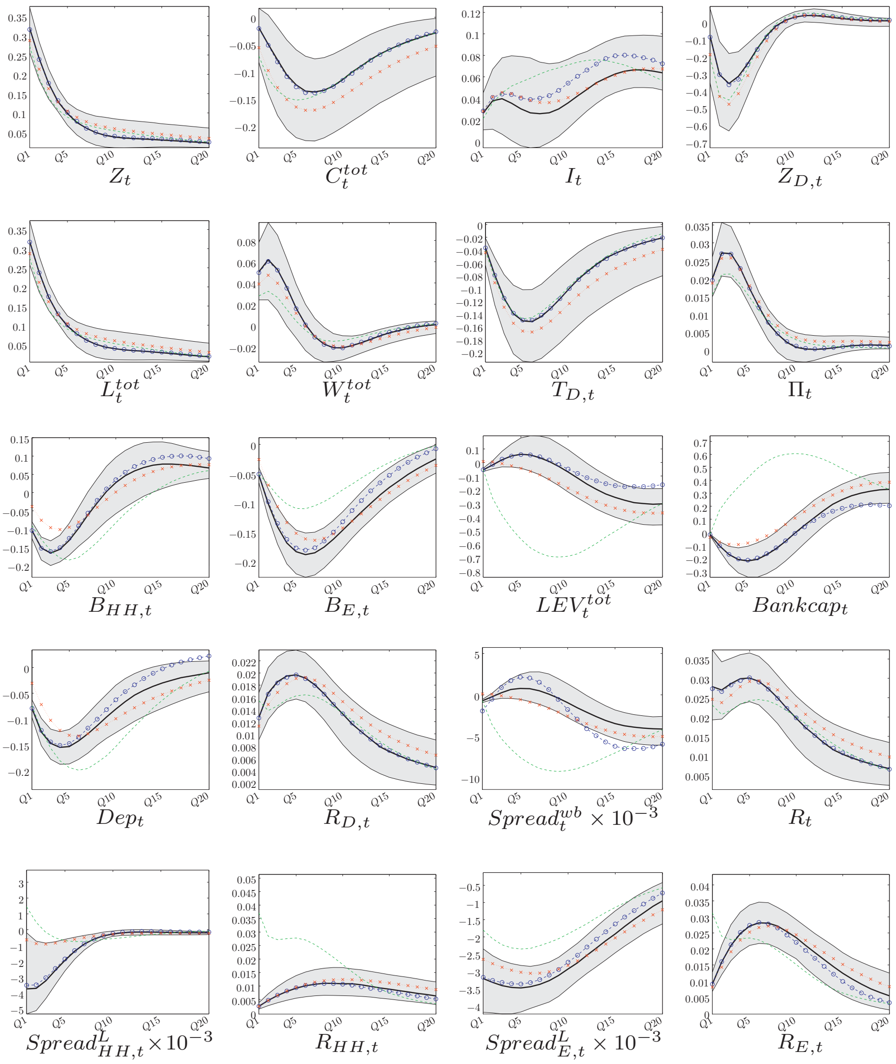


Fig. 4: Impulse Response Functions associated to a shock on ε_t^G. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

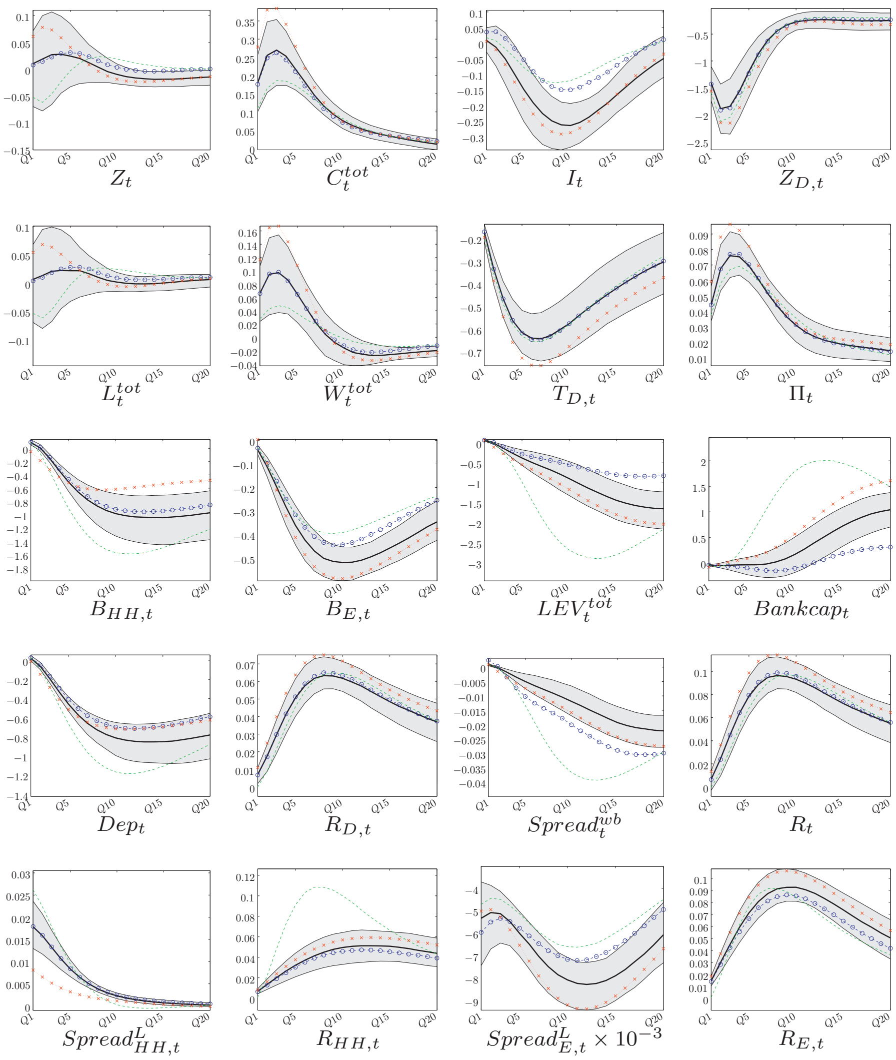


Fig. 5: Impulse Response Functions associated to a shock on ε_t^B. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

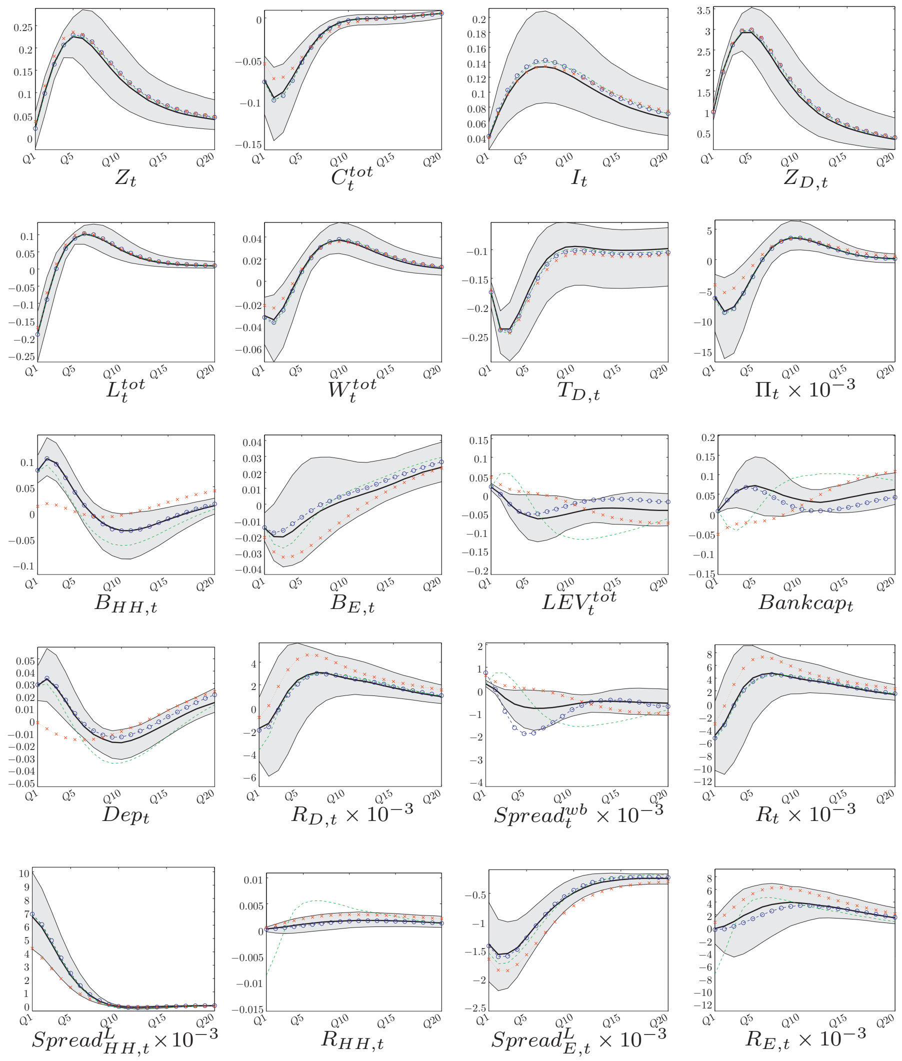


Fig. 6: Impulse Response Functions associated to a shock on $\varepsilon_t^{A_D}$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

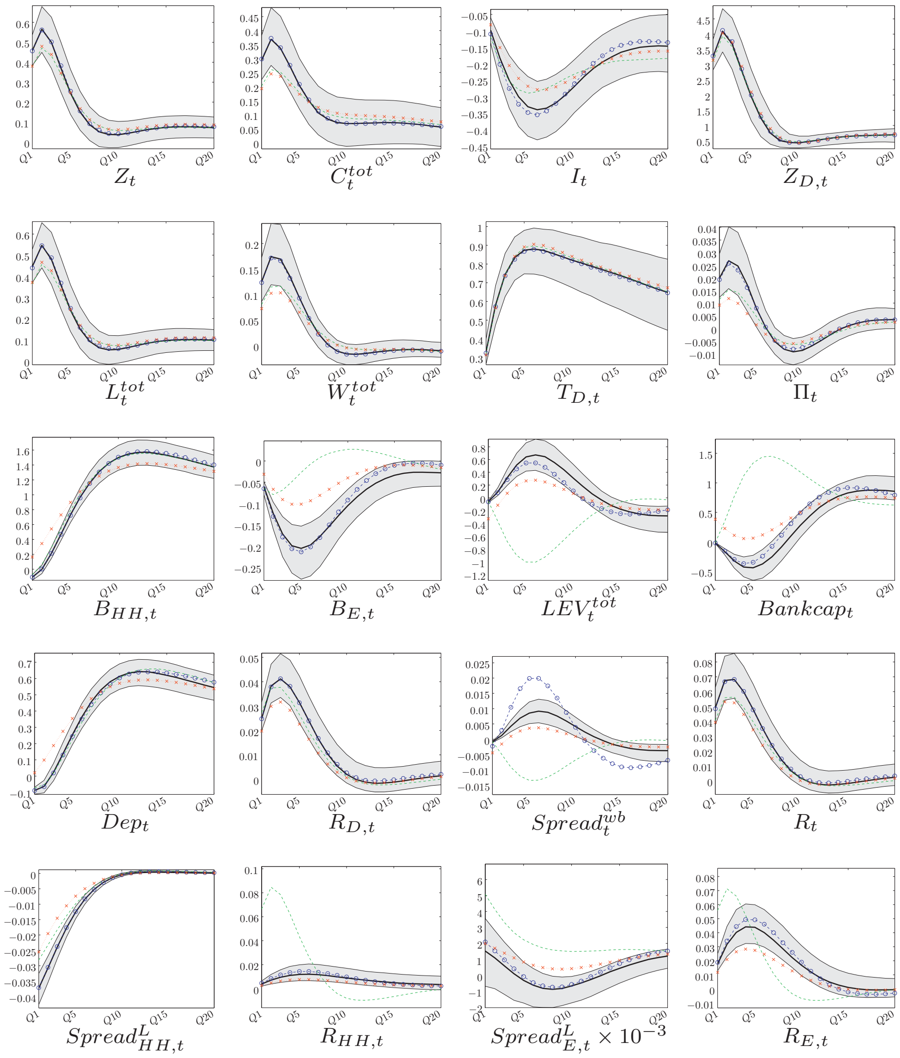


Fig. 7: Impulse Response Functions associated to a shock on ε_t^D. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

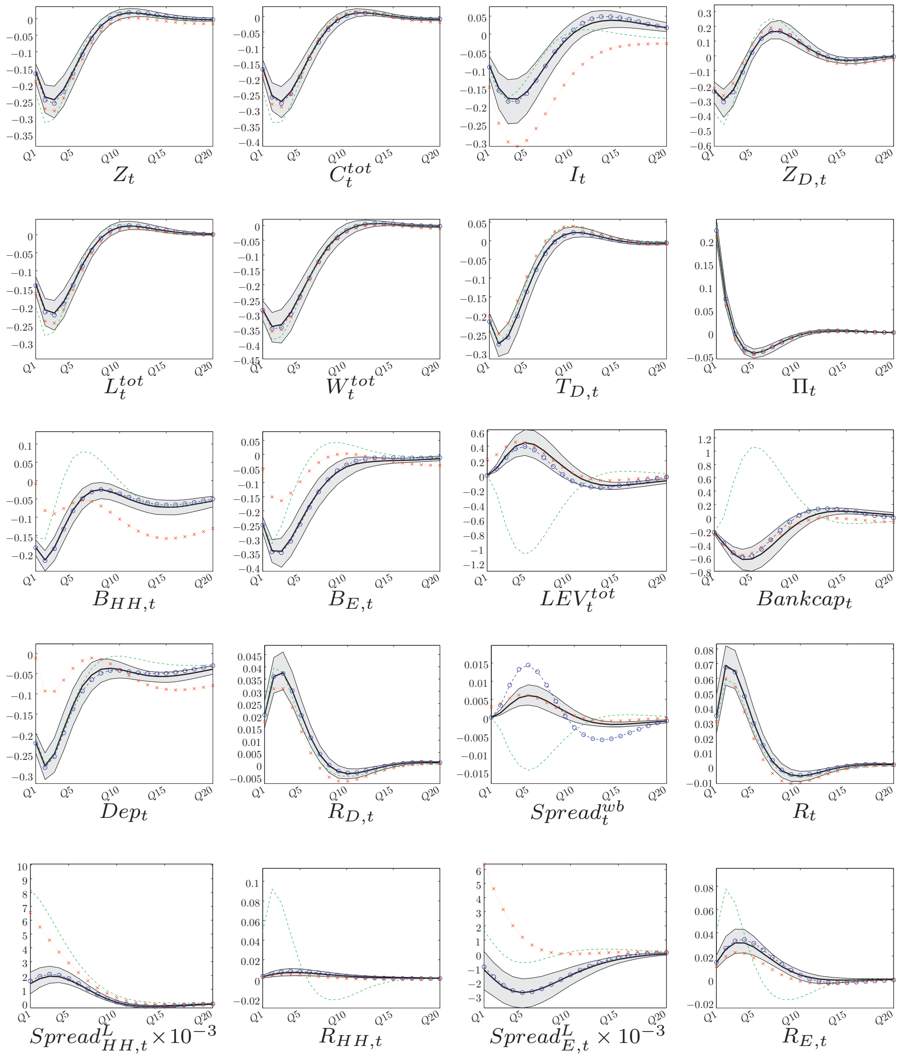


Fig. 8: Impulse Response Functions associated to a shock on ε_t^P. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

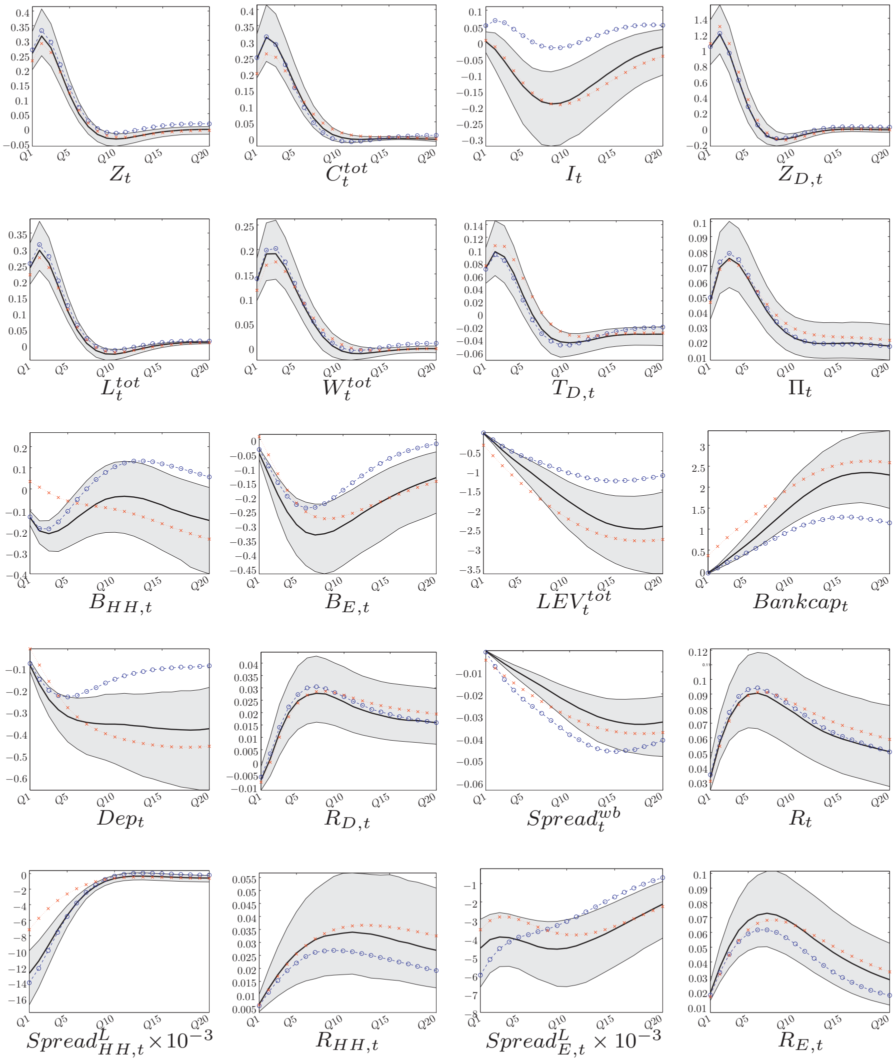


Fig. 9: Impulse Response Functions associated to a shock on $\varepsilon_{D,t}^R$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

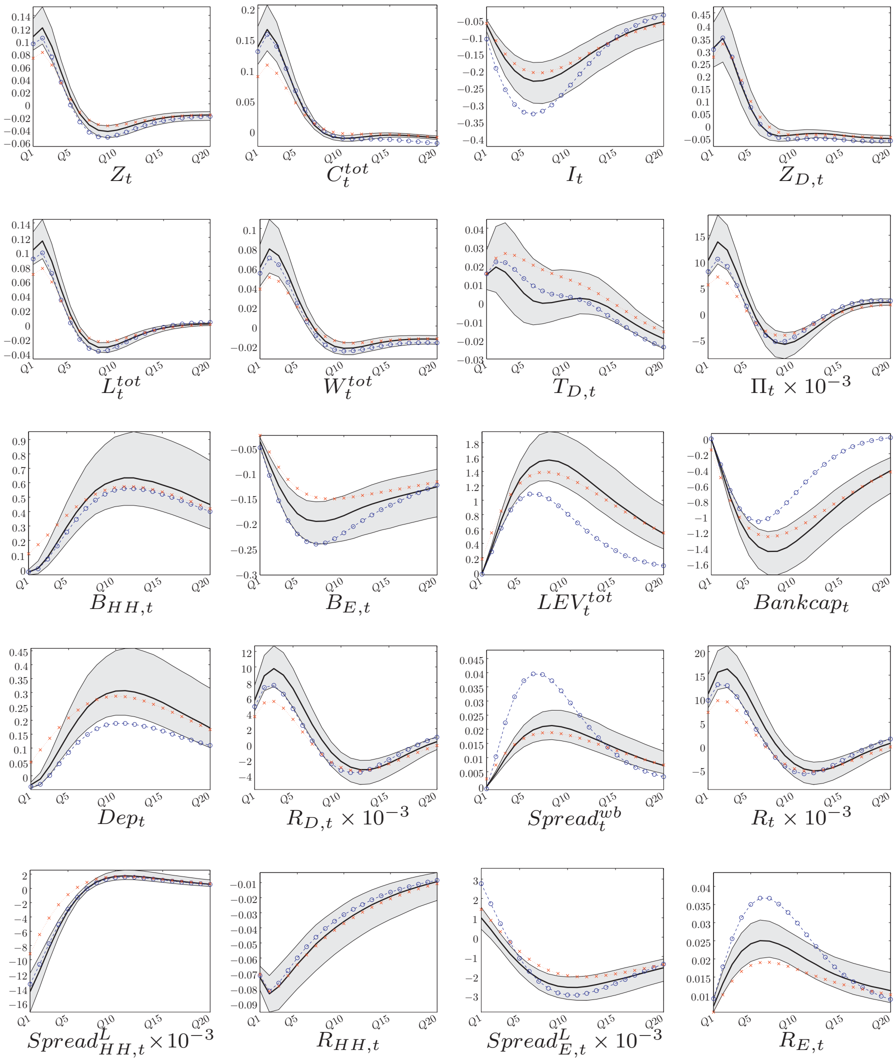


Fig. 10: Impulse Response Functions associated to a shock on $\varepsilon_{HH,t}^{R}$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

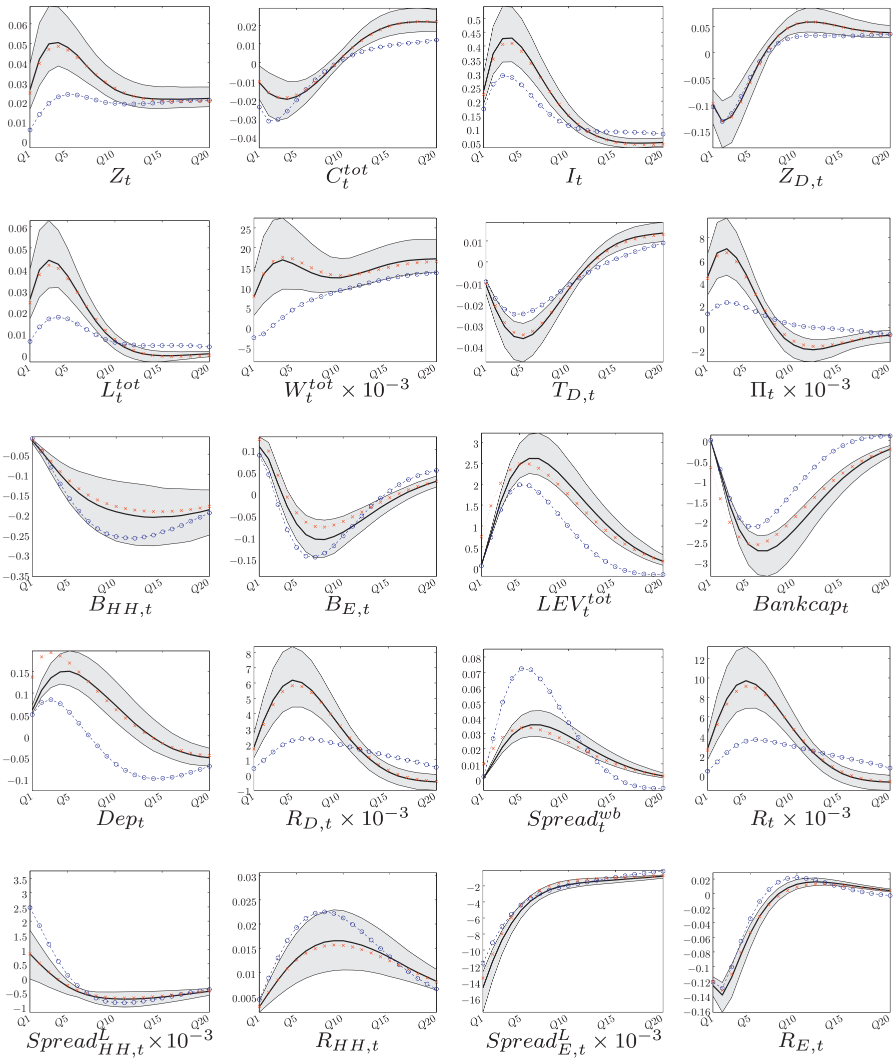


Fig. 11: Impulse Response Functions associated to a shock on $\varepsilon^R_{E,t}$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

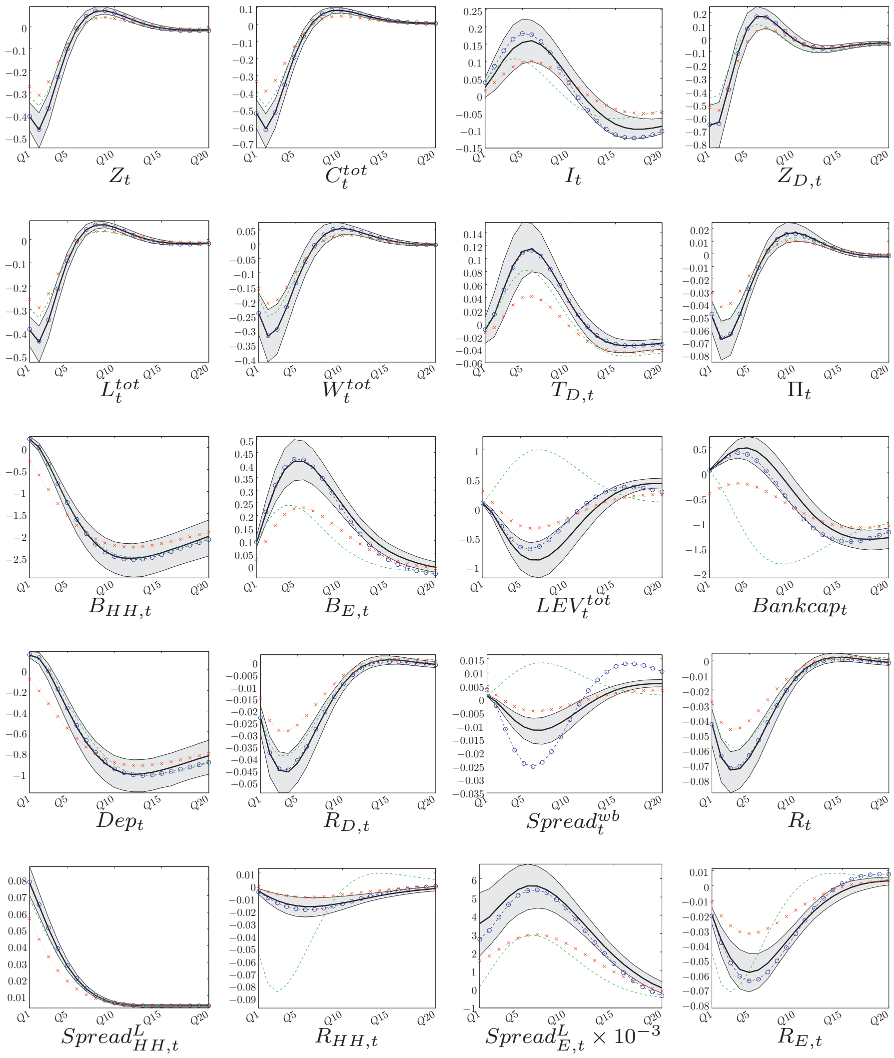


Fig. 12: Impulse Response Functions associated to a shock on $\varepsilon^{\sigma}_{HH,t}$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

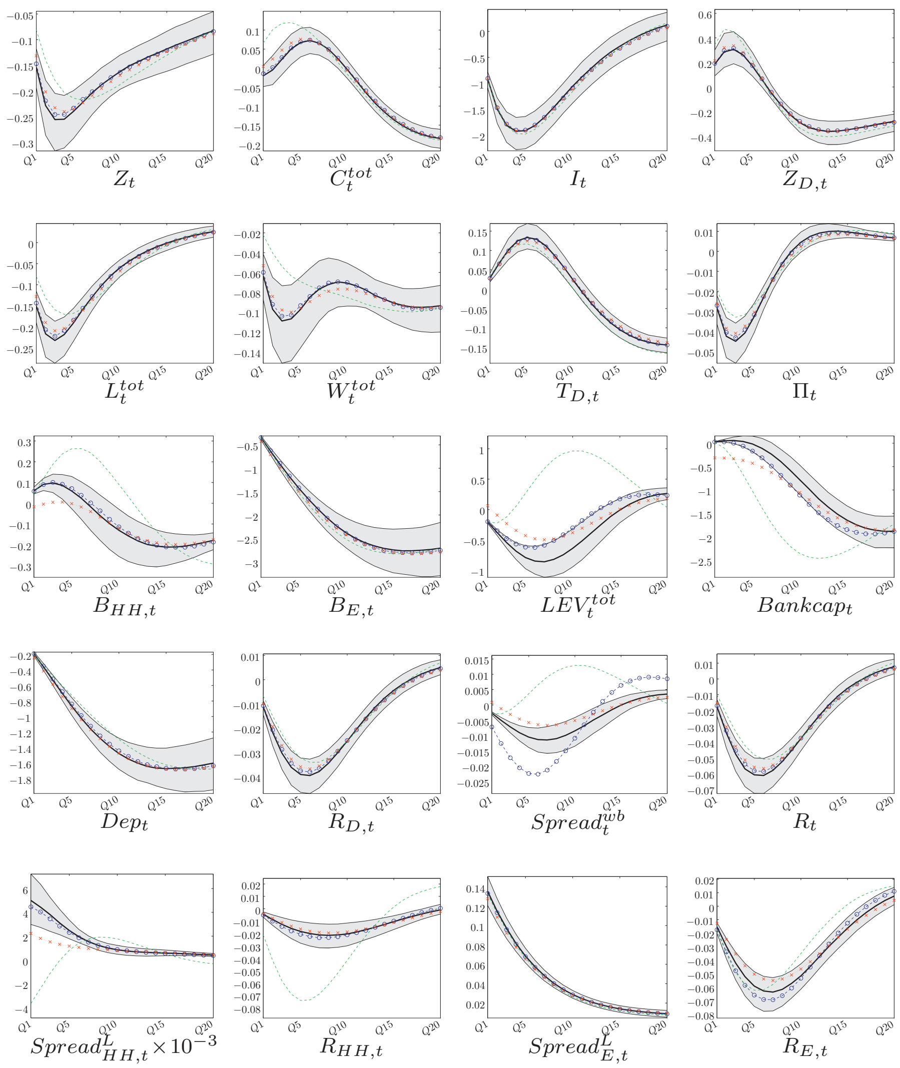


Fig. 13: Impulse Response Functions associated to a shock on $\varepsilon^{\sigma}_{E,t}$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

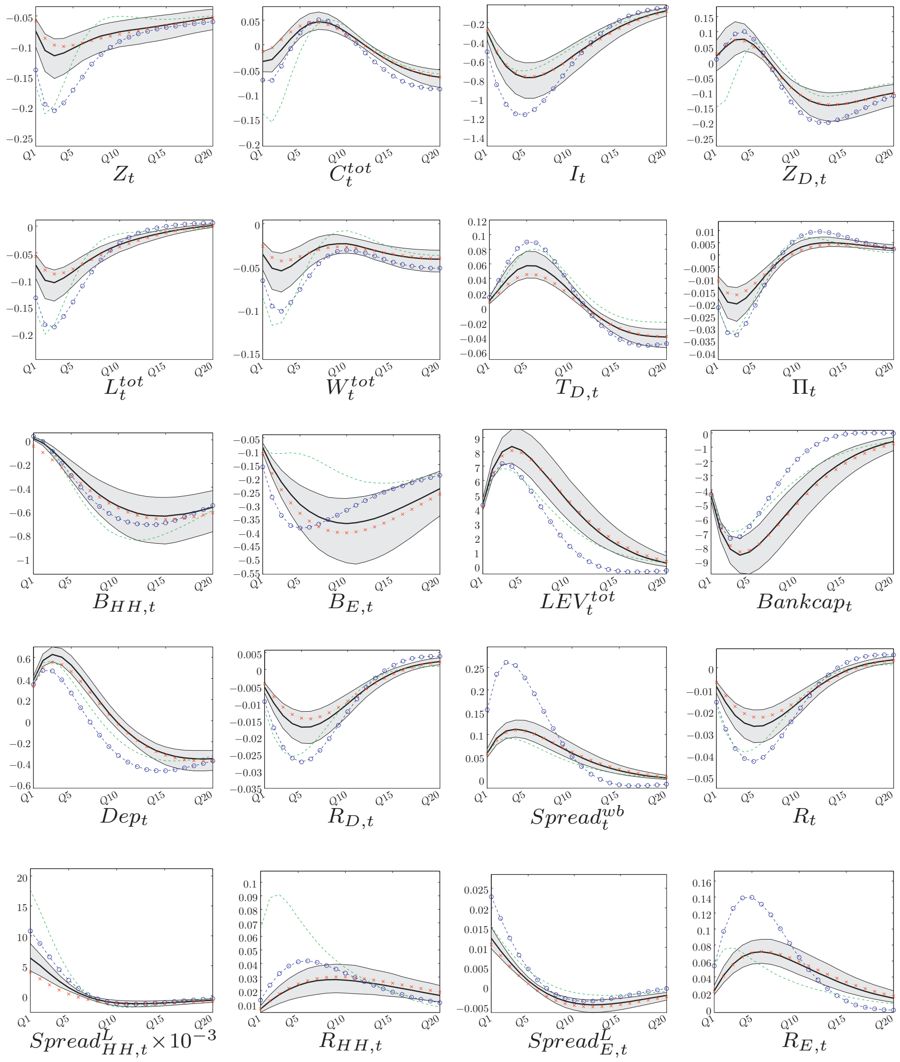


Fig. 14: Impulse Response Functions associated to a shock on $\varepsilon_t^{Bankcap}$. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

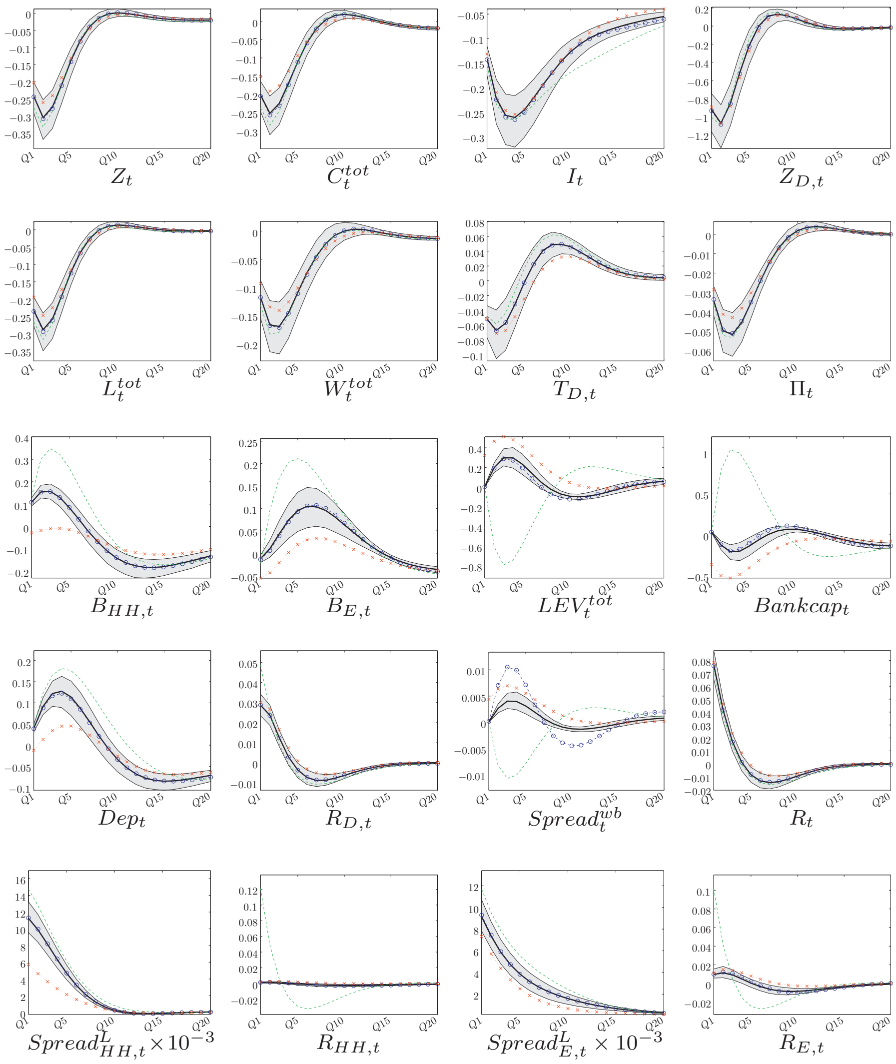


Fig. 15: Impulse Response Functions associated to a shock on ε_t^R. *Benchmark model (plain lines and shaded areas), model with high bank capital channel (blue dotted lines with circle), model without imperfect interest rate pass-through (green dotted lines), model with pre-determined lending rates (red dashed lines with cross).*

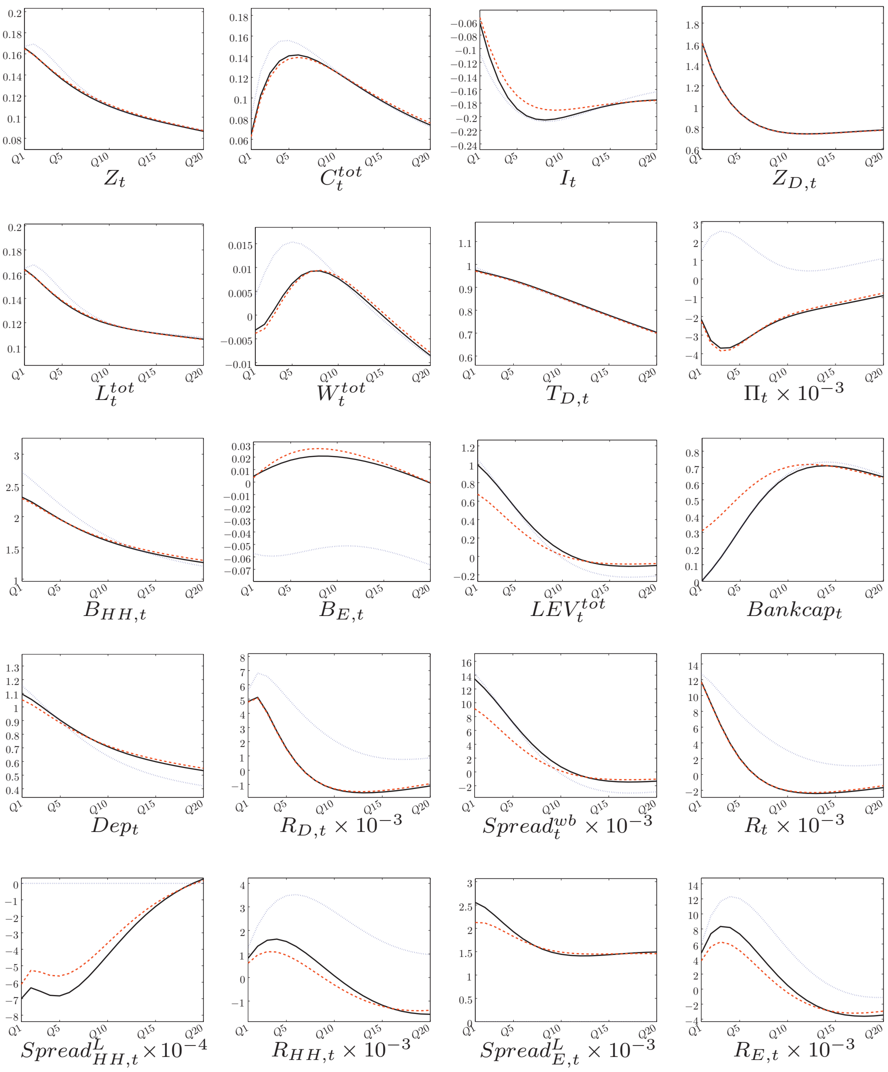


Fig. 16: Impulse Response Functions associated to a shock on ε_t^D. *Without nominal and real rigidities in the housing sector: benchmark (black plain lines), pre-determined lending rates (red dotted lines), binding collateral constraint (blue dashed lines).*

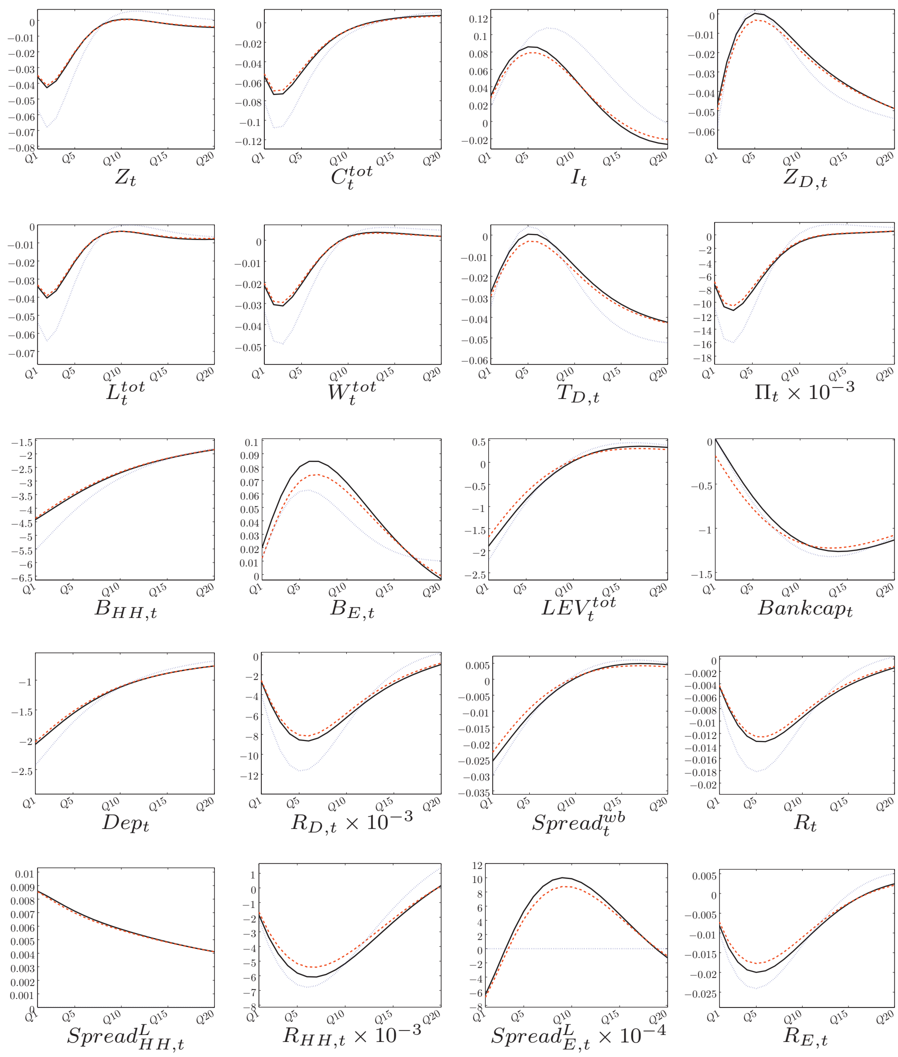


Fig. 17: Impulse Response Functions associated to a shock on $\varepsilon^{\sigma}_{HH,t}$. *Without nominal and real rigidities in the housing sector: benchmark (black plain lines), pre-determined lending rates (red dotted lines), binding collateral constraint (blue dashed lines).*

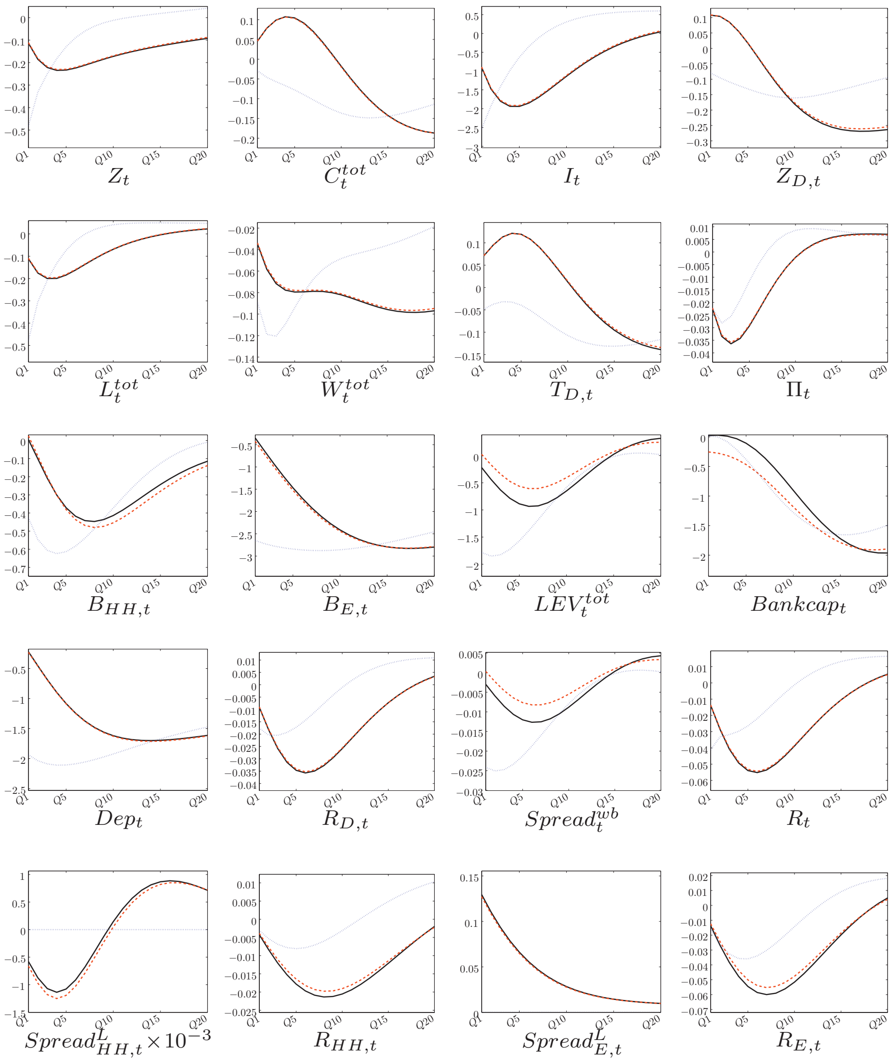


Fig. 18: Impulse Response Functions associated to a shock on $\varepsilon^{\sigma}_{E,t}$. *Without nominal and real rigidities in the housing sector: benchmark (black plain lines), pre-determined lending rates (red dotted lines), binding collateral constraint (blue dashed lines).*

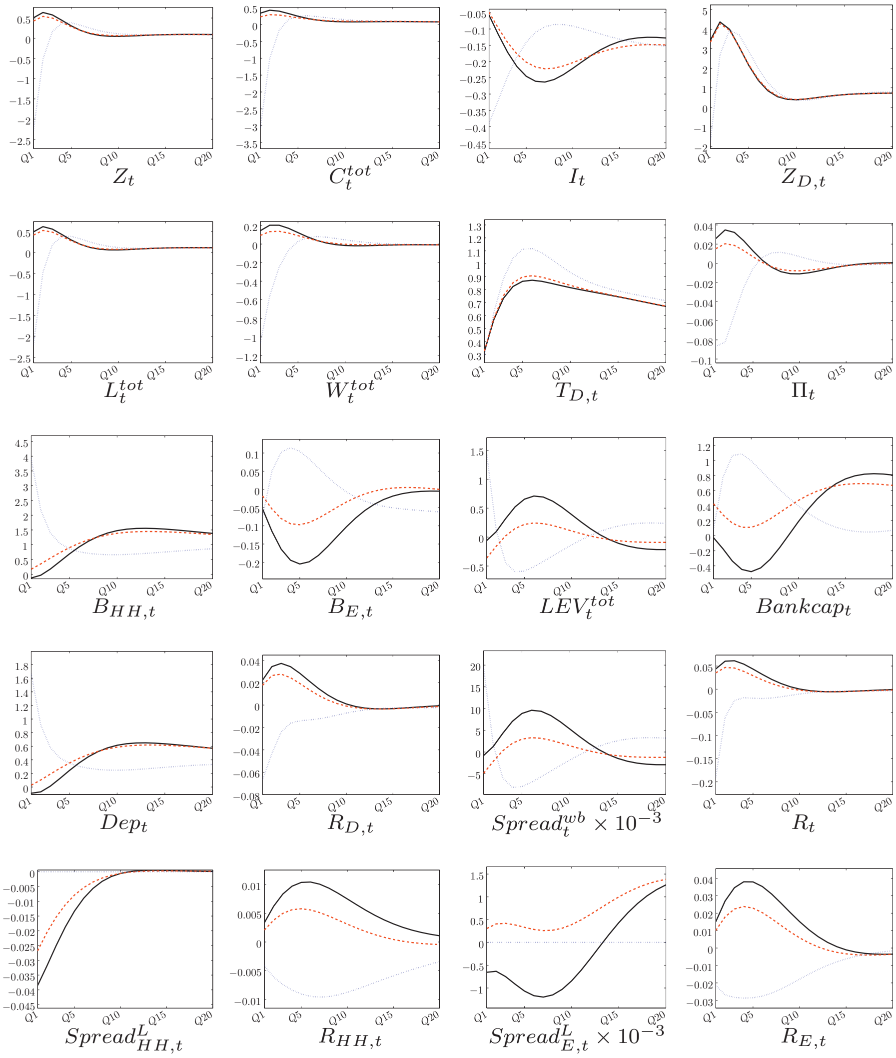


Fig. 19: Impulse Response Functions associated to a shock on ε_t^D. *With nominal and real rigidities in the housing sector: benchmark (black plain lines), pre-determined lending rates (red dotted lines), binding collateral constraint (blue dashed lines).*

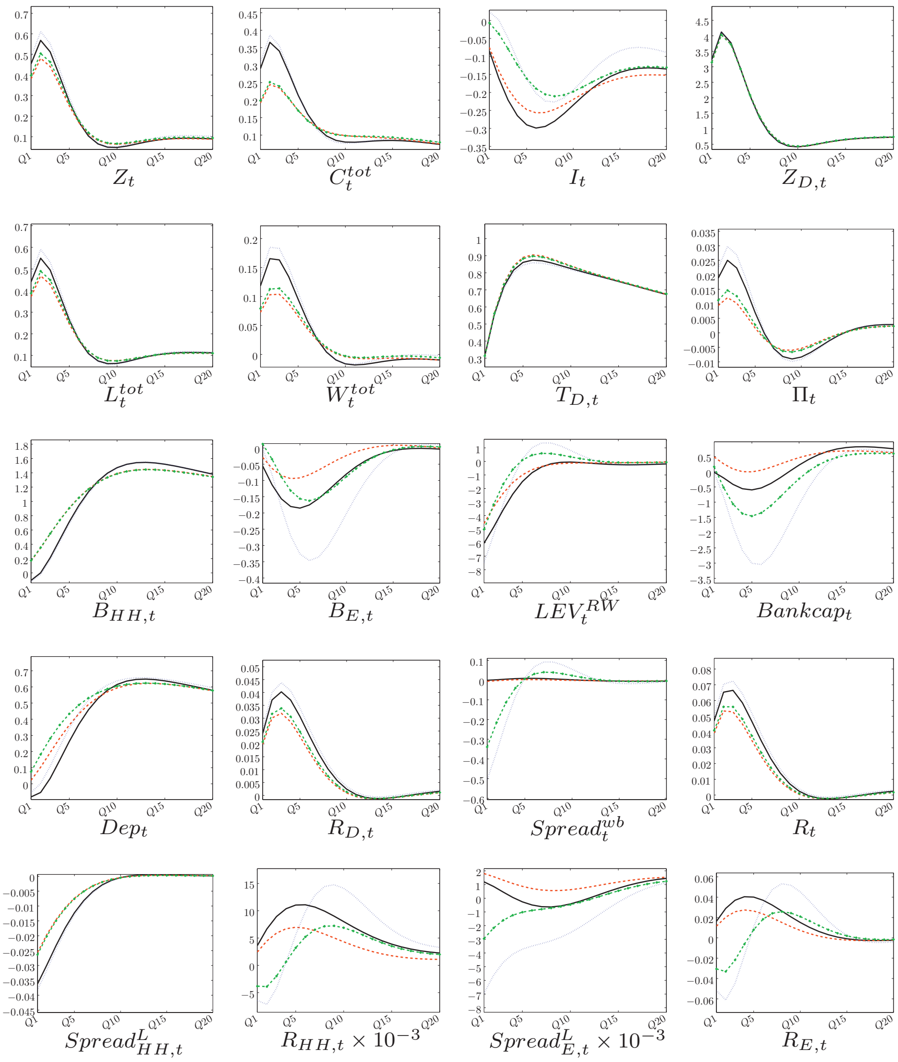


Fig. 20: Impulse Response Functions associated to a shock on ε_t^D. *benchmark (black plain lines), pre-determined lending rates (red dotted lines), benchmark Basle II (blue dashed lines), pre-determined lending rates Basle II (green cross lines).*

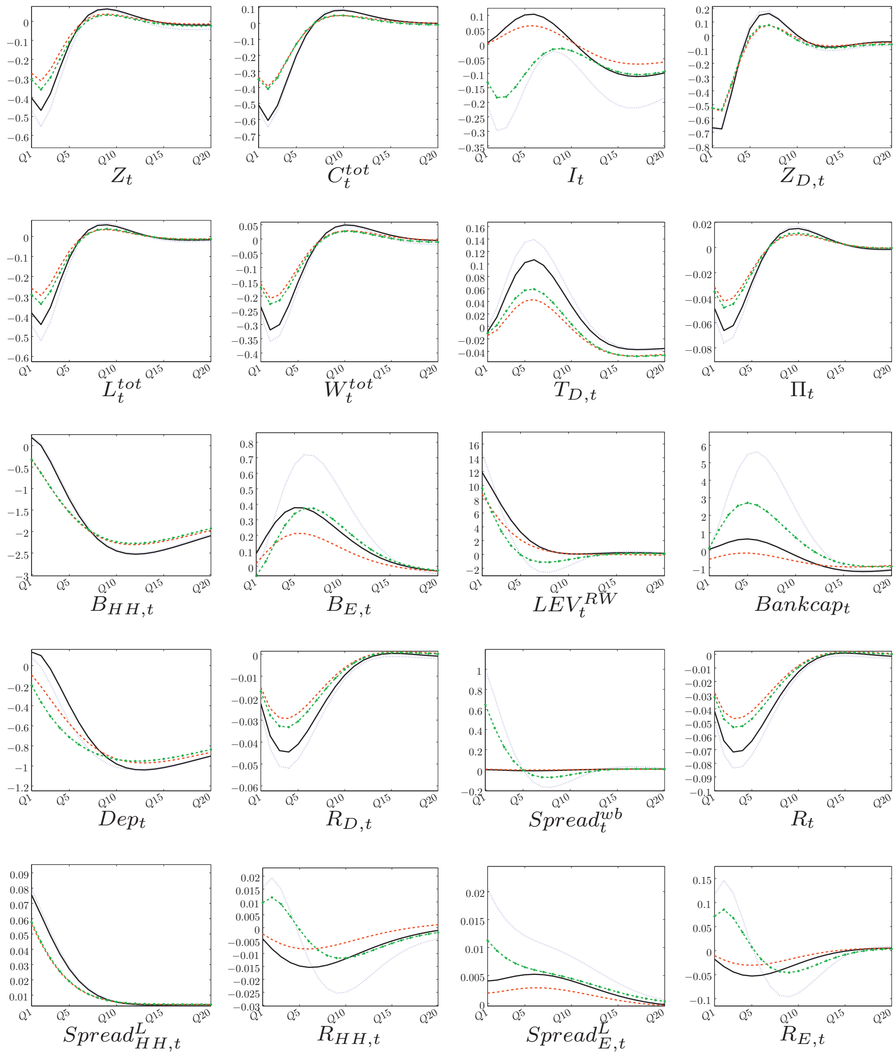


Fig. 21: Impulse Response Functions associated to a shock on $\varepsilon^{\sigma}_{HH,t}$. *benchmark (black plain lines), pre-determined lending rates (red dotted lines), benchmark Basle II (blue dashed lines), pre-determined lending rates Basle II (green cross lines).*

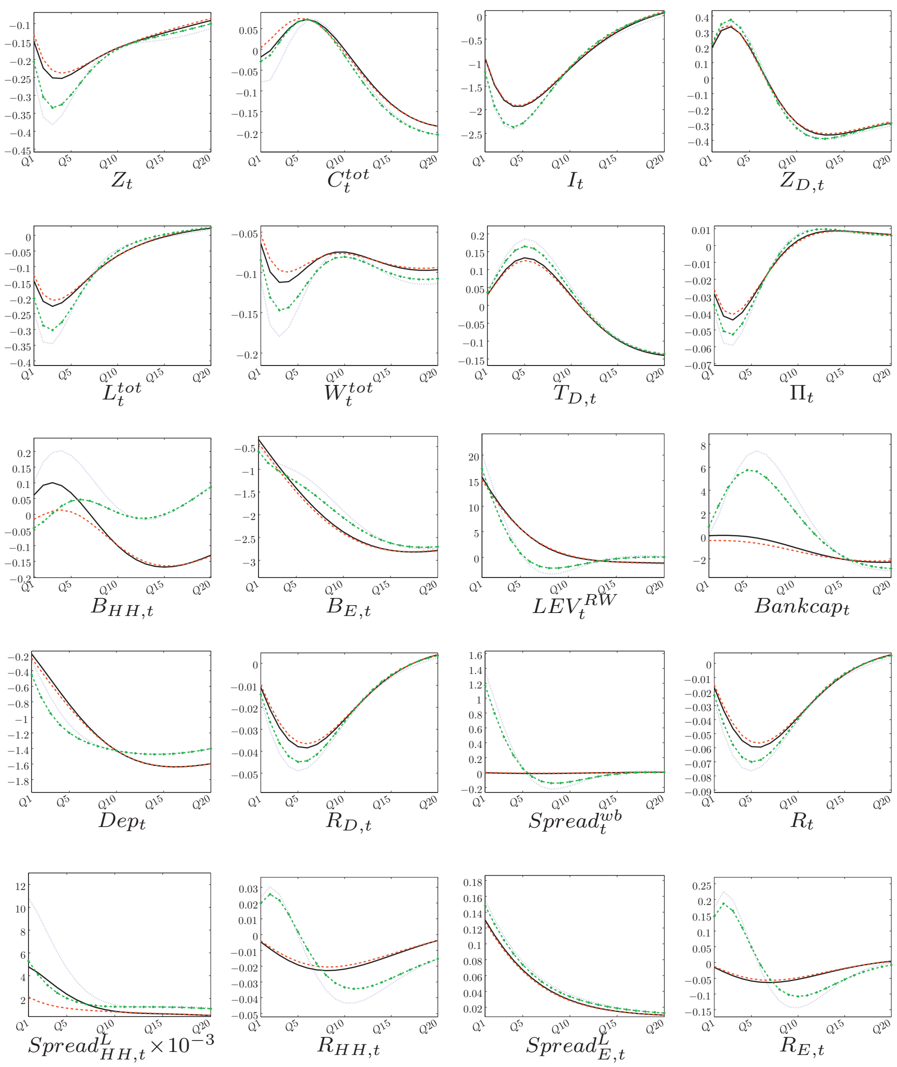


Fig. 22: Impulse Response Functions associated to a shock on $\varepsilon_{E,t}^{\sigma}$. *benchmark (black plain lines), pre-determined lending rates (red dotted lines), benchmark Basle II (blue dashed lines), pre-determined lending rates Basle II (green cross lines).*

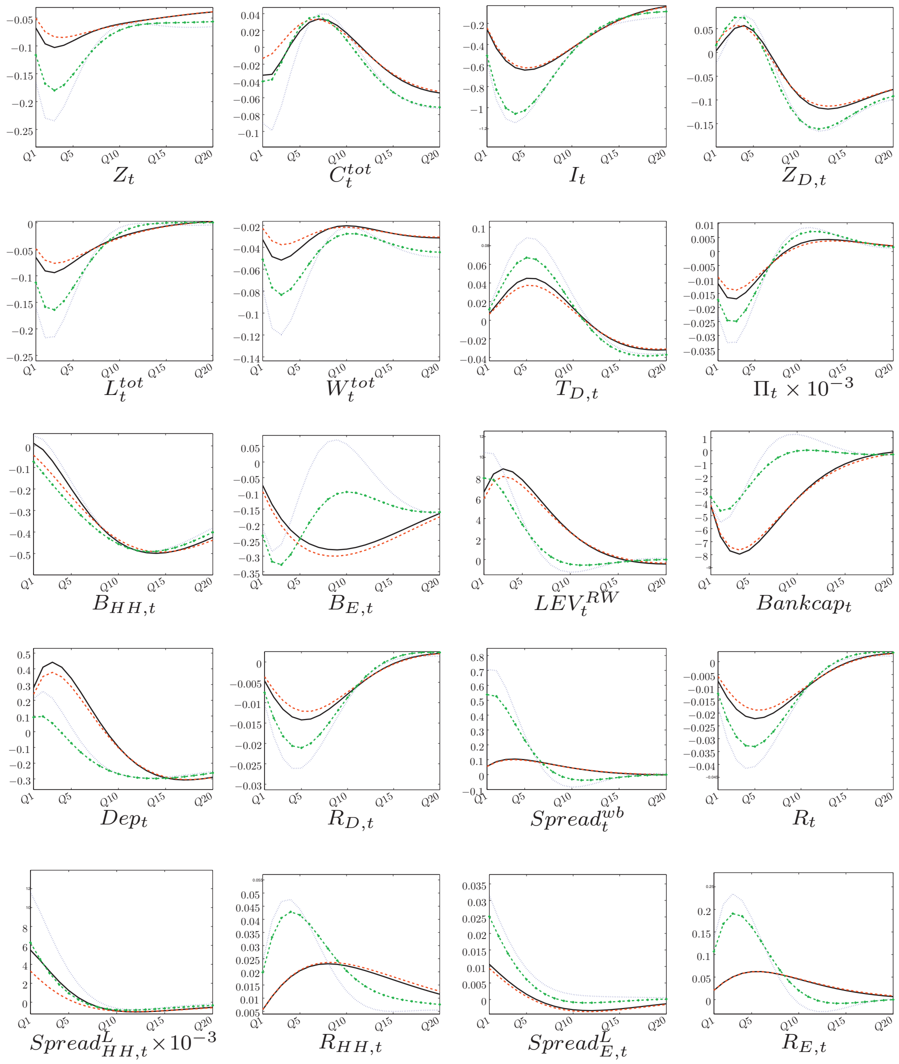


Fig. 23: Impulse Response Functions associated to a shock on $\varepsilon_t^{Bankcap}$. *benchmark (black plain lines), pre-determined lending rates (red dotted lines), benchmark Basle II (blue dashed lines), pre-determined lending rates Basle II (green cross lines).*

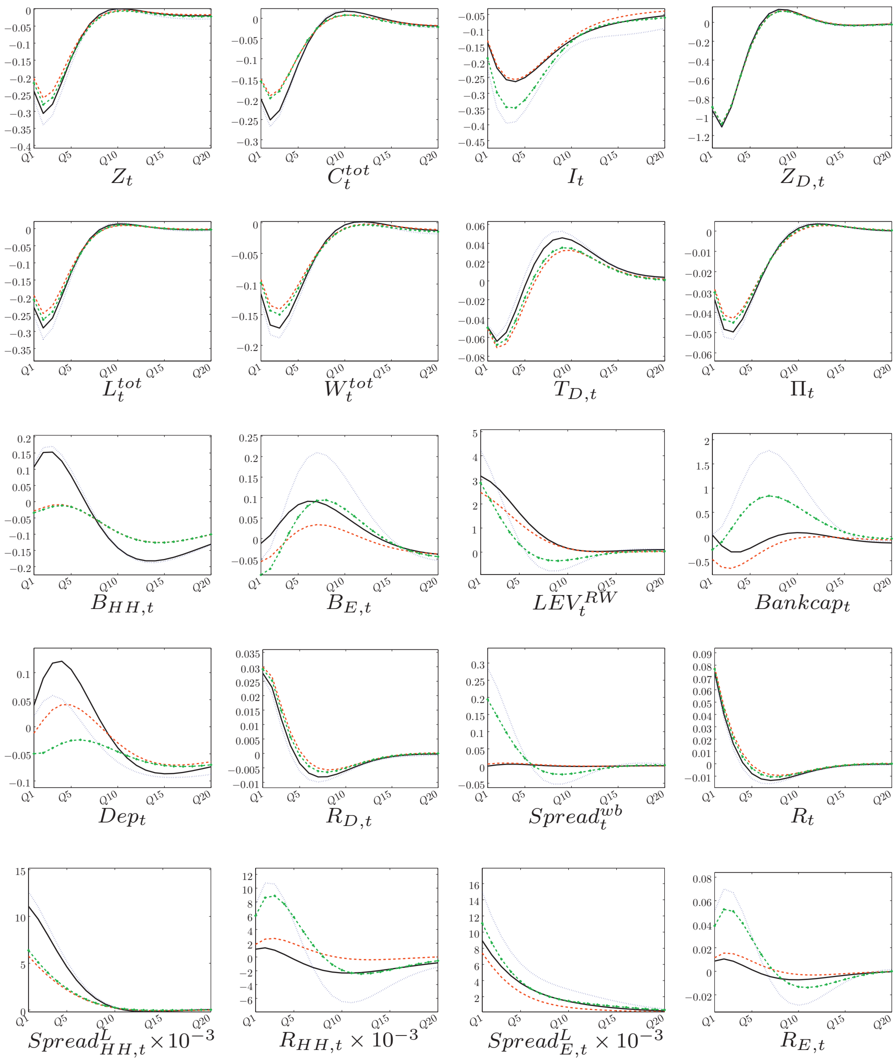


Fig. 24: Impulse Response Functions associated to a shock on ε_t^R. *benchmark (black plain lines), pre-determined lending rates (red dotted lines), benchmark Basle II (blue dashed lines), pre-determined lending rates Basle II (green cross lines).*

Fig. 25: Risk weights under *Basel I* and *Basel II*

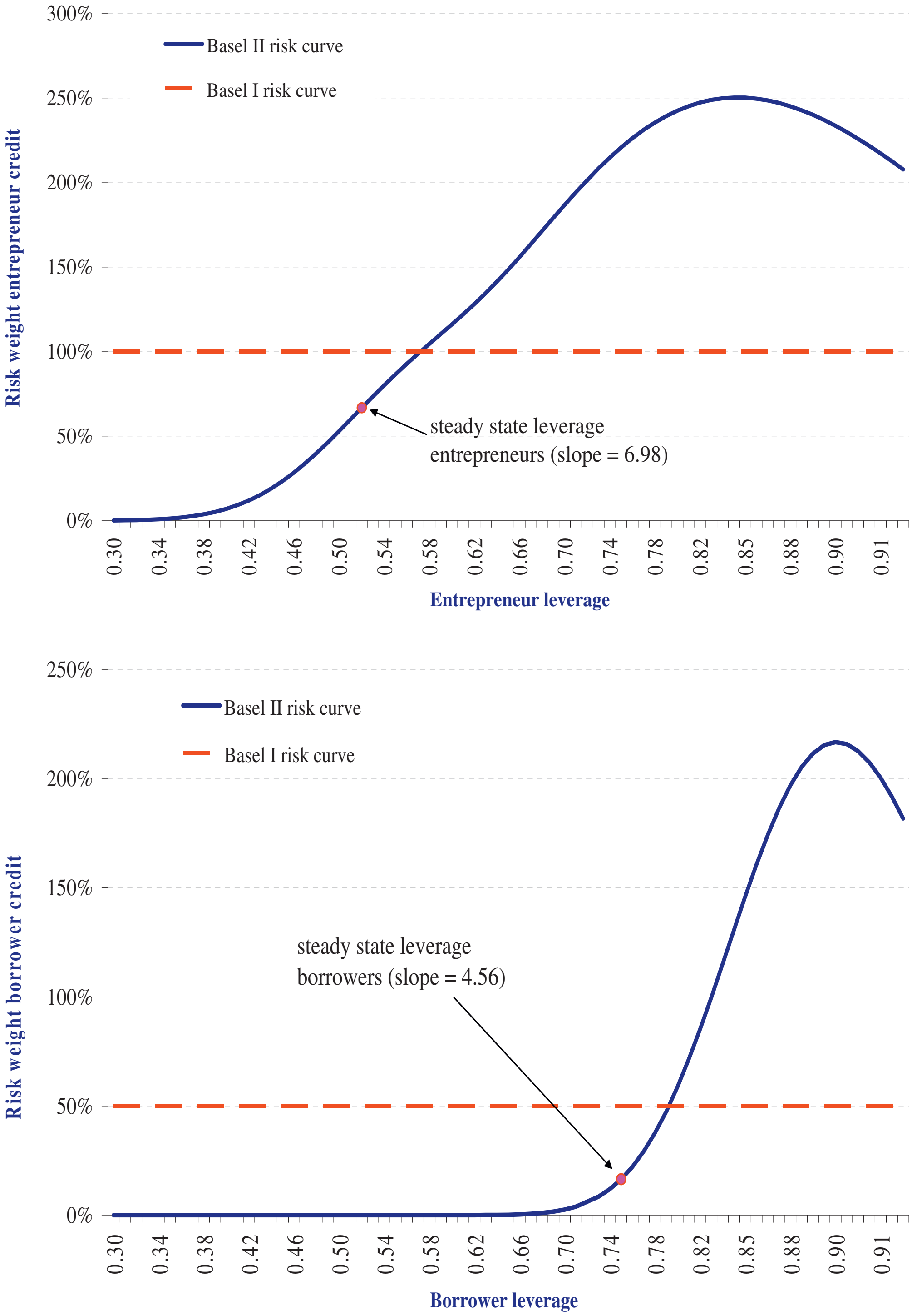


Fig. 26: Transitional dynamics to higher capital requirement for different implementation dates: *benchmark model*

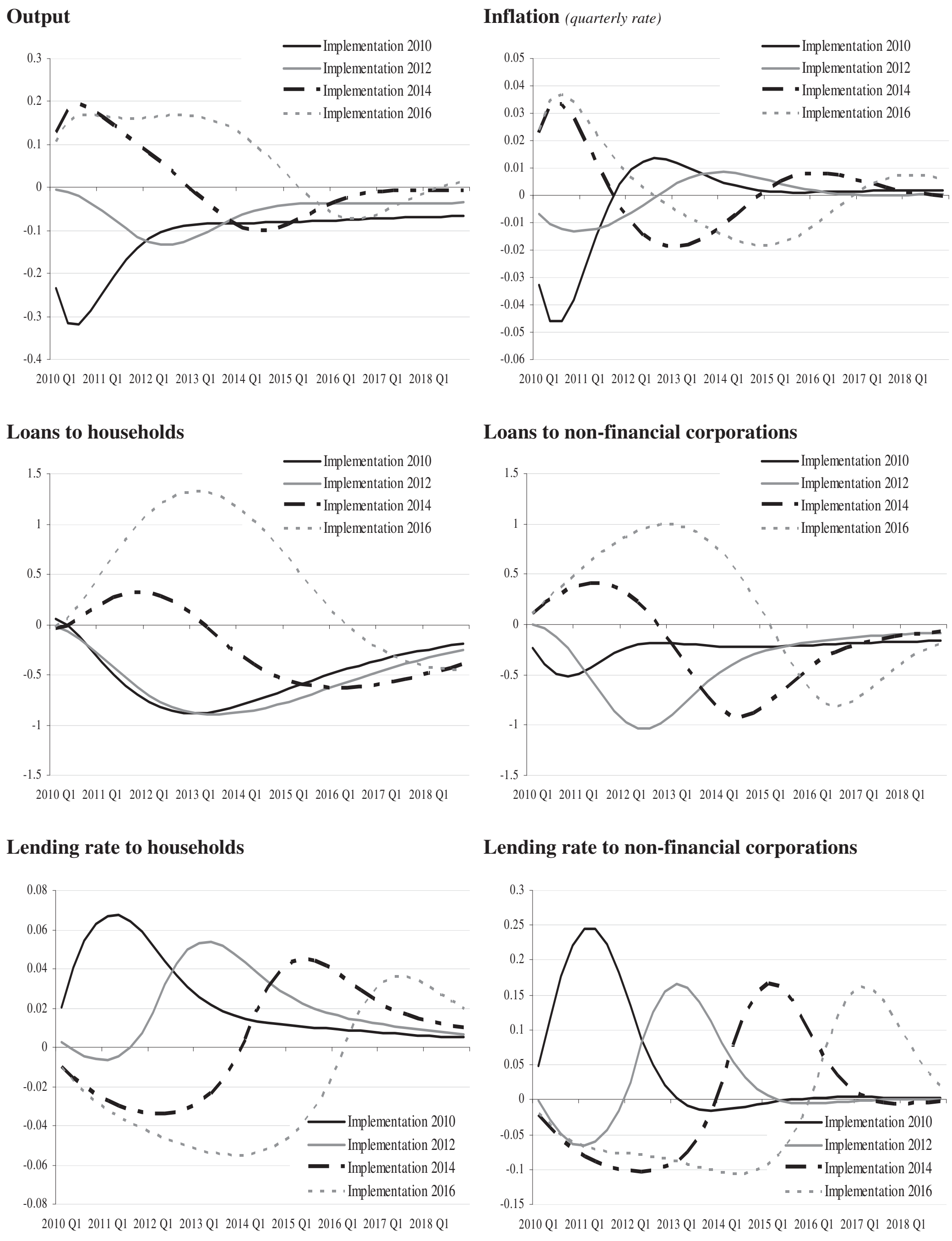
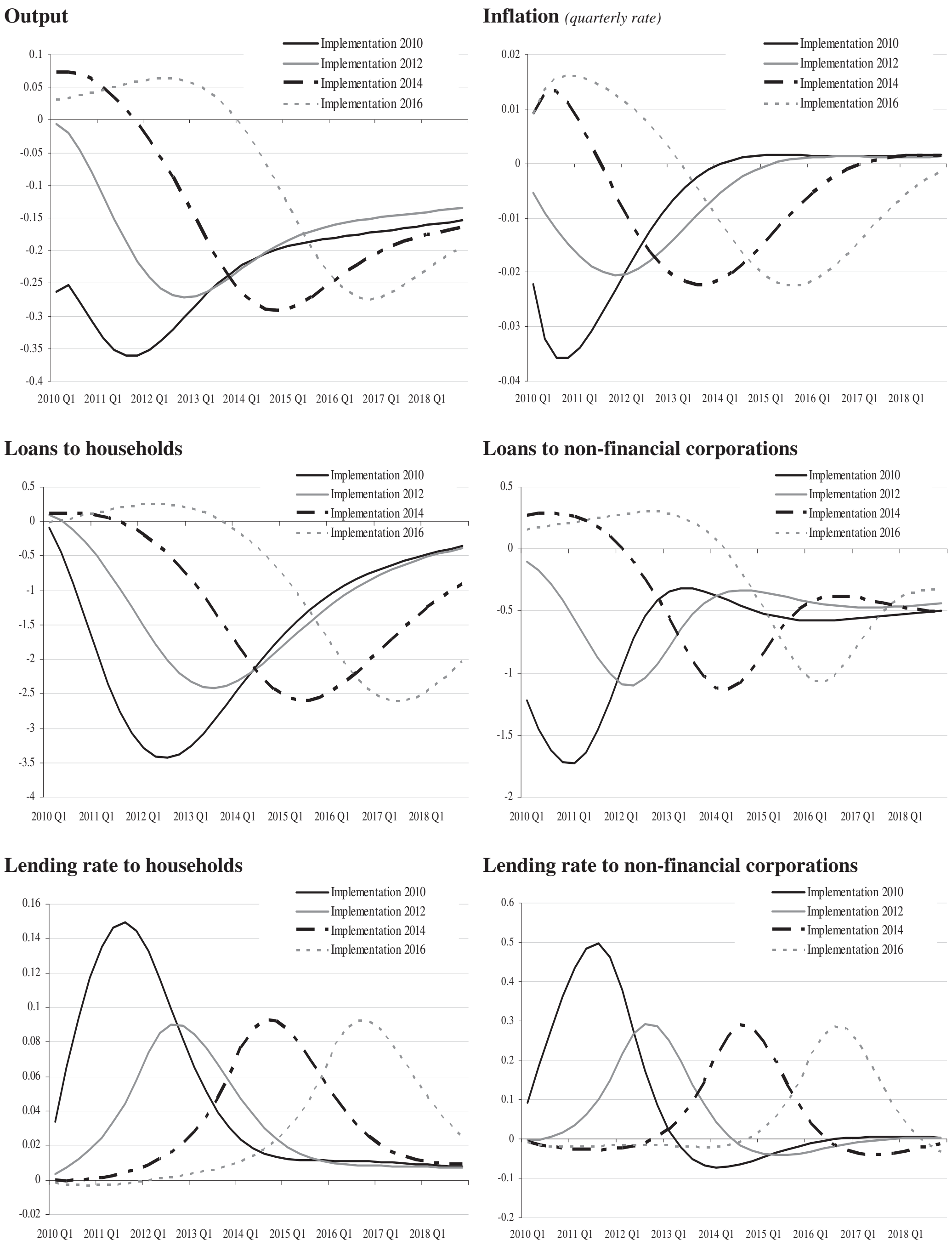


Fig. 27: TRANSITIONAL DYNAMICS TO HIGHER CAPITAL REQUIREMENT FOR DIFFERENT IMPLEMENTATION DATES: *model with binding collateral constraints*



Tab. 8: OPTIMIZED MONETARY AND MACROPRUDENTIAL POLICY RULES

Loss function						
λ_π				1		1
λ_z				4		4
λ_r				0.75		0.75
λ_{lev}				0		0.0001
Regulatory regime	*Basel I all shocks*	Basel I *bench.*	Basel I	Basel II	Counter-cyclical	Counter-cyclical
Optimized policy parameters						
ρ	*0.98*	0.95	0.96	0.93	0.997	0.96
r_π	*43.90*	43.90	52.06	52.07	43.91	43.91
$r_{\Delta\pi}$	*0.53*	0.75	1.12	1.13	-0.43	0.43
r_y	*0.57*	0.75	0.04	0.07	0.92	0.93
$r_{\Delta y}$	*0.56*	1.74	2.30	2.24	1.61	1.99
r_{T_D}	*0.20*	0.68	0.41	0.63	0.00	0.26
$r_{\Delta h}$	-	-	0.45	0.63	0.00	0.36
r_Q	-	-	0.01	0.07	0.00	0.00
$r_{\Delta e}$	-	-	-0.08	-0.12	0.00	0.02
ρ^{bc}	-	-	-	-	0.78	0.77
r_y^{bc}	-	-	-	-	113.00	0.00
$r_{\Delta y}^{bc}$	-	-	-	-	0.40	0.00
$r_{T_D}^{bc}$	-	-	-	-	0.03	0.13
$r_{\Delta h}^{bc}$	-	-	-	-	-0.05	0.01
r_Q^{bc}	-	-	-	-	-1.91	-0.38
$r_{\Delta e}^{bc}$	-	-	-	-	-0.43	-0.11
Relative STD to bench. (in %)						
ΔZ_t	-	100.0	80.3	102.3	16.5	78.6
Π_t	-	100.0	139.8	116.7	71.6	138.2
R_t	-	100.0	72.0	91.9	29.7	65.1
$T_{D,t}$	-	100.0	100.0	96.1	104.6	100.6
$B_{HH,t}$	-	100.0	97.0	84.7	227.8	103.2
$B_{E,t}$	-	100.0	99.9	80.4	136.8	94.4
$Leverage_t$	-	100.0	99.0	230.1	482.4	94.6
$\mathcal{L}$	-	0.34	0.23	0.40	0.03	0.32