Monetary policy and housing prices in an estimated DSGE for the US and the euro area.*

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Abstract

We estimate a two-country Dynamic Stochastic General Equilibrium model for the US and the euro area including relevant housing market features and examine the monetary policy implications of housing-related disturbances. In particular, we derive the optimal monetary policy cooperation consistent with the structural specification of the model. Our estimation results reinforce the existing evidence on the role of housing and mortgage markets for the US and provide new evidence on the importance of the collateral channel in the euro area. Moreover, we document the various implications of credit frictions for the propagation of macroeconomic disturbances and the conduct of monetary policy. We find that allowing for some degree of monetary policy response to fluctuations in the price of residential goods improves the empirical fit of the model and is consistent with the main features of optimal monetary policy response to housing-related shocks.

Keywords: Housing, credit frictions, Optimal monetary policy, New open economy macroeconomics, Bayesian estimation.

JEL classification: E4, E5, F4.

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Non-Technical Summary

The macroeconomic literature has recently shown a particular interest in understanding the role played by credit market frictions faced by households in determining business cycle dynamics and monetary policy conduct. A common feature across the existing theoretical frameworks is the influence of housing collateral on households consumption decisions.

In this paper, we aim at analyzing the importance of housing markets and household credit frictions on monetary policy setting within an open-economy framework. Our contribution intends to bridge a gap between the growing strand of literature focusing on credit frictions in closed economies characterized by the presence of nominal rigidities and the existing estimated New Open Economy Macroeconomics models. We estimate a two-country Dynamic Stochastic General Equilibrium model for the US and the euro area including relevant housing market features and examine the monetary policy implications of housing-related disturbances. In order to put into perspective the monetary policy response to economic disturbances originating in the housing sector, we also derive the optimal monetary policy cooperation consistent with the structural specification of the model.

The original contribution of the paper covers several dimensions. First, our results reinforce the existing evidence on the role of housing and mortgage markets for the US and provide new evidence on the importance of the collateral channel in the euro area. Second, we find that structural housing-related shocks have significant spillovers to non-residential consumption through the collateral channel and therefore the share of borrowers in the economy. In terms of international spillovers, the transmission of housing preference shocks on economic activity is assessed to be relatively limited and lower than in the case of demand shocks affecting the tradable sector. Third, housing shocks play a key role in generating negative comovement across countries for both real housing prices and residential investment. Finally, it turns out that allowing for a direct monetary policy response to house prices in the interest rate feedback rule improves the empirical fit of the model. From a normative perspective, some degree of monetary policy reaction to fluctuations in the price of residential goods is consistent with the main features of optimal monetary policy response to housing-related shocks. The augmented Taylor rule estimation turns out to be welfare-improving compared with the benchmark case, in particular for the US economy.

1 Introduction

This paper aims at analyzing the importance of housing markets and household credit frictions on monetary policy conduct within an open-economy framework. In doing so, our contribution intends to bridge a gap between the growing strand of literature focusing on credit frictions in closed economies characterized by the presence of nominal rigidities[1], and the existing estimated New Open Economy Macroeconomics models [2]. We estimate a two-country Dynamic Stochastic General Equilibrium model for the US and the euro area including relevant housing market features and examine the monetary policy implications of housing-related disturbances.

The macroeconomic literature has recently shown a particular interest in understanding the role played by credit market frictions faced by households in determining business cycle dynamics. More specifically, the conduct of monetary policy in the presence of such frictions has attracted a special attention. A common feature across the existing theoretical frameworks is the influence of housing collateral on households consumption decisions. The empirical evidence suggests the existence of a fraction of consumers in the economy who face binding collateral constraints when approaching loans and mortgage markets. As a result, institutional arrangements in such markets, as well as different housing market structures can potentially affect households' home-purchasing and consumption decisions in a significant way. Most of the existing literature has been focusing on a closed-economy setup, thus abstracting from international factors and cross-country spillovers[3].

In modeling the closed economy setup, we follow a recent strand of literature which - like Kiyotaki and Moore [1997] - considers a dual structure on the household side, 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 [2007]and Notarpietro [2007], we define a two-agent, two-sector economy for each country, where the impatient agents face collateral requirements when asking for mortgages or loans. Firms produce nondurable consumption goods (which can be traded internationally) and residential goods (which are considered non-tradable). 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 [2007] and Notarpietro [2007], who report the relevance of housing market shocks in shaping consumption dynamics in the US. We focus here on the role of housing market factors and credit frictions in explaining both closed and open-economy fluctuations. In particular, we estimate structural parameters such as the relative share of borrowers in the two economies, and we show how they affect the transmission mechanism of housing market and monetary policy shocks both domestically and internationally.

The use of an explicit two-country setup allows for estimating and testing for the existence of structural

[1]See Iacoviello [2005], Iacoviello and Neri [2007], Monacelli [2006], and Notarpietro [2007] among others.

[2]See Adjemian et al. [2008], Adolfson et al. [2005],De Walque et al. [2005], and Rabanal and Tuesta [2006]

[3]An exception is Christensen et al. [2007], who estimate a small open economy model for Canada.

differences across the two continental economies. On the open-economy side, we introduce most of the common features of estimated open-economy DSGE models, following closely Adjemian et al. [2008]. In particular, we assume that financial markets are incomplete internationally. However, we do not allow for international trade of private debt, so that the borrowers can only access domestic credit markets; the savers can instead trade two nominal risk-less bonds denominated in the domestic and foreign currency respectively. The model is estimated on US and euro area quarterly data, over the period 1981 I: 2005 IV, by making use of full-information Bayesian techniques.

Moreover, in order to put into perspective the monetary policy response to economic disturbances originating in the housing sector, we derive the optimal monetary policy cooperation consistent with the structural specification of the model. As in Adjemian et al. [2008], the Ramsey approach to optimal monetary policy cooperation is computed by formulating an infinite-horizon Lagrangian problem of maximizing the conditional aggregate welfare of both countries subject to the full set of non-linear constraints forming the competitive equilibrium of the model. We solve the equilibrium conditions of the optimal allocation using second-order approximations to the policy function. In this paper, we restrict our analysis to the assessment of the optimal policy tolerance for relative house price fluctuations. We do not intend to explore systematically all the factors which shape optimal policy in our modeling framework. Such an exercise would go beyond the scope of the present contribution and is left for further research. Instead, we consider the optimal monetary policy response to housing-related shocks which, under standard Taylor rules, generate strong relative house price changes and ample asymmetry between savers' and borrowers' reactions.

The main contributions of the paper cover several dimensions. First, our results reinforce the existing evidence on the role of housing and mortgage markets for the US and provide new evidence on the importance of the collateral channel in the euro area. In particular, we estimate different versions of the model, considering high or low shares of borrowers in the economy. Our results suggest notably that the share of impatient households is higher in the US than in the euro area. We also find that the estimated shares of borrowers are quite sensitive to the specification of *a priori* distributions, which ultimately should be set based on appropriate economic grounds.

Second, in terms of economic propagation of non-housing related shocks, the presence of credit frictions alters significantly the relative responses of aggregate consumption and non-residential investment. Moreover, we find that structural housing-related shocks have significant spillovers on non-residential consumption through the collateral channel and the share of borrowers in the economy. Nonetheless, the residential sector is somewhat unaffected by shifts in the share of borrowers due to its dual nature of flexible-price, non-traded goods producing sector. In terms of international spillovers, the transmission of housing preference shocks on economic activity is found to be relatively limited and lower than in the case of demand shocks affecting the tradable sector. Finally, housing shocks play a key role in generating negative comovement across countries for both real housing prices and residential investment.

Third, we find that allowing for a monetary policy response to house prices improves the empirical fit of the model, and paves the way for a deeper analysis of optimal monetary policy cooperation in the proposed framework[4]. From a normative perspective, some degree of monetary policy reaction to fluctuations in the price of residential goods is consistent with the main features of optimal monetary policy response to housing-related shocks. Based on welfare computations when only housing shocks are allowed, the estimated Taylor rule augmented with real housing prices turns out to be welfare-improving compared with the benchmark case, in particular for the US economy. Beyond this, the optimal allocation suggests that the heterogenous responses across households and the associated welfare losses in terms of imperfect risk sharing should be counteracted, even at the cost of short term inflation volatility. Compared with the estimated rules, our results indicate noticeably that the optimal international transmission of positive housing-related shocks leads to a more pronounced monetary policy tightening in the foreign country and to a negative adjustment of housing prices and quantities as well as domestic demand for non-residential goods.

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 the international propagation of shocks in the estimated model. In section 5 we investigate the monetary policy response to housing shocks, both from an historical perspective - by estimating Taylor rules augmented with real housing prices - and through an analysis of the optimal allocation.

2 Theoretical model

The world economy is constituted by two symmetric countries, Home (H) and Foreign (F). Each country is modeled as a two-agent, two-sector economy, producing residential and non residential goods[5]. Non-residential final goods are produced by a continuum of "single-good-firms" indexed on $[0, 1]$, mixing local production with imports. More precisely, in each country final producers for local sales and inputs operate in perfect competition and aggregate a continuum of differentiated products purchased from Home and Foreign intermediate-sector firms. The latter are monopolistic competitors and exert some market power through the setting of prices. The residential-goods sector has a similar structure, but final and intermediate goods are not traded.

We assume that in each country there exists a continuum of infinitely-lived households, the number of which is proportional to the number of firms. Following the seminal contribution of Kiyotaki and Moore [1997], we consider two types of households in each country, differing in their relative intertemporal discount factor. More precisely, a fraction $(1 - \omega)$ of households in country H (and, symmetrically, $(1 - \omega^*)$ in F) are relatively more patient, and the remaining ω (resp. ω^*) are impatient. Households receive utility from consuming both nonresidential and residential goods, and disutility from labor. Residential goods are treated here as *durable* goods, and serve two purposes: they can be either directly consumed or used as collateral in the mortgage market. Private debt is generated in equilibrium, as the result of intertemporal trade among the patient agents (who act as lenders, or savers), and the impatient agents (who act as net borrowers). The existence of frictions in household credit markets is captured by impos-

[4] We use the expressions "house price" and "price of residential goods" as synonymous in the text.

[5] We follow closely Iacoviello and Neri [2007] and Notarpietro [2007] in defining the closed-economy setup for each country.

ing a perpetually binding collateral constraint on the entire group of impatient agents[6].

We present the structure of the model and some derivations for country H only, for the sake of brevity. Analogous derivations hold true for country F.

2.1 The borrower's program

Each impatient agent $b \in [0, \omega]$ receives utility from the following instantaneous utility function:

$$W_t^b = E_t \left\{ \sum_{j \geq 0} \beta^j \left[\begin{array}{c} \frac{1}{1-\sigma_X} \left(\widetilde{X}_{t+j}^b \right)^{1-\sigma_X} - \frac{\varepsilon_{t+j}^L \overline{L}_C}{1+\sigma_{LC}} \left(L_{C,t+j}^b \right)^{1+\sigma_{LC}} \\ -\frac{\varepsilon_{t+j}^L \overline{L}_D}{1+\sigma_{LD}} \left(L_{D,t+j}^b \right)^{1+\sigma_{LD}} \end{array} \right] \varepsilon_{t+j}^\beta \right\} \quad (1)$$

where $\widetilde{X}_t^b$ is an index of consumption services derived from non-residential final goods (C^b) and residential stock (D^b):

$$\widetilde{X}_t^b \equiv \left[\left(1 - \varepsilon_t^D \omega_D\right)^{\frac{1}{\eta_D}} \left(\widetilde{C}_t^b - h_B \widetilde{C}_{t-1}^b \right)^{\frac{\eta_D - 1}{\eta_D}} + \varepsilon_t^D \omega_D^{\frac{1}{\eta_D}} \left(\widetilde{D}_t^b \right)^{\frac{\eta_D - 1}{\eta_D}} \right]^{\frac{\eta_D}{\eta_D - 1}} \quad (2)$$

with the parameter h_B 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 labor in each sector, $L_{C,t}^b$ and $L_{D,t}^b$. 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 impatient's labor supply is equal to 1 in steady state.

Impatient agents in each country can trade a nominal risk-less bond denominated in the domestic currency, but they cannot tap the international financial markets to finance their expenditure plans. In addition, they do not save nor accumulate capital. Total savings and investment decisions in each country are implemented by the savers, as we show later.

Under these assumptions, each borrower maximizes her utility function (1) subject to an infinite sequence of real budget constraints[7]:

$$\begin{aligned} \frac{P_t}{\underline{P}_t} \widetilde{C}_t^b + T_{D,t} \left(\widetilde{D}_t^b - (1-\delta) \widetilde{D}_{t-1}^b \right) + \frac{R_{t-1} \widetilde{B}_{H,t-1}^b}{\pi_t \underline{P}_{t-1}} &= \frac{\widetilde{B}_{H,t}^b}{\underline{P}_t} + \frac{\widetilde{A}_t^b + \widetilde{TT}_t^b}{\underline{P}_t} \\ &+ (1 - \tau_{w,t}) \frac{W_{C,t}^b L_{C,t}^b + W_{D,t}^b L_{D,t}^b}{\underline{P}_t} \end{aligned} \quad (3)$$

[6]As a consequence, we will use the terms *impatient (patient)* and *borrower (saver)* as interchangeable throughout, with a slight abuse of terminology.

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

where $\delta \in (0,1)$ is the depreciation rate and $T_{D,t} \equiv \frac{P_{D,t}}{\underline{P}_t}$ is the relative price of residential goods in terms of non-residential goods, $\widetilde{B}^b_{H,t}$ is the stock of nominal debt issued by the borrower at time t, R_{t-1} is the nominal interest rate paid on the existing amount of debt $\widetilde{B}^b_{H,t-1}$ and π_t is the gross non-residential good inflation rate. $W^b_{C,t}$ and $W^b_{D,t}$ denote the borrower's nominal wages in the two sectors. $\widetilde{TT}^b_t$ are government transfers and $\tau_{w,t}$ is a time-varying labor tax. Finally, $\widetilde{A}^b_t$ is a stream of income coming from state-contingent securities, allowing the borrowers to hedge against wage income risk. Given separability of preferences, trading such assets ensures that all borrowers have identical consumption plans. Therefore, we can drop the superscript b and simply use a $\tilde{}$ to denote variables related to the borrowers.

We also introduce a consumption tax which affects the price of the distributed goods serving final consumption. The after-tax consumer price index (CPI) is denoted $P_t = (1+\tau_{C,t})\,\underline{P}_t$ where $\underline{P}_t$ is the price of the distribution good gross of consumption tax. Such a time-varying consumption tax could in principle rationalize the CPI inflation rate shocks that we introduce to estimate the model. We design the CPI shocks as $\frac{(1+\tau_{C,t})}{(1+\tau_{C,t-1})} = \varepsilon^{CPI}_t$.

At each period in time, all the borrowers have limited access to credit markets, as summarized by the following (nominal) collateral constraint:

$$\widetilde{B}_{H,t} \leq \varepsilon^{LTV}_t (1-\chi)\,\mathbb{E}_t\left\{P_{D,t+1}\widetilde{D}_t\frac{1}{R_t}\right\}$$

where $\chi \in [0,1]$ is the fraction of the residential good that cannot be used as a collateral. Such a parameter is an indirect measure of the flexibility of the mortgage market. The term $(1-\chi)$ thus provides a proxy for the observed loan-to-value ratio, which is subject to a stationary stochastic shock ε^{LTV}_t. The collateral constraint can be conveniently rewritten in real terms as follows:

$$\widetilde{b}_{H,t} \leq \varepsilon^{LTV}_t (1-\chi)\,\mathbb{E}_t\left\{T_{D,t+1}\widetilde{D}_t\frac{\pi_{t+1}}{R_t\;\varepsilon^{CPI}_{t+1}}\right\} \tag{4}$$

where $\widetilde{b}_{H,t} \equiv \frac{B_H}{\underline{P}_t}$.
Summing up, the impatient agent maximizes (1) subject to the infinite sequence of (3) and (4) holding with equality[8]. We report the first order conditions for this problem in the Appendix.

2.2 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 and make decisions on investment plans to build the capital stock which will be rented out to intermediate firms. The savers can trade two nominal risk-less bonds denominated in the domestic and foreign currency. Financial markets are assumed to be incomplete internationally. We introduce a risk premium on the international financing of domestic consumption expenditures. Such risk premium is a function of real

[8] It is possible to show that the collateral constraint always binds in the deterministic steady state, under general conditions. We assume here that it continues to bind in a sufficiently small neighborhood of the steady state, so that the model can be solved by taking a first order approximation.

holdings of foreign assets in the entire economy. Each patient agent receives instantaneous utility from the same type function (1) adopted for the impatient[9]:

$$\mathcal{W}_t^s = \mathbb{E}_t \left\{ \sum_{j \geq 0} \gamma^j \left[\begin{array}{c} \frac{1}{1-\sigma_X} \left(X_{t+j}^s \right)^{1-\sigma_X} - \frac{\varepsilon_{t+j}^{L,s} \widetilde{\overline{L}}_C}{1+\sigma_{LC}} \left(L_{Ct+j}^s \right)^{1+\sigma_{LC}} \\ - \frac{\varepsilon_{t+j}^{L,s} \widetilde{\overline{L}}_D}{1+\sigma_{LD}} \left(L_{Dt+j}^s \right)^{1+\sigma_{LD}} \end{array} \right] \varepsilon_{t+j}^{\beta} \right\} \tag{5}$$

where X_t^s is given by

$$X_t^s \equiv \left[\left(1 - \varepsilon_t^D \omega_D \right)^{\frac{1}{\eta_D}} \left(C_t^s - h_S C_{t-1}^s \right)^{\frac{\eta_D - 1}{\eta_D}} + \varepsilon_t^D \omega_D^{\frac{1}{\eta_D}} \left(D_t^s \right)^{\frac{\eta_D - 1}{\eta_D}} \right]^{\frac{\eta_D}{\eta_D - 1}} \tag{6}$$

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

$$\frac{P_t}{\underline{P}_t} C_t^s + T_{D,t} \left(D_t^s - (1-\delta) D_{t-1}^s \right) + I_t^s + \frac{B_{H,t}^s}{\underline{P}_t} + \frac{S_t B_{F,t}^s}{\underline{P}_t \varepsilon_t^{\Delta S} \Psi \left(\frac{\mathbb{E}_t S_{t+1}}{S_{t-1}} - 1, \frac{S_t \left(B_{F,t} - \overline{\overline{B}}_F \right)}{\underline{P}_t} \right)}$$

$$= \frac{R_{t-1} B_{H,t-1}^s}{\pi_t \underline{P}_{t-1}} + \frac{S_t R_{t-1}^* B_{F,t-1}^s}{\pi_t \underline{P}_{t-1}} + \sum_{j=C,D} \left[R_t^{k,j} u_t^j K_t^j - \Phi \left(u_t^j \right) K_t^j \right]$$

$$+ \frac{(1-\tau_{w,t}) \left(W_{C,t}^s L_{C,t}^s + W_{D,t}^s L_{D,t}^s \right) + A_t^s + \Pi_t^s + TT_t^s}{\underline{P}_t}$$

where S_t is the nominal exchange rate, TT_t^s are government transfers and Π_t^s are distributed profits. Capital is sector-specific and the savers have to decide in which sector to invest. The expression

$$R_t^{k,j} u_t^j K_t^j - \Phi \left(u_t^j \right) K_t^j$$

represents the sector-specific nominal return on the real capital stock minus the cost associated with variations in the degree of capital utilization[10]. Savers have access to international bond trading: $B_{H,t}^s$ and $B_{F,t}^s$ are individual holdings of domestic and foreign bonds denominated in local currency The risk premium function $\Psi(\cdot,\cdot)$ is differentiable, decreasing in both arguments and verifies $\Psi(0,0) = 1$. The functional form used for the risk premium is $\Psi(X,Y) = \exp\left(-\chi_{\Delta S} X - 2\chi Y\right)$. The term $\varepsilon_t^{\Delta S}$ is a unitary-mean disturbance affecting the risk premium.

As for the borrowers, we maintain the assumption that state-contingent assets are traded among the savers, in order to hedge against wage income. The corresponding stream of income is denoted A_t^s. As a result, all savers have identical consumption plans in equilibrium. 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.

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

[10]Following Smets and Wouters [2007], we assume that the income obtained from renting out capital services depends on the level of capital augmented for its utilization rate. Moreover, the cost of capacity utilization is zero when capacity is fully used ($\Phi(1) = 0$). The functional form for the adjustment costs on capacity utilization is $\Phi(X) = \frac{\overline{\overline{R^k}}}{\varphi} \left(\exp\left[\varphi \left(X - 1 \right) \right] - 1 \right)$.

In the following, we make use of the saver's and borrower's *user costs* of residential investment (the exact definition can also be found in the Appendix). The user cost indicators are driving the substitution effects between durable and non-durable goods for each household type. The aggregate user cost, denoted $R_D^{aggregate}$, is defined as the weighted average of the saver's and borrower's user costs.

2.3 Labor supply and wage setting

In both countries, households provide differentiated labor services. We assume that the fractions of patient and impatient agents are uniformly distributed across the range of labor services. As a consequence, on aggregate the total supply of a given labor service is identical across types. In each sector j $(j = C, D)$ a continuum of unions operate as monopolistic suppliers of the differentiated labor services. Every union represents workers of a certain type. For the sake of simplicity, we assume that unions sell their continuum of labor services (over the interval $[0, 1]$) to a perfectly competitive firm, which in turns transforms them into an aggregate labor input using the technology

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

where $\mu_w = \frac{\theta_w}{\theta_w - 1}$ and $\theta_w > 1$ is the elasticity of substitution between differentiated labor services. Therefore, in each sector j, union z faces a labor demand curve with constant elasticity of substitution $L_{j,t}(z) = \left(\frac{W_{,t}(z)}{W_t} \right)^{-\frac{\mu_w}{\mu_w - 1}} L_t^j$, where $W_t^j = \left(\int_0^1 W_{j,t}(z)^{\frac{1}{1-\mu_w}} \mathrm{d}z \right)^{1-\mu_{iw}}$ is the aggregate wage rate.

Unions set wages on a staggered basis. Every period, each union faces a constant probability $1 - \alpha_w^j$ 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:

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

where $\Pi_t = \frac{P_t}{P_{t-1}}$ and ξ_w^j denotes the degree of indexation in each sector. Taking into account that unions might not be able to choose their nominal wage optimally in the future, the optimal nominal wage $\widetilde{W}_{j,t}(z)$ is chosen to maximize the weighted average across households types of 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.

2.4 Investment decisions

The patient agents in each country own capital and rent it out to the intermediate goods-firms at the sector-specific rental rate $R_t^{k,j}$ $(j = C, D)$. Investment is constituted by the distributed non-residential good only. The savers choose the investment and capacity utilization in each sector to maximize their intertemporal utility, subject to the intertemporal budget constraint and the capital accumulation equation:

$$K_t^j = (1 - \delta_K) K_{t-1}^j + \varepsilon_t^I \left[1 - S\left(\frac{I_t^j}{I_{t-1}^j} \right) \right] I_t^j \tag{7}$$

where $\delta_K \in [0,1]$ is the depreciation rate of capital, S is a non-negative adjustment cost function formulated in terms of the gross rate of change in investment, I_t^j/I_{t-1}^j, and ε_t^I is an efficiency shock to the technology of capital accumulation, common to both sectors. The functional forms adopted are $S(x) = \phi/2\ (x-1)^2$ for country H and $S(x) = \phi^*/2\ (x-1)^2$ for country F, with ϕ and ϕ^* constant.

2.5 Distribution sector for non-residential goods

Non-residential goods in each country are produced by a continuum of companies that, operating under perfect competition, mix local production with imports. There is a home bias in aggregation, n, which pins down the degree of openness in steady state. The $\iota - th$ distributor technology, $\forall \iota \in [0,1]$, is given by

$$Y_\iota = \left[n_t^{\frac{1}{\xi}} Y_{\iota,H}^{\frac{\xi-1}{\xi}} + (1-n_t)^{\frac{1}{\xi}} Y_{\iota,F}^{\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

in the domestic country and

$$Y_\iota^* = \left[(1-n_t^*)^{\frac{1}{\xi}} Y_{\iota,H}^{*\ \frac{\xi-1}{\xi}} + n_t^{*\ \frac{1}{\xi}} Y_{\iota,F}^{*\ \frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

in the foreign country, with ξ denoting the elasticity of substitution between bundles Y_H and Y_F. The degrees of home bias are subject to shocks. As only the difference of openness rates enters the linearized aggregate equations in the absence of adjustment costs on imports, home bias shocks are given by $n_t = n\sqrt{\varepsilon_t^{\Delta n}}$ and $n_t^* = \frac{n}{\sqrt{\varepsilon_t^{\Delta n}}}$.

Cost minimization determines import demands:

$$\begin{aligned} Y_{H,t} &= n_t \left(T_{H,t}\right)^{-\xi} Y_t,\ Y_{F,t} = (1-n_t)\left(T_t\, T_{H,t}\right)^{-\xi} Y_t \\ Y_{F,t}^* &= n_t^* \left(T_{F,t}^*\right)^{-\xi} Y_t^*,\ Y_{H,t}^* = (1-n_t^*) \left(\frac{T_{F,t}^*}{T_t^*}\right)^{-\xi} Y_t^* \end{aligned} \tag{8}$$

Before-tax distribution prices are defined by:

$$\begin{aligned} \underline{P}_t &= \left[n_t P_{H,t}^{1-\xi} + (1-n_t) P_{F,t}^{1-\xi} \right]^{\frac{1}{1-\xi}} \\ \underline{P}_t^* &= \left[n_t^* P_{F,t}^{*1-\xi} + (1-n_t^*) P_{H,t}^{*1-\xi} \right]^{\frac{1}{1-\xi}} \end{aligned}$$

whereas $T_t = \frac{P_{F,t}}{P_{H,t}}$ and $T_t^* = \frac{P_{F,t}^*}{P_{H,t}^*}$ denote the interior terms of trade. We also make use of the relative prices $T_{H,t} = \frac{P_{H,t}}{\underline{P}_t}$ and $T_{F,t}^* = \frac{P_{F,t}^*}{\underline{P}_t^*}$.

2.6 Final non-residential goods sector

In country H, final producers for local sales and imports are in perfect competition and aggregate a continuum of differentiated intermediate products from home and foreign intermediate sector. Y_H and Y_F are sub-indexes of the continuum of differentiated goods produced respectively in country H and F. The elementary differentiated goods are imperfect substitutes with an elasticity of substitution denoted $\frac{\mu}{\mu-1}$. Final goods are produced with the following technology $Y_H = \left[\int_0^1 Y(h)^{\frac{1}{\mu}} \mathrm{d}h\right]^\mu$ and $Y_F =$

$\left[\int_0^1 Y(f)^{\frac{1}{\mu}} \mathrm{d}f\right]^{\mu}$. In the country F, the corresponding indexes are given by $Y_F^* = \left[\int_0^1 Y^*(f)^{\frac{1}{\mu}} \mathrm{d}f\right]^{\mu}$ and $Y_H^* = \left[\int_0^1 Y^*(h)^{\frac{1}{\mu}} \mathrm{d}h\right]^{\mu}$. For a domestic product h, we denote $p(h)$ its price on local market and $p^*(h)$ its price on the foreign import market. The domestic-demand-based price indexes associated with imports and local markets in both countries are defined as $P_H = \left[\int_0^1 p(h)^{\frac{1}{1-\mu}} \mathrm{d}h\right]^{1-\mu}$, $P_H^* = \left[\int_0^1 p^*(h)^{\frac{1}{1-\mu}} \mathrm{d}h\right]^{1-\mu}$, $P_F^* = \left[\int_0^1 p^*(f)^{\frac{1}{1-\mu}} \mathrm{d}f\right]^{1-\mu}$ and $P_F = \left[\int_0^1 p(f)^{\frac{1}{1-\mu}} \mathrm{d}f\right]^{1-\mu}$. Domestic demand is allocated across the differentiated goods as follows

$$\begin{cases} \forall h \in [0,1] \quad Y(h) = \left(\frac{p(h)}{P_H}\right)^{-\frac{\mu}{\mu-1}} Y_H, \quad Y^*(h) = \left(\frac{p^*(h)}{P_H^*}\right)^{-\frac{\mu}{\mu-1}} Y_H^* \\ \forall f \in [0,1] \quad Y(f) = \left(\frac{p(f)}{P_F}\right)^{-\frac{\mu}{\mu-1}} Y_F, \quad Y^*(f) = \left(\frac{p^*(f)}{P_F^*}\right)^{-\frac{\mu}{\mu-1}} Y_F^* \end{cases}$$

2.7 Intermediate non-residential firms

Intermediate goods producers are monopolistic competitors and produce differentiated products using a Cobb-Douglas mixing labour and capital services $\widetilde{K}_t(\bullet) = u_t(\bullet)K_t(\bullet)$:

$$\begin{cases} Y_t(h) = \varepsilon_t^A \left(u_t^C K_{t-1}^C(h)\right)^{\alpha_C} L_t^C(h)^{1-\alpha_C} - \Omega_C \qquad \forall h \in [0,1] \\ Y_t^*(f) = \varepsilon_t^A \left(u_t^{C*} K_{t-1}^{C*}(f)\right)^{\alpha_C} L_t^{C*}(f)^{1-\alpha_C} - \Omega_C^* \qquad \forall f \in [0,1] \end{cases}$$

where ε_t^A and ε_t^{A*} are exogenous technology parameters. Each firm sells its products both in the local and in the foreign market. We denote $Y_H(h)$ and $Y_H^*(h)$ (respectively $Y_F^*(f)$ and $Y_F(f)$) the local and foreign sales of domestic producer h (respectively foreign producer f) and we define $L_H^C(h)$ and $L_H^{C*}(h)$ (respectively $L_F^{C*}(f)$ and $L_F^C(f)$) the corresponding labor demand.

Local firms set prices on a staggered basis *à la* Calvo [1983]. In each period, a firm h (resp. f) faces a constant probability $1-\alpha_H$ (resp. $1-\alpha_F^*$) of being able to re-optimize its nominal price. The average duration of a rigidity period is then $\frac{1}{1-\alpha_H}$ (resp. $\frac{1}{1-\alpha_F^*}$). If a firm cannot re-optimize its price, the price evolves according to the following simple rule:

$$p_t(h) = \Pi_{H,t-1}^{\gamma_H} \overline{\Pi}^{1-\gamma_H} p_{t-1}(h)$$

with γ_H denoting price indexation.

Concerning exports, we assume that, in country H, a fraction η (respectively η^* in country F) of exporters exhibit producer-currency-pricing (PCP) while the remaining firms exhibit local-currency-pricing (LCP). Consequently, aggregate export prices denominated in foreign currency are given by

$$P_H^* = \left[\eta \left(\frac{P_{H,t}}{S_t}\right)^{\frac{1}{1-\mu}} + (1-\eta)\, \tilde{P}_H^{*\frac{1}{1-\mu}}\right]^{1-\mu}, \text{ and } P_F = \left[\eta^* \left(S_t P_{F,t}^*\right)^{\frac{1}{1-\mu}} + (1-\eta^*)\, \tilde{P}_F^{\frac{1}{1-\mu}}\right]^{1-\mu}.$$

The aggregate LCP export price indices are accordingly defined as

$$\tilde{P}_H^* = \left[\frac{1}{1-\eta} \int_\eta^1 p^*(h)^{\frac{1}{1-\mu}} dh\right]^{1-\mu}, \text{ and } \tilde{P}_F = \left[\frac{1}{1-\eta^*} \int_{\eta^*}^1 p(f)^{\frac{1}{1-\mu}} df\right]^{1-\mu}.$$

We define the following relative prices $R\tilde{E}R_H = \frac{S\tilde{P}_H^*}{P_H}$, $R\tilde{E}R_F = \frac{\tilde{P}_F}{SP_F^*}$ and $\tilde{T} = \frac{\tilde{P}_F}{P_H}$. Export margins relative to local sales are denoted $RER_H = \frac{SP_H^*}{P_H}$ and $RER_F = \frac{P_F}{SP_F^*}$. In the presence of international price discrimination, these ratios measure the relative profitability of foreign sales compared with the local ones. Finally, $RER_t = \frac{S_t P_t^*}{P_t}$ is the real exchange rate.

In modeling the firms' decision problem we follow closely Adjemian et al. [2008], to which the reader is referred for details and derivations.

2.8 Residential goods sectors

Final producers of residential goods operate in perfect competition and aggregate a continuum of differentiated domestic intermediate products. Final and intermediate residential goods are non-traded. The elementary differentiated goods are imperfect substitutes with elasticity of substitution denoted $\frac{\mu_D}{\mu_D - 1}$. Final goods are produced with the following technology $Z_D = \left[\int_0^1 Z_D(h)^{\frac{1}{\mu_D}} \mathrm{d}h\right]^{\mu_D}$. For a domestic product h, we denote $p_D(h)$ its price. The aggregate price index is defined as $P_D = \left[\int_0^1 p_D(h)^{\frac{1}{1-\mu_D}} \mathrm{d}h\right]^{1-\mu_D}$. Domestic demand is allocated across the differentiated goods as follows: $Z_D(h) = \left(\frac{p_D(h)}{P_D}\right)^{-\frac{\mu_D}{\mu_D - 1}} Z_D$.

Residential goods are produced by combining capital, labor and land. We assume that in every period of time the savers are endowed with a given amount of land, which they sell to the firms in a fixed quantity. We assume that the supply of land is exogenously fixed and that each residential goods intermediate firm takes the price of land as given in its decision problem. Producers make use of a Cobb-Douglas technology as follows:

$$\begin{cases} Z_{D,t}(h) = \varepsilon_t^{A_D} \left(u_t^D K_{t-1}^D(h)\right)^{\alpha_D} L_t^D(h)^{1-\alpha_D-\alpha_{\mathcal{L}}} \mathcal{L}(h)_t^{\alpha_{\mathcal{L}}} - \Omega_D & \forall h \in [0,1] \\ Z_{D,t}^*(f) = \varepsilon_t^{A_D *} \left(u_t^{D*} K_{t-1}^{D*}(f)\right)^{\alpha_D} L_t^{D*}(h)^{1-\alpha_D *-\alpha_{\mathcal{L}}*} \mathcal{L}^*(f)_t^{\alpha_{\mathcal{L}}*} - \Omega_D^* & \forall f \in [0,1] \end{cases}$$

where $\varepsilon_t^{A_D}$ and $\varepsilon_t^{A_D *}$ are exogenous technology parameters and $\mathcal{L}_t(h)$ denotes the endowment of land used by producer h at time t.

As in the non-residential sector, firms are monopolistic competitors. For local sales, firms set prices on a staggered basis à la Calvo [1983], with a constant probability $1 - \alpha_D$ of being able to re-optimize their nominal price. Indexation to past and steady-state inflation is allowed, in a similar way to the one discussed for the non-residential goods firms. If a firm cannot re-optimize its price, the price evolves according to the following simple rule:

$$p_{D,t}(h) = \Pi_{D,t-1}^{\gamma_D} \overline{\Pi}^{1-\gamma_D} p_{D,t-1}(h)$$

with γ_D denoting the degree of price indexation. We also include a time varying tax on firms' revenues which is affected by an iid shock: $1 - \tau_{Dt} = (1 - \overline{\overline{\tau_D}})\varepsilon_t^{P_D}$.

The details of the residential goods firms' problem are spelled out in the Appendix.

2.9 Government and monetary authority

In each country, public expenditures $\overline{\overline{G}}$ are subject to random shocks ε_t^G. The government finances public spending with labor tax, production and distribution taxes and lump-sum transfers.

Monetary policy is specified in terms of an interest rate rule targeting CPI inflation, detrended log-output and their first difference. In the benchmark specification, we do not include housing prices in the interest rate rules. Written in deviation from the steady state, the interest feedback rule used has the form:

$$r_t = \rho r_{t-1} + (1-\rho)\left(r_\pi \pi_{t-1} + r_y y_{t-1}\right) + r_{\Delta\pi}\left(\pi_t - \pi_{t-1}\right) + r_{\Delta y}\left(y_t - y_{t-1}\right) + \log\left(\varepsilon_t^R\right) \tag{9}$$

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

2.10 Market clearing conditions

Aggregate investment and capital stock are given by:

$$I_t^j = (1-\omega)\, I_t^{sj} \tag{10}$$

$$K_t^j = (1-\omega)\, K_t^{sj} \tag{11}$$

for $j = C, D$. Similar relations apply for country F.

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

$$Y_t = \omega \widetilde{C}_t + (1-\omega) C_t + I_t^C + I_t^D + \overline{\overline{G}}\varepsilon_t^G + \Phi\left(u_t^C\right) K_{t-1}^C + \Phi\left(u_t^D\right) K_{t-1}^D \tag{12}$$

$$Y_t^* = \omega^* \widetilde{C}_t^* + (1-\omega^*) C_t^* + I_t^{C*} + I_t^{D*} + \overline{\overline{G}}\varepsilon_t^{G*} + \Phi\left(u_t^{C*}\right) K_{t-1}^{C*} + \Phi\left(u_t^{D*}\right) K_{t-1}^{D*} \tag{13}$$

Aggregate non-residential productions satisfy:

$$Z_t = \varepsilon_t^A \left(u_t^C K_{t-1}^C\right)^{\alpha_C} \left(L_t^C\right)^{1-\alpha_C} - \Omega_C \tag{14}$$

$$Z_t^* = \varepsilon_t^{A*} \left(u_t^{C*} K_{t-1}^{C*}\right)^{\alpha_C} \left(L_t^{C*}\right)^{1-\alpha_C} - \Omega_C^* \tag{15}$$

Market clearing conditions in non-residential goods markets lead to the following relations:

$$Z_t = n_t \Delta_{H,t} \left(T_{H,t}\right)^{-\xi} Y_t + (1-n_t^*)\, \Delta_{H,t}^* \left(\frac{T_{F,t}^*}{T_t^*}\right)^{-\xi} Y_t^* \tag{16}$$

$$Z_t^* = n_t^* \Delta_{F,t}^* \left(T_{F,t}^*\right)^{-\xi} Y_t^* + (1-n_t)\, \Delta_{F,t} \left(T_t T_{H,t}\right)^{-\xi} \tag{17}$$

where $\Delta_{H,t} = \int_0^1 \left(\frac{p_t(h)}{P_{H,t}}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}h$, $\Delta_{H,t}^* = \int_0^1 \left(\frac{p_t^*(h)}{P_{H,t}^*}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}h$, $\Delta_{F,t}^* = \int_0^1 \left(\frac{p_t^*(f)}{P_{F,t}^*}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}f$ and $\Delta_{F,t} = \int_0^1 \left(\frac{p_t(f)}{P_{F,t}}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}f$ measure price dispersions among products of country H and F, either sold locally or exported.

Similarly, aggregate productions of residential goods read:

$$Z_{D,t} = \varepsilon_t^{A_D} \left(u_t^D K_{t-1}^D\right)^{\alpha_D} \left(L_t^D\right)_t^{1-\alpha_D-\alpha_{\mathcal{L}}} \mathcal{L}_t^{\alpha_{\mathcal{L}}} - \Omega_D \tag{18}$$

$$Z_{D,t}^* = \varepsilon_t^{A_D*} \left(u_t^{D*} K_{t-1}^{D*}\right)^{\alpha_D} \left(L_t^{D*}\right)_t^{1-\alpha_D-\alpha_{\mathcal{L}}} \mathcal{L}_t^{*\alpha_{\mathcal{L}}} - \Omega_D^* \tag{19}$$

Market clearing conditions for the residential markets are

$$Z_{D,t} = \Delta_{D,t} \left[\omega \left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}\right) + (1-\omega)\left(D_t - (1-\delta)D_{t-1}\right)\right] \tag{20}$$

$$Z_{D,t}^* = \Delta_{D,t}^* \left[\omega^* \left(\widetilde{D}_t^* - (1-\delta)\widetilde{D}_{t-1}^*\right) + (1-\omega^*)\left(D_t^* - (1-\delta)D_{t-1}^*\right)\right] \tag{21}$$

where $\Delta_{D,t} = \int_0^1 \left(\frac{p_{D,t}(h)}{P_{D,t}}\right)^{-\frac{\mu_D}{\mu_D-1}} \mathrm{d}h$ and $\Delta_{D,t}^* = \int_0^1 \left(\frac{p_{D,t}^*(h)}{P_{D,t}^*}\right)^{-\frac{\mu_D}{\mu_D-1}} \mathrm{d}h$ measure price dispersions among non-residential intermediate goods of country H and F.

Equilibrium in the bond markets implies that $B_{H,t}^* + B_{H,t} = \widetilde{B}_{H,t}$ and $B_{F,t} + B_{F,t}^* = \widetilde{B}_{F,t}^*$. Moreover, demand for bonds denominated in currency F issued by agents in country H is given by

$$\begin{aligned} \frac{S_t B_{F,t}}{\underline{P}_t R_t^*} - \frac{B_{H,t}^*}{\underline{P}_t R_t} &= \frac{S_t B_{F,t-1}}{\underline{P}_t} - \frac{B_{H,t-1}^*}{\underline{P}_t} \\ &+ T_{H,t} Y_{H,t} + \underline{RER}_t \frac{T_{F,t}^*}{T_t^*} Y_{H,t}^* - Y_t \end{aligned} \tag{22}$$

where $\underline{RER}_t$ is the real exchange rate measured with consumer prices net of consumption taxes.
The aggregate conditional welfare measures for each type of agent in each country are defined by $\mathcal{W}_{H,t}^B = \int_0^\omega \mathcal{W}_t^b \mathrm{d}b$ and $\mathcal{W}_{H,t}^S = \int_{1-\omega}^1 \mathcal{W}_t^s \mathrm{d}s$, and $\mathcal{W}_{F,t}^{B*} = \int_0^{\omega^*} \mathcal{W}_t^{b*} \mathrm{d}b$ and $\mathcal{W}_{F,t}^{S*} = \int_{1-\omega^*}^1 \mathcal{W}_t^{s*} \mathrm{d}s$, respectively.

3 Bayesian Estimation

The model is estimated on US and euro area data by means of Bayesian likelihood methods. For each country, we consider 11 key macroeconomic quarterly time series from 1981q1 to 2005q4 [11] : output, consumption, non-residential fixed investment, hours worked, real wages, GDP deflator inflation rate, CPI inflation rate, 3 month short-term interest rate, residential investment, real house prices and total household debt. We also introduce in the estimation the exchange rate and the US current account[12]. All variables are linearly detrended prior to estimation.

In the following, country H represents the US and country F, the euro area. Euro area parameters and shocks are therefore denoted with a *, in line with the model description of the previous section. We summarize here the exogenous stochastic shocks that we introduce:

[11] The choice of the estimation sample reflects the availability of housing sector data for the Euro Area.
[12] See Appendix for a detailed description of the dataset.

- Efficient shocks: technology (ε_t^A, ε_t^{A*}, $\varepsilon_t^{A_D}$, $\varepsilon_t^{A_D*}$), investment (ε_t^I, ε_t^{I*}), labor supply (ε_t^L, ε_t^{L*}), public expenditure (ε_t^G, ε_t^{G*}), consumption preferences (ε_t^B, ε_t^{B*}), housing preferences (ε_t^D, ε_t^{D*}), relative home bias ($\varepsilon_t^{\Delta n}$), loan-to-value ratio (ε_t^{LTV}, ε_t^{LTV*}).

- Inefficient shocks: PPI markups (ε_t^P, ε_t^{P*}), CPI markups (ε_t^{CPI}, ε_t^{CPI*}), external finance risk premium (ε_t^Q, ε_t^{Q*}), UIP ($\varepsilon_t^{\Delta S}$).

- Monetary policy shocks (ε_t^R, ε_t^{R*}).

We also allow for the existence of common factors on some specific shocks. The motivation relies on the two-country nature of the model, which is supposed to capture cross-country dynamics only, while leaving the interactions between the two regions and the rest of the world unexplained. However, shocks originating from the rest of the world, or unspecified spillovers cannot be ruled out ex ante. Therefore, we modify the shocks structure to account for additional sources of economic fluctuations. As a first step, we include possible common factors on productivity shocks in the non-residential sector (f_t^A), CPI markup shocks (f_t^{CPI}) and monetary policy shocks (f_t^R) [13].

In addition, like Adjemian et al. [2008], we introduce some correlations among structural shocks, to account for possible unmodelled spillovers. In particular, since we use US total net trade instead of bilateral net trade data in estimation, we introduce a correlation between the US home bias preference shock and the euro area public expenditure shock. Such correlation - denoted ρ_{n,G^*} - is meant to capture rest-of-the-world shocks that affect the US current account, with moderate immediate impact on euro area output. Moreover, considering the weak structural interpretation attributed to UIP shocks in a first-order approximation of the model, it seems justified to allow for links with other shocks. Hence, we include in the estimation some correlation terms between the UIP shock and other efficient shocks, in order to account for the impact of fundamental shocks on the time-varying risk premium. In particular, we consider correlations between the UIP shock and the US non-residential productivity shock ($\rho_{A,\Delta S}$) and between the UIP shock and government expenditure shocks in both areas ($\rho_{G,\Delta S}$) and ($\rho_{G^*,\Delta S}$). The presence of such terms helps the model generating the observed positive comovement between consumption and business investment.

3.1 Calibrated parameters

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

In particular, the discount factors are calibrated to 0.99 for the patient agents and 0.96 for the impatient agents[14]. The calibration is the same for the US and the Euro Area. The implied equilibrium real interest rate is 4% in annual terms[15]. The depreciation rate for housing, δ, is equal to 0.01, corresponding to

[13] The three common factors were selected on the basis of their significance in explaining macroeconomic fluctuations and the implied marginal data density.

[14] See e.g. Iacoviello [2005] and Iacoviello and Neri [2007] and Monacelli [2006] for a thorough discussion of the calibration of the discount factors in a similar setup.

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

an annual rate of 4%, whereas the depreciation rate of capital is set to 0.1. Markups are constant across countries and 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 in both countries. 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 relative shares of inputs in production are 0.3 for capital 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, and reduce the share of capital to 0.2, in order to maintain the level of labor intensity unchanged. Regarding nominal rigidities in the residential goods sector, we assume flexible prices as in Iacoviello and Neri [2007].

Finally, we calibrate the loan-to-value ratio (determined by the terms $(1-\chi)$ and $(1-\chi^*)$), to 0.8 in both areas. Although these two parameters could in principle be included in the estimation set, keeping them fixed - at the same level - helps focusing the attention on the estimation of the relative shares of borrowers (ω and ω^*). Moreover, existing empirical studies[16] document the presence of a substantial degree of heterogeneity within the euro area in terms of mortgage markets flexibility, with some countries as the Netherlands being close to the US, and others (e.g. Germany and Italy) displaying a much smaller degree of flexibility. The proposed calibration of χ^* thus provides an approximated average across European countries.

3.2 Prior distributions

Prior distributions of the structural parameters are assumed to be the same across countries, following a common practice in the literature[17]. The standard errors of the structural shocks are assumed to follow a Uniform distribution over the [0,6] interval[18], while the persistence parameters follow a Beta distribution with mean 0.5 and standard deviation 0.2. The UIP-correlations are normally distributed in the (0,1) interval, whereas the remaining correlation terms are uniformly distributed.

About the parameters of the monetary policy reaction function, we follow Smets and Wouters [2005]and Adjemian et al. [2008] 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 short-run response to inflation and output gap, the prior distributions are a Normal with mean 1.5 and standard deviation 0.25, and a Gamma with parameters 0.12 and 0.05, respectively. About preference parameters, the intertemporal elasticity of substitution, which is common to both household types, follows a Gamma distribution with mean 1 and standard deviation 0.375. The habit formation parameters are specific to savers and borrowers, following a Beta distribution with parameters 0.5 and 0.1. The elasticity of labor supply is the same for both household types and sectors, and has a Gamma(2, 0.75) prior distribution. On the production side, the adjustment cost parameter for investment and the capacity utilization elasticity, which are common to residential and non-residential sectors, follow re-

[16]See Calza et al. [2007].

[17]See, among others, Smets and Wouters [2005].

[18]Four shocks deviate from this assumption: ε_t^Q , which is uniformly distributed over $[0,20]$, ε_t^H and ε_t^{Q*}, which are $U[0,10]$, and ε_t^{I*} , which follows an Inverted Gamma $(0.5, Inf)$.

spectively a Normal(4, 1.5) and a Beta(0.5, 0.15) prior distributions. 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. The indexation parameters are instead centered around 0.5, with a standard deviation of 0.15. Finally, concerning the open economy parameters, we use fairly noninformative distributions for the elasticity of intratemporal substitution, the parameters related to the share of PCP producers, the degree of home bias in consumption and the elasticity of foreign exchange risk premium with respect to past exchange rate changes. The prior on the elasticity of the risk premium to net foreign assets is a Normal(1,0.25), the parameter being re-scaled by a factor 100.

The main estimated parameters driving the aggregate amount of credit frictions in both economies are the country-specific shares of impatient agents (ω and ω^*). In the benchmark estimation, the priors for those parameters are set as Beta distribution, with mean 0.35 and standard deviation 0.05. This choice is similar to the one of Iacoviello and Neri [2007]. 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. Given the crucial role of ω and ω^* in the model, we also investigate the fit of the model with alternative prior distributions. We return to this in the next section.

3.3 Posterior distributions

Table 1 reports the mode, the mean and the 10th and 90th percentiles of the posterior distribution of the structural parameters, obtained using the Metropolis - Hastings algorithm. Some of the results are similar to estimates found in the literature using similar models without housing sector for the US and the euro area (see for example Smets and Wouters [2005] or Adjemian et al. [2008]). We concentrate on the features which may be more closely related to our expanded modeling framework with respect to the sectoral structure of the economy and the heterogeneity of households' types.

Among the stochastic exogenous disturbances, the government expenditure, UIP risk premium and housing preference shocks have the highest estimated persistence. In particular, the estimated means for the autoregressive parameter of the housing preference shocks are 0.97 for the US and 0.99 for the Euro Area. Such a high estimated degree of persistence suggests that the process will tend to explain a lot of the long horizon forecast error variance of the real variables. In general, the housing sector processes display a high persistence, as the estimated values for ρ_{AD}, ρ_{LTV} and ρ_H all lie above 0.93 in both countries.

About the behavioral parameters, the intertemporal elasticity of substitution, σ_C, is well below the prior mean: the estimated posterior means are in fact 0.64 for the U.S. and 1.06 for the Euro Area. The habit persistence parameters (h_B and h_S, respectively) indicate a much lower degree of persistence in the consumption plans of the borrowers, as opposed to the savers, in both areas. The estimated degrees of price stickiness in the non-residential goods sector are generally higher than the prior mean (0.75), and in particular the estimates are higher in the Euro Area than in the U.S., confirming a result reported in Smets and Wouters [2005] and Adjemian et al. [2008]. In the benchmark estimation, residential property prices are specified as flexible. This assumption is supported by estimations of Calvo parameters for the residential goods price setting very close to zero in both countries (results not reported here). Given such low levels of nominal rigidities, we preferred to keep the flexible price assumption. Wages are estimated to be slightly more flexible in the Euro Area, both in the non-residential and in the residential sector. All the indexation parameters, however, seem to be poorly identified, as indicated by the similarity of prior and posterior distributions.

Regarding open economy parameters, results in the benchmark model are broadly similar to the ones of Adjemian et al. [2008], with nonetheless a lower estimate for the trade elasticity. Finally, about the monetary policy reaction function, the baseline estimates tend to suggest that monetary policy reacted relatively more strongly to inflation in the U.S. than in the Euro Area over the estimation sample. Interest rate smoothing was also more pronounced in the Euro Area.

We turn now to the parameters capturing the share of borrowers in each economy (ω and ω^*). In the baseline specification, the estimated posterior modes are 0.24 and 0.19, respectively for the US and the euro area. Those values are below the prior mean which is set at 0.25. The shape of the posterior distributions suggests that data are not very informative on this direction. We conduct some sensitivity analysis on the prior distributions for those parameters. Table 4 reports the estimates obtained when the prior distributions for ω and ω^* are shifted towards a mean of 0.5. In this case the estimated posterior modes are 0.46 and 0.42, respectively. Again, a look at prior and posterior distributions suggests a lack of information from the data. We also estimated the model using uniform priors which led to posterior values for the shares around 5% (estimation not reported here). Note that, even with uninformative priors, the estimation does not set the share of borrowers to 0, which would be possible in our parametric setting. In terms of marginal log-data density, it reaches -2485.19 for the benchmark specification, compared to -2509.115 with the high share priors and -2478.3 with the uniform priors.

Overall, our results suggests that ω and ω^* are not strongly identified given the dataset used. The presence of borrowers does not seem to be rejected given that 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. A possible explanation for such a weak identification is linked to the informational content of the observable variables as opposed to the model-generated series. Although the model defines individual consumption plans for borrowers and savers, in practice only aggregate consumption data are observable in each sector, for a given country. Therefore, it is difficult to extract information on individual characteristics - such as habit persistence in consumption, or the relative weight of patient and impatient agents in the group of consumers - from aggregate data. Consequently, the prior distributions will have a substantial impact on the posterior estimates and should be carefully chosen based on economic information which may not be adequately reflected in the dataset. Even if it deteriorates the marginal data density, we privileged priors for the benchmark estimation which are similar to Iacoviello and Neri [2007] and seem satisfying in terms of steady state aggregate levels of households' debt compared to GDP.

3.4 Second order moments

Table 5 compares some selected second-order moments implied by the estimated model with the corresponding moments measured in the data. We use both linearly detrended and HP-filtered data [19].

The volatilities of US residential and business investment are slightly underestimated in the model with respect to the data. In the euro area, the estimated standard deviation of residential investment is higher than the observed one, whereas the volatilities of house prices and business investment are lower. About the open economy variables, the estimates tend to overweight the volatility of the exchange rate and underweight the volatility of the current account. Overall, we obtain a better match between the data and the estimated model when we use HP-filtered series.

In terms of real variables comovement, we match the sign of almost all correlations. In particular, we replicate the negative comovement between the exchange rate and the current account, and the negative correlation between *relative* consumption and the real exchange rate, thus accounting for the *consumption-real exchange rate anomaly* (see Chari et al. [2002]). Our general setup, including various types of shocks, thus appears to be more appropriate than standard stylized NOEM models in generating such an observed feature of the data. Given our set of common shocks across countries, the cross-country correlation of output is positive in the model but lower than in the data. The measured comovement of consumption in the data is not robust to the filtering method nor to slight modifications in the sample length, but it seems that the model generates too low correlation. The presence of common trends in the exogenous shocks to non-residential goods productivity, monetary policy and CPI helps the model generating enough cross-country spillovers, which are reflected into small but positive international correlations in real activity.

Turning now to the housing variables, the correlations of consumption and residential investment with real house prices are qualitatively reproduced by the model, albeit on the low side concerning consumption. However, the correlations of consumption and aggregate output with residential investment generated by the model are substantially below the sample ones. This may suggest the introduction of some common shocks across sectors like government spending or productivity. Regarding the cross-country correlations of housing prices and residential investment, some attention should be paid regarding the measurement of international comovement in the housing sector data. On the full sample, the comovement of residential investment is negative when we use detrended data but positive with HP filtering. For real housing prices, the correlation is positive and lower with HP filtering than with detrending. Against this background, the model implies almost no correlation for both housing prices and residential investment. Given the uncertainty about the *true* evidence to match, it is important to identify the type of structural disturbances which can allow for either positive or negative cross-country correlations. This issue we will be touched upon in the next section.

Indeed, although the full-sample cross-country correlation of house prices is positive, the comovement

[19] More precisely, the different sepcifications of the model are all estimated on linearly detrended data. When reporting second-order moments, we filter the model statistics using linear detrending and HP filter, respectively. Columns 2 to 4 and 5 to 8 in Table 5 thus compare model-generated moments with the data, using the same filtering procedure.

becomes negative if we exclude the period 1998 q1: 2005 q4. During such period in fact, house prices in both countries show some clear evidence of a higher local trend, which a simple linear detrending procedure cannot completely offset. Over the same period, residential investment also shows signs of a trend, especially in the US. Therefore, when we rely on the most stable part of our dataset, we can infer that a negative international comovement is actually observed in the data for both house prices and residential investment. All in all, it is very likely that the size of our sample is not large enough to capture the unconditional second order moments of housing data given the considerable length of cyclical fluctuations in the housing sector. The dataset may actually only cover two medium-term housing cycles.

A final consideration regards the implications of stronger credit frictions in terms of simulated moments. Table 5 also presents the outcome from the estimated model with high priors on the shares of borrowers whose posterior parameter estimates are reported in Table 4. The High Borrower specification seems to improve upon the benchmark model in several dimensions. First, the domestic correlations between consumption and housing variables are slightly higher. Moreover, the cross-country correlations of consumption, and to a lesser extent, housing variables increase marginally.

4 Credit frictions and the international business cycle

In this section, we provide a positive analysis of the role played by housing market functioning on the transmission mechanism of macroeconomic disturbances and as a source of economic fluctuations. The impulse response functions analyzed here are based on the benchmark estimated model. On a systematic basis, the effect of credit frictions are illustrated by comparing the outcome of the benchmark model to the one obtained by assuming either that borrowers are absent, or that their share in the economy corresponds to the High Borrower case. In the following, we first examine the contribution of housing shocks to business cycle fluctuations. Then, the sensitivity of macroeconomic propagation to the presence of financially constrained consumers is explored in detail.

4.1 Contribution of housing shocks to economic fluctuations

Table 6 presents the unconditional variance decomposition of the macroeconomic variables, emphasizing the contribution of housing-related structural shocks. The aggregate role of housing shocks (both on the supply side, as in the case of technology and LTV-ratio shocks, and on the demand side, as for the housing preference shock) is particularly relevant in explaining the dynamics of housing production and house prices, for which those shocks explain around 90% of the variance. Housing preference shocks are the main determinants of real house price fluctuations while they have a more limited role and contribute less than sector-specific productivity shocks in explaining residential investment. Concerning household debt in the two areas, housing preference and loan-to-value ratio (LTV) shocks generate more than 75% of volatility. This reflects the model mechanics, with the borrowers adjusting very sharply and immediately to shocks that directly impact the collateral constraint. This is obviously the case for LTV shocks, as well as housing preference shocks, through their sizeable influence on real housing prices. Overall, the relative flexibility of house prices allows for significant adjustments in the face of sectoral shocks.

On the non-residential goods sector, the spillovers of housing-related shocks are moderate. Housing preference shocks explain around 5% and 3% of consumption volatility in the euro area and the US respectively, while the contribution of LTV shocks and productivity shocks is lower. Regarding other domestic variables, a relevant feature concerns the effects of housing preference shocks on CPI inflation and nominal interest rate fluctuations, which are ranging between 5 and 10% in the euro area. Such results are related to the higher persistence of the shock for the euro area as shown in the previous subsection.

Turning to the open economy dimension, housing shocks are essentially affecting a non-tradable sector with flexible prices. Consequently, with interest rate feedback rules targeting non-residential inflation rate, both the direct trade channel and the scope for exchange rate adjustment in the cross-country propagation of housing shocks are relatively muted compared with disturbances originating from the tradable sector. Regarding more specifically the international spillovers on activity, the role of housing shocks is indeed quite limited. Beyond this, note that the estimated model implies a relatively low transmission of domestic shocks across countries[20].

In order to explore the sensitivity of the structural decomposition of business cycle fluctuations to the amount of credit frictions in the economy, Table 7 replicates the previous exercise by setting first the share of borrowers to zero in both countries, and second by fixing them at their estimated values obtained for the High Borrower case in Table 4. We observe first that the structural decomposition of house price and residential investment fluctuations are hardly affected by the size of credit-constrained consumers in the economy. Therefore, the main implications of varying the borrowers' shares can be analyzed through the aggregate substitution effect between residential and non-residential goods, which guides the magnitude of the macroeconomic transmission to consumption and non-residential investment, for a given impact on the price and quantities in the residential sector. The main variable affected is household consumption: the contribution of housing-related shocks reaches 23% in the US and 17% in the euro area with high shares of borrowers, against less than 1% when borrowers are absent. Aggregate output is also more sensitive to housing shocks when stronger credit frictions are activated.

4.2 The propagation of non housing-related shocks

We concentrate now on the propagation of some selected shocks, not directly related to the housing market. For the sake of simplicity, we focus on the transmission of US shocks.

4.2.1 Monetary policy shock

The impulse response are presented in Figure 1. An increase in the short-term interest rate reduces domestic demand in both sectors and generates a contraction of output. The combination of higher interest rates and lower house prices leads the borrowers to reduce debt, thus amplifying the negative effect of the shock on aggregate consumption and output. Noticeably, the reduction in the inflation rate,

[20] A limited role for cross-country spillovers is a usual result in the literature (see Adjemian et al. [2008] among others).

brought about by the weakening of economic activity, is detrimental to the borrowers, since it increases the ex-post value of existing debt. As a result, the monetary shock becomes more contractionary when the share of borrowers in the economy increases. The rise in the interest rate induces an exchange rate appreciation. On balance, the current account deteriorates. The US monetary contraction produces a positive spillover effect on foreign aggregate output. The exchange rate adjustment together with monetary policy tightening in the euro area generates substantial substitution effects away from residential investment and domestic demand for tradable goods.

Absent the possibility of borrowing (i.e. when $\omega = \omega^* = 0$), the monetary transmission mechanism only works through nominal rigidities, as in a standard NOEM model. Without the collateral channel, the impact response of domestic consumption and output is significantly weaker. The interest rate increase is still sufficient to generate an exchange rate appreciation. The resulting adjustment in net imports implies a larger positive spillover on foreign output with respect to the baseline case.

4.2.2 Labor supply shock

We consider now a labor supply shock (see Figure 2) as a paradigmatic example of a supply shock that symmetrically hits both sectors of production[21]. An increase in labor supply in both sectors generates downward pressures on real wages, which gradually lead to higher labour demand. Inflation falls below baseline due to a fall in the real marginal cost and monetary policy accommodates the supply shock. Production increases in both sectors, with house prices featuring a hump-shaped response. The impact on aggregate consumption is quite sensitive to the share of borrowers in the economy: individual responses to the shock are in fact very different. The response of the savers is standard: a labor supply shock generates an increase in consumption - via the intratemporal optimal trade-off between consumption and labor. Noticeably, the increase in house prices drives the savers' user cost of residential investment up[22], implying a substitution effect in favor of non-residential consumption. On the other hand, the borrowers respond to a negative labour income shock in the short term by reducing their present consumption of both goods, as they do not smooth consumption intertemporally. As a consequence, debt decreases, despite the potentially positive incentive to borrow generated by higher house prices and lower interest rates. Aggregate consumption will therefore reflect more one behavior or the other, depending on the relative weights attached to the individual responses. With higher borrowers' share, the substitution effects away from non-residential consumption towards residential investment are amplified, as shown by the lower aggregate user cost of housing, which accentuates the downward pressures on inflation and the extend of policy accommodation.

The exchange rate depreciates, driven by the fall in the interest rate. The expenditure - switching effect dominates and the current account experiences a surplus. As a result, a negative spillover is generated on foreign output, whereas domestic demand and residential investment in the euro area both rise as more goods are imported at lower prices and lower interest rate boosts durable goods expenditures. Foreign private debt also increases, as a result of both higher house prices and a lower interest rate.

[21]The stochastic structure of the model also includes two sector-specific productivity shocks, which however have very different effects because of the different degrees of nominal rigidities in the two sectors.

[22]The definition of the saver's (and the borrower's) user cost of residential investment is given in the Appendix.

The specific role of the borrowers is quite intuitive. Increasing their share generates a negative impact response of consumption to the shock, thus calling for a sharper reduction in the interest rate. The exchange rate in turn depreciates more and the negative spillover on foreign output is more pronounced. Conversely, absent the borrowers, the reverse holds true: domestic consumption increases more (reflecting the savers' decisions), the short-term interest rate decreases by a smaller amount, causing a reduced depreciation and generating a smaller spillover on foreign output.

4.2.3 Government spending shock

A positive shock to government expenditure (which by assumption only refers to the non-residential goods sector) generates very different responses across the two groups of agents (see Figure 3). The savers, behaving as standard consumption smoothers, perceive the negative wealth effect associated with an increase in the expected future stream of taxes and thus reduce their current consumption. Ricardian equivalence holds true for them. The borrowers instead act as non-smoothing consumers, so an increase in current income - generated by higher government expenditure - fosters higher consumption of both goods. However, debt falls on impact and remains negative for some periods, due to lower house prices and a higher interest rate[23].

The impact response of aggregate consumption deserves some attention. Two factors interplay to determine consumption dynamics. Increasing the share of borrowers emphasizes the positive income effect of higher government expenditure, and mutes the negative wealth effect. Nominal rigidities also play a role. In the goods market, price stickiness in the non-residential sector implies that firms tend to respond to the increase in aggregate demand by shifting up labor demand. However, nominal wage rigidity does not allow for significant increases in wage income. Conversely, absent nominal rigidities in the labor market, wages would adjust upwards to the shift in labor demand and provide additional income to both agents. As a result, consumption would decrease by less. Interestingly, the combination of flexible wages and a high share of borrowers would suffice to generate a positive response of consumption to a government expenditure shock. With the benchmark calibration, a positive consumption response is obtained for a borrower share of around 75%.

Turning to the open-economy effects of the shock, the increase in the interest rate (in response to higher aggregate demand) implies an exchange rate appreciation and a current account deficit, as both relative output and relative price effects worsen the external position. A positive spillover effect is generated on foreign output (with a multiplier of around 0.2), via the change in the terms of trade. Here again, the exchange rate adjustment together with higher interest rate dampen foreign residential investment, real house prices and domestic demand for tradable goods. Noticeably, the response of foreign consumption is a more negative effect the lower the share of borrowers in the domestic economy.

[23]The fall in house prices follows from the sector-specific nature of the government expenditure shock, which is assumed to refer to the non-residential sector only. Therefore, the relative demand for housing falls.

4.2.4 UIP shock

The UIP shock - defined as a risk premium shock in the modified UIP condition - causes a strong nominal exchange rate appreciation and a current account deterioration (see Figure 4). The interest rate decreases in the Home country, whereas it increases by almost the same magnitude in the Foreign country. Domestic demand increases in both sectors, while output decreases, reflecting a fall in net exports. Inflation is correspondingly lower in the Home country and higher in the Foreign economy. In particular, domestic household debt jumps on impact. The combined effect of higher house prices and a lower interest rate offsets in fact the negative impact of lower CPI inflation on the borrowers' balance sheets. The opposite holds true in the Foreign country, where household debt falls. As the shock directly hits the interest rate, the effects of varying the share of borrowers are mainly concentrated on the response of consumption. Absent the borrowers, the partial offsetting effect of lower inflation on consumption is eliminated, and the demand for nonresidential goods is correspondingly higher. Again, the opposite effect is observed in the Foreign country, where consumption falls more.

4.3 The propagation role of housing shocks

4.3.1 Housing preference shock

A housing preference shock is defined here as an exogenous stochastic perturbation to the marginal rate of substitution between non-residential and residential consumption in the utility function of each agent. A positive housing preference shock thus generates a surge in housing demand and house prices (see Figures 5 and 6). Both effects are quite persistent over time, so that prices and quantities are still well above their steady state value after 20 quarters. The most interesting effect concerns the impact response of consumption, which is positive and increasing in the share of borrowers in the economy. The positive response of aggregate consumption is due to the *collateral channel*: by issuing more debt - made possible by the positive valuation effect of higher house prices on the existing collateral - the borrowers can finance extra consumption, thus consuming immediately more. Monetary policy responds to a generalized increase in domestic demand by raising the interest rate, which in turn causes an exchange rate appreciation. The current account deteriorates by a small amount on impact and the excess domestic demand in the source country leads to a positive effect on foreign output. The size of this spillover ranges between 0.05 and 0.1 which is, as expected, less than the multipliers emanating from demand shocks on the tradable sector. The exchange rate adjustment coupled with a monetary policy tightening induces in the foreign country a broad substitution effect away from nonresidential and domestically produced residential goods. As a result, house prices and residential investment fall below baseline in the foreign country.

All the above-mentioned effects are amplified when the share of borrowers increases: the amplification reflects notably the mechanical aggregation effect across the two different groups of consumers. Without borrowing instead, the response of domestic consumption to the housing preference shock is muted. Intuitively, without impatient households, there is no positive effect of higher house prices on consumption, because there is no collateral to be affected. The increase in house prices generates a higher user cost of housing for the savers (who now represent the entire group of households in the economy) and calls for a substitution from residential investment to consumption. However, the overall increase in domestic aggregate demand is lower than in the presence of borrowers. The required increase in the interest rate is therefore much smaller, and so is the exchange rate appreciation. The effect on the current account is also reduced, so that the spillover on foreign output falls by a half relative to the baseline case.

4.3.2 Housing technology shock

A positive productivity shock in the residential sector generates a sharp and persistent reduction in house prices, which are more flexible than nonresidential goods prices (see Figures 7 and 8). Intuitively, firms in the housing sector can almost fully exploit the technology improvement by adjusting prices and quantities in opposite directions. Residential investment indeed increases significantly on impact, with a persistent effect. The behavior of domestic demand follows from the individual responses to the shock. For the savers, an increase in housing supply, accompanied by a reduction in prices, generates a higher demand for residential investment. Moreover, the decrease in house prices lowers the savers' user cost of housing, generating a substitution effect from nonresidential to residential goods. Wage income also increases for the savers, who are accommodating the increase in labor demand in the residential-goods sector through the provision of more labor supply. The reverse holds true for the borrowers. A sustained decrease in house prices induces a negative *valuation effect* on the existing collateral, making borrowing more costly. As a result, the borrowers demand less of both goods compared with the savers, and debt decreases on impact in the source country. In addition, the borrowers have a stronger incentive to substitute residential investment for consumption goods in order to relax their collateral constraint. The resulting negative aggregate effect on consumption reduces CPI inflation, while aggregate output increases slightly.

Turning to the open-economy dimension, the transmission crucially depends on the response of monetary policy to aggregate demand. In the benchmark case, aggregate demand increases - reflecting the large increase in housing demand which offsets the fall in consumption - and inflation falls. The central bank responds by raising the interest rate. As a result, the exchange rate appreciates. The effect on the current account is very close to zero, and a very small positive spillover is generated on foreign output. Foreign demand for domestically-produced goods falls, as well as house prices and debt.

Increasing the share of borrowers in the Home country reinforces the substitution effect in favor of residential goods (as portrayed by a lower aggregate user cost of housing), which dampens the initial response of aggregate consumption. Aggregate output also falls below its steady state level in the first quarter after the shock. Given the downward pressures on consumer prices, monetary policy responds by *decreasing* the nominal interest rate, and the exchange rate appreciation is reduced by one half with respect to the baseline case. The current account now improves more, and a marginal negative spillover is generated on foreign output, with a small but positive substitution effect from the nonresidential to the residential goods sector. Conversely, setting the share of borrowers to zero increases Home output, and calls for an *increase* in the nominal interest rate. The exchange rate appreciation becomes larger than in the benchmark case, the current account now deteriorates, and the the positive spillover on Foreign output is stronger.

4.3.3 Loan-to-value ratio shock

A positive shock to the LTV ratio corresponds to an exogenous, temporary increase in the availability of funds to the borrowers in the domestic economy (see Figures 9 and 10). The borrowers thus demand more of both goods, driving house prices up. In particular, the relative flexibility of prices in the housing sector originates a sharp and sustained increase in house prices, whereas consumption-goods inflation moves slowly, due to nominal rigidities. Debt increases, fostered by the positive valuation effect of higher house prices on the existing collateral, and by the exogenous increase in the LTV ratio. The rise in house prices increases the user cost of housing for the savers and generates a substitution effect from residential investment to consumption. The increase in inflation calls for an interest rate rise. As a consequence, the exchange rate appreciates on impact and the current account deteriorates in the short term. However, the initial exchange rate appreciation is rapidly followed by a depreciation of a similar magnitude. The LTV shock generates a positive spillover on foreign output. The size of the spillover on economic activity is however smaller compared with the housing preference shocks notably due to a more moderate exchange rate adjustment. A broad substitution effect is observed in the Foreign economy, away from residential goods and domestically produced non-residential goods.

An increase in the share of borrowers reinforces the collateral channel in the Home country[24] . Demand and prices increase more in both sectors, thus requiring a stronger response of monetary policy to inflation. The exchange rate swings are more pronounced, and all of the previously described spillover effects on the Foreign country are amplified.

4.4 Summing up

This section has provided a detailed description of the internal propagation mechanism of the model, with a special focus on the role played by housing markets and collateral constraints. Overall, the presence of credit frictions has the effect of altering the relative responses of aggregate consumption and non-residential investment to exogenous shocks. More precisely, moving the share of borrowers is implicitly equivalent to attributing more or less importance to credit constraints and thus influences the propagation of standard demand and supply shocks. In the case of a government expenditure shock, for instance, increasing the share of borrowers implies less negative (eventually positive) effects on aggregate consumption, but at the same time generates a larger crowding out effect on private non-residential investment. The introduction of housing-specific shocks generates nontrivial dynamics. In particular, housing preference and loan-to-value ratio shocks are based on the *collateral channel*, and determine an immediate increase in household debt. The impact on aggregate consumption and investment are thus both positively influenced by an increase in the share of borrowers.

The housing sector plays a special role in the model, due to its dual nature of flexible-price, non-traded goods producing sector. On the one hand, prices and quantities are free to adjust almost instantaneously

[24]Clearly, we do not consider the case of no borrowers, which would imply the absence of a debt channel, and prevent the existence of any LTV-ratio shocks.

to external shocks, so that impact responses are usually large. On the other hand, as the residential investment good is non-traded, sectoral shocks typically generate very small, indirect spillover effects on foreign country variables. The residential sector is therefore somewhat unaffected by shifts in the share of borrowers: the impact responses of prices and quantities are large enough that varying the size of the borrowers' group only marginally affects the overall adjustment. Nonetheless, structural housing-related shocks generate significant spillovers to non-residential consumption through the collateral channel and therefore the share of borrowers in the economy.

Turning to the open economy dimension, the housing-related shocks expand the dynamic correlation properties of the model which may help capturing important features of the dataset. In particular, there is evidence that the cross-country comovement of residential investment and house prices may have been negative over extended period of time. The traditional "closed economy" set of non-housing related shocks generally induces positive correlation in both house prices and residential investment across countries. Only open economy shocks like foreign exchange risk premium or relative home bias disturbances generate strong asymmetric responses for most of the variables across countries. The introduction of housing shocks turns out to be helpful on this dimension. While housing technology shocks require a large share of borrowers in order to generate a negative correlation between home and foreign residential investment, the same result is obtained in the baseline estimation for housing preference, and to a lesser extent, loan-to-value ratio shocks. More specifically, the increase in domestic demand induced by larger borrowing leads to an interest rate raise and an exchange rate appreciation. Exports of non-residential goods increase; in the Foreign country the increase in the interest rate reduces the demand for residential investment, which in turn drives house prices down. Housing preference shocks can thus reproduce sizeable negative international comovement in residential investment.

5 Monetary policy and housing prices

In this section, we examine the relationship between monetary policy and house prices along two dimensions. First, we evaluate whether the historical policy conduct for the US and the euro area features a specific response to house prices. Second, we compare the macroeconomic transmission of housing shocks under the estimated Taylor rules to the one generated by optimal monetary policy cooperation. An in depth analysis of the normative prescriptions that could be derived from our rich modeling framework is beyond the scope of the present paper.

5.1 The macroeconomic allocation with augmented Taylor rule specifications

We review here the main properties of the estimated model with augmented Taylor rules, i.e. when relative house price changes are added as policy target variables in the interest rate feedback rules for the US and the euro area. Thereafter, we comment on the empirical performance of such alternative specifications as well as on the implications for the macroeconomic propagation of shocks and the sources of business cycle fluctuations.

The last three columns of Table 4 report the results obtained once we allow monetary policy to respond to variations in house price inflation. The modified Taylor rule reads:

$$r_t = \rho r_{t-1} + r_{\Delta\pi}(\pi_t - \pi_{t-1}) + (1-\rho)(r_\pi \pi_{t-1} + r_y y_{t-1}) + r_{\Delta_y}\Delta y_t + r_{\Delta T_D}\Delta t_{D,t} + \log(\varepsilon_t^R) \qquad (23)$$

We use a N(0,0.5) prior distribution for the parameters $r_{\Delta T_D}$ and $r^*_{\Delta T_D}$, in order to allow for both positive and negative responses to house price inflation. The corresponding estimated posterior modes are 0.10 in the US and 0.17 in the euro area, respectively. Both central banks thus mildly increase the interest rate in response to positive housing inflation rates. The estimated posterior modes for the remaining parameters in the rule do not significantly change in the modified specification, with the only exception of r^*_π, which increases from 0.84 to 1.47. Several studies have indeed documented the weak identification of the inflation level term in the policy rule, whose inference proves not to be robust to slight changes in priors or rule specification (see Adjemian et al. [2007] or Adjemian et al. [2008] for example).

Interestingly, the inclusion of these two additional coefficients in the estimation set largely improves the fit of the model: the log marginal density increases from -2485.19 in the benchmark specification to -2450.12 in the augmented-rule case. We could therefore conclude that a more accurate historical description of monetary policy in the US and the euro area - over the estimation sample, at least - should include a systematic response to house price inflation.

Beyond marginal data density comparison, we assess the model's ability to replicate the selected second moments reported in Table 5: along this dimension, the augmented Taylor rule model does not provide a strong departure from the patterns obtained in the benchmark case. At the margin, the augmented Taylor rule model reduces the correlation between non-residential consumption and real house prices compared with the benchmark case, notably for the US, which may be less in line with data. At the same time, regarding the root mean square errors, evaluated in sample, the augmented Taylor rule model provides some improvements on most of the variables, in particular on real quantities (results not reported here).

Some further observations concern the historical role of housing preference shocks in explaining business cycle fluctuations. Augmenting the monetary policy rule has two main consequences (results not reported here). First, it is immediate to note that housing preference shocks account for a larger fraction of the policy rate volatility. The interest rate in fact is now allowed to endogenously respond to fluctuations in house prices, which in turn are mainly driven by housing preference shocks in the model. Fluctuations in the policy rate will thus partly reflect the need to counteract the effect of inflationary demand shocks in the housing sector. Second, and related to the previous point, housing preference shocks explain much less of residential investment volatility, and to a lesser extent, of real house price fluctuations. The effect is robust across countries. In the benchmark specification, a positive demand shock in the housing sector - which moves residential investment and house prices in the same direction - has a large and significant effect on residential investment. When monetary policy is allowed to respond to housing inflation, the interest rate will move up in response to a positive demand shock. As a consequence, the cost of borrowing will increase, dampening the initial increase in the demand for housing. Overall, residential investment will fluctuate less in response to movements in prices when the central bank is more reactive. Real house price fluctuations will be reduced as well by the counteracting effect of the monetary tightening.

Both effects are immediately recognized by looking at the impulse response functions associated to a housing preference shock, reported in Figure 11. When monetary policy responds to housing inflation, a larger increase in the policy rate is required in response to the shock. The tightening reduces the initial increase in house prices and partially counterbalances the surge in residential investment. Moreover, the overall effect on non-residential consumption becomes negative, for the amplified increase in the interest rate neutralizes the positive collateral effect on consumption.

Summing up, it seems that, given our structural description of the housing market functioning, some degree of systematic response to house price inflation in the historical monetary policy conduct for the US and the Euro Area is supported by the data. Such a specification of monetary policy rules however would not generate a positive response of nonresidential consumption after a housing preference shock.

5.2 The optimal monetary policy response to housing shocks

To derive the international monetary policy coordination we proceed as Adjemian et al. [2008]: The Ramsey approach to optimal monetary policy cooperation is computed by formulating an infinite-horizon Lagrangian problem of maximizing the conditional expected social welfare subject to the full set of non-linear constraints forming the competitive equilibrium of the model. The first order conditions to this problem are obtained using symbolic Matlab procedures.

Since we are mainly interested in comparing the macroeconomic stabilization performances of different monetary policy regimes within a medium scale open economy framework including a wide set of shocks and frictions, we assume a fiscal intervention, namely subsidies on labor and goods markets, to offset the first order distortions caused by the presence of monopolistic competition in the markets. From an operational perspective, we have to face the issue that the zero lower bound is an occasionally binding constraint. To avoid high probabilities of hitting the zero bound under the Ramsey allocation, we thus follow Woodford [2003] by introducing in the households welfare for each country a quadratic term penalizing the variance of the nominal interest rate:

$$\mathcal{W}_{H,t}^{R} = \mathcal{W}_{H,t}^{B} + \mathcal{W}_{H,t}^{S} + \lambda_R \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(R_{t+j} - R^{\star}\right)^2$$

$$\mathcal{W}_{F,t}^{R} = \mathcal{W}_{F,t}^{B*} + \mathcal{W}_{F,t}^{S*} + \lambda_R^{*} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(R_{t+j}^{*} - R^{\star}\right)^2$$

where λ_R and λ_R^* are the weights attached to the cost on nominal interest rate fluctuations. Instead of fixing this parameter to match a particular value of the probability to hit the zero bound, we pragmatically choose calibration of those parameters so that, under the operational optimal monetary policy coordination, the unconditional variance of the nominal interest rates are close to the ones obtained with the estimated rules. The penalty needed to achieve those standard deviations is substantially higher in the US than in the euro area. Under this assumption, the probability to hit the zero bound is reasonably low, even for a zero steady state inflation which implies that the steady state real rate is more than three times the standard deviation of the interest rate. Note that with the indexation schemes introduced in the price and wage settings, the Ramsey steady state is consistent with any level of inflation rate.

Compared with Adjemian et al. [2008], the introduction of a housing sector and patient households facing financial constraints brings several important dimensions to the analysis of optimal monetary policy cooperation. On the supply side, monetary policy has to face policy tradeoffs from the sector dimensions of the economy which are compounded by the nominal rigidities on the wage setting (see for example Aoki [2001] on this point). Moreover, the presence of durable goods has meaningful implications for the optimal allocation, as exposed in Erceg and Levin [2005]. Finally, households heterogeneity and collateral constraints may not only change the policy dilemma regarding price stability and the stabilization of real quantities, but also introduce an additional policy objective related to the dispersion of allocations across household types.

5.2.1 Housing preference shock

Thereafter, we do not intend to explore systematically all those factors. Such an exercise would be beyond the scope of the present paper and is left for further research. We restrict our analysis to the assessment of the optimal policy tolerance for relative house price fluctuations. More specifically, we consider the optimal monetary policy response to housing demand shocks since this source of disturbance activates, under standard Taylor rules, strong relative house price changes and ample asymmetry between savers' and borrowers' reactions.

Figures 11 and 12 compare the impulse response functions to housing demand shocks when monetary policy is specified either as the estimated interest rate rules of the benchmark model, as the estimated interest rate rules augmented with real house prices, or as the optimal international cooperation. The structural parameters are fixed at the mode of their posterior distribution from the benchmark model estimation. Compared with the IRFs presented in Section 2 of this paper, differences can arise due to the fact that we assume here that public subsidies are offsetting steady state distortions.

Regarding domestic transmission, the optimal allocation generates a more muted response of real house prices and residential investment than with the benchmark policy rules. The optimal spillover of a positive housing demand shock to non-residential consumption is negative and on balance, aggregate output contracts. Those features are qualitatively present in the macroeconomic propagation under the augmented interest rate rules, albeit with a more pronounced pattern. The interest rate response under the optimal policy and the augmented rules is more restrictive than with the benchmark rules. Regarding the international spillovers, the exchange rate appreciates more on impact with the optimal and the augmented rules. In the foreign country, the optimal allocation implements a sharper adjustment of real variable variables while strongly stabilizing the inflation rates. Comparing the impulse responses to US or euro area shocks, it appears that the similarities between the optimal policy and the augmented interest rate rules, notably on the domestic transmission, are stronger for the US.

In order to provide some perspectives on the role of credit frictions in the optimal response to house prices, the same exercise has been conducted setting the share of borrowers to zero. The corresponding IRFs are reported in Figures 13 and 14. Some degree of control on house prices is still apparent in the optimal allocation. However, the "lean against the wind" features of the augmented policy rules now differ more from the optimal allocation.

Those results can also be illustrated using simple welfare-based interest rate rules. In order to substantiate more the comparison between the augmented policy rules and the optimal monetary policy cooperation, the two coefficients on the real house price terms of the augmented policy rules have been chosen to maximize the aggregate welfare under housing preference shocks, keeping the other parameters fixed. As expected, both optimal coefficients are positive but lower than in the estimated version of the augmented policy rules; in addition the optimal response to house prices is higher for the US at 0.04 than for the euro area, at 0.02.

5.2.2 Other housing-related shocks

Figure 15 shows the IRFs of a US housing sector productivity shock under, respectively, the benchmark interest rate rule, the augmented one and the optimal monetary policy cooperation. Compared with the benchmark rule, the optimal policy decreases the interest rate on impact in the source country, reverting it back quickly afterwards. This mitigates slightly the decline in real house prices and limits the substitution effect in favor of residential goods and. The response of output, consumption and investment is therefore higher in the optimal allocation and the downward pressures on domestic prices are muted. The optimal policy leads to an exchange rate depreciation on impact followed by an appreciation while the reverse is true with the benchmark interest rate rule. In the euro area, monetary policy is more restrictive in the short-term in the optimal allocation, inducing a negative adjustment for all quantities and real house prices. The augmented Taylor rule shares qualitatively the features of the optimal policy concerning the domestic transmission: monetary policy accommodates the productivity shock, limiting the fall in house prices and supporting domestic demand for non-residential goods. However, the policy response to the real house price decline is too strong compared with the optimal allocation, which ends up being more destabilizing for both prices and quantities. Consequently, the international transmission under the augmented Taylor rule works through a significant exchange rate depreciation of the dollar which penalizes euro area output but supports its domestic demand for non-residential goods as well as residential investment. Euro area domestic inflation declines and monetary policy decreases slightly the nominal interest rate. Such a propagation contrasts significantly with the optimal one. It seems that the optimal policy calls - in this particular configuration - for a shift interest rate adjustment, domestically and abroad, in order to counteract the strong asymmetric reactions across household types and therefore improving the risk sharing both within and between countries. A deeper analysis of such conjectures is left for future research. We limit here our assessment on the apparent response of monetary policy to house price fluctuations which seems to be amplified in the optimal allocation.

Turning now to the case of LTV shocks, as reported in Figure 16, we observe first that the benchmark interest rate rule and the augmented one have, broadly speaking, similar properties, given the moderate fluctuations in real house prices. Compared to the Taylor rules, the optimal policy strongly increases interest rate in the source country after a positive LTV shock. Such a policy tightening drives real house prices and residential investment below baseline in the short-term, which limits the positive effects on consumption and leads to a small decline in aggregate output. The optimal policy is therefore using the flexibility of house prices to counteract the relaxation of the collateral constraint coming from the LTV shock. This induces a substantial appreciation of the nominal exchange rate on impact compared with the benchmark case. Abroad, the short-term transmission on output is more positive in the optimal allocation but more pronounced interest rate increases induce a negative response of housing variables and domestic demand.

Overall, this section shows that, given our structural specification of housing market functioning in the US and the euro area, the historical monetary policy conduct seems consistent with traditional interest rate feedback rules augmented for real house prices. From a normative perspective, some degree of monetary policy reaction to fluctuations in the price of residential goods is consistent with the main features of optimal monetary policy response to housing-related demand shocks. Based on welfare computations when only housing shocks are allowed, the augmented Taylor rule estimation turns out to be welfare-improving compared with the benchmark case, in particular for the US economy. Beyond this, the optimal allocation suggests that the heterogenous response across households and the associated welfare losses in terms of imperfect risk sharing should be counteracted, even at the cost of moderate short term inflation volatility. The optimal international transmission of positive housing-related shocks leads to monetary policy tightening in the foreign country and to a negative adjustment of housing prices and quantities as well as domestic demand for non-residential goods.

6 Conclusions

In this paper we have provided an original framework to explore the importance of housing markets and credit frictions for the monetary policy conduct in open economy. We have reproduced some stylized facts for the US and the euro area, and provided a systematic analysis of cross-country business cycle dynamics. In particular, we have established that while the collateral channel generates significant effects of housing-related shocks on real activity domestically, the international spillovers are relatively smaller than in the case of shocks affecting the tradable sector. Regarding monetary policy, we have documented that, from a positive perspective, an accurate historical representation of monetary policy conduct in the two areas should allow the central bank to respond to housing price movements. Moreover, from a normative standpoint, such a policy conduct is found to be welfare improving. Our results point to at least two directions. First, a better characterization of credit frictions may be required in order to characterize the cross-country propagation of housing shocks, and the related borrowing dynamics. Second, a deeper analysis of the optimal monetary policy cooperation under housing-related credit frictions may reinforce the preliminary results obtained here. We plan to explore such dimensions in future work.

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A Supplementary model description

A.1 The borrower's program

The impatient agent maximizes (1) under (3) and (4) holding with equality[25]. We report the corresponding first order conditions in the next paragraph.
Let us denote

$$\widetilde{\mathcal{U}\prime}_{X,t} = \varepsilon_t^{\beta} \widetilde{X}_t^{-\sigma_C} \tag{24}$$

$$\widetilde{\mathcal{U}\prime}_{C,t} = \left(1-\varepsilon_t^D\omega_D\right)^{\frac{1}{\eta_D}} \left(\widetilde{C}_t - h_B\widetilde{C}_{t-1}\right)^{-\frac{1}{\eta_D}} \widetilde{X}_t^{\frac{1}{\eta_D}} \widetilde{\mathcal{U}\prime}_{X,t} \tag{25}$$
$$-\beta h_B \left(1-\varepsilon_t^D\omega_D\right)^{\frac{1}{\eta_D}} \left(\frac{\widetilde{C}_t}{\widetilde{X}_t}\right)^{-\frac{1}{\eta_D}} \mathbb{E}_t \left\{ \begin{array}{c} \left(1-\varepsilon_{t+1}^D\omega_D\right)^{\frac{1}{\eta_D}} \\ \left(\widetilde{C}_{t+1} - h_B\widetilde{C}_t\right)^{-\frac{1}{\eta_D}} \widetilde{X}_{t+1}^{\frac{1}{\eta_D}} \widetilde{\mathcal{U}\prime}_{X,t+1} \end{array} \right\}$$

$$\widetilde{\mathcal{U}\prime}_{D,t} = \varepsilon_t^D \omega_D^{\frac{1}{\eta_D}} \left(\frac{\widetilde{D}_t}{\widetilde{X}_t}\right)^{-\frac{1}{\eta_D}} \widetilde{\mathcal{U}\prime}_{X,t} \tag{26}$$

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

$$\widetilde{\Lambda}_t = \widetilde{\mathcal{U}\prime}_{C,t} \tag{27}$$

and

$$\begin{aligned} \widetilde{\Lambda}_t T_{D,t} \quad = \quad & (1-\chi)\,\varepsilon_t^{LTV} \Psi_t \widetilde{\Lambda}_t \mathbb{E}_t \left\{ T_{D,t+1} \frac{\pi_{t+1}}{R_t \varepsilon_t^{CPI}} \right\} \\ & + \widetilde{\mathcal{U}\prime}_{D,t} + \beta\,(1-\delta)\,\mathbb{E}_t \left\{ \widetilde{\Lambda}_{t+1} T_{D,t+1} \right\} \end{aligned} \tag{28}$$

where $\frac{\widetilde{\Lambda}_t}{1+\tau_{C,t}}$ and $\frac{\widetilde{\Lambda}_t}{1+\tau_{C,t}}\Psi_t$ are the multipliers associated to constraint (3) and (4), respectively.
Finally, the marginal value of additional borrowing is defined by the following "modified" version of the standard Euler equation

$$\Psi_t = 1 - \beta \mathbb{E}_t \left\{ \frac{\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t} \frac{R_t}{\pi_{t+1}} \right\} \tag{29}$$

The set of optimality conditions is completed by the intratemporal trade-off between consumption and leisure, which is analyzed in detail later. By rearranging equation (28) it is possible to define the borrower's *user cost* of residential investment as follows:

$$\widetilde{R}_D = T_{D,t} \left(1 - \varepsilon_t^{LTV} (1-\chi)\, \Psi_t E_t \left\{ \frac{T_{D,t+1}}{T_{D,t}} \frac{\pi_{t+1}}{R_t \varepsilon_t^{CPI}} \right\} - \beta\,(1-\delta)\, E_t \left\{ \frac{\widetilde{\Lambda}_{t+1}}{\widetilde{\Lambda}_t} \frac{T_{D,t+1}}{T_{D,t}} \right\} \right) \tag{30}$$

A.2 The saver's program

Let us denote

$$\mathcal{U}\prime_{X,t} = \varepsilon_t^{\beta} X_t^{-\sigma_C} \tag{31}$$

[25] It is possible to show that the collateral constraint always binds in the deterministic steady state, under general conditions. We assume here that continues to hold in a sufficiently small neighborhood of the steady state, so that the model can be solved by taking a first order approximation.

$$\mathcal{U}\prime_{C,t} = \left(1-\varepsilon_t^D\omega_D\right)^{\frac{1}{\eta_D}}\left(C_t - hC_{t-1}\right)^{-\frac{1}{\eta_D}} X_t^{\frac{1}{\eta_D}}\mathcal{U}\prime_{X,t} \tag{32}$$
$$-\gamma h\left(1-\varepsilon_t^D\omega_D\right)^{\frac{1}{\eta_D}}\left(\frac{C_t}{X_t}\right)^{-\frac{1}{\eta_D}}\mathbb{E}_t\left\{\begin{array}{c}\left(1-\varepsilon_{t+1}^D\omega_D\right)^{\frac{1}{\eta_D}}\left(X_{t+1}\right)^{\frac{1}{\eta_D}}\\ \left(C_{t+1}-hC_t\right)^{-\frac{1}{\eta_D}}\mathcal{U}\prime_{X,t+1}\end{array}\right\}$$

$$\mathcal{U}\prime_{D,t} = \varepsilon_t^D\omega_D^{\frac{1}{\eta_D}}\left(\frac{D_t}{X_t}\right)^{-\frac{1}{\eta_D}}\mathcal{U}\prime_{X,t} \tag{33}$$

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

$$\Lambda_t = \mathcal{U}\prime_{C,t} \tag{34}$$

and

$$\Lambda_t T_{D,t} = \mathcal{U}\prime_{D,t} + \gamma\left(1-\delta\right)\mathbb{E}_t\left\{\Lambda_{t+1}T_{D,t+1}\right\} \tag{35}$$

where $\frac{\Lambda_t}{1+\tau_{C,t}}$ is the multiplier associated with the budget constraint.
Patient households in both countries are allowed to trade in two one-period nominal bonds, a domestic and a foreign one. First order conditions corresponding to the quantity of contingent bonds imply that

$$\Lambda_t = R_t\gamma\mathbb{E}_t\left[\Lambda_{t+1}\frac{P_t}{P_{t+1}}\right] \tag{36}$$

$$\Lambda_t = R_t^*\varepsilon_t^{\Delta S}\Psi\left(\frac{\mathbb{E}_t S_{t+1}}{S_{t-1}} - 1, \frac{S_t\left(B_{F,t} - \overline{\overline{B}}_F\right)}{\underline{P}_t}\right)\beta\mathbb{E}_t\left[\Lambda_{t+1}\frac{S_{t+1}P_t}{S_t P_{t+1}}\right]$$

where R_t and R_t^* are one-period-ahead nominal interest rates for country H and F respectively.
The previous equations imply an arbitrage condition on bond prices which corresponds to a modified uncovered interest rate parity (UIP):

$$\frac{R_t}{R_t^*\varepsilon_t^{\Delta S}\Psi\left(\frac{\mathbb{E}_t S_{t+1}}{S_{t-1}} - 1, \frac{S_t\left(B_{F,t}-\overline{\overline{B}}_F\right)}{\underline{P}_t}\right)} = \frac{\mathbb{E}_t\left[\Lambda_{t+1}\frac{S_{t+1}P_t}{S_t P_{t+1}}\right]}{\mathbb{E}_t\left[\Lambda_{t+1}\frac{P_t}{P_{t+1}}\right]} \tag{37}$$

Rearranging equation (35) yields the definition of the saver's *user cost* of residential investment:

$$R_D = T_{D,t}\left(1-\gamma\left(1-\delta\right)E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\frac{T_{D,t+1}}{T_{D,t}}\right\}\right) \tag{38}$$

A.3 Labor supply and wage setting

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

$$\frac{\widetilde{W}_{j,t}}{P_t} = \left(\mu_w\frac{\omega\mathcal{H}_{1,t}^{wj,b} + (1-\omega)\mathcal{H}_{1,t}^{wj,s}}{\omega\mathcal{H}_{2,t}^{wj,b} + (1-\omega)\mathcal{H}_{2,t}^{wj,s}}\right)^{\frac{\mu_w - 1}{\mu_w\left(1+\sigma_{Lj}\right)-1}}$$

where

$$\widetilde{\mathcal{H}}^{wj}_{1,t} = \varepsilon^B_t \varepsilon^L_t \widetilde{\overline{L}}_j \left(L^j_t\right)^{1+\sigma_{Lj}} \left(\frac{w^j_t}{1+\tau_{C,t}}\right)^{\frac{\left(1+\sigma_{Lj}\right)\mu_{iw}}{\mu_{iw}-1}} + \alpha_{wj}\beta\mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi^{\xi_{wj}}_t\left[\overline{\Pi}\right]^{1-\xi_{wj}}}\right)^{\frac{\left(1+\sigma_{Lj}\right)\mu_w}{\mu_w-1}}\widetilde{\mathcal{H}}^{wj}_{1,t+1}\right] \quad (39)$$

$$\mathcal{H}^{wj}_{1,t} = \varepsilon^B_t \varepsilon^L_t \overline{L}_j \left(L^j_t\right)^{1+\sigma_{Lj}} \left(\frac{w^j_t}{1+\tau_{C,t}}\right)^{\frac{\left(1+\sigma_{Lj}\right)\mu_{iw}}{\mu_{iw}-1}} + \alpha_{wj}\gamma\mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi^{\xi_{wj}}_t\left[\overline{\Pi}\right]^{1-\xi_{wj}}}\right)^{\frac{\left(1+\sigma_{Lj}\right)\mu_w}{\mu_w-1}}\mathcal{H}^{wj}_{1,t+1}\right] \quad (40)$$

and

$$\widetilde{\mathcal{H}}^{wj}_{2,t} = \left(1-\tau_{w,t}\right)\Lambda_t L^j_t \left(\frac{w^j_t}{1+\tau_{C,t}}\right)^{\frac{\mu_{iw}}{\mu_{iw}-1}} + \alpha_{wj}\beta\mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi^{\xi_{wj}}_t\left[\overline{\Pi}\right]^{1-\xi_{wj}}}\right)^{\frac{1}{\mu_w-1}}\widetilde{\mathcal{H}}^{wj}_{2,t+1}\right] \quad (41)$$

$$\mathcal{H}^{wj}_{2,t} = \left(1-\tau_{w,t}\right)\widetilde{\Lambda}_t L^j_t \left(\frac{w^j_t}{1+\tau_{C,t}}\right)^{\frac{\mu_{iw}}{\mu_{iw}-1}} + \alpha_{wj}\gamma\mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi^{\xi_{wj}}_t\left[\overline{\Pi}\right]^{1-\xi_{wj}}}\right)^{\frac{1}{\mu_w-1}}\mathcal{H}^{wj}_{2,t+1}\right] \quad (42)$$

with w^j_t denoting the aggregate real wage in each sector.
Finally, the aggregate wage dynamics in each sector is given by:

$$\left(\frac{w^j_t}{1+\tau_{C,t}}\right)^{\frac{1}{1-\mu_w}} = \left(1-\alpha_{wj}\right)\left(\mu_w\frac{\omega\widetilde{\mathcal{H}}^{wj}_{1,t}+(1-\omega)\mathcal{H}^{wj}_{1,t}}{\omega\widetilde{\mathcal{H}}^{wj}_{2,t}+(1-\omega)\mathcal{H}^{wj}_{2,t}}\right)^{-\frac{1}{\mu_w\left(1+\sigma_{Lj}\right)-1}} + \alpha_{wj}\left(\frac{w^j_t}{1+\tau_{C,t-1}}\right)^{\frac{1}{1-\mu_w}}\left(\frac{\Pi_t}{\Pi^{\xi_{wj}}_{t-1}\overline{\Pi}^{1-\xi_{wj}}}\right)^{\frac{-1}{1-\mu_w}} \quad (43)$$

A.4 Residential goods sectors

Let us denote the real marginal cost faced by residential goods producers by

$$MC_{D,t} = \frac{w_t^{(1-\alpha_D-\alpha_{\mathcal{L}})}\left[R^{k,D}_t\right]^{\alpha_D}\left[p_{lt}\right]^{\alpha_{\mathcal{L}}}}{\varepsilon^{A_D}_t\alpha^{\alpha_D}_D\left(1-\alpha_D-\alpha_{\mathcal{L}}\right)^{(1-\alpha_D-\alpha_{LAND})}\left(\alpha_{\mathcal{L}}\right)^{\alpha_{\mathcal{L}}}T_{D,t}} \quad (44)$$

where p_{lt} denotes the relative price of land deflated by non-residential goods price.
Cost minimization implies that

$$p_{lt} = \alpha_{\mathcal{L}}T_{D,t}\frac{Z_{D,t}}{\mathcal{L}_t} \quad (45)$$

and

$$\frac{w_t L^D_t}{R^{k,D}_t u^D_t K^D_{t-1}} = \frac{1-\alpha_D-\alpha_{\mathcal{L}}}{\alpha_D} \quad (46)$$

The first order condition associated with the firm's choice and the dynamics of residential goods inflation are given by

$$\mathcal{Z}_{D1,t} = \widetilde{\Lambda}_t MC_{D,t}Y_{D,t}\frac{T_{D,t}}{1+\tau_{C,t}} + \alpha_D\gamma\mathbb{E}_t\left[\left(\frac{\Pi_{D,t+1}}{\Pi^{\gamma_D}_{D,t}\overline{\Pi}^{1-\gamma_D}}\right)^{\frac{\mu_D}{\mu_D-1}}\mathcal{Z}_{D1,t+1}\right] \quad (47)$$

$$\mathcal{Z}_{D2,t} = (1-\tau_{D,t})\widetilde{\Lambda}_t Y_{D,t} \frac{T_{D,t}}{1+\tau_{C,t}} + \alpha_D \gamma \mathbb{E}_t \left[\left(\frac{\Pi_{D,t+1}}{\Pi_{D,t}^{\gamma_D} \overline{\Pi}^{1-\gamma_D}} \right)^{\frac{1}{\mu-1}} \mathcal{Z}_{D2,t+1} \right] \tag{48}$$

and

$$1 = \alpha_D \left(\frac{\Pi_{D,t}}{\Pi_{D,t-1}^{\gamma_D} \overline{\Pi}^{1-\gamma_D}} \right)^{\frac{1}{\mu_D - 1}} + (1-\alpha_D) \left(\mu_D \frac{\mathcal{Z}_{D1,t}}{\mathcal{Z}_{D2,t}} \right)^{\frac{1}{1-\mu_D}} \tag{49}$$

B Data

US series come from the BEA, the BLS, the Census Bureau and the Federal Reserve Board. In particular, real house prices in the US are computed using the Census Bureau index (house price index for new one-family houses sold including value of lot). US household debt is obtained by the Federal Reserve Board Flow of Funds as a measure of total debt outstanding, held by domestic nonfinancial sectors. Euro area data are taken from Fagan et al (2001) and Eurostat. Concerning the euro area, 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[26]. Residential investment is taken from Eurostat national accounts and is backcasted using national sources. Households' debt for the euro area also comes from the ECB and Eurostat[27]. The exchange rate is the euro/dollar exchange rate. Due to statistical problems in computing long series of bilateral current account and current account for the euro area, we use the US current account as a share of US GDP. Aggregate real variables are expressed in per capita terms by dividing through with working age population. All the data are detrended before the estimation. Our structural description of the US and euro area interactions assumes no rest-of-the-world and therefore remains, from a global point of view, a reduced-form representation. As already mentioned, in order to take into account sources of economic fluctuations emanating from other countries, we allow first for common structural shocks. But we also introduce a correlation between the home bias preference shock and the euro area public expenditure shock. Since we use the US total net trade instead of bilateral net trade, we intend to capture, through this variable, rest-of-the-world shocks that affect the US current account with moderate immediate impact on euro area output. The correlation between the home bias shock and the Euro Area public expenditures shock ($\rho_{\Delta n,G}$), which acts as a GDP residual shock, is meant to control for this drawback. Notice however that using total US trade instead of bilateral trade broadens the data information on the rest of the world. Finally, given that, in the first order approximation of the model, the UIP shock has a weak structural interpretation, examining the links with other shocks seems justified. Consequently, correlations between the UIP shock and other efficient shocks are incorporated in the estimation and may account for the impact of fundamental shocks on time-varying risk premium. In practice, the benchmark model features a correlation between the UIP shocks and the US productivity shocks ($\rho_{A,\Delta S}$) as well as the government expenditure shocks ($\rho_{G,\Delta S}$, $\rho_{G^*,\Delta S}$) from both countries. Those correlations

[26] we applied some statistical interpolation methods to generate quarterly series

[27] See ECB Monthly Bulletin, October 2007, for the description of the data used

were also selected according to their significance and the improvement brought to the marginal data density[28].

Tab. 1: PARAMETER ESTIMATES 1

Shock names	*A priori* beliefs			*A posteriori* beliefs			
	Distribution	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
σ_t^A	Uniform	3	1.73	0.35	0.35	0.29	0.41
σ_t^B	Uniform	3	1.73	1.04	1.08	0.81	1.34
σ_t^G	Uniform	3	1.73	3.02	3.08	2.68	3.46
σ_t^L	Uniform	3	1.73	0.90	1.09	0.49	1.67
σ_t^I	Uniform	3	1.73	0.78	2.06	0.41	4.26
σ_t^Q	Uniform	10	5.77	5.71	5.79	2.99	8.56
σ_t^R	Uniform	3	1.73	0.15	0.15	0.13	0.18
σ_t^P	Uniform	3	1.73	0.23	0.24	0.20	0.27
$\sigma_t^{A_D}$	Uniform	3	1.73	1.21	1.22	1.05	1.39
σ_t^{LTV}	Uniform	3	1.73	1.11	1.13	0.99	1.26
σ_t^H	Uniform	5	2.89	3.56	3.94	2.31	5.49
σ_t^{A*}	Uniform	3	1.73	0.50	0.52	0.41	0.63
σ_t^{B*}	Uniform	3	1.73	2.20	2.27	1.20	3.18
σ_t^{G*}	Uniform	3	1.73	2.15	2.21	1.85	2.57
σ_t^{L*}	Uniform	3	1.73	0.25	0.29	0.15	0.42
σ_t^{I*}	Uniform	3	1.73	0.24	0.35	0.12	0.59
σ_t^{Q*}	Uniform	5	2.89	3.28	3.53	1.92	5.03
σ_t^{R*}	Uniform	3	1.73	0.10	0.11	0.09	0.12
σ_t^{P*}	Uniform	3	1.73	0.27	0.27	0.23	0.31
$\sigma_t^{A_D*}$	Uniform	3	1.73	0.85	0.85	0.74	0.96
σ_t^{LTV*}	Uniform	3	1.73	0.77	0.78	0.68	0.89
σ_t^{H*}	Uniform	3	1.73	1.41	1.44	1.12	1.76
$\sigma_t^{\Delta S}$	Uniform	3	1.73	0.26	0.31	0.15	0.47
$\sigma_t^{\Delta n}$	Uniform	3	1.73	0.41	0.43	0.35	0.50
$\sigma_t^{P_F}$	Uniform	3	1.73	0.13	0.13	0.09	0.16
$\sigma_t^{P_H*}$	Uniform	3	1.73	0.21	0.22	0.18	0.25
F_t^A	Uniform	3	1.73	0.02	0.12	0.00	0.22
F_t^R	Uniform	3	1.73	0.01	0.03	0.00	0.08
F_t^{CPI}	Uniform	3	1.73	0.13	0.13	0.10	0.17

[28]The correlation between the home bias shock and EA government expenditures is introduced by adding a term $\rho_{\Delta n,G}\epsilon_t^{\Delta n}$ in the AR(1) of the EA government spending exogenous. The correlations with the UIP shock are introduced by adding terms like $(\varepsilon_t^A)^{\rho_{A,\Delta S}}$ in the risk premium exogenous $\varepsilon_t^{\Delta S}$

Tab. 2: PARAMETER ESTIMATES 2

Parameter names	*A priori* beliefs			*A posteriori* beliefs			
	Distribution	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ρ_{AA}	Beta	0.5	0.2	0.82	0.62	0.28	0.92
ρ_{RR}	Beta	0.5	0.2	0.23	0.37	0.06	0.72
ρ_{CCPI}	Beta	0.5	0.2	0.21	0.26	0.07	0.44
ρ_{A}	Beta	0.5	0.2	0.90	0.90	0.86	0.93
ρ_{B}	Beta	0.5	0.2	0.71	0.71	0.63	0.79
ρ_{G}	Beta	0.5	0.2	0.83	0.82	0.75	0.90
ρ_{L}	Beta	0.5	0.2	0.11	0.13	0.03	0.23
ρ_{I}	Beta	0.5	0.2	0.89	0.76	0.56	0.96
ρ_{A_D}	Beta	0.5	0.2	0.98	0.96	0.93	0.99
ρ_{LTV}	Beta	0.5	0.2	0.93	0.93	0.89	0.97
ρ_{H}	Beta	0.5	0.2	0.97	0.97	0.94	0.99
ρ_{A^*}	Beta	0.5	0.2	0.92	0.92	0.89	0.95
ρ_{B^*}	Beta	0.5	0.2	0.46	0.46	0.29	0.62
ρ_{G^*}	Beta	0.5	0.2	0.89	0.89	0.85	0.93
ρ_{L^*}	Beta	0.5	0.2	0.09	0.12	0.02	0.22
ρ_{I^*}	Beta	0.5	0.2	0.47	0.50	0.16	0.83
$\rho_{A_D^*}$	Beta	0.5	0.2	0.97	0.94	0.90	0.99
ρ_{LTV^*}	Beta	0.5	0.2	0.96	0.96	0.94	0.98
ρ_{H^*}	Beta	0.5	0.2	1.00	0.99	0.99	1.00
$\rho_{\Delta S}$	Beta	0.5	0.2	0.92	0.91	0.85	0.97
$\rho_{\Delta n}$	Beta	0.5	0.2	0.99	0.97	0.94	1.00
$\rho_{I,C}$	Uniform	5	2.89	0.63	0.75	0.32	1.15
$\rho_{I*,C*}$	Uniform	5	2.89	0.26	0.29	0.09	0.48
$\rho_{G^*,\Delta n}$	Uniform	7.5	4.33	4.47	4.30	2.87	5.72
$\rho_{A,\Delta S}$	Normal	0	1	0.02	0.02	-0.22	0.24
$\rho_{G,\Delta S}$	Normal	0	1	0.03	0.04	0.00	0.09
$\rho_{G^*,\Delta S}$	Normal	0	1	-0.09	-0.09	-0.13	-0.05

Tab. 3: PARAMETER ESTIMATES 3

Parameter names	*A priori* beliefs			*A posteriori* beliefs			
	Distribution	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ	Normal	4	1.5	5.55	5.31	3.31	7.32
φ	Beta	0.5	0.15	0.78	0.77	0.65	0.90
σ_C	Gamma	1.5	0.375	0.64	0.63	0.50	0.76
h	Beta	0.5	0.1	0.58	0.56	0.45	0.68
h_B	Beta	0.5	0.1	0.31	0.32	0.19	0.45
σ_{L_C}	Gamma	2	0.75	2.55	2.77	1.49	4.10
ξ_{w_C}	Beta	0.75	0.05	0.83	0.82	0.79	0.86
ξ_{w_D}	Beta	0.75	0.05	0.84	0.84	0.80	0.88
γ_{w_C}	Beta	0.5	0.15	0.42	0.44	0.22	0.66
γ_{w_D}	Beta	0.5	0.15	0.59	0.56	0.32	0.81
ξ_p	Beta	0.75	0.05	0.89	0.89	0.86	0.92
γ_p	Beta	0.5	0.15	0.55	0.54	0.38	0.70
ϕ^*	Normal	4	1.5	2.47	2.60	1.44	3.71
φ^*	Beta	0.5	0.15	0.89	0.87	0.78	0.95
σ_C^*	Gamma	1.5	0.375	1.06	1.10	0.94	1.24
h^*	Beta	0.5	0.1	0.83	0.77	0.63	0.90
h_B^*	Beta	0.5	0.1	0.28	0.30	0.19	0.41
σ_{LC}^*	Gamma	2	0.75	1.53	1.69	0.92	2.40
ξ_{wC}^*	Beta	0.75	0.05	0.81	0.81	0.78	0.84
ξ_{wD}^*	Beta	0.75	0.05	0.81	0.81	0.77	0.86
$\gamma_{w_C^*}$	Beta	0.5	0.15	0.26	0.28	0.12	0.44
$\gamma_{w_D^*}$	Beta	0.5	0.15	0.44	0.47	0.22	0.70
ξ_p^*	Beta	0.75	0.05	0.92	0.92	0.91	0.94
γ_p^*	Beta	0.5	0.15	0.51	0.51	0.38	0.64
λ_e	Beta	0.75	0.05	0.79	0.78	0.75	0.82
ρ	Beta	0.75	0.1	0.79	0.79	0.74	0.83
r_π	Normal	1.5	0.25	1.78	1.79	1.49	2.07
$r_{\Delta\pi}$	Gamma	0.3	0.1	0.26	0.26	0.18	0.34
r_Y	Gamma	0.12	0.05	0.11	0.11	0.06	0.15
$r_{\Delta Y}$	Gamma	0.12	0.05	0.17	0.18	0.13	0.24
ρ^*	Beta	0.75	0.1	0.84	0.83	0.78	0.88
r_π^*	Normal	1.5	0.25	0.84	0.90	0.69	1.12
$r_{\Delta\pi}^*$	Gamma	0.3	0.1	0.16	0.17	0.11	0.22
r_Y^*	Gamma	0.12	0.05	0.17	0.17	0.12	0.23
$r_{\Delta Y}^*$	Gamma	0.12	0.05	0.14	0.15	0.10	0.20
ξ	Uniform	3	1.7321	1.27	1.55	0.92	2.18
n	Uniform	0.5	0.2887	0.98	0.98	0.97	0.98
η	Beta	0.5	0.28	0.98	0.90	0.80	1.00
η^*	Beta	0.5	0.28	0.86	0.80	0.62	1.00
χ	Normal	1	0.25	0.83	0.89	0.49	1.28
$\chi_{\Delta S}$	Uniform	0.5	0.2887	0.21	0.21	0.13	0.29
ω	Beta	0.35	0.05	0.24	0.23	0.18	0.29
ω^*	Beta	0.35	0.05	0.19	0.20	0.15	0.24

Tab. 4: PARAMETER ESTIMATES COMPARISON

Parameters	High borrowers' share			Augmented Taylor Rule		
	Mode	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ	4.70	2.50	6.46	5.11	3.38	7.08
φ	0.77	0.66	0.88	0.83	0.73	0.92
σ_C	0.67	0.54	0.83	0.75	0.67	0.86
h	0.49	0.36	0.63	0.59	0.46	0.69
h_B	0.38	0.25	0.51	0.36	0.23	0.53
σ_{L_C}	2.09	1.12	3.49	1.68	0.92	2.95
ξ_{w_C}	0.82	0.78	0.85	0.80	0.76	0.84
ξ_{w_D}	0.84	0.79	0.88	0.84	0.78	0.87
γ_{w_C}	0.46	0.25	0.72	0.42	0.22	0.70
γ_{w_D}	0.60	0.37	0.83	0.63	0.35	0.82
ξ_p	0.89	0.85	0.91	0.89	0.86	0.91
γ_p	0.51	0.35	0.68	0.49	0.34	0.66
ϕ^*	1.69	0.78	3.22	4.34	3.15	6.33
φ^*	0.84	0.74	0.93	0.93	0.85	0.97
σ_C^*	0.99	0.57	1.20	0.79	0.68	0.96
h^*	0.37	0.21	0.68	0.82	0.73	0.89
h_B^*	0.31	0.19	0.44	0.35	0.21	0.49
$\sigma_{L_C}^*$	1.54	0.88	2.80	1.52	0.93	2.58
$\xi_{w_C}^*$	0.81	0.78	0.85	0.81	0.78	0.84
$\xi_{w_D}^*$	0.82	0.77	0.86	0.82	0.77	0.86
$\gamma_{w_C}^*$	0.36	0.18	0.55	0.27	0.12	0.43
$\gamma_{w_D}^*$	0.48	0.23	0.72	0.40	0.21	0.68
ξ_p^*	0.94	0.92	0.95	0.91	0.88	0.93
γ_p^*	0.49	0.35	0.60	0.59	0.46	0.73
λ_e	0.79	0.75	0.82	0.80	0.77	0.83
ρ	0.78	0.74	0.83	0.79	0.73	0.83
r_π	1.90	1.62	2.20	1.86	1.54	2.20
$r_{\Delta\pi}$	0.29	0.20	0.38	0.28	0.19	0.37
r_Y	0.12	0.08	0.18	0.10	0.05	0.14
$r_{\Delta Y}$	0.20	0.15	0.26	0.14	0.10	0.19
ρ^*	0.86	0.81	0.91	0.88	0.83	0.91
r_π^*	1.39	0.84	1.84	1.47	1.15	1.85
$r_{\Delta\pi}^*$	0.19	0.13	0.28	0.20	0.13	0.27
r_Y^*	0.18	0.12	0.27	0.06	0.03	0.11
$r_{\Delta Y}^*$	0.25	0.18	0.33	0.16	0.12	0.20
$r_{\Delta T_D}$				0.10	0.07	0.14
$r_{\Delta T_D}^*$				0.17	0.13	0.23
ξ	1.47	0.96	2.20	1.08	0.85	1.62
n	0.98	0.97	0.98	0.98	0.97	0.98
η	0.98	0.82	1.00	0.97	0.78	1.00
η^*	0.78	0.63	1.00	0.76	0.58	0.98
χ	0.96	0.48	1.33	0.85	0.42	1.25
$\chi_{\Delta S}$	0.19	0.12	0.26	0.19	0.12	0.29
ω	0.46	0.40	0.51	0.22	0.18	0.28
ω^*	0.42	0.37	0.48	0.19	0.15	0.24

Tab. 5: COMPARISON OF SECOND-ORDER MOMENTS

	DETRENDED				HP FILTERED			
	data	Baseline	High Borr.	Aug. Taylor	data	Baseline	High Borr.	Aug. Taylor
Standard deviation								
US								
Z_t	2.14	1.91	1.99	2.03	1.25	1.18	1.27	1.30
C_t	1.90	1.76	1.93	1.76	0.84	1.07	1.28	1.11
I_t	6.11	5.03	5.45	5.52	3.78	2.62	2.89	3.01
Z_{Dt}	11.21	9.17	9.18	8.43	6.51	5.22	5.27	4.99
T_{Dt}	4.87	4.32	4.12	3.48	1.34	2.19	2.13	1.92
Π_t	0.27	0.30	0.31	0.29	0.18	0.26	0.26	0.25
R_t	0.46	0.30	0.35	0.30	0.30	0.22	0.25	0.22
Euro Area								
Z_t^*	1.67	1.15	1.48	2.17	0.88	0.84	0.93	1.19
C_t^*	1.76	1.16	1.66	1.82	0.83	0.74	1.05	0.96
I_t^*	5.47	3.16	3.86	5.56	2.75	2.13	2.31	2.93
Z_{Dt}^*	3.34	6.12	6.47	5.60	1.90	3.28	3.30	3.20
T_{Dt}^*	6.24	3.17	3.17	2.78	1.88	1.55	1.51	1.33
Π_t^*	0.37	0.36	0.35	0.40	0.21	0.29	0.28	0.32
R_t^*	0.37	0.27	0.30		0.19	0.17	0.19	0.16
ΔS_t	4.80	5.75	5.02	5.24	4.39	5.41	4.74	4.98
CA_t	1.28	0.66	0.70	0.78	0.46	0.39	0.42	0.44
Correlations								
Z_t, C_t	0.80	0.68	0.70	0.70	0.84	0.69	0.72	0.73
Z_t, I_t	0.64	0.72	0.67	0.74	0.65	0.65	0.60	0.72
Z_t, Z_{Dt}	0.52	0.17	0.15	0.12	0.62	0.08	0.08	-0.01
T_{Dt}, C_t	0.12	0.30	0.31	0.10	0.47	0.32	0.43	0.02
Z_{Dt}, T_{Dt}	0.25	0.40	0.41	0.38	0.35	0.49	0.50	0.45
Z_{Dt}, C_t	0.74	0.12	0.12	0.05	0.68	0.08	0.13	-0.05
Z_t^*, C_t^*	0.93	0.65	0.77	0.84	0.83	0.74	0.78	0.84
Z_t^*, I_t^*	0.92	0.65	0.72	0.87	0.90	0.71	0.68	0.85
Z_t^*, Z_{Dt}^*	0.24	0.04	0.04	0.05	0.14	0.00	0.04	0.04
T_{Dt}^*, C_t^*	0.52	0.11	0.16	0.16	0.57	0.15	0.31	0.08
Z_{Dt}^*, T_{Dt}^*	0.41	0.42	0.39	0.34	0.25	0.42	0.42	0.37
Z_{Dt}^*, C_t^*	0.34	-0.07	-0.06	-0.07	0.20	-0.02	0.05	0.01
Z_t, Z_t^*	0.22	0.09	0.14	0.14	0.27	0.13	0.17	0.16
C_t, C_t^*	-0.03	-0.17	-0.03	-0.06	0.09	-0.04	0.05	0.08
Z_{Dt}, Z_{Dt}^*	-0.47	0.00	0.01	0.00	0.23	0.00	0.02	0.03
T_{Dt}, T_{Dt}^*	0.15	-0.03	0.00	-0.01	0.06	-0.01	0.04	0.07
$\Delta S_t, CA_t$	-0.23	-0.34	-0.24	-0.28	-0.15	-0.34	-0.22	-0.22
C_t^{rel}, RER_t	-0.29	-0.21	-0.34	-0.25	-0.21	-0.26	-0.33	-0.16

Tab. 6: SHOCKS DECOMPOSITION OF UNCONDITIONAL VARIANCES

	Domestic Housing			Other Domestic	Non Domestic
	$\epsilon_t^{A_D}$	ϵ_t^{LTV}	ϵ_t^{D}		
US					
Z_t	0.34	0.39	2.45	87.61	9.21
C_t	1.32	1.30	2.99	74.60	19.79
Z_{Dt}	57.65	0.04	31.93	9.98	0.40
T_{Dt}	7.87	0.08	80.11	9.37	2.57
Π_t	0.15	0.01	0.02	66.21	33.61
R_t	0.09	0.48	2.11	87.53	9.79
B_t	2.94	36.16	49.26	10.55	1.09
Euro Area					
Z_t^*	0.09	0.25	4.79	84.97	9.90
C_t^*	0.68	0.92	4.54	71.47	22.39
Z_{Dt}^*	59.51	0.04	34.36	5.62	0.47
T_{Dt}^*	5.62	0.08	85.36	5.37	3.57
Π_t^*	0.03	0.01	3.42	56.89	39.65
R_t^*	0.05	0.14	8.97	75.13	15.71
B_t^*	1.97	31.16	42.92	23.18	0.77
ΔS_t	0.01	0.00	0.57	17.60	81.82
CA_t	0.00	0.01	0.84	11.24	87.91

Tab. 7: SHOCKS DECOMPOSITION OF UNCONDITIONAL VARIANCES: VARYING THE SHARE OF BORROWERS.

	No Borrowers			High Borrowers' share		
	Domestic housing	Other Domestic	Non Domestic	Domestic housing	Other Domestic	Non Domestic
US						
Z_t	1.35	89.85	8.80	9.76	80.90	9.34
C_t	0.94	78.62	20.44	22.65	61.25	16.10
Z_{Dt}	89.74	9.83	0.43	89.47	10.13	0.40
T_{Dt}	87.42	9.68	2.90	88.70	9.07	2.23
Π_t	0.20	65.22	34.58	0.26	67.38	32.36
R_t	0.59	89.16	10.25	10.21	80.92	8.87
B_t	-	-	-	89.10	9.92	0.98
Euro Area						
Z_t^*	4.37	84.61	11.02	9.44	82.41	8.15
C_t^*	0.63	73.95	25.42	16.91	69.90	13.19
Z_{Dt}^*	94.04	5.54	0.42	93.54	5.95	0.51
T_{Dt}^*	91.01	5.50	3.49	91.16	5.31	3.53
Π_t^*	5.40	54.02	40.58	2.52	60.61	36.87
R_t^*	13.77	68.58	17.65	8.38	79.64	11.98
B_t^*	-	-	-	76.95	22.25	0.80
ΔS_t	0.72	17.35	81.93	0.65	18.33	81.02
CA_t	1.23	10.23	88.54	0.80	13.19	86.01

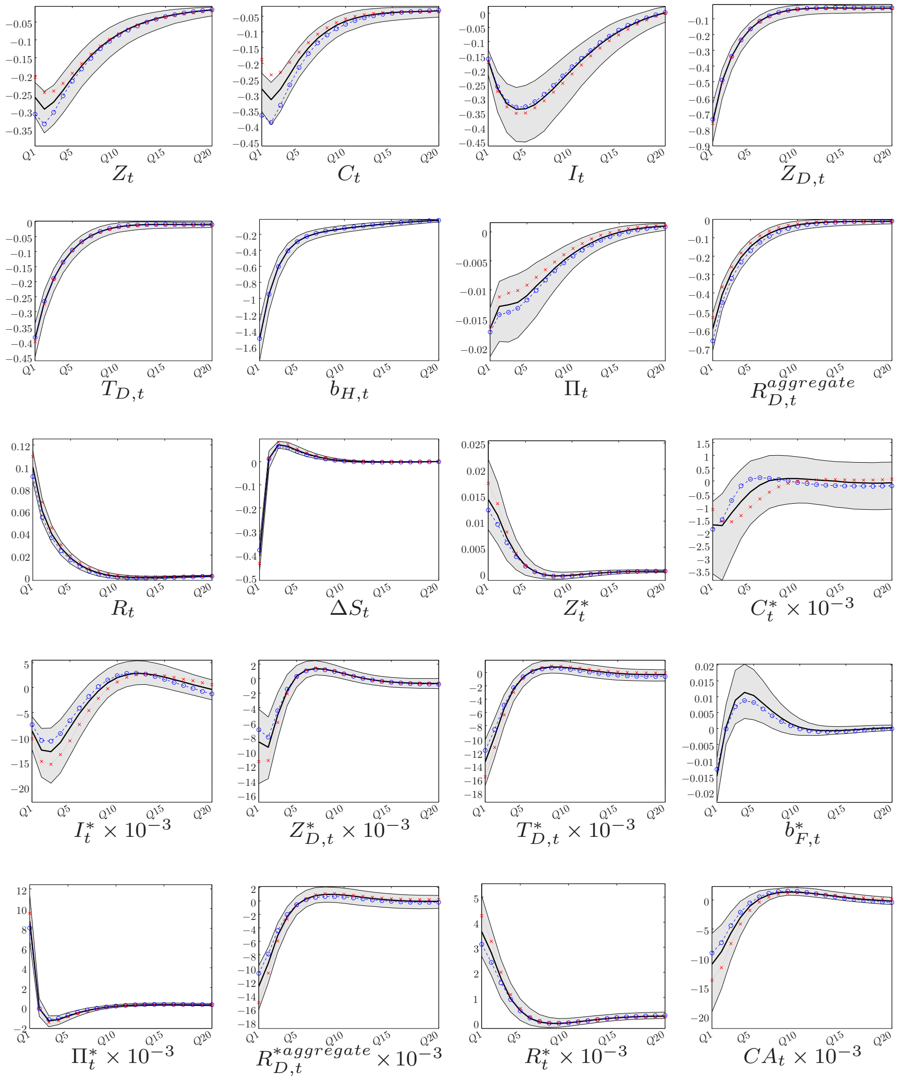

Fig. 1: Impulse Response Functions associated to a shock on ϵ_t^R. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

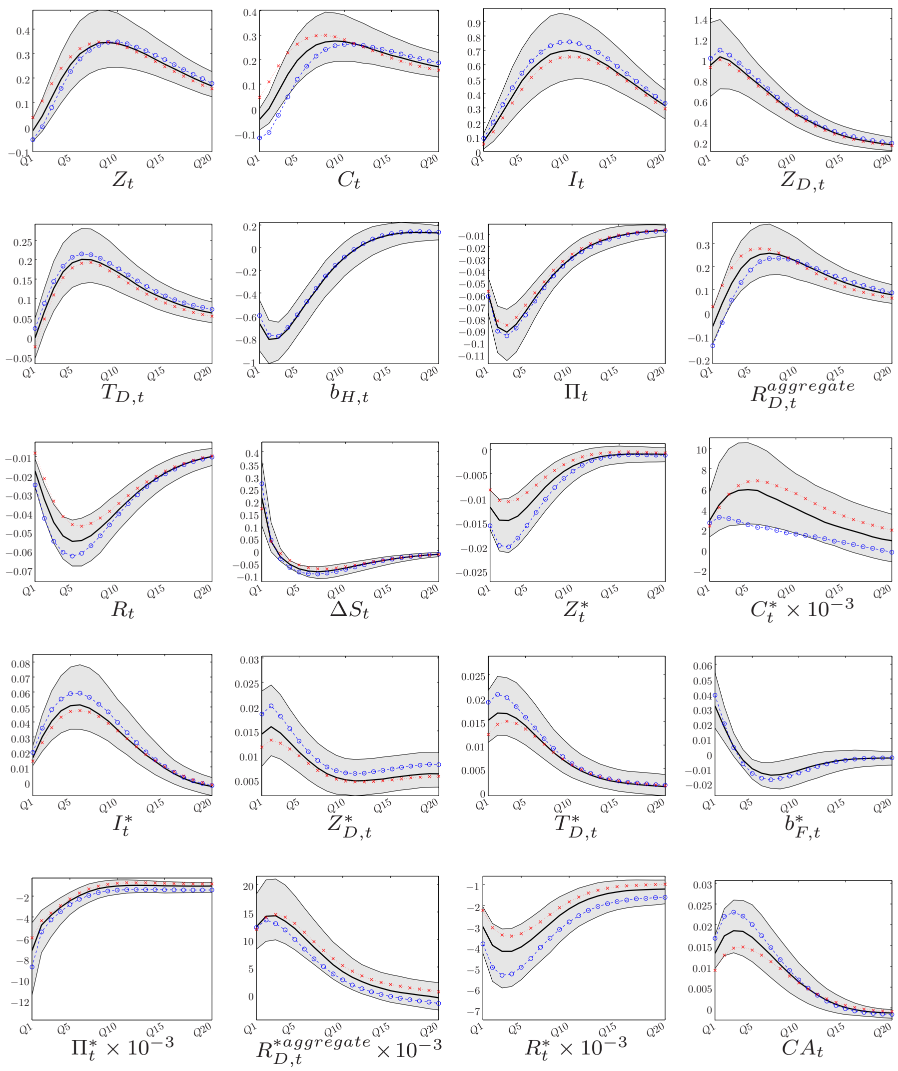

Fig. 2: Impulse Response Functions associated to a shock on ϵ_t^L. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

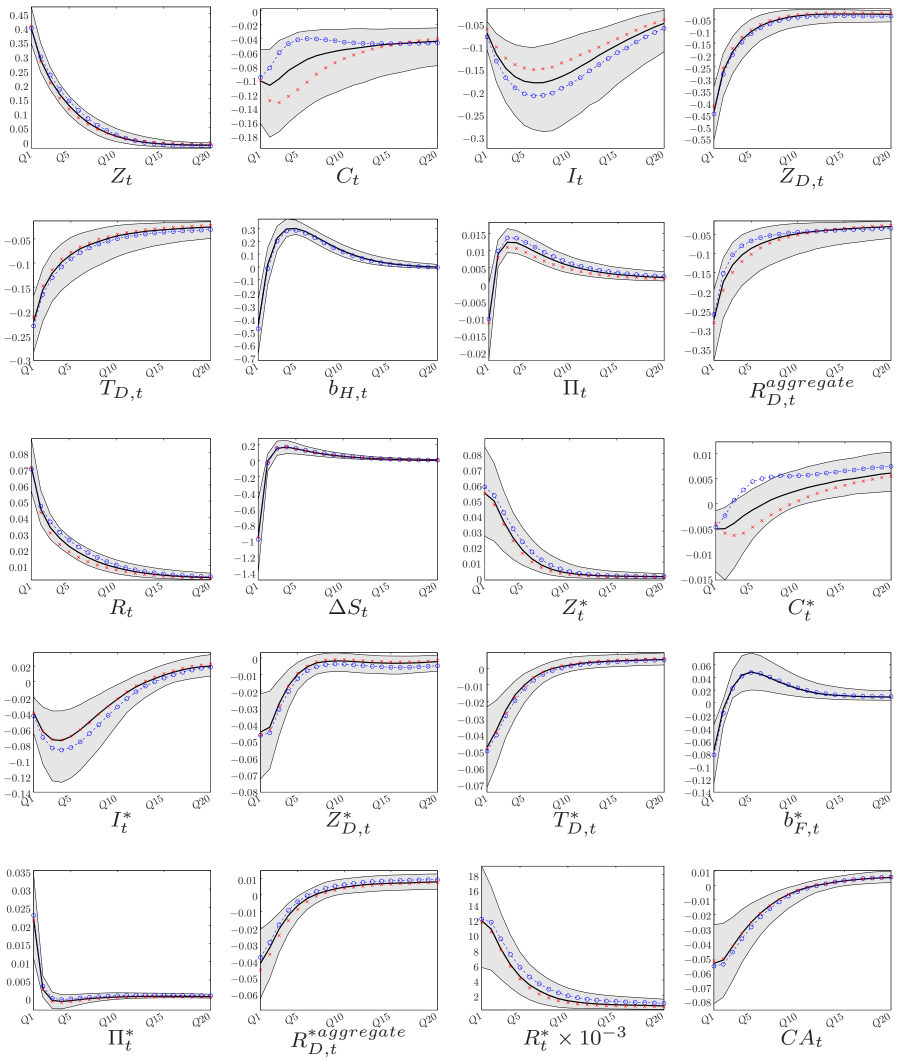

Fig. 3: Impulse Response Functions associated to a shock on ϵ_t^G. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

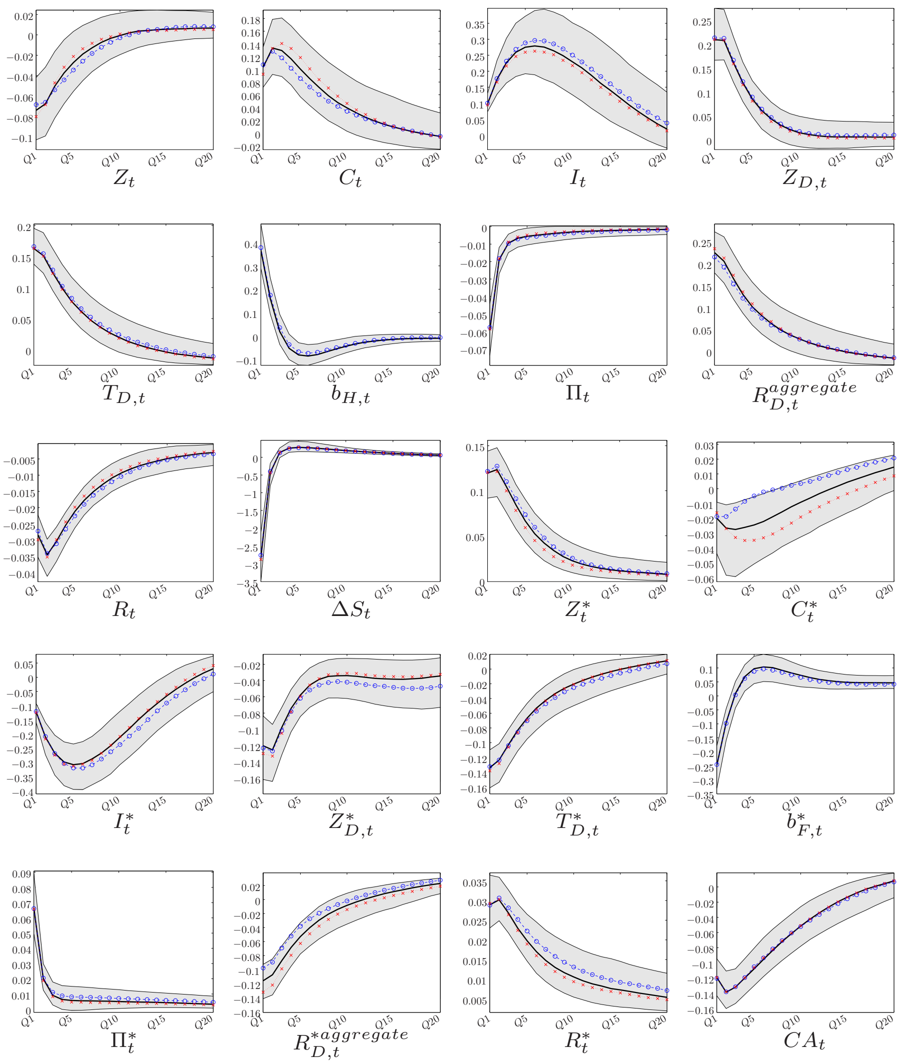

Fig. 4: Impulse Response Functions associated to a shock on $\epsilon_t^{\Delta S}$. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

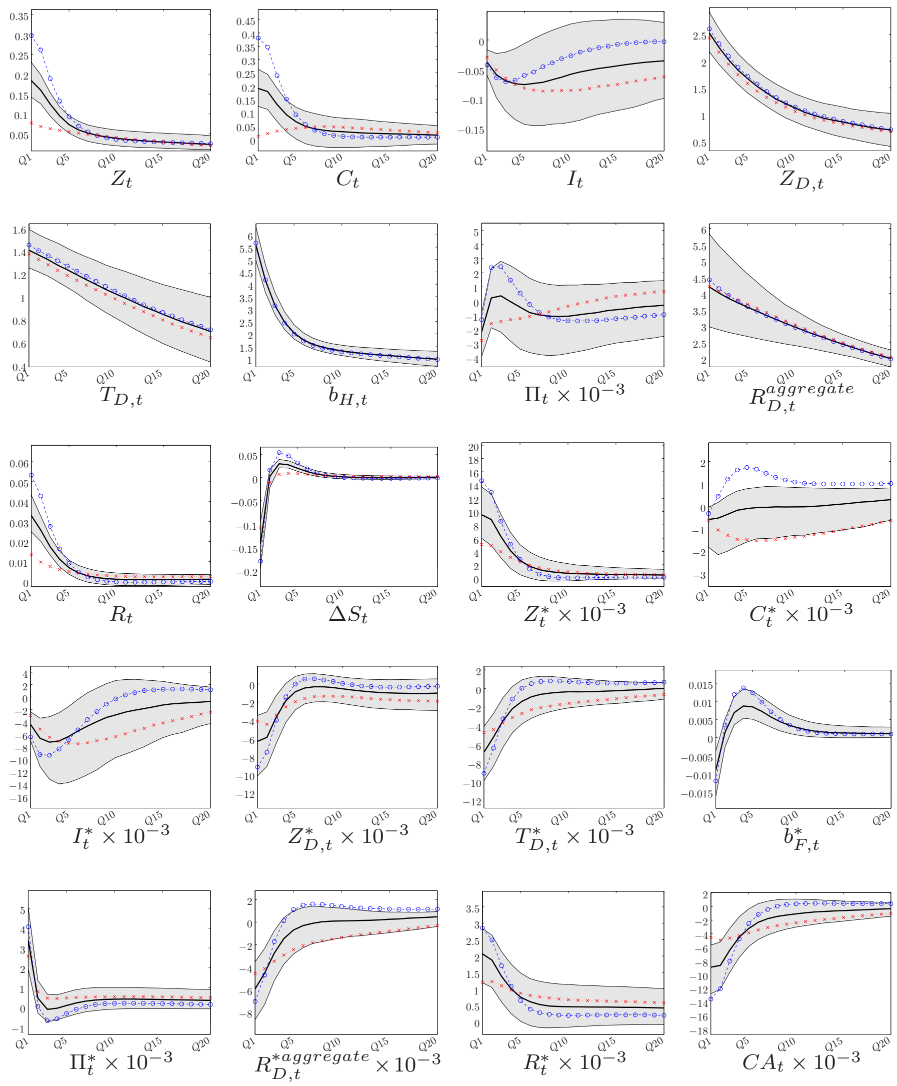

Fig. 5: Impulse Response Functions associated to a shock on ϵ_t^D. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

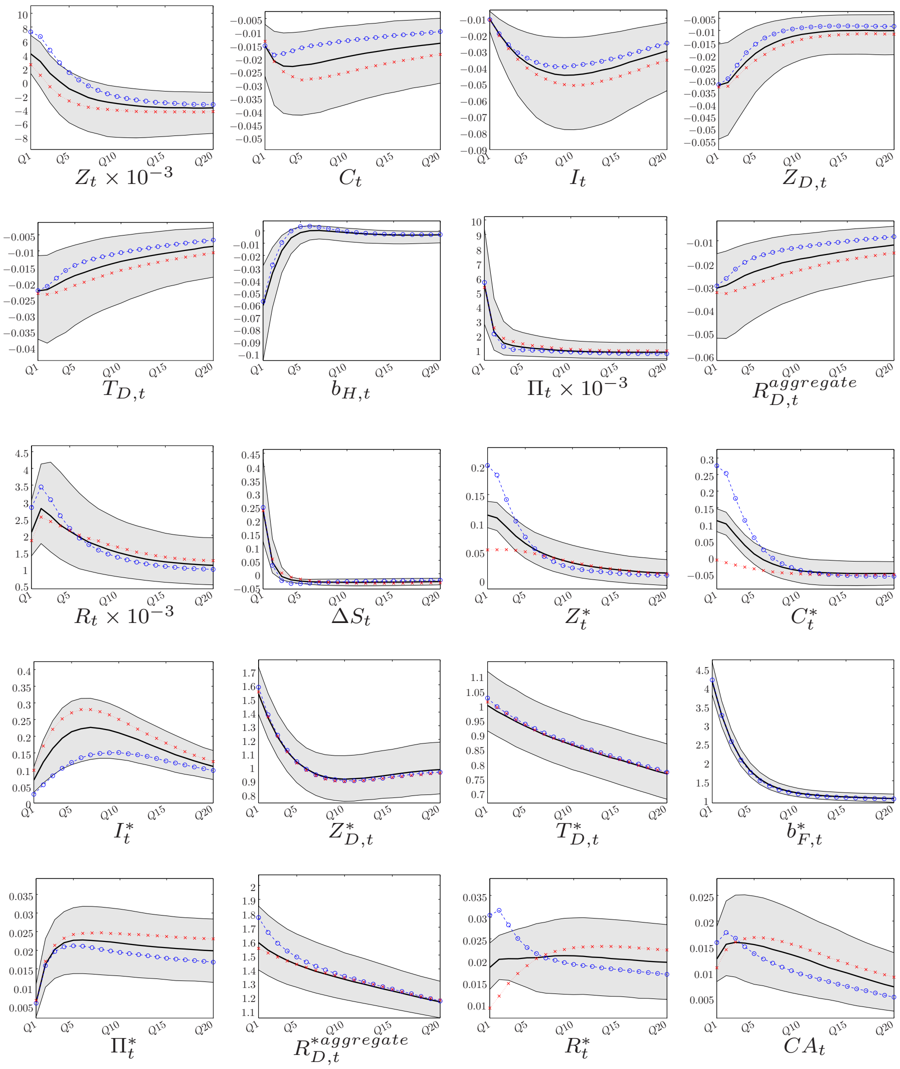

Fig. 6: Impulse Response Functions associated to a shock on ϵ_t^{D*}. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

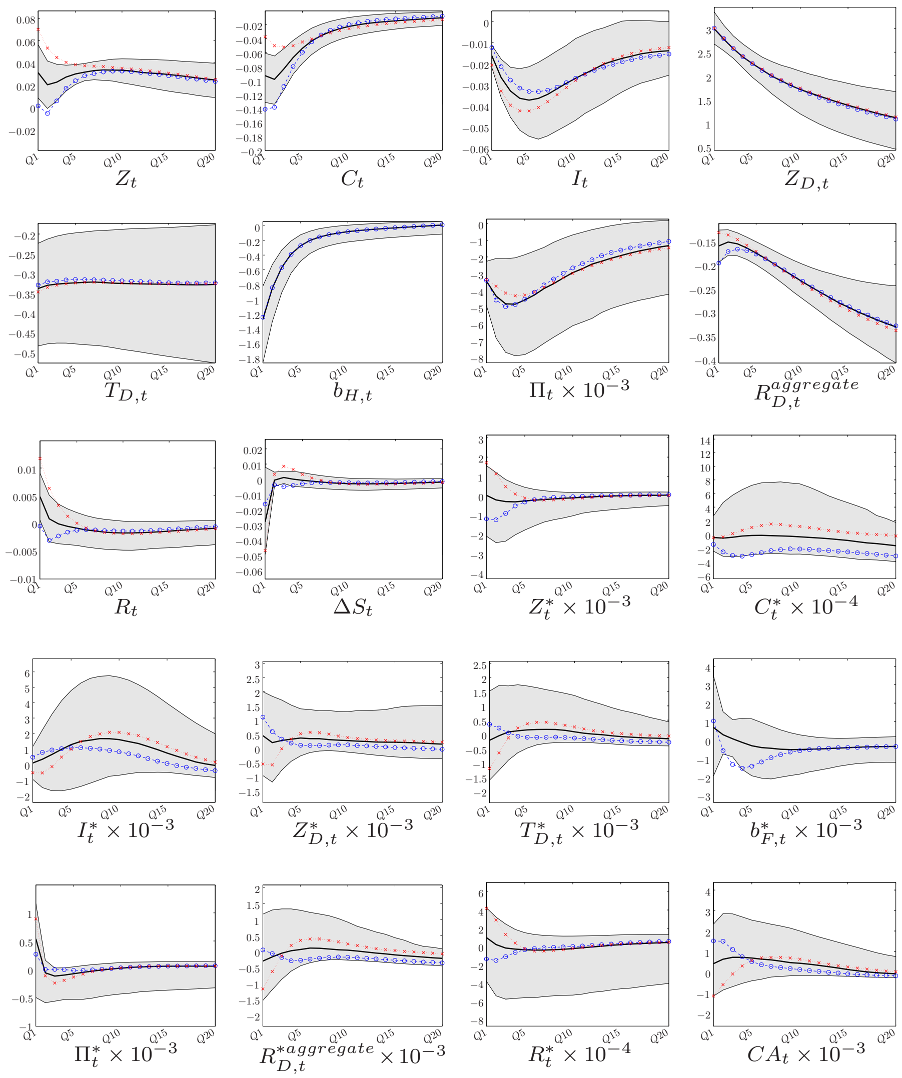

Fig. 7: Impulse Response Functions associated to a shock on $\epsilon_t^{A_D}$. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

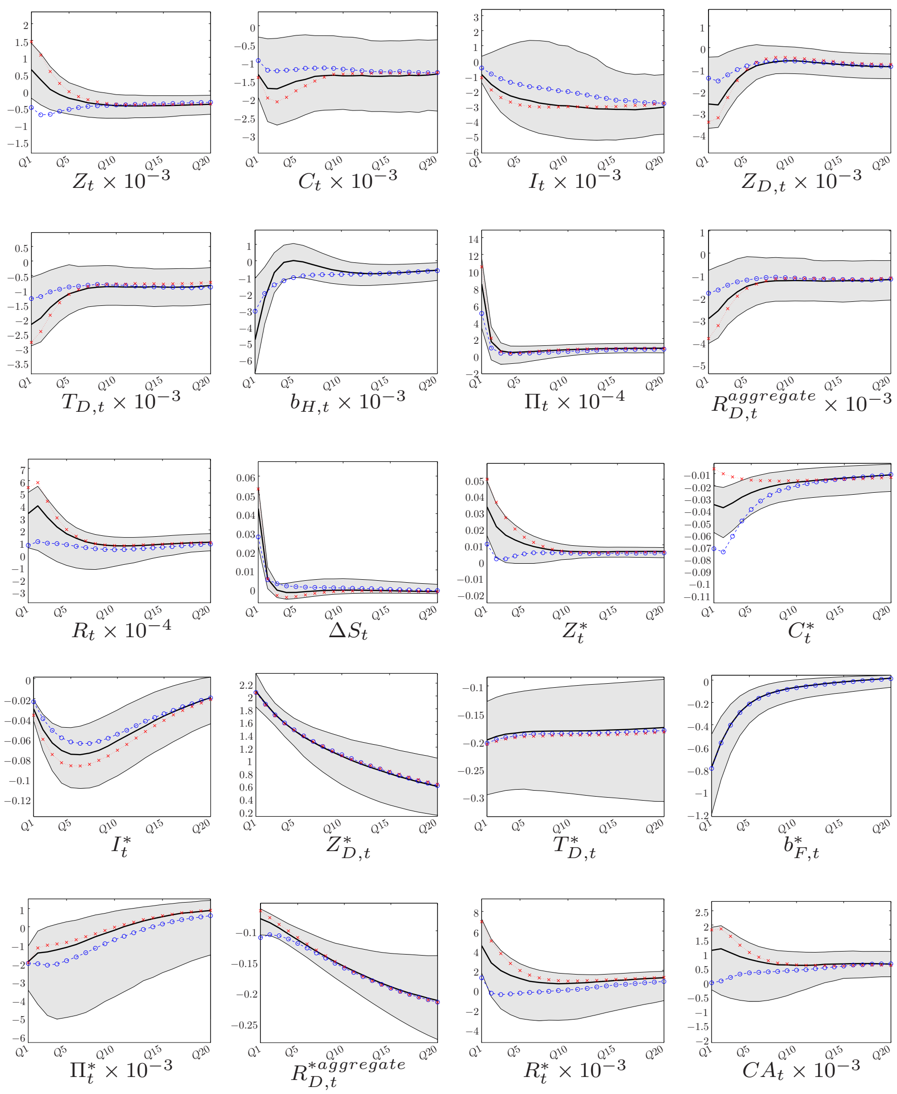

Fig. 8: Impulse Response Functions associated to a shock on $\epsilon_t^{A_D*}$. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

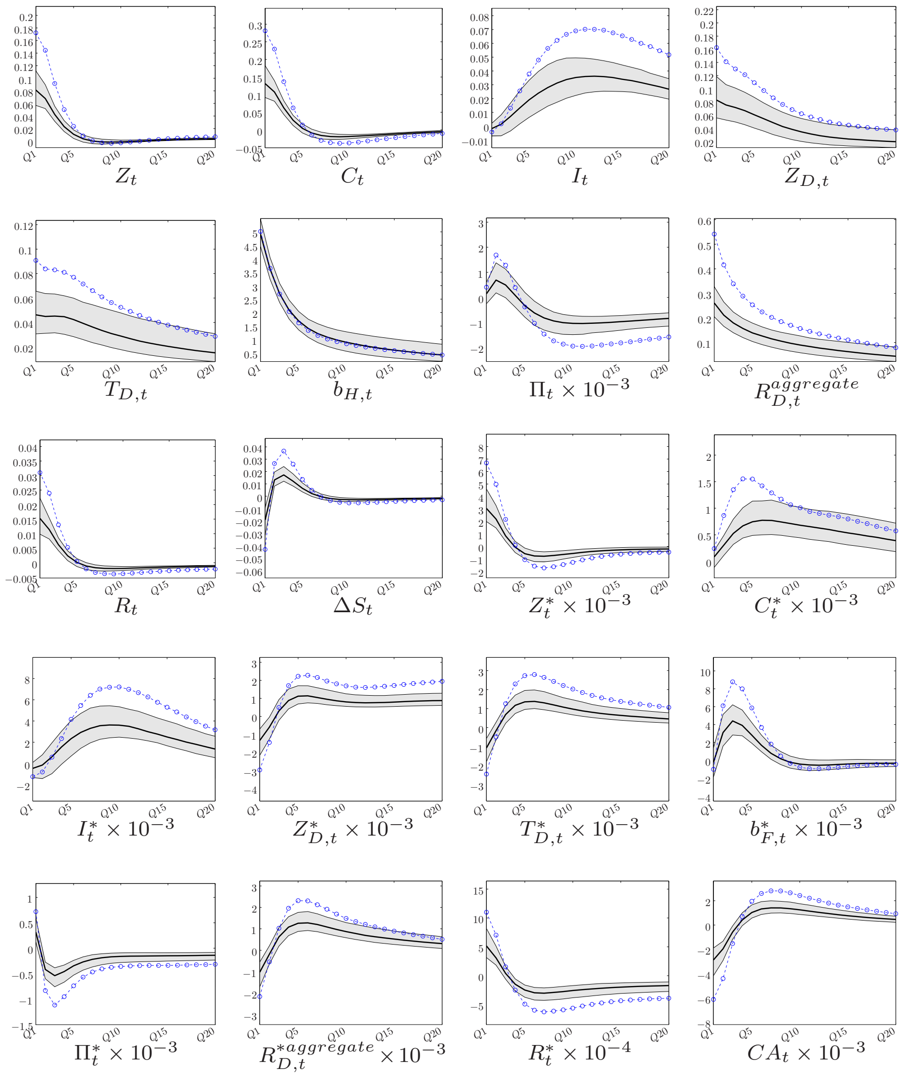

Fig. 9: Impulse Response Functions associated to a shock on ϵ_t^{LTV}. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

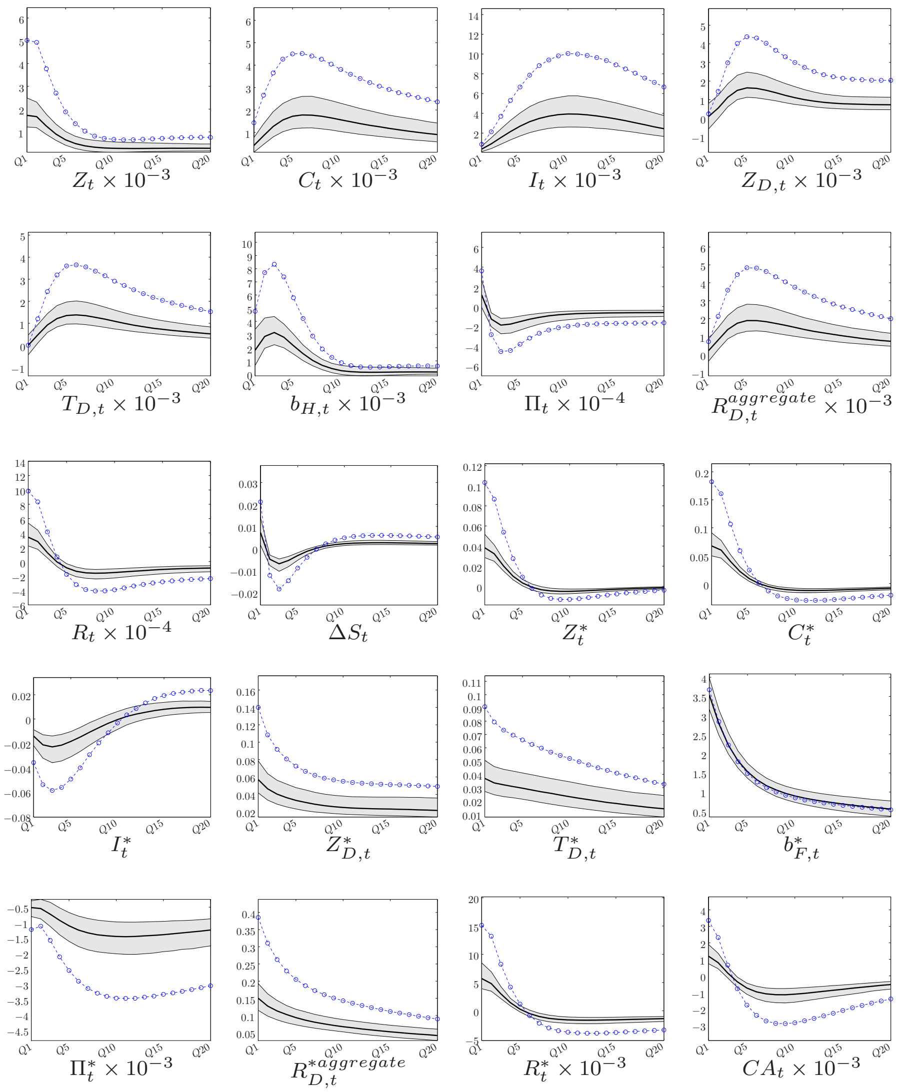

Fig. 10: Impulse Response Functions associated to a shock on ϵ_t^{LTV*}. *Benchmark model (plain lines and shaded areas), model with high borrowers (dotted lines with circle), model with no borrowers (dashed lines with cross).*

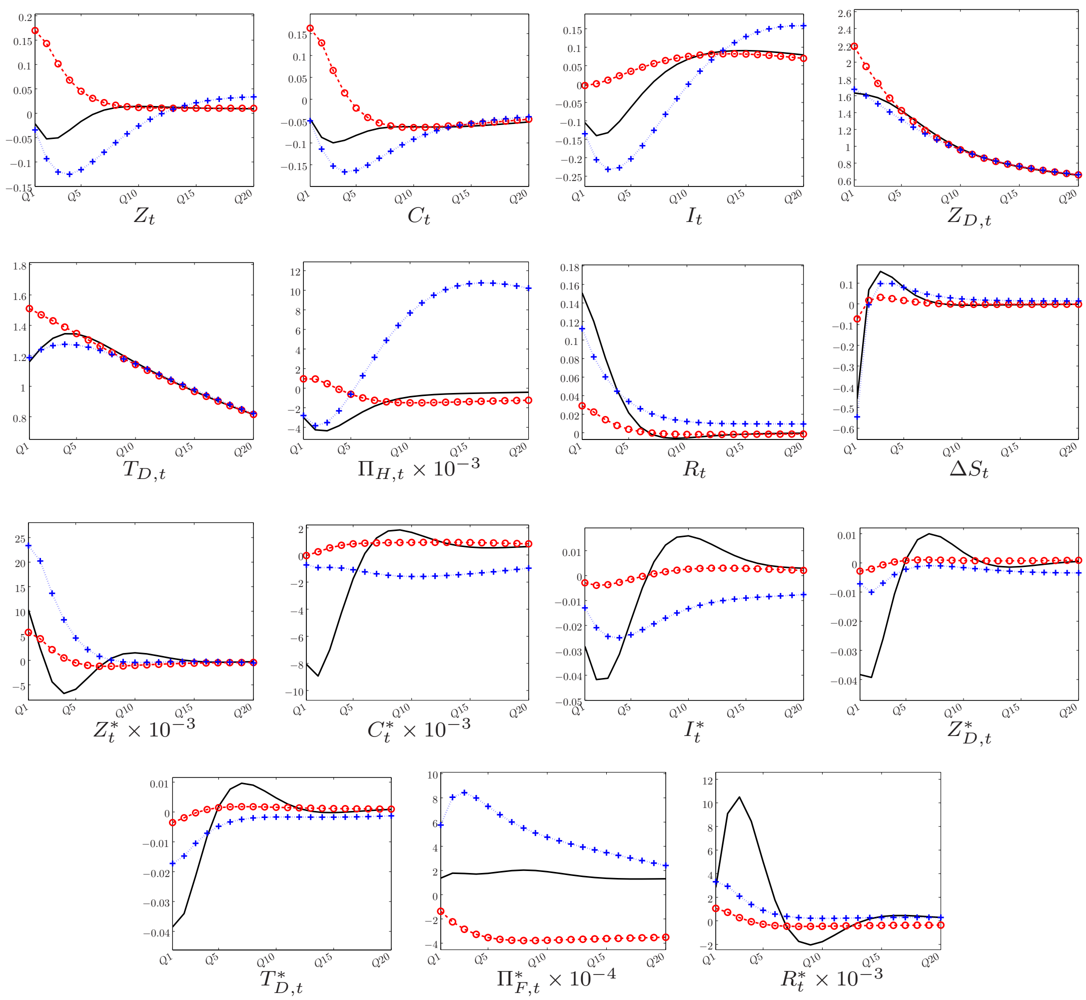

Fig. 11: Impulse Response Functions associated to a shock on ϵ_t^D. *Optimal cooperation (plain lines), Benchmark Estimated Rules (dotted and circle lines), Augmented Estimated Rules (dashed and cross lines).*

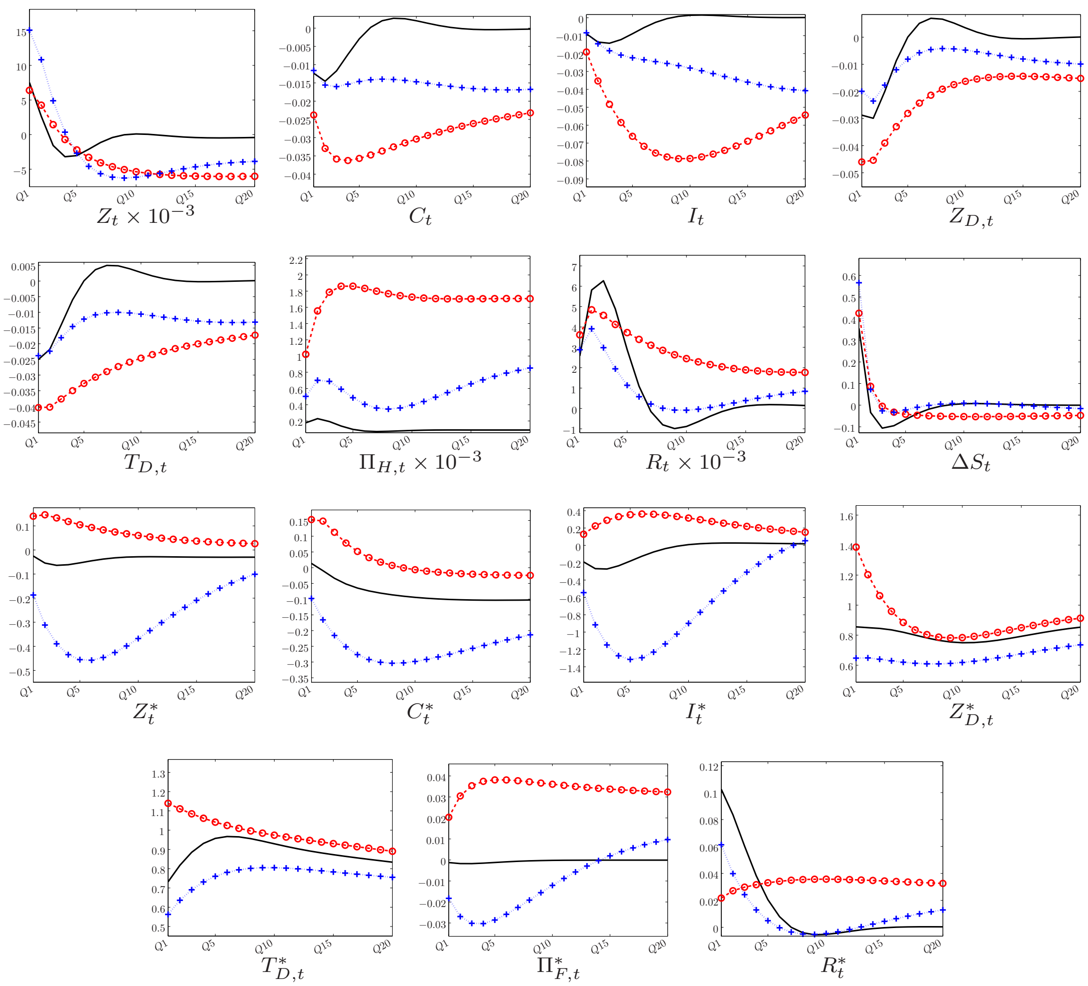

Fig. 12: Impulse Response Functions associated to a shock on ϵ_t^{D*}. *Optimal cooperation (plain lines), Benchmark Estimated Rules (dotted and circle lines), Augmented Estimated Rules (dashed and cross lines).*

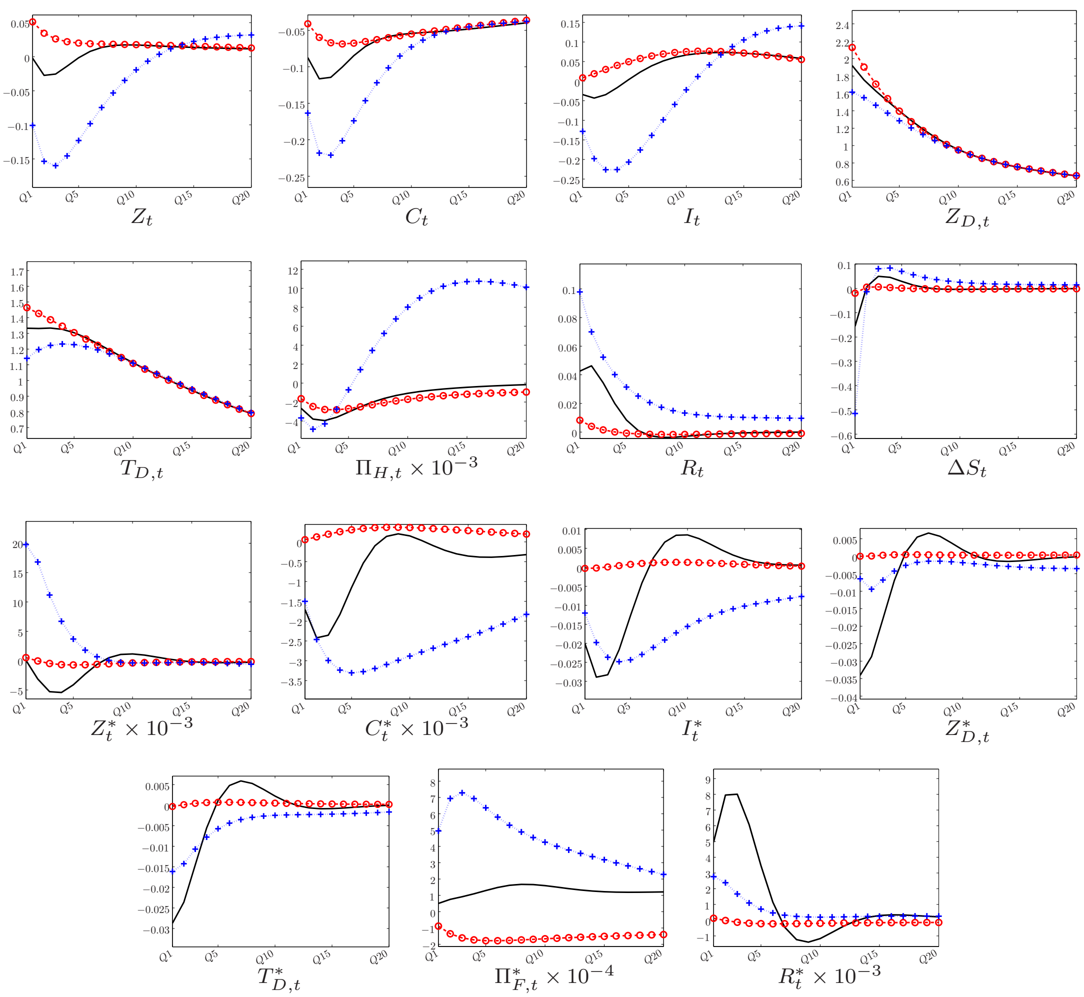

Fig. 13: Impulse Response Functions associated to a shock on ϵ_t^D. **No borrower case**. *Optimal cooperation (plain lines), Benchmark Estimated Rules (dotted and circle lines), Augmented Estimated Rules (dashed and cross lines).*

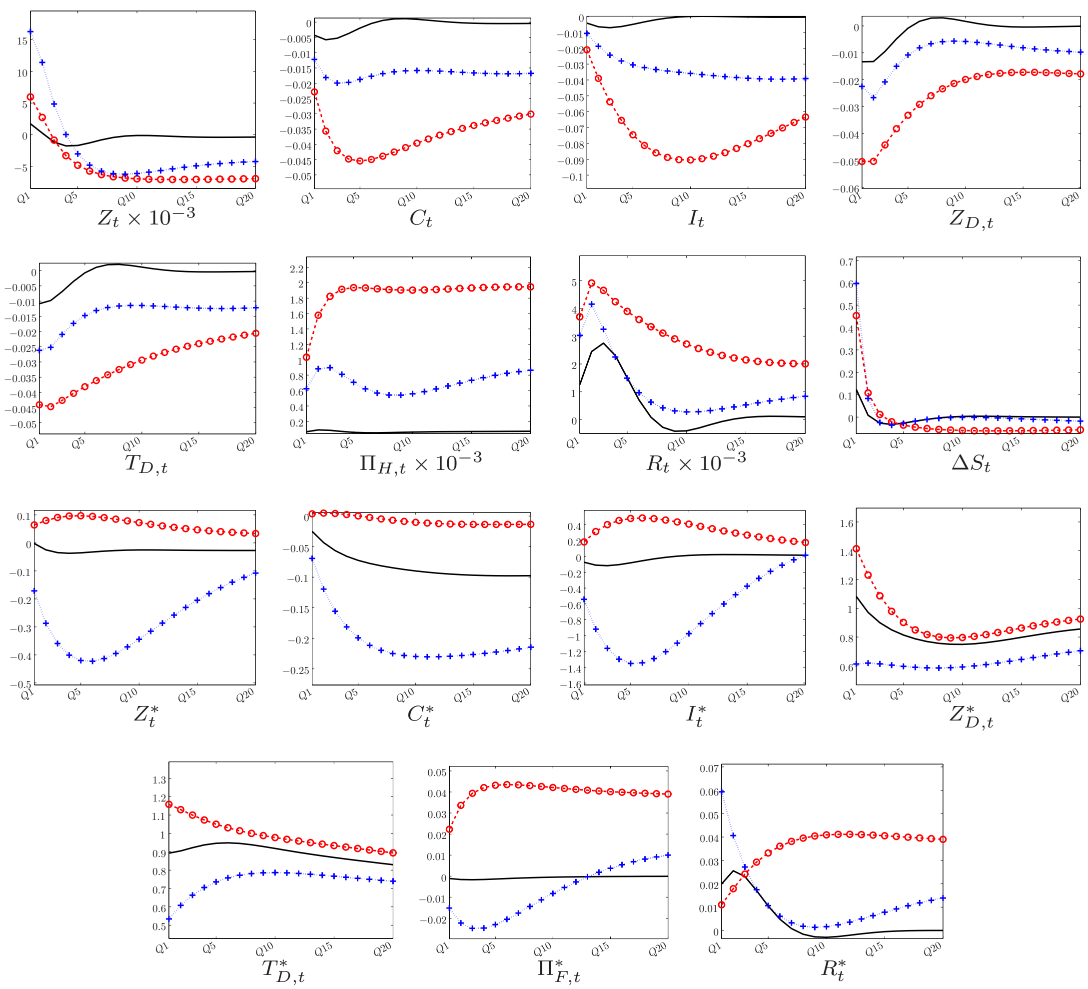

Fig. 14: Impulse Response Functions associated to a shock on ϵ_t^{D*}. **No borrower case**. *Optimal cooperation (plain lines), Benchmark Estimated Rules (dotted and circle lines), Augmented Estimated Rules (dashed and cross lines).*

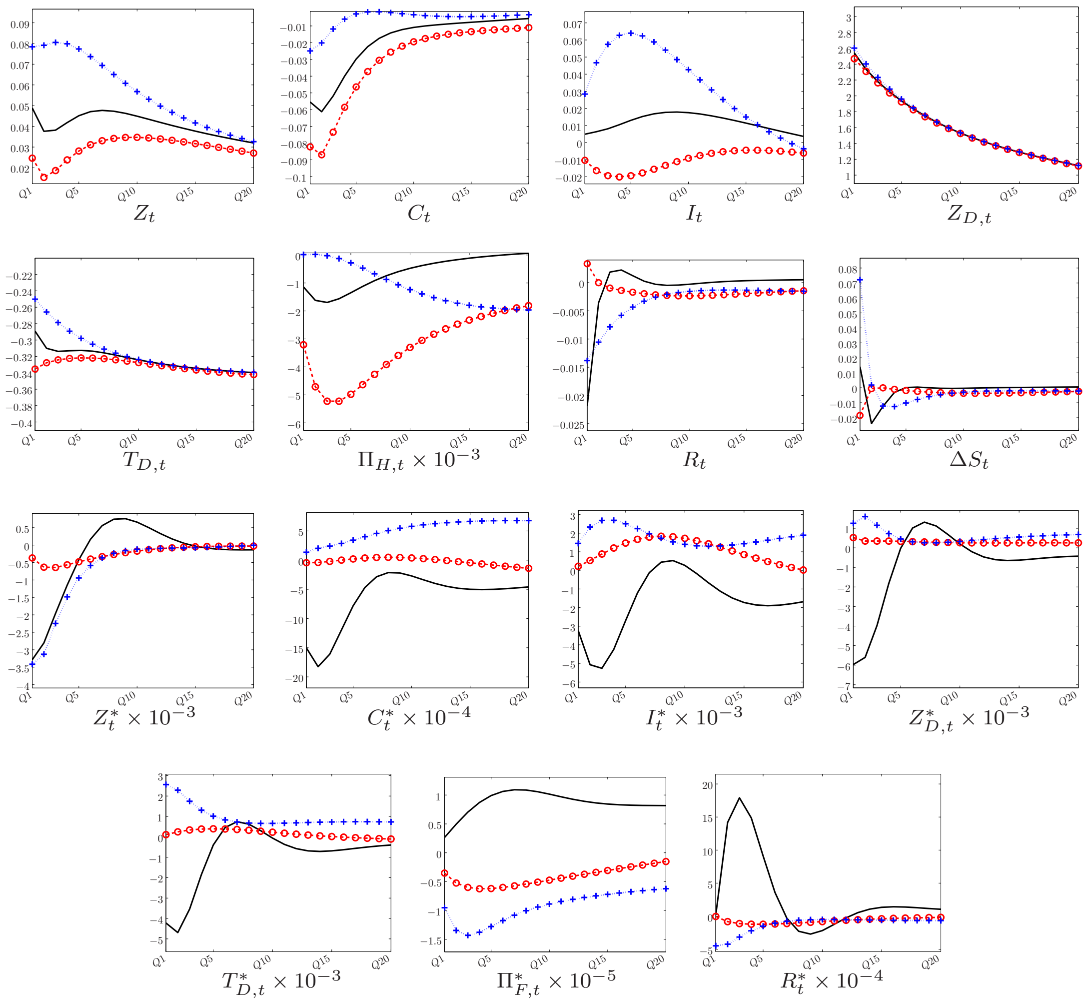

Fig. 15: Impulse Response Functions associated to a shock on $\epsilon_t^{A_D}$. *Optimal cooperation (plain lines), Benchmark Estimated Rules (dotted and circle lines), Augmented Estimated Rules (dashed and cross lines).*

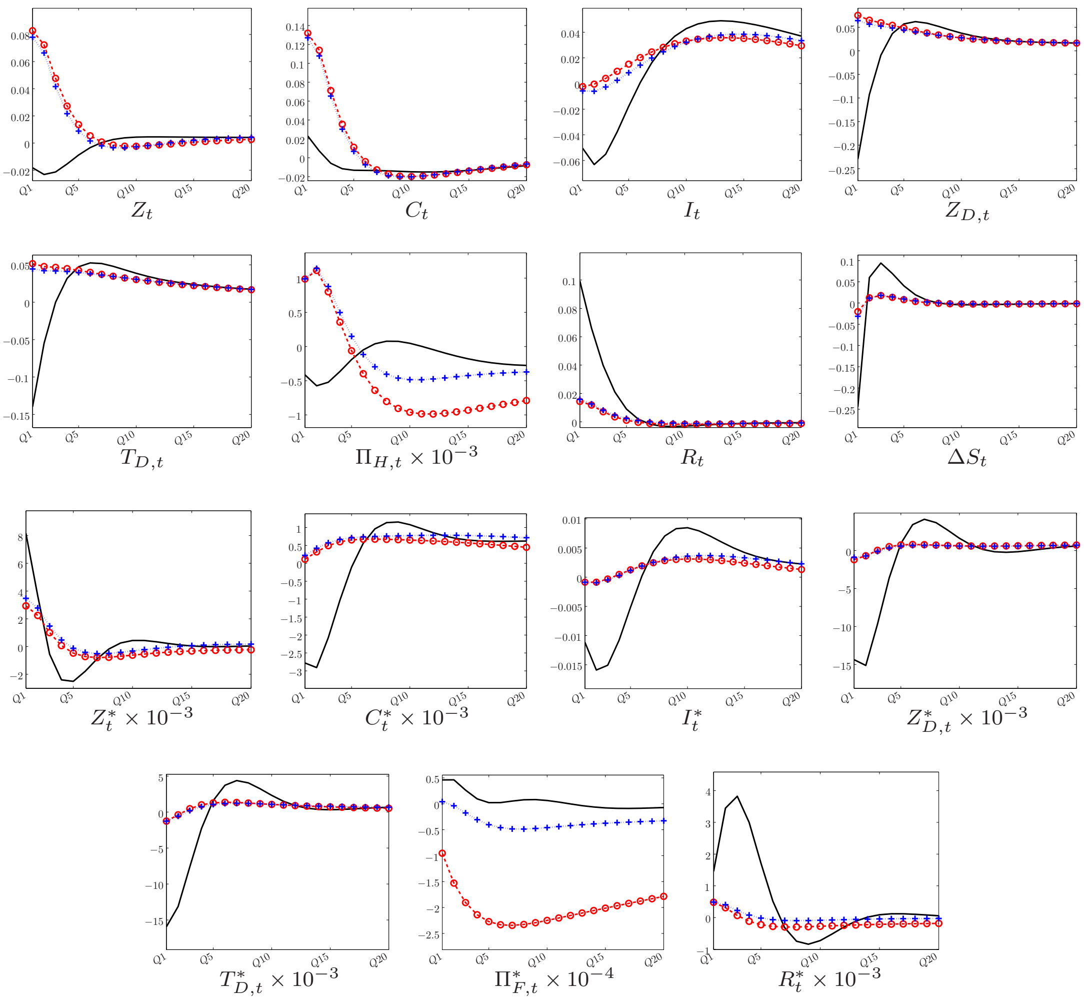

Fig. 16: Impulse Response Functions associated to a shock on ϵ_t^{LTV}. *Optimal cooperation (plain lines), Benchmark Estimated Rules (dotted and circle lines), Augmented Estimated Rules (dashed and cross lines).*