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# House Prices, Capital Inflows and Macroprudential Policy<sup>☆</sup>

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## Abstract

This paper evaluates the monetary and macroprudential policies that mitigate the procyclicality arising from the interlinkages between current account deficits and financial vulnerabilities. We develop a two-country dynamic stochastic general equilibrium (DSGE) model with heterogeneous households and collateralised debt. The model predicts that external shocks are important in driving current account deficits that are coupled with run-ups in house prices and household debt. In this context, optimal policy features an interest-rate response to credit and a LTV ratio that countercyclically responds to house price dynamics. By allowing an interest-rate response to changes in financial variables, the monetary policy authority improves social welfare, because of the large welfare gains accrued to the Savers. The additional use of a countercyclical LTV ratio that responds to house prices, increases the ability of borrowers to smooth consumption over the cycle and is Pareto improving. Domestic and foreign shocks account for a similar fraction of the welfare gains delivered by such a policy.

JEL classification: C33, E51, F32, G21

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## 1. Introduction

Between 1974-2006, U.S. house prices and households leverage increased by about 60 and 20 per cent, respectively. See Figure 1. The housing developments were also associated with a growing current account deficit which reached 6 per cent of GDP by the end of 2006. The global transmission of such vulnerabilities increased policy makers interest in policies that could mitigate the procyclicality arising from the interlinkages between global imbalances and domestic financial vulnerabilities.

This paper evaluates various policy actions. We begin by revisiting the long standing debate on whether monetary policy should react to financial cycles. We contribute to the debate by considering a direct response to either credit or house prices in the interest-rate rule of the central bank. We also explore the effects of macroprudential policy, given the recent policy debate which questions the traditional (micro) focus of financial stability policies and suggests the need for preventive (macro-prudential) policies that mitigate financial cycles and their economy-wide effects. We focus on the loan-to-value (LTV) ratio as a macroprudential tool and assess the ability of LTV ratio policies to provide a stable provision of loans to households in the face of both domestic and external shocks.<sup>1</sup> The use of dynamic macroprudential policy requirements has been suggested by The Basel Committee on the Global Financial System.<sup>2</sup>

We address the role of monetary and macroprudential policy in the interlinkages between global imbalances and financial vulnerabilities through the lens of a stochastic general equilibrium model. First, we develop a two-country dynamic stochastic general equilibrium (DSGE) model with heterogeneous households and collateral constraints. At the core of the model is the borrowers-lenders setup developed by Kiyotaki and Moore (1997) and extended to the household sector by Iacoviello (2005). The domestic economy features two types of households that differ in terms of the rate at which they discount the future. In equilibrium, one type of households borrows whereas the other type lends. Credit constraints arise because lenders cannot force borrowers to repay. Thus, houses are also used as loan collateral in the domestic

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<sup>1</sup>Note that the LTV ratio has already been used in several countries to restrain credit growth and mitigate house price cycles, see Lim et al. (2011).

<sup>2</sup>See Basel Committee on the Global Financial System (2010).

credit market. We assume that the foreign economy is populated by savers and runs a current account surplus. The foreign economy is thus willing to extend credit to the domestic economy and finance their current account deficit.<sup>3</sup>

We consider both domestic and external sources of economic fluctuations. Capital inflow shocks are modeled as both preference shocks to the foreign economy and as risk premium shocks. A positive shock to preferences makes foreign agents more patient and, thus, more willing to save, while a lower risk premium makes foreign borrowing less costly. We show that foreign shocks lead to both an increase in capital inflows and a persistent current account deficit. The greater availability of foreign funds leads to an increase in domestic consumption and housing investment. Due to a higher demand for housing, house prices rise, exacerbating the financial accelerator effect linked to the existence of housing collateral. Domestic shocks, such as housing preference shocks and credit shocks, generate similar results. However, in the calibrated version of the model, foreign shocks explain around 50 per cent of the volatility of the current account and 20 per cent of the variability of house prices. Monetary policy shocks account for about 30 per cent of the volatility in the current account but do not have a substantial effect on house prices. Housing preference shocks are an important driver of house prices and household credit but only explain a limited fraction of fluctuations in the current account.

In this model's context, we explore the benefits of policies that target changes in financial variables. We start by exploring whether monetary policy should explicitly recognize financial stability goals. To this end we investigate the optimality of an interest-rate response to changes in financial variables. Further, we investigate whether the use of dynamic LTV ratio policies can raise social welfare above what monetary policy could achieve by allowing for an interest-rate response to financial variables. Thus, we assess the additional benefits of allowing the LTV ratio to vary in a counter-cyclical manner. We first consider the optimal interest-rate response to changes in household credit or house-prices. We then search for the optimal LTV ratio response to variables that reflect domestic or global financial cycles. In order to

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<sup>3</sup>Close economy models of the housing market with borrowing constraints have been developed by Iacoviello (2005) and Campbell and Hercowitz (2005). For open economy extensions, see Christensen et al. (2013) for a small open economy and Iacoviello and Minetti (2006) and Punzi (2013) for two-country economy versions, among others.

draw meaningful conclusions about the desirability of alternative policies, we compare their performance on the basis of welfare criteria.

Our results show that an interest-rate response to changes in financial variables reduces macroeconomic volatility. In particular, an interest rate that directly responds to fluctuations in household credit is preferred in terms of social welfare. However, we find that the social welfare gains associated with this policy are due to the large welfare gains accrued to the Savers. An interest rate response to household credit reduces the volatility of both financial variables and the real interest rate. This results in a reduction in the volatility of the interest income of Savers which helps to stabilize their housing investment and consumption over the business cycle. At the same time, by reducing the volatility of financial variables, this policy limits the amplification effect of the collateral constraint and, thus, the Borrowers' ability to invest and consume. As a result, the welfare of one group of agents is increased at the cost of a reduction in the welfare of the other group.

We argue that the additional use of a countercyclical LTV ratio that optimally responds to changes in house prices improves social welfare relative to a constant LTV ratio policy. Limiting leverage and domestic borrowing capacity during periods of expansion and facilitating the use of credit during recessionary periods helps Borrowers to smooth consumption over time. In particular, the LTV ratio rule that optimally responds to fluctuations in house prices eliminates the trade-off between the Savers' and Borrowers' welfare. Thus, a policy that optimally combines an interest rate response to household credit with the use of dynamic requirements for the loan-to-value (LTV) ratios is Pareto improving.

Further, in terms of stabilization effects, this policy is more successful than others in reducing the volatility of both financial variables and the real interest rate. The analysis conducted in this paper does not target the smoothing out of specific shocks. By investigating the importance of varying sources of fluctuations, we find that the optimality of this policy is not driven by particular shocks. Indeed, domestic and foreign shocks account for a similar fraction of the welfare gains delivered by such a policy.

The rest of the paper is organized as follows. The next section reviews the related literature. Section 2 presents the details of the model. Section 3 discusses the calibration of the model. Section 4 reports the quantitative implications and the dynamics of the model. Section 5 describes the welfare analysis and Section 6 presents the results under the optimized rules. Section 7 presents some additional results and Section 8 concludes.

### *1.1. Related Literature*

The connection between global imbalances and the build-up of domestic financial imbalances has been widely recognized.<sup>4</sup> Bernanke (2005) and Bernanke (2010) introduced the “global saving glut hypothesis”, which argued that countries running current account surpluses have contributed to the permissive financial conditions in the U.S. and encouraged the recent credit boom. Several authors have documented that large capital inflows have been used to finance the U.S. economy, notably the housing market, during periods of low domestic saving rates (e.g. Bertaut et al. (2012), Sa and Wieladek (2011), Sa et al. (2012), Tillmann (2013), Warnock and Warnock (2009)). Other authors have instead shown that the liberalization of the domestic financial market was the driver behind house price dynamics (e.g. Favilukis et al. (2013)) while some have argued that the run-up in house prices in the U.S. was mainly due to loose monetary policy (e.g. Taylor (2007), Bracke and Fidora (2012), Borio and Disyatat (2011)).

Recently, the interaction between global imbalances and the dynamics of house prices and household debt has also been analyzed using DSGE models. Ferrero (2013) links current account deficits to house prices in a New-Keynesian open economy model in which the U.S. borrows from a representative international saver. He finds that a looser monetary policy combined with lower collateral requirements can explain about 60 per cent of the increase in real house prices and about 25 per cent of the current account deficit since the 2000s. Other authors explore the interlinkages between domestic and global imbalances in open economy models augmented with domestic borrowers and lenders, and collateralized household debt. In particular, Justiniano et al. (2014) argue that the dynamics of foreign capital flows account for between one fourth and one third of the recent cycle in the U.S. house prices and household debt, respectively. Punzi (2013) shows that in a two-country real business cycle model rising housing prices generate a long-lasting accumulation of external debt, inducing high investment and low savings. As a result, an economy with a booming housing market needs to finance

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<sup>4</sup>The build up of financial and global imbalances in advanced economies has been at the center of policy and academic debates even before the recent crisis. Indeed, while during the period of the Great Moderation many variables showed reduced volatility, the volatility of international capital flows increased, thereby increasing the vulnerability of the financial system. See Obstfeld (2012) and Borio and Disyatat (2011). Fogli and Perri (2006) argue that the decreasing volatility in the U.S. business cycle during the period of the Great Moderation has generated the large and persistent U.S. current account deficit.

its consumption and investment by accumulating long-lasting foreign debt which result in a current account deficit. This effect is amplified by high financial integration and financial deregulation. Our paper is similar to the above papers in that we develop a model that links house prices and current account dynamics. However, we use a more complex setup that allows us to: (1) account for both domestic and external shocks as potential sources of fluctuation in both house prices and the current account; (2) assess the importance of dynamic LTV ratio requirements in the mortgage market as well as their interaction with monetary policy. Therefore, we develop a stochastic general equilibrium model that combines the presence of interlinkages between the housing market and the current account, as in Ferrero (2013), with the presence of domestic borrowers and lenders, as in Justiniano et al. (2014) and Punzi (2013).<sup>5</sup> For the purpose of our paper, it seems necessary to distinguish between a domestic credit market and international capital flows. Indeed, investigating the role of LTV ratio policies while at the same time abstracting from the presence of a domestic credit market does not allow us to distinguish between policies that regulate lending to domestic households and those aimed at regulating international financial flows.<sup>6</sup> Since mortgages are mainly funded through the domestic mortgage market, it would not be realistic to assume that changes in the LTV ratio policies also apply to cross border lending. Therefore, we develop a model that distinguish between international and domestic credit flows.

This paper is also related to the growing literature on macroprudential policy. Several previous papers have explored the effects of macroprudential tools using stochastic general equilibrium models (e.g. Angeloni and Faia (2013), Angeloni et al. (2010), Christensen et al. (2011), Collard et al. (2012), Schmitt-Grohe and Uribe (2012)). However, only a few studies have assessed the role of a dynamic use of macroprudential instruments in models of the housing market. Using closed-economy models of the housing market, Kannan et al. (2012) and Angelini et al. (2014) show that an active use of macroprudential instruments, such as LTV ratios or capital requirements, generates sizable gains when the economy is hit by financial shocks. Lambertini et al. (2013) show that countercyclical LTV ratio requirements coupled with an interest-rate response to financial variables is socially optimal in a model with

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<sup>5</sup>The analysis developed by Justiniano et al. (2014) abstracts from cyclical fluctuations and varying sources of uncertainty, whereas the findings presented by Punzi (2013) are based on a model of the real business.

<sup>6</sup>The analysis of policies that regulate cross-border lending and international credit flows is beyond the scope of this paper.



run-ups in house prices that are induced by news-shock-driven cycles. Allowing a fraction of households to employ simple moving-average forecast rules, Gelain et al. (2013) argue that a debt-to-income type constraint is the most effective macroprudential tool to dampen the resulting excess volatility in house prices and debt. In this paper, we extend the standard DSGE housing model (i.e. a model with heterogeneity in time preferences and housing as a collateral) by introducing a role for housing market imperfections in the propagation of international business cycles. Thus, we contribute to previous findings by exploring the effectiveness of dynamic LTV ratio requirements and their interaction with monetary policy to ensure the stability of the financial system when both domestic and external shocks hit the economy.<sup>7</sup>

## 2. The Model

The model analyzes two large economies: a domestic and a foreign country.<sup>8</sup> Our framework combines heterogeneity of time preferences with collateral constraints. It also features housing market imperfections in the propagation of international business cycles. The domestic economy is populated by two types of households that trade domestic loanable bonds: patient (denoted by 1) and impatient (denoted by 2). Patient households have a higher propensity to save, i.e.  $\beta_1 > \beta_2$ . Housing is treated as a durable good with its demand depending on both the service flow and asset value of housing units. The service flow is assumed to be proportional to the real value of the individual housing stock holding. The model allows for constrained agents who collateralize the value of their homes. This financial friction results in the familiar financial accelerator mechanism. The economy is also populated by perfectly competitive intermediate-goods-producing firms, retailers that operate in a monopolistically competitive market, capital and house producers, and a monetary authority that follows a standard Taylor-type interest rate rule. Finally, the domestic country borrows from the foreign country which is populated only by patient agents (denoted by  $s$ ).

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<sup>7</sup>See Bank of International Settlements 2010.

<sup>8</sup>For simplicity, the model assumes the domestic and foreign economies are at equal size.

## 2.1. Households

Households supply labour and derive utility from consumption,  $c_{j,t}$ , housing services,  $h_{j,t}$ , and hours worked,  $L_{j,t}$ ,

$$\max E_0 \sum_{t=0}^{\infty} (\beta_j)^t \left[ \ln(c_{j,t}) + \gamma_{h,t} \varkappa \ln h_{j,t} - \frac{v_L}{\eta} (L_{j,t})^\eta \right],$$

where  $j = \{1, 2\}$  denotes the two types of households and  $\varkappa$  is the housing weight in the utility. As common in the literature, housing services are assumed to be proportional to the stock of houses held by the household and  $\gamma_{h,t}$  is a shock to the preference for housing services.<sup>9</sup>

**Lenders.** Patient households accumulate properties for housing purposes,  $h_{1,t}$ , trade domestic-currency loanable bonds,  $b_{1,t}$ , and foreign-currency bonds,  $b_t^*$ , and receive dividends from firms,  $F_t$ . They also invest in physical capital,  $k_t$ , that is then rented to the final-goods-producing firms at the rate  $R_t^k$ . Thus, they maximize their expected utility subject to the following budget constraint

$$\begin{aligned} c_{1,t} + q_{h,t}(h_{1,t} - (1 - \delta_h)h_{1,t-1}) + q_{k,t}(k_t - (1 - \delta_k)k_{t-1}) + b_{1,t} + s_t b_t^* &= \dots \\ &= w_{1,t}L_{1,t} + R_t^k k_{t-1} + \frac{R_{t-1}b_{1,t-1}}{\pi_t} + s_t \frac{\varsigma_{t-1}R_{t-1}^* b_{t-1}^*}{\pi_t^*} + F_t, \end{aligned} \quad (1)$$

where  $q_{h,t}$  is the price of housing,  $q_{k,t}$  is the price of capital,  $w_{1,t}$  are real wages,  $\pi_t = P_t/P_{t-1}$  and  $\pi_t^* = P_t^*/P_{t-1}^*$  are, respectively, the domestic and foreign gross inflation rate, and  $s_t$  is the real exchange rate. The stock of housing and capital depreciate at rates  $\delta_h$  and  $\delta_k$ , respectively. All the variables, except for the gross nominal interest rates on domestic and foreign bonds,  $R_t$ , and  $R_t^*$ , are expressed in real terms. The return on foreign debt depends on a country specific risk premium,  $\varsigma_t$ , that is required for the model to feature a stationary distribution.<sup>10</sup> This risk premium,  $\varsigma_t$ , is a positive convex function that depends on the ratio of net foreign assets to domestic output:

$$\varsigma_t = \exp \left[ \varphi \left( \frac{s_t b_t^*}{Y_t} \right) + \gamma_{\varsigma,t} \right],$$

where  $\gamma_{\varsigma}$  represents a risk-premium shock.

**Borrowers.** Impatient households maximize their expected utility subject to the following budget constraint

$$c_{2,t} + q_{h,t}(h_{2,t} - (1 - \delta_h)h_{2,t-1}) = w_{2,t}L_{2,t} - \frac{R_{t-1}b_{2,t-1}}{\pi_t} + b_{2,t}, \quad (2)$$

<sup>9</sup>See, for example Iacoviello (2005), Iacoviello and Neri (2010) and Liu et al. (2013).

<sup>10</sup>See Schmitt-Grohe and Uribe (2003) for further details.

and a borrowing constraint:

$$b_{2t} \leq m E_t \frac{q_{h,t+1} \pi_{t+1} h_{2t}}{R_t} \gamma_{m,t}. \quad (3)$$

Borrowing is limited to a fraction of the value of the borrowers' housing stock, where  $(1 - m)$  is the cost that lenders pay when repossessing the asset in the case of default.<sup>11</sup> We assume that agents' funding conditions may change due to the occurrence of a temporary shock to the valuation of the collateral asset, i.e. a credit shock,  $\gamma_{m,t}$ .<sup>12</sup> Impatient households do not have direct access to foreign lending.

## 2.2. Firms and Price Setting

The Intermediate Sector. There is a continuum of monopolistically competitive firms indexed by  $i \in [0, 1]$  that produce intermediate goods,  $y(i)$ , using the following technology:

$$y(i)_t = \gamma_{z,t} \left[ (L(i)_{1,t})^\gamma (L(i)_{2,t})^{1-\gamma} \right]^{1-\alpha} k(i)_{t-1}^\alpha, \quad (4)$$

where  $\gamma_{z,t}$  is an aggregate productivity shock,  $k$  is rented capital,  $L_1$  and  $L_2$  is labour supplied by patient and impatient agents, respectively. As in Iacoviello (2005) and Iacoviello and Neri (2010), we assume that different labour types are complements.<sup>13</sup>

We introduce price rigidities in the model following the New Keynesian literature. Thus, at time  $t$ , each intermediate firm revises its price with a probability  $(1 - \theta)$  as in Calvo (1983), leading to the following New Keynesian Phillips curve:

$$\log \left( \frac{P_t}{P_{t-1}} \right) = \beta_1 \left[ E_t \log \left( \frac{P_{t+1}}{P_t} \right) \right] + \epsilon_\pi \log \left( \frac{X_t}{X} \right) \quad (5)$$

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<sup>11</sup>It is possible to show that, in the present framework, impatient households borrow up to the maximum in the neighborhood of the deterministic steady state. Consider the Euler equation of the impatient household evaluated at the deterministic steady state  $\mu_2 = \left(1 - \frac{\beta_2}{\beta_1 \pi}\right) U_{c_2} > 0$ , where  $\mu_2$  is the Lagrange multiplier associated to the borrowing constraint.

<sup>12</sup>An exogenous change in the valuation of the collateral asset could reflect endogenous variations in the access to credit generated by credit supply shocks originated in the banking sector (which are not modelled in the present framework). Thus, this change is independent from the borrowers' decisions. For a similar modelling of credit shocks see also Khan and Thomas (2013), Shourideh and Zetlin-Jones (2012), Guerrieri and Lorenzoni (2011) and Jermann and Quadrini (2012).

<sup>13</sup>The primary motivation for this assumption is to obtain a closed-form solution for the steady-state of the model.

where  $\epsilon_\pi = \frac{(1-\theta)(1-\beta_1\theta)}{\theta}$  and  $X_t$  represents the marginal cost of production. Intermediate firms are owned by the patient households.

The Final-Goods-Producing Firms. The final good,  $Y_t$ , is produced by perfectly competitive firms using  $y_t(i)$  units of each type of intermediate good  $i$  and a constant return to scale, a diminishing marginal product, and a constant elasticity of substitution technology:

$$Y_t \leq \left[ \int_0^1 y_t(i)^{\frac{\xi-1}{\xi}} di \right]^{\frac{\xi}{\xi-1}}, \quad (6)$$

where  $\xi > 1$  is the constant-elasticity-of-substitution parameter. The price of an intermediate good,  $y_t(i)$ , is denoted by  $P_t(i)$  and is taken as given by the competitive final-good-producing firms. Solving for cost minimization yields a constant-price-elasticity demand function for each goods type  $i$  which is homogeneous to degree one in the total final output,  $y_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{-\xi} y_t$ , and the domestic price index  $P_t = \left[ \int_0^1 P_t(i)^{1-\xi} di \right]^{1/(1-\xi)}$ .

### 2.3. Capital Producers

Capital producers combine a fraction of the final goods purchased from retailers as investment goods,  $I_{k,t}$ , to combine it with the existing capital stock in order to produce new capital goods.<sup>14</sup> Capital production is subject to an adjustment cost specified as  $\frac{\psi_k}{2} \left( \frac{I_{k,t}}{k_{t-1}} - 1 \right)^2 I_{k,t-1}$ , where  $\psi_k$  governs the slope of the capital producers adjustment cost function. Capital producers choose the level of  $I_{k,t}$  that maximizes their profits

$$\max_{I_{k,t}} q_t^k I_{k,t} - \left( I_{k,t} + \frac{\psi_k}{2\delta_k} \left( \frac{I_{k,t}}{k_{t-1}} - \delta_k \right)^2 k_{t-1} \right).$$

From profit maximization, it is possible to derive the supply of capital

$$q_t^k = \left[ 1 + \frac{\psi_k}{2\delta_k} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right) \right], \quad (7)$$

where  $q_t^k$  is the relative price of capital. In the absence of investment adjustment costs,  $q_t^k$  is constant and equal to one.

The usual capital accumulation equation holds

$$I_{k,t} = k_t - (1 - \delta_k) k_{t-1}. \quad (8)$$

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<sup>14</sup>See, among others, Bernanke et al. (1999), Christiano et al. (2005) and Christensen and Dib (2008).

#### 2.4. Housing Producers

We assume that housing producers act in a way that is analogous to the production of capital. That is, they combine final goods with the existing housing stock and produce new units of installed houses. Housing production is subject to an adjustment cost specified as  $\frac{\psi_h}{2\delta_h} \left( \frac{I_{h,t}}{h_{t-1}} - \delta_h \right)^2 h_{t-1}$ . For a similar formulation, see Aoki et al. (2004) and Christensen et al. (2013). From profit maximization, it is possible to derive the supply of housing

$$q_t^h = \left[ 1 + \frac{\psi_h}{2\delta_h} \left( \frac{I_{h,t}}{h_{t-1}} - \delta_h \right) \right], \quad (9)$$

where new housing capital goods are sold at a price  $q_t^h$ . This equation is similar to the Tobin's  $q$  relationship for investment in which the marginal cost of a unit of housing is related the marginal cost of adjusting the housing stock.<sup>15</sup>

The aggregate stock of housing,  $h_t = h_{1,t} + h_{2,t}$ , is accumulated according to

$$I_{h,t} = h_t - (1 - \delta_h) h_{t-1}. \quad (10)$$

#### 2.5. Monetary Policy

We assume that, in the benchmark economy, the monetary authority follows a simple interest-rate rule

$$R_t = \left( \frac{\pi_t}{\pi} \right)^{\phi_\pi} \varepsilon_{r,t} \quad (11)$$

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<sup>15</sup>A variety of approaches have been followed in the literature regarding the modelling of the supply of housing. Some authors abstract from housing investment and assume that the supply of houses is fixed in the short run (i.e. Iacoviello (2005) and Ferrero (2013)); others assume that housing are produced just by using final goods, thus, the stock of housing evolves according to the standard investment equation without adjustment costs (i.e. Campbell and Hercowitz (2005), Campbell and Hercowitz (2009), Calza et al. (2013) and Justiniano et al. (2014)) and some also assume that housing producers act in a way that is analogous to the production of capital. That is, they combine final goods with the existing housing stock and produce new units of installed houses and housing production is subject to an adjustment cost (i.e. Aoki et al. (2004) and Christensen et al. (2013)). An alternative formulation for the production of housing would require an explicit production function as for instance in Iacoviello and Neri (2010). This latter modelling choice would not affect the transmission of domestic and foreign shocks. Indeed, as already highlighted by Iacoviello and Neri (2010) “land works in a way similar to an adjustment cost on housing, since it limits the extent to which the housing stock can be adjusted. In response to shocks, a larger land share reduces the volatility of housing investment and increases the volatility of house prices”. Our model's results under an explicit production function of housing are available upon request.

where the nominal interest rate is adjusted in response to deviations of inflation from its target,  $\frac{\pi_t}{\pi}$ , and  $\varepsilon_{r,t}$  is an i.i.d. monetary policy shock.

## 2.6. Current Account Equation

Domestic output,  $Y_t$ , can be consumed, invested or exported

$$Y_t + D_t^* = C_t + q_{k,t}I_t^k + q_{h,t}I_t^h,$$

where  $C_t = c_{1,t} + c_{2,t}$ ,  $I_{h,t} = h_t - (1 - \delta_h)h_{t-1}$ ,  $I_{k,t} = k_t - (1 - \delta_k)k_{t-1}$  and  $D_t^* = s \left( b_t^* - \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} \right) - \frac{\varphi}{2} (b_t^* - b^*)^2$ .

The trade balance equals

$$TB_t = Y_t - C_t - q_{k,t}I_t^k - q_{h,t}I_t^h = -D_t^*, \quad (12)$$

and

$$CA_t = -TB_t + \frac{s(R_{t-1}^* - 1)b_{t-1}^*}{\pi_t^*} = s \left( b_t^* - \frac{b_{t-1}^*}{\pi_t^*} \right).$$

The last equation states that the current account is the sum of the service account, i.e. the interest required to service existing debt, and the trade account, which is the trade balance expressed as the difference between output, consumption and investments.<sup>16</sup>

## 2.7. Rest of the World

The foreign economy is assumed to be a saver economy that runs a current account surplus. For simplicity, there is only one representative household in the foreign economy. This household also holds all the capital rented to firms, workers in the production of consumption goods and saves. The foreign agent problem is similar to the domestic Savers'. The foreign agent's expected utility is summarized by

$$\max E_0 \sum_{t=0}^{\infty} \beta_s^t \gamma_{b,t} \left[ \ln(c_{s,t}) + \varkappa \ln h_{s,t} - \frac{v_L}{\eta} (L_{s,t})^\eta \right],$$

where  $\beta_s^t = \beta_1^t$  and  $\gamma_{b,t}$  is an exogenous shock to the foreign consumer's impatience.

Firms produce consumption goods, capital and new houses as in (4)-(11). Adjustment costs are defined identically to those in the domestic economy. Price rigidities are also introduced as in the domestic economy, see (5). The foreign monetary authority follows an interest rate rule as in (12).

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<sup>16</sup>A similar definition is found in Obstfeld and Rogoff (1995) and Ghironi (2006).

## 2.8. Exogenous Factors

Shocks to productivity,  $\gamma_{z,t}$ , house preferences,  $\gamma_{h,t}$ , domestic borrowing limits,  $\gamma_{m,t}$ , the risk premium,  $\gamma_{\varsigma,t}$ , and the foreign discount factor,  $\gamma_{b,t}$ , follow an autoregressive process of order one

$$\ln \gamma_t = \rho_\gamma \ln \gamma_{t-1} + \varepsilon_{\gamma,t},$$

where  $\gamma = \{z, h, m, \varsigma, b\}$ ,  $\rho_\gamma$  is the persistence parameter and  $\varepsilon_{\gamma,t}$  is a i.i.d. white noise process with mean zero and variance  $\sigma_\gamma^2$ . Monetary policy shocks,  $\varepsilon_{r,t}$ , are instead i.i.d.

## 3. Calibration

The model is calibrated at quarterly frequency using US National Accounts and Flow of Funds data over the period 1974:1-2008:1. For the foreign economy, we use data on real house prices and the short nominal interest rate for the G7 excluding the US.<sup>17</sup> Due to limitations in the availability of cross-country data on house prices, the sample used for the calibration begins in 1974:1. Figures 2 and 3 plot the data used in the calibration, whereas Table 1 reports the targets used for the calibration.

Table 2 reports the parameter values. A first set of parameters describing preferences and technology are calibrated using steady state targets. The discount factor of the Savers,  $\beta_1$ , is set equal to 0.99, such that the average annual rate of return is about 4%. In the model, the Savers own 100% of physical capital wealth. Thus, we consider the Savers to represent the top wealth decile of households in the model economy. Wolff (2010), using the 1983, 1989, 1992, 1995, 1998, 2001 and 2007 Federal Reserve Board's Surveys of Consumer Finances, documents that the share of income and the share of housing wealth held by the top decile of US households are about 40% and 60%, respectively.<sup>18</sup> Thus, we calibrate the discount factor of the borrowers,  $\beta_2$ , and the production parameter,  $\gamma$ , in order to match two ratios for the borrowers: a share of income of about 60% and a share of housing wealth of about 40%. The Borrower's discount factor is somewhat lower than the value used by other authors.<sup>19</sup> However, it does fall in the range of the empirical distribution of discount factors

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<sup>17</sup>We thank Luciana Juvenal of the Federal Reserve Bank of St. Louis for kindly providing this data. Source: Fratzscher et al. (2010).

<sup>18</sup>The Savers' income share of 40% is also consistent with the long-run average measured by Piketty and Saez (2003). Updated data through 2010 are available from Emmanuel Saez's website.

<sup>19</sup>See, among others, Iacoviello (2005), Campbell and Hercowitz (2009), Iacoviello and Neri (2010).

calculated by Carroll and Samwick (1997) using information on the elasticity of assets with respect to uncertainty, i.e. the two standard deviation bands range in the interval (0.91, 0.99).

The depreciation of the housing stock,  $\delta_h$ , is calibrated in order to match a ratio of residential investment to GDP of 4.5574%. The loan-to-value ratio,  $m$ , and the housing weight in the utility,  $\varkappa$ , are jointly calibrated to match (i) a ratio of total housing wealth to GDP of 127.849%, and (ii) a ratio of household credit to total housing wealth of 45.45%. The resulting loan-to-value ratio is 0.73. Under this calibration, the model is also able to deliver a ratio of household credit to GDP of 55.30%, as in the data.

The following steady state relationship is used to calibrate the stock of foreign debt relative to annual GDP ( $b^*$ ) in order to match the US trade deficit to annual GDP figure of 2.73%:

$$b^*(1 - R^*) = -TB \quad (13)$$

We borrow the remaining parameters from the existing literature. Since the labor disutility parameter  $\nu_L$  only affects the scale of the economy, we normalize it to one. The parameter  $\eta$  is set to 2 such that the Frisch elasticity of labor supply equals one. The average net markup equals 10 per cent and the Calvo parameter,  $\theta$ , is set to 0.67. We set the capital share in production,  $\alpha$ , equal to 0.30 and the depreciation of productive capital  $\delta_k$  to 0.025. The adjustment cost parameters are set equal to 0.5.

The second set of parameters determining the stochastic properties of the model are calibrated to match key moments of the data. All series are in real terms and their log value is linearly detrended. First, we parameterize the technology shock,  $\gamma_{z,t}$ , following the standard Solow residuals approach. We construct a series for the capital stock using end-of-period balance sheet data from the Flow of Funds Accounts as in Jermann and Quadrini (2012). Given the value of  $\alpha$  and the empirical series for GDP, the stock of capital and total hours worked we construct the  $z_t$  series.

The standard deviations of the housing preference shock,  $\sigma_{h,t}$ , credit shock,  $\sigma_{m,t}$ , the monetary policy shock,  $\sigma_{r,t}$ , the risk premium shock,  $\sigma_{\varsigma,t}$ , and the foreign discount factor,  $\sigma_{b,t}$ , are jointly calibrated to match the unconditional standard deviation of the current account as a share of domestic GDP, the standard deviation of real house prices relative to GDP, the standard deviation of housing value relative to household credit, the relative standard deviation of domestic and foreign real house prices, the relative standard deviation of domestic and foreign short term interest rates. Hitting these targets requires an autoregressive process



of all shocks equal to 0.98, except for the monetary policy shock that is assumed to be i.i.d. Table 2 reports the values of the calibrated parameters.

#### 4. Quantitative Implications and Model Dynamics

In this section, we explore the transmission mechanism of domestic and foreign shocks and we assess the relative importance of shocks for key macroeconomic variables. Figure 4 analyzes the impact of risk premiums (solid line) and foreign preference shocks (starred line). A negative 1 per cent innovation to the risk premium,  $\gamma_{\varsigma,t}$ , increases the willingness of foreign investors to accumulate U.S. assets. This is because U.S. assets are considered safer and more liquid, while a positive shock to foreign preferences,  $\gamma_{b,t}$ , makes foreign agents more patient and, thus, more willing to save. Both shocks lead to an increase in capital inflows and thus, a current account deficit. On impact, a 1 per cent increase in  $\gamma_{\varsigma,t}$  and  $\gamma_{b,t}$ , leads to a change in the current account of 7.5 per cent. In the case of a foreign preference shock, the current account quickly returns to the steady state level, and reverses after 5 quarters, whereas a risk premium shock leads to a more persistent current account deficit. The greater availability of foreign funds generates a greater availability of credit to domestic borrowers as well as an increase in the domestic consumption of both non-durable goods and housing. Due to the higher demand for housing, house prices rise which exacerbate the financial accelerator effects linked to the existence of housing collateral. In response to inflow shocks, the model generates co-movement between domestic consumption and housing production. Household credit increases by about 30 and 50 per cent in response to a 1 per cent innovation to the foreign preference and risk premium shock, respectively. The increase in domestic consumption and house prices is more moderate. Both rise by around 5 per cent for the foreign preference shocks and 6 per cent for the risk premium shock. The increase in housing investment is less pronounced. These findings are consistent with both Bernanke (2005) and Sa and Wieladek (2011) and support the global savings glut hypothesis.

Figure 5-6 show the impulse responses to domestic shocks. In Figure 5, we analyse the effects of a positive one per cent housing preference shock (solid line) and credit shock (starred line). An increase in the weight of housing service in the utility function,  $\gamma_{h,t}$ , makes households more willing to consume houses rather than consumption goods. Credit shocks instead temporarily change the households' access to domestic credit due to variations in the valuation of the collateral asset,  $\gamma_{m,t}$ . Both shocks generate an increase in the policy interest

rate, real house prices and household credit. The increase in the policy interest rate attracts foreign savings and also makes domestic savers willing to borrow from abroad in order to lend domestically at a higher rate. Consumption and residential investment also increase. The domestic economy runs a current account deficit of 0.25 per cent and 0.4 per cent for the housing preference shock and credit shock, respectively. The economy displays larger amplification in response to a credit shock relative to a housing preference shock. However, in both cases, the impact on house prices and the current account is more moderate than in the case of foreign shocks.

Finally, in Figure 6, we report the impulse responses to a 1 per cent positive productivity shock (solid line) as well as an expansionary monetary policy shock (starred line). Both shocks generate an increase in house prices, household credit, consumption and residential investment. However, due to expansionary conditions in the domestic economy, the saver optimally reduces the foreign debt, leading to a current account surplus.

In order to understand the relative importance of the shocks in the theoretical model, we report their contribution to the volatility of the main variables of interest, such as current account (to GDP), house prices and household credit. Results are reported in Table 3. Foreign shocks account for about 50 per cent of the volatility in the current account to GDP and about 20 per cent of house prices. Housing preference shocks explain about 70 per cent of the volatility in house prices but only 12 per cent of volatility in the current account to GDP. Domestic shocks explain almost all the variation of household credit, with about 66 per cent of its variation accounted for by the housing preference shock and 30 per cent by credit shocks. Monetary policy shocks account for 30 per cent of the volatility of the current account to GDP but have a limited effect on house prices and household credit.

In sum, foreign shocks account for a sizable fraction of volatility in the current account as a share of GDP, followed by monetary policy shocks. Housing preference shocks are the most important domestic shocks in explaining the volatility of house prices and household credit.<sup>20</sup>

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<sup>20</sup>Productivity shocks have no influence in the variance decomposition of the current account, house price and household debt.

## 5. Welfare

In order to draw meaningful conclusions about the desirability of alternative policies, we compare their performance on the basis of welfare criteria. By using household welfare as the objective function of the policy authority, we avoid the problem of adopting ad-hoc loss functions that may not be optimal in this model. The welfare analysis is based on the approach commonly used in the DSGE literature.<sup>21</sup> The individual welfare of each household is measured by the conditional expectation of lifetime utility as of time  $t$

$$V_{jt} \equiv \max E_t \left[ \sum_{t=0}^{\infty} \beta_j^t U(c_{jt}, h_{jt}, l_{jt}) \right]$$

Thus, we augment the set of equilibrium conditions of the model with two equations and two unknowns  $V_{1t}$  and  $V_{2t}$

$$V_{jt} = U(c_{jt}, h_{jt}, l_{jt}) + \beta_j^t E_t V_{jt+1}, \quad (14)$$

where  $V_{jt} = \{V_{1t}, V_{2t}\}$  denotes the welfare of the Borrowers and Savers, respectively. We aggregate individual welfare in a social welfare function, i.e. a weighted average of the welfare of the two groups of agents:

$$\tilde{V}_t \equiv [\varphi_1 V_{1t} + \varphi_2 V_{2t}], \quad (15)$$

where  $\varphi_j = (1 - \beta_j)$ . The weights are chosen such that, given a constant consumption stream, the Borrowers and the Savers achieve the same level of utility. Note that, without correcting for the difference in the discount factors, the social welfare function would deliver an implicit higher weight on welfare for the Savers.<sup>22</sup>

Following previous literature, we compute the welfare implied by the various rules, conditional on the initial state ( $t = 0$ ) being the deterministic steady state.<sup>23</sup> As in Schmitt-Grohe

<sup>21</sup>See among others, Kim and Kim (2003), Faia and Monacelli (2007), Erceg et al. (2000), Schmitt-Grohe and Uribe (2005b), Schmitt-Grohe and Uribe (2007a), and Schmitt-Grohe and Uribe (2007b).

<sup>22</sup>The social weights used in the analysis ensure the same utility weights across agents that discount future utility at different rates, as in Mendicino and Pescatori (2008). Let us assume unit weights in (15), i.e.  $\varphi_1 = \varphi_2 = 1$ . In the steady state, Savers' lifetime utility is  $V_1 = \frac{1}{(1-\beta_1)}U_1$ , whereas Borrowers' is  $V_2 = \frac{1}{(1-\beta_2)}U_2$ . Thus,  $\tilde{V} \equiv \left[ \frac{1}{(1-\beta_1)}U_1 + \frac{1}{(1-\beta_2)}U_2 \right]$  with  $\frac{1}{(1-\beta_2)} < \frac{1}{(1-\beta_1)}$ . Given the parameter values assigned to  $\beta_1$  and  $\beta_2$ , the weight on the welfare of Savers is five times higher than that on Borrowers. In contrast, weighting  $V_1$  by  $\varphi_1 = (1 - \beta_1)$  and  $V_2$  by  $\varphi_2 = (1 - \beta_2)$ , avoids spurious redistribution effects. See Lambertini et al. (2013) for sensitivity to the use of alternative weighting criteria.

<sup>23</sup>See for instance Schmitt-Grohe and Uribe (2007a) and Faia and Monacelli (2007).

and Uribe (2007a), we assess the effects of simple policy rules, i.e. rules that imply a response of the policy instrument to a few observable macroeconomic variables. These variables guarantee local uniqueness of the rational expectations equilibrium and are optimal in the sense that they maximize social welfare. Thus, the optimized interest-rate and LTV ratio rules are ranked in terms of social welfare levels. The welfare effects of the alternative rules are quantified on the basis of a consumption-equivalent measure, i.e. the percentage increase in individual consumption that would make the welfare of each type of agent under the baseline policy equal to the welfare under the optimized rule. Table 4 panel A.1 (rule i) reports the individual and social welfare levels under the baseline policy used for the calibration of the model, i.e. a monetary policy rule that features a 1.5 interest rate response to inflation coupled with a constant LTV ratio  $m$  equal to 0.73.

## 6. Optimized Policy Rules

In recent decades, there has been a great deal of emphasis on assessing the ability of monetary policy to dampen housing and credit cycles.<sup>24</sup> However, since the recent financial crisis, the design of a new policy framework that restrains the build-up of credit and house price dynamics has been central to both policy and academic debates. A large number of papers explores the macroeconomic effects of macroprudential policies, such as LTV ratios, capital requirements and reserve requirements in general equilibrium models. In the following, we first explore the optimality of an interest-rate response to financial variables. Further, we study the effects of alternative LTV ratio policies in stabilizing fluctuations in household credit and housing prices.<sup>25</sup>

### 6.1. Interest Rate Response to Financial Variables

First, we investigate whether monetary policy should explicitly target fluctuations in financial variables. Thus, we evaluate the welfare implications of alternative interest-rate rules

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<sup>24</sup>See, among others, Bernanke and Gertler (2001), Gilchrist and Leahy (2002), Faia and Monacelli (2007) and Iacoviello (2005).

<sup>25</sup>This model is linearized around a deterministic steady-state. Thus, it is not able to deal with bubbles or other types of unsustainable dynamics. Hence, the purpose of the proposed macroprudential policies is to stabilize house price cycles and credit cycles rather than correcting imbalances.

that react to either changes in household credit or house prices

$$R_t = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y} \left(\frac{x_t}{x_{t-1}}\right)^{\phi_x} \varepsilon_{r,t} \quad (16)$$

where  $y_t$  is output and  $x_t = \{b_t, q_t\}$ .<sup>26</sup> Table 4 (panel A.2) reports the combination of parameters that deliver the highest welfare given an interest-rate rule that targets either household credit (rule iii) or house prices (rule iv). Both rules feature a moderate response to financial variables and no response to GDP growth.<sup>27</sup> The optimized rules also require an aggressive response to inflation.

It is important to highlight that the social welfare maximizing interest-rate response to financial variables is not a Pareto improvement beginning from the baseline policy, i.e. (rule i). In other words, under an interest-rate response to financial variables, the welfare of one group of agents is increased at the cost of a reduction in the welfare of the other group. Responding to financial variables improves social welfare only due to the large individual welfare gains accrued to the Savers.

A nominal interest-rate response to changes in financial variables implies a more contained response of the real interest rate to shocks and thus, a less sizable effect on the housing investment and borrowing decisions of households. Let us consider the case of an unanticipated expansionary of monetary policy. See Figure 8. This shock induces agents to increase their current expenditures. Demand pressure raises current inflation and the current ex-post real rate declines. Similar to Ferrero (2013), expansionary monetary policy generate a lower real interest rate and an increase in house prices.<sup>28</sup> Given the collateral constraint, which allows households to borrow more against the higher value of their house, and given the lower desire to save, Borrowers increase their level of indebtedness and housing investment. As implied by the Euler equation, a reduction in real interest rates affects the Savers' consumption/saving plan allocation. As a result, they reduce investment in housing. When the interest rate reacts to the increase in financial variables (rule iii) and (iv) the real interest rate declines by less. Thus, Savers benefit from a less substantial reduction in their interest rate income and, in

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<sup>26</sup>We search over a three dimensional grid, with the ranges for the three parameters being [1.1,10] for  $\phi_\pi$ , [0,3] for  $\phi_y$ , and [0,3] for  $\phi_x$ . The grid step for each parameter is 0.1.

<sup>27</sup>As reported in (rule ii), a positive response to output growth reduces social welfare even in the case of the baseline interest-rate rule that does not include a response to changes in financial variables.

<sup>28</sup>However, the present model can generate this result abstracting from exchange rate regime.

turn, reduce less of their housing investment. Since this policy limits the amplification effect of the collateral constraint, by mitigating the increase in housing value, Borrowers suffer from a reduced increase in the availability of credit. The effect is more sizable under an interest-rate response to variations in household credit.

Figure 7 shows how individual and social welfare change with respect to an interest-rate response to the financial variables while leaving the output and inflation coefficients unchanged to the optimized values. Some observations are in order. First, the optimized responses to inflation and output deliver higher social and Savers welfare even in the absence of a response to financial variables, i.e.  $\phi_b = \phi_q = 0$ . Regarding (rule iv), the Borrowers welfare is always below the baseline policy (rule i) welfare level, independently of the response to house prices. In contrast, for the Borrowers welfare to be above the level reached under the baseline policy, (rule iii) would require a much more aggressive response to credit growth than the coefficient that maximizes social welfare.

## 6.2. Dynamic LTV Requirements

Second, we investigate the implications of adopting dynamic LTV ratio requirements as macroprudential tools. In particular, we allow the LTV ratio to vary in a counter-cyclical manner around a pre-established steady state cap,  $m$ . We explore the effectiveness of a countercyclical LTV ratio rule of the following class

$$\frac{m_t}{m} = \left( \frac{x_t}{x} \right)^{-\varphi_x},$$

where  $x_t$  denotes a variety of key measures of macroeconomic and financial conditions, i.e.  $x_t = \left\{ q_t^h, b_{2t}, y_t, \frac{q_t^h}{q_t^*} \right\}$  and  $\varphi_x \geq 0$ . The optimality of a countercyclical response of the LTV ratio to output, household credit and house prices has already been investigated in the context of closed economy models of the housing market.<sup>29</sup> In this paper, we also consider the differential between domestic and foreign real house prices, a variable that may capture global financial cycles.

Table 5 reports the coefficients of the LTV ratio rules that respond to each of the selected variables and deliver the highest welfare. The analysis is conducted conditional on monetary policy being conducted as in the optimized (rule iii) or (iv). We also include the welfare levels

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<sup>29</sup>See for instance Lambertini et al. (2013) and Angelini et al. (2014).

under the constant LTV ratio, i.e.  $m_t = m$ , for reference. We compute the welfare gains of adopting each optimized LTV ratio rule with respect to the policy of a constant LTV ratio by compensating variations. That is, we measure the percentage change in consumption under the constant LTV ratio case that would give households the same unconditional expected utility as in the stochastic economy under each optimized rule.

Panel B.1 of Table 5 explores the optimality of an active LTV ratio policy when monetary policy follows (rule iii). LTV rules that respond to household credit, output or the house price differential are not optimal. In contrast, adopting a dynamic LTV ratio rule that responds in a countercyclical manner to house prices increases social welfare and results in a Pareto improvement. Further, allowing for a countercyclical response to house prices resolves the trade-off between Borrowers' and Savers' welfare introduced by the interest-rate response to household debt. Indeed, (rule vii) implies a welfare level for both agents that is higher than the level under both (rule iii) and the baseline policy (rule i) (see Table 4).

Panel B.2 of Table 5 reports the results for the optimized LTV ratio rules under the assumption that monetary policy follows (rule iv). Allowing for a countercyclical response of the LTV ratio to either changes in house prices or in the house price differential improves upon a constant LTV ratio in terms of social welfare. However, differently from (rule vii), the optimized LTV ratio (rule xi) and (xii) exacerbate the trade-off between Savers' and Borrowers' welfare. In fact, compared with (rule iv), both rules induce even larger gains for the Savers and larger costs for the Borrowers. The Borrowers' welfare level under (rule xi) and (xii) remains below the welfare level reached under the baseline policy, i.e. (rule i).

In terms of individual welfare, the largest gains for the Savers are experienced under the optimized interest rate rule that responds to changes in house prices coupled with a LTV ratio rule that optimally responds to changes in house price (rule xi) followed by a LTV ratio that respond to changes in the house price differential (rule xii). In contrast, the Borrowers are better off under the optimized interest-rate response to household credit coupled with the optimal LTV ratio response to house prices (rule vii). Across all rules, the greatest social welfare is reached under the policy that features an interest rate response to credit growth and a countercyclical response of the LTV ratio to house prices (rule vii). Notice that from the starting point of the baseline policy (rule i) and a constant LTV policy (rule iii), (rule vii) leads to a Pareto improvement.

In order to develop some intuition about the beneficial effects of a policy that optimally

combines an interest-rate response to household credit with a LTV ratio response to house prices, Figure 9 compares the effects of an unanticipated monetary policy loosening under (rule iii) and (vii). A LTV ratio that countercyclically reacts to changes in house prices, reduces the increase credit availability in response to an expansionary shock. A countercyclical LTV prevents a strong relaxation of the collateral constraint stemming from upward pressure on house prices. This, in turn, implies a larger decline in the real interest rate compared with the case of a constant LTV ratio (rule iii). Thus, the increase in the availability of credit is dampened even though servicing loans is less costly. This policy improves the Borrowers' ability to invest in housing. As for the Savers, the larger decline in their interest income results on impact in a more pronounced decline in housing demand. The initial effect is, however, counter-balanced by a larger increase over the medium term. Similar results hold for the other shocks.

## 7. Understanding the Mechanism

In the following, we evaluate the ability of the optimized rules to stabilize macroeconomic and financial cycles. Further, we assess the role of alternative sources of business cycle fluctuations in determining social welfare gains.

### 7.0.1. *Stabilization Effect*

This paper's analysis follows the more recent strand of the monetary policy literature and directly, evaluates alternative policies on their ability to improve social welfare. Thus, we do not target the volatility of a particular set of variables, as in the traditional loss function approach. The results presented in the previous section, however, show that the Pareto-improving policy, i.e. (rule vii), mitigates financial cycles and dampens the response of the real interest rate to shocks when compared to the baseline case (rule i).

In the following, we assess the stabilization effects of the alternative policies presented in Section 6 by investigating their impact on the unconditional volatility of key variables. See Table 6 (panel I).<sup>30</sup> Panel A of Table 6 considers the optimized interest-rate rule that targets

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<sup>30</sup>The model-based standard deviations are reported in terms of their ratios to the values delivered under the baseline policy (rule i). Thus, figures larger than unity indicate higher volatility than what is delivered by the baseline policy (rule i). The opposite is true for values below one.



changes in household credit, whereas Panel B refers to the interest-rate rule that targets changes in real house prices. For each interest rate rule, we consider both a constant LTV and a countercyclical LTV ratio.

Compared to the baseline policy, all optimized rules reduce the volatility of both household credit and total consumption relative to output. The interest-rate rule that targets house prices (rule iv) also reduces the volatility of house prices and housing investment. In contrast, the interest-rate rule that targets credit growth (rule iii) reduces the volatility of the real interest rate. LTV ratios that optimally respond to financial variables (rule vii, xi and xii) further reduce the volatility of total consumption to output. Note that a LTV ratio response to the differential between domestic and foreign house prices (rule xii) also reduces the volatility of both international credit flows and the house price differential. Overall, the policy (rule vii) is more successful than other policies in reducing the volatility of both financial variables and the real interest rate.

It is important to highlight that the reduction in the volatility of total consumption featured by all optimized policies is driven by a reduction in the volatility of the consumption by Savers. In fact, under most optimized rules, the volatility of Borrower' consumption is larger than under the baseline policy (rule i). The only exception is (rule vii), i.e. the interest-rate rule that responds to credit growth coupled with a LTV ratio that countercyclically responds to house prices. Differently from other policies, (rule vii) is a Pareto improvement. See Tables 4 and 5.

The underlying mechanism behind the welfare and macroeconomic effects of (rule vii) is linked to two main features of the theoretical model: collateralizes debt and debt contracts in nominal terms. As highlighted in previous papers, debt contracts in nominal terms introduce private risk generated by the uncertain returns.<sup>31</sup> Thus, in our model, the policy authority can improve social welfare by stabilizing the ex-post real interest rate which helps to offset the distortion related to the presence of debt contracts in nominal terms. The stabilization of the real interest rate resulting from an interest-rate response to household credit reduces

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<sup>31</sup>See Christiano et al. (2004), Christiano et al. (2010) for an analysis on the distortion related to the presence of assets in nominal terms in a model with financial frictions at the firms' level, and Mendicino and Pescatori (2008) for further discussion on the implications of nominal debt contracts in a model with collateralized household debt.

the volatility of the interest income of Savers which in turn helps to stabilize their housing investment and consumption over the cycle. This policy is therefore welfare improving for the Savers.

The reduction in the volatility of the debt-services also reduces the uncertainty about the repayment of the debt for the Borrowers. However, by reducing the volatility of financial variables, this policy also limits the amplification effect of the collateral constraint. An interest-rate response to household credit coupled with a constant LTV, i.e. (rule iii), reduces the ability of Borrowers to smooth consumption and investment over the cycle. Thus, it makes this group of agents worse off compared to the baseline policy (rule i). Panel A documents the increase in the volatility of Borrowers' consumption under (rule iii).

The additional use of a countercyclical response of the LTV to house prices (rule vii) tightens the collateral constraint during periods of expansion and relaxes the borrowing constraint during periods of recession. This helps Borrowers smooth consumption and housing investment over time and improves their welfare.

Table 6 also discloses the changes in the level of aggregate variables under each policy experiment. Household credit and housing investment are highest under (rule vii). This result is in line with the stabilization properties of the same policy framework. Overall, the large social welfare gains reported under (rule vii) are associated with sizable stabilization effects and a higher long-run level of credit, investment and, thus, consumption, as summarized by the higher social welfare level.

### *7.0.2. Domestic vs External Shocks*

The analysis conducted in this paper does not attempt to design optimal policies conditional on some particular shocks. Instead, it is based on the assumption that various sources of business cycle fluctuations can affect the economy. Thus, we do not target the smoothing out of specific shocks. In the following, we investigate what happens when the economy is only subject to either domestic or external shocks. To address this question, we compare the performance of the optimized policy rules under three cases: all shocks, only domestic shocks, only foreign shocks.

Table 7 reports the results. For each set of shocks, Panel A of Table 7 reports the welfare levels under the baseline policy (rule i), whereas Panel B reports the results under the optimized interest-rate rules that target household credit (rule iii), or house prices (rule iv).

Panel C reports the results under the countercyclical LTV ratio policies. All welfare gains are computed with respect to the baseline policy. Notice that the individual welfare levels under all shocks are the same as in Tables 4 and 5.

First, let us consider the Pareto improving policy (rule vii). We find that the optimality of this policy is not driven by particular sources of fluctuations. In fact, both domestic and foreign shocks account for a similar fraction of the welfare gains delivered by (rule vii). It is important to highlight that, independently of the sources of fluctuations considered, this remains the only improving Pareto policy. Thus, both Savers and Borrowers benefit from a LTV ratio rule that optimally responds to fluctuations in house prices coupled with the optimized interest-rate rule that responds to credit growth independently of the sources of fluctuations hitting our model economy.

Regarding the other rules, the ranking across (rule i), (iii) and (iv) holds only under domestic shocks,. In contrast, under the occurrence of foreign shocks, the gains implied by an interest-rate response to domestic financial variables vanish if the LTV ratio is constant. See Panel B. Foreign shocks strongly favour a countercyclical LTV ratio. In particular, (rule xii) is the social welfare maximizing rule. Differently from (rule vii), the social gains from the use of this policy framework reflect the large welfare gains accrued to the Savers. It is important to notice that in the current setup, patient households trade both domestic-currency bonds and foreign-currency bonds. Thus, this group of agents benefits from the stabilization of international credit flows implied by a countercyclical LTV ratio response to fluctuations in the house price differential. Table 6, Panel B reports the standard deviation of the foreign debt to GDP under the alternative optimized rules.

## 8. Conclusion

The latest U.S. housing boom was coupled with both a widening of the current account deficit and increasing capital inflows. In this paper, we contribute to the understanding of (i) the inter-linkages between the evolution of the U.S. current account balance and house prices, (ii) the effects of macro-prudential policy and its interaction with monetary policy. We do this in a framework that mimics the dynamics of the housing market and the current account. With this purpose in mind, we develop a quantitative model of two large economies calibrated to match key features of the U.S. and the rest of the G7 countries.

Our results suggest that risk premium shocks account for a large fraction of variation in the U.S. current account as a share of GDP and a non-negligible fraction of the volatility of U.S. house prices. Monetary policy shocks account for a substantial fraction of variations in the current account but have a limited effect on house prices, while other domestic shocks, such as housing preference and credit shocks, do not account for a sizable fraction of fluctuations in the current account.

In the context of this model, we explore the stabilization effects of monetary and LTV ratio policy which target financial variables. The design of a new policy framework able to stabilize credit and house price dynamics is central to the current policy debate. Unlike previous papers, we explore the effects of dynamic LTV ratio requirements in a model that also considers external shocks. We find that a policy that features a countercyclical LTV ratio that responds to house price dynamics and an interest-rate rule that targets credit dampens macroeconomic and financial fluctuations and is Pareto improving.

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Table 1: Targets

Annual rate of return	4%
Borrowers share housing wealth	40%
Borrowers share of income	60%
Residential investment/GDP	4.56%
Housing wealth to GDP	127.85%
Household Credit to total housing wealth	45.45%
Trade deficit to annual GDP	2.73%
std (real house prices)/std (GDP)	2.98%
std (housing value)/std (household credit)	1.15%
std(US real house prices)/std (foreign real house prices)	1.39%
std(US term interest rates)/std(foreign short term interest rates)	1.26%
std (current account/GDP)	1.09%

Table 2: Parameters' Values

$\beta_1$	Discoun factor Savers	0.99	$\theta$	Calvo parameter	0.67
$\beta_2$	Discount factor Borrowers	0.95	$\gamma$	labor share in production	0.057
$\nu^L$	Labor preference parameter	1	$\alpha$	capital share in production	0.3
$\eta$	Laborpreferenceparameter	2	$X_{ss}$	marg.cost of production	1.10
$\varkappa$	Housing preference parameter	0.17	$\psi_h$	Adj cost housing	0.5
$m$	Loan-to-value ratio	0.73	$\psi_k$	Adj cost capital	0.5
$\delta_h$	Housing depreciation parameter	0.0089	$\varphi$	risk premium elasticity	0.001
$\delta_k$	Capital depreciation parameter	0.025	$\phi_\pi$	taylor-rule parameter	1.5

Table 3: Variance Decomposition

	Housing Preference ( $\gamma_{h,t}$ )	Monetary Policy ( $\varepsilon_{r,t}$ )	Credit Shock ( $\gamma_{m,t}$ )	Risk Premium ( $\gamma_{\varsigma,t}$ )	Foreign Disc. Factor ( $\gamma_{b,t}$ )
$CA_t$	12.15	33.22	5.22	49.07	0.03
$q_{h,t}$	70.28	0.25	8.77	20.02	0.04
$b_{2t}$	66.55	0.63	30.74	1.99	0.01

The table reports the variance share of key shocks of the forecast errors of the current account ( $CA_t$ ), house prices ( $q_{h,t}$ ) and household debt ( $b_{2t}$ ).

Table 4: Welfare Gains – Interest Rate Rules

		Welfare		
		Social	Savers	Borrowers
<u>A.1 Ad Hoc Interest-Rate Rules (m=0.73)</u>				
(i)	$\phi_\pi=1.5;$	0.2865	5.9140	4.5472
(ii)	$\phi_\pi=1.5; \phi_y=0.5;$	0.2826	5.9241 (0.0101)	4.4680 (-0.3952)
<u>A.2 Optimized Interest-Rate Rules (m=0.73)</u>				
(iii)	$\phi_\pi=7.1; \phi_y=0; \phi_b=1.8;$	0.3636	15.8605 (10.4580)	4.1007 (-2.2076)
(iv)	$\phi_\pi=4; \phi_y=0; \phi_q=1.9;$	0.3629	14.2531 (8.6967)	4.4076 (-0.6954)

Second-order approximation. In parenthesis, individual welfare gains w.r.t. the baseline policy, i.e. interest-rate response to inflation coupled with a constant LTV ratio, rule (i).

Negative welfare gains indicate losses.  $\phi_i = [\pi, y, b, q]$  indicates the inflation coefficients in the interest-rate rule.

Table 5: Welfare Gains – LTV Ratio Rules

		Welfare		
		Social	Savers	Borrowers
<hr/>				
B.1 Optimized LTV ( $\phi_\pi=7.1; \phi_y=0; \phi_b=1.8$ )				
$m = 0.73$ (rule iii)		0.3636	15.8605	4.1007
(v)	$\varphi_b = 0$	0.3636	15.8605	4.1007
			-	-
(vi)	$\varphi_y = 0$	0.3636	15.8605	4.1007
			-	-
(vii)	$\varphi_q = 1.4$	0.7229	21.7343	10.1121
			(6.0497)	(35.0629)
(viii)	$\varphi_{q/q^*} = 0$	0.3636	15.8605	4.1007
			-	-
<hr/>				
B.2 Optimized LTV ( $\phi_\pi=4; \phi_y=0; \phi_q=1.9$ )				
$m = 0.73$ (rule iv)		0.3629	14.2531	4.4076
(ix)	$\varphi_b = 0$	0.3629	14.2531	4.4076
			-	-
(x)	$\varphi_y = 0$	0.3629	14.2531	4.4076
			-	-
(xi)	$\varphi_q = 1.8$	0.6525	54.4806	2.1534
			(49.5222)	(-10.6590)
(xii)	$\varphi_{q/q^*} = 1.9$	0.5723	52.5722	0.9320
			(46.6958)	(-15.9519)

Second-order approximation. In parenthesis, individual welfare gains w.r.t. the constant LTV policy, i.e. rule (iii) in PANEL B.1 AND rule (iv) in PANEL B.2. Negative welfare gains indicate losses.  $\phi_i$ , with  $i = [\pi, y, b, q]$ , indicates the coefficients in the interest-rate rule, whereas  $\varphi_j$ , with  $j = [q, b]$ , indicates the coefficients in the LTV rule.

Table 6: Level and Stabilization Effect – Interest Rate Rules

	(A)		(B)		
Monetary Policy:	$\phi_\pi=7.1; \phi_y=0; \phi_b=1.8;$		$\phi_\pi=4; \phi_y=0; \phi_q=1.9;$		
LTV Policy:	$m = 0.73$	$\varphi_q = 1.4$	$m = 0.73$	$\varphi_q = 1.8$	$\varphi_{q/q^*} = 1.9$
	(rule iii)	(rule vii)	(rule iv)	(rule xi)	(rule xii)
(I) std relative to baseline					
$b_2/Y$	0.9527	0.2426	0.8857	0.9248	0.9092
$q_h/Y$	1.0753	0.6034	0.9161	1.1305	1.0256
IH/Y	1.0604	0.5875	0.8836	1.0511	0.9542
C/Y	0.6724	0.3184	0.6652	0.4411	0.4040
$C_1/Y$	0.4704	0.2434	0.5261	0.3292	0.2963
$C_2/Y$	1.3191	0.5437	1.1996	1.6283	1.5046
Real Rate	0.9945	0.3603	1.2585	1.2476	1.2016
$B_F/Y$	1.2082	0.3499	1.1591	1.1591	0.4684
$q_h/q_h^*$	1.0048	1.3553	1.0070	1.6148	0.9200
(II) mean relative to baseline					
$b_2/Y$	1.1940	2.6539	1.0481	1.0481	2.0307
$q_h/Y$	1.3335	0.3670	1.1815	1.1815	0.0600
IH/Y	0.8474	1.6065	0.7854	0.7854	1.1991

Second-order approximation. Stochastic mean and standard deviations under the full set of shocks computed under the optimized interest-RATE rules. The table report the values in percentage difference w.r.t. baseline policy (rule i).

Table 7: Welfare Gains and Sources of Fluctuations

		Social Welfare	Savers' Gains	Borrowers' Gains
(A) Baseline Policy				
rule i	$\phi_\pi = 1.5; m = 0.73$			
	<i>all shocks</i>	0.2865	-	-
	<i>domestic</i>	0.2662	-	-
	<i>foreign</i>	0.1541	-	-
(B) Constant LTV				
rule iii	$\phi_\pi = 7.1; \phi_y = 0; \phi_b = 1.8; m = 0.73$			
	<i>all shocks</i>	0.3636	(10.4420)	(-2.1933)
	<i>domestic</i>	0.4272	(19.1439)	(-1.4080)
	<i>foreign</i>	0.0802	(-3.6539)	(-3.6013)
rule iv	$\phi_\pi = 4; \phi_y = 0; \phi_q = 1.9; m = 0.73$			
	<i>all shocks</i>	0.3629	(8.6966)	(-0.6955)
	<i>domestic</i>	0.4243	(17.1122)	(0.0077)
	<i>foreign</i>	0.0851	(-3.9875)	(-2.7922)
(C) Dynamic LTV				
rule vii	$\phi_\pi = 7.1; \phi_y = 0; \phi_b = 1.8; \varphi_q = 1.4$			
	<i>all shocks</i>	0.7229	(17.1405)	(32.0822)
	<i>domestic</i>	0.5758	(11.7185)	(21.9835)
	<i>foreign</i>	0.4954	(13.8812)	(23.5304)
rule xi	$\phi_\pi = 4; \phi_y = 0; \phi_q = 1.9; \varphi_q = 1.8$			
	<i>all shocks</i>	0.6525	(62.5249)	(-11.2804)
	<i>domestic</i>	0.5119	(5.0813)	(-14.8115)
	<i>foreign</i>	0.4508	(30.9152)	(2.7749)
rule xii	$\phi_\pi = 4; \phi_y = 0; \phi_q = 1.9; \varphi_{q/q^*} = 1.9$			
	<i>all shocks</i>	0.5723	(59.4514)	(-16.5364)
	<i>domestic</i>	0.3079	(26.9073)	(-17.8457)
	<i>foreign</i>	0.5041	(52.7356)	(-7.0935)

Second-order approximation. Social welfare level and individual welfare gains w.r.t. the baseline policy (rule i).

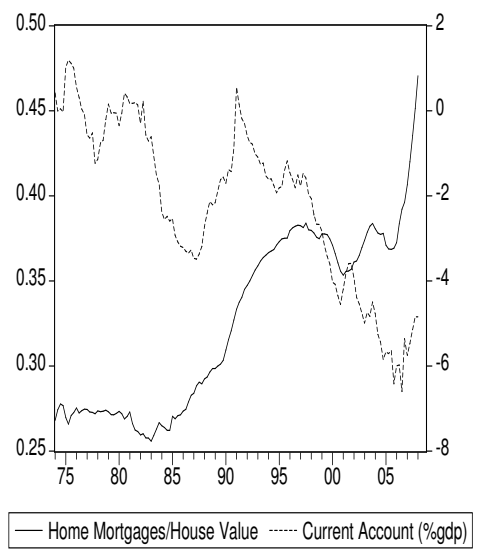
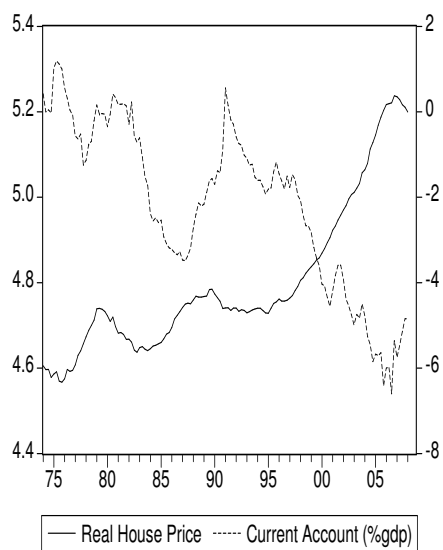


Figure 1: Current Account (%gdp) (right axes) vs Real House Price (left panel, left axes) and Real Home Mortgage to House Value (right panel, left axes).

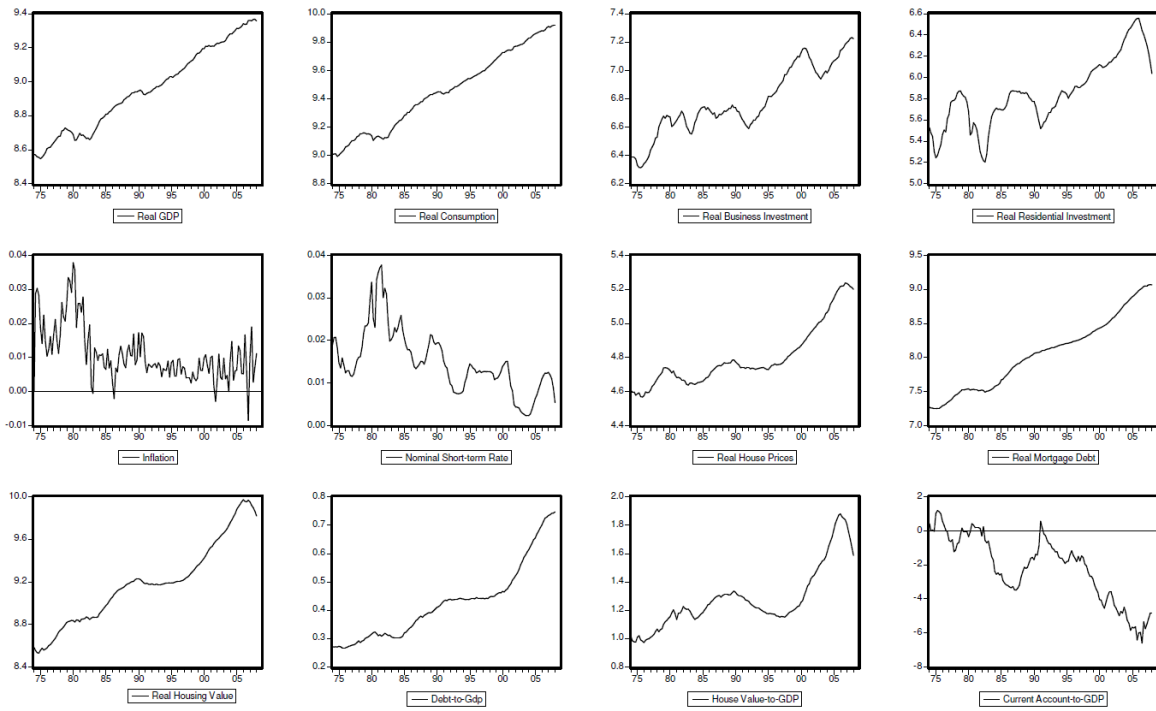


Figure 2: U.S. Data



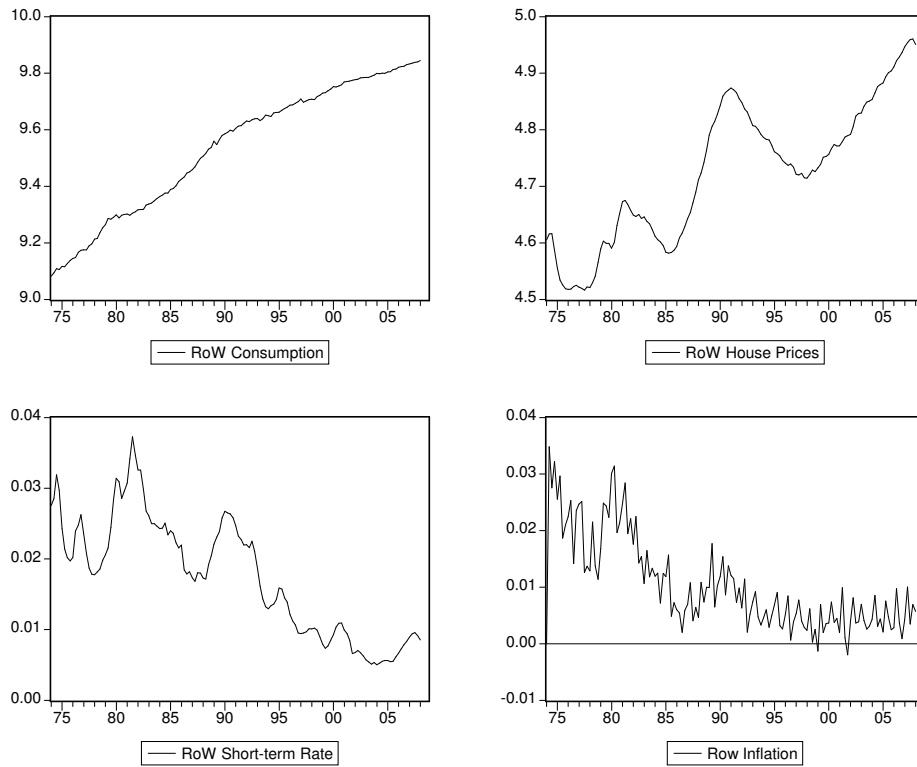


Figure 3: Rest of the World Data

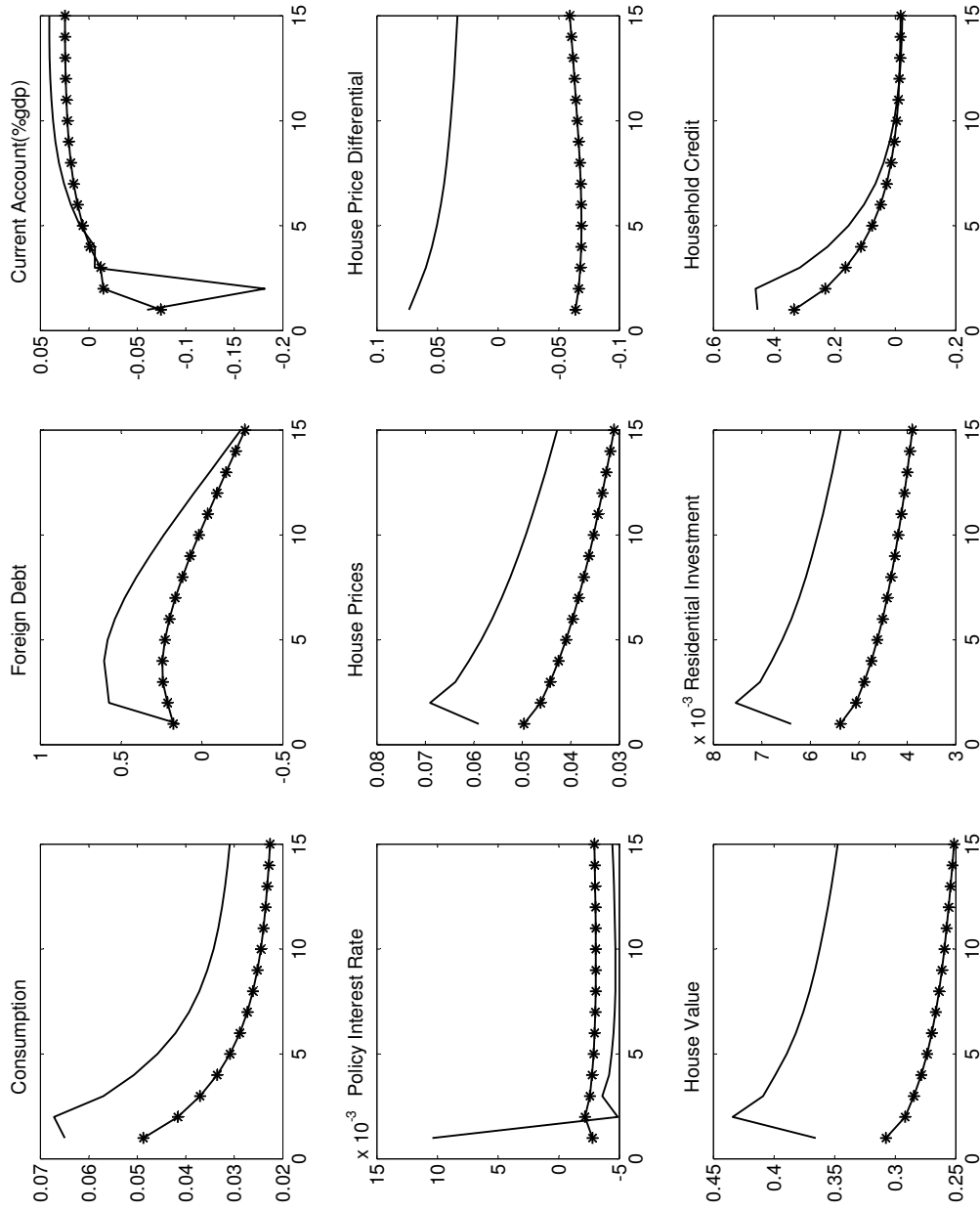


Figure 4: Risk Premium Shock (solid line) and Foreign Preference Shock (starred line).

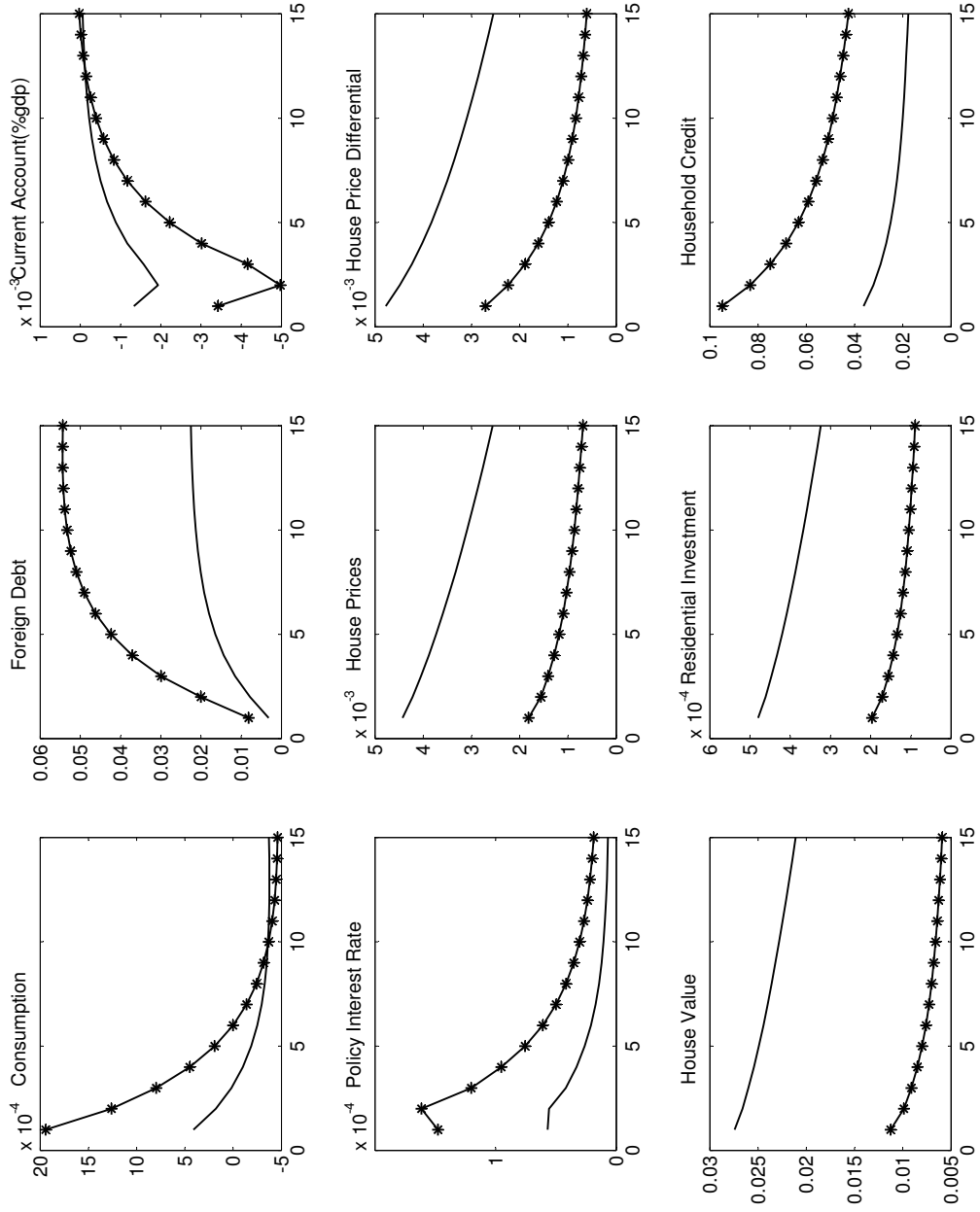


Figure 5: Housing Preference Shock (solid line) and Credit Shock (starred line).

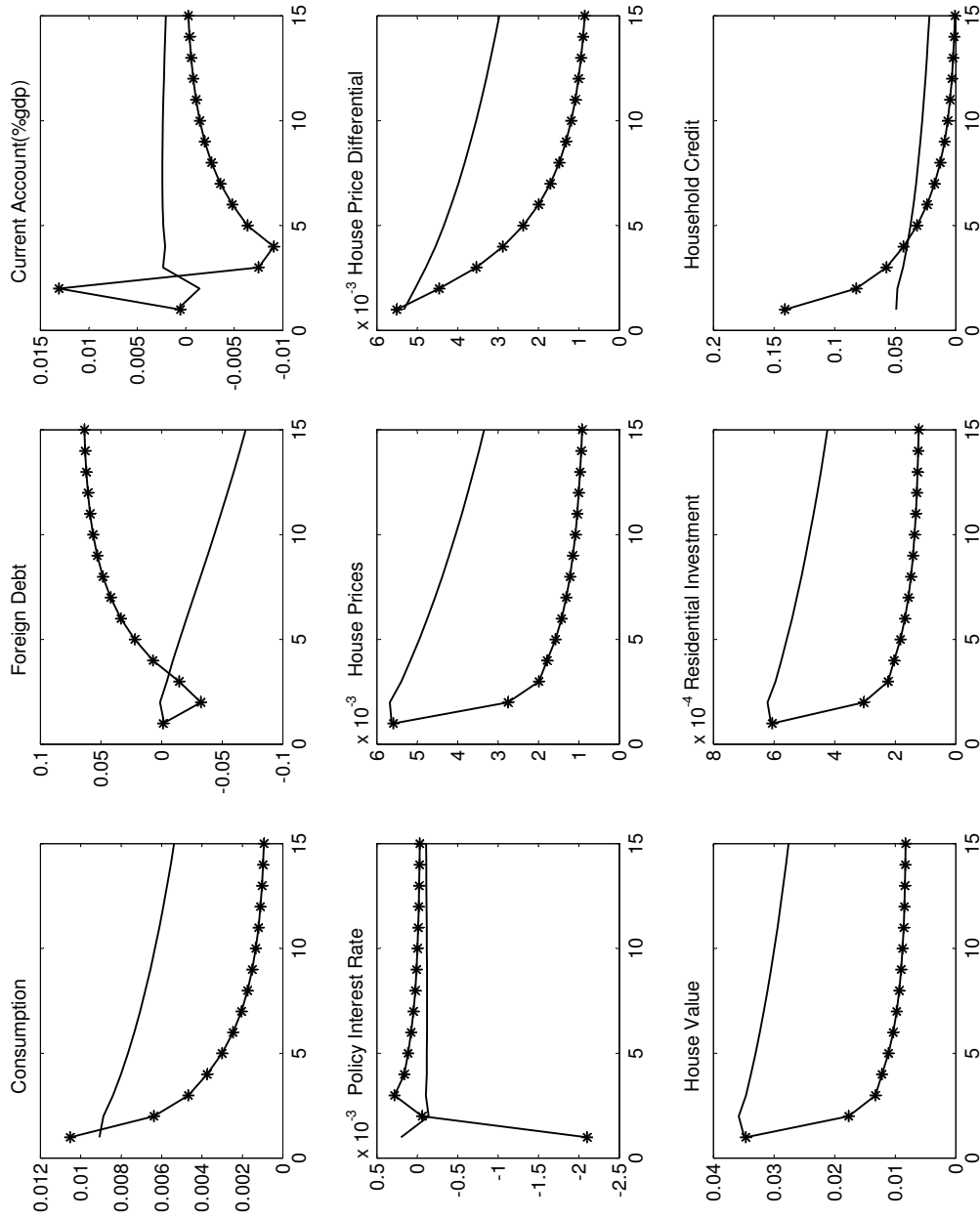


Figure 6: Productivity Shock (solid line) and Monetary Policy Shock (starred line).

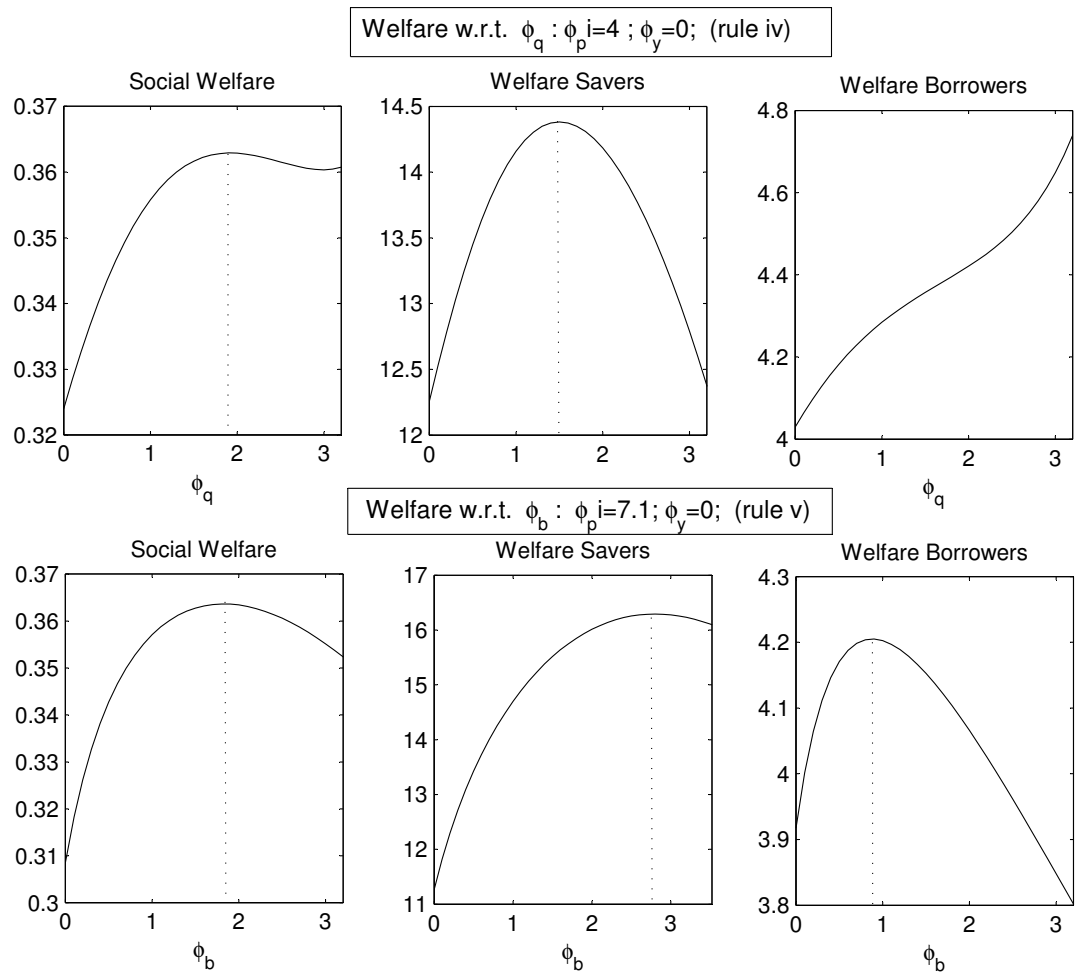


Figure 7: Welfare w.r.t. interest-rate response to financial variables.

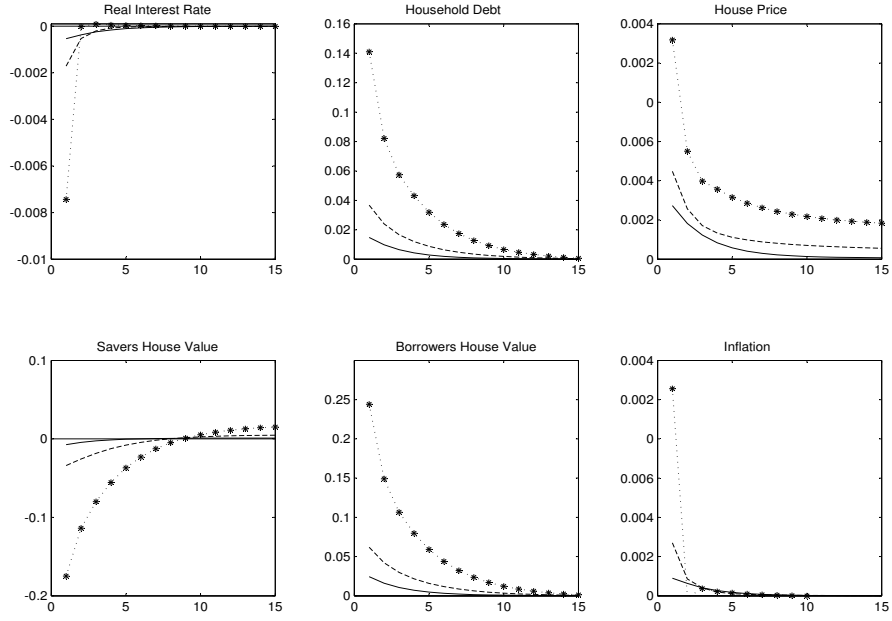


Figure 8: Monetary policy shock under rule i (starred line), rule iii (solid line) and rule iv (dashed line)

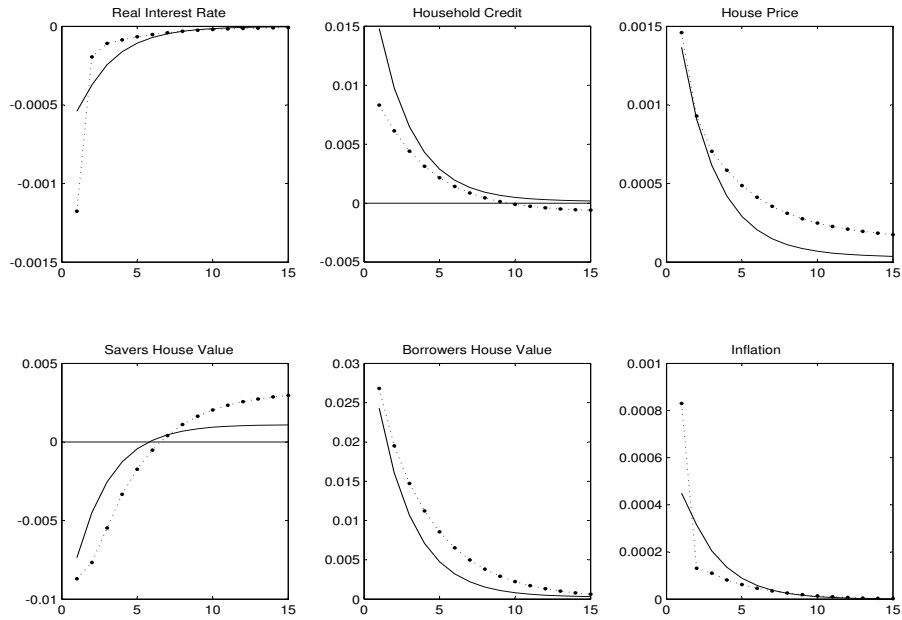


Figure 9: Monetary policy shock under rule iii (solid line) and rule vii (dashed-dotted line)