Macroprudential policy and imbalances in the euro area*

Michał Brzoza-Brzezina[†] Marcin Kolasa[‡] Krzysztof Makarski[§]

August 2012

PRELIMINARY

Abstract

Since its creation the euro area suffered from imbalances between its core and peripheral members. This paper checks whether macroprudential policy applied to the peripheral countries could contribute to providing more macroeconomic stability in this region. To this end we build a two-economy macrofinancial DSGE model and simulate the effects of macroprudential policies under the assumption of asymmetric shocks hitting the core and the periphery. We find that macroprudential policy is able to partly make up for the loss of independent monetary policy in the periphery. Moreover, LTV policy seems more efficient than regulating capital adequacy ratios. However, for the policies to be effective, they must be decentralized. Area-wide policy may even aggravate the problem.

JEL: E32, E44, E58

Keywords: euro-area imbalances, macroprudential policy, DSGE with banking sector

*The views expressed herein are those of the authors and not necessarily those of the National Bank of Poland or the Warsaw School of Economics. We would like to thank Matthieu Bussiere, Tomasz Chmielewski and Bartosz Maćkowiak for helpfull discussions. Comments received at the joint NBP/SNB seminar and NBP workshop are gratefully acknowledged as well.

[†]National Bank of Poland and Warsaw School of Economics; Email: michal.brzoza-brzezina@nbp.pl.

[‡]National Bank of Poland and Warsaw School of Economics; Email: marcin.kolasa@nbp.pl.

[§]National Bank of Poland and Warsaw School of Economics; Email: krzysztof.makarski@nbp.pl.

1 Introduction

Since the euro area was created, large imbalances have built up in some of its relatively poor members. These imbalances concerned in particular the housing market. As can be seen from Figure 1, residential investment in Greece, Ireland, Portugal and Spain, a group of euro area members that we will refer to as the periphery, nearly doubled from 1999 to 2006, while it stagnated in the rest (core) of the currency union. A qualitatively similar picture can be observed for mortgage loans and real house prices: while their growth was moderate in the core, they were booming in the periphery. These developments contributed to substantial GDP growth differentials within the euro area, i.e. countries experiencing housing booms were growing at a relatively high pace. These trends got reversed when the housing market bubble burst, leading to a sharp slowdown in the peripheral economies. A subsequent deterioration of fiscal revenues sparked tensions on the financial markets that spread over the whole Europe, severely undermining the stability of the banking system and even threatening a break-up of the common currency area.

It has been established in the literature that the main source of these asymmetric developments was a sharp fall in the periphery's interest rates following their euro area accession, combined with an easy access to cross-border borrowing (see e.g. ECB, 2003; Honohan and Leddin, 2006; Blanchard, 2007; Andrés et al., 2010). However, evidence from estimated dynamic stochastic general equilibrium (DSGE) models also points at asymmetric shocks to productivity and preferences (Andrés et al., 2010) or housing market prices (in't Veld et al., 2012) as important drivers of the observed divergences between the core and the periphery.

Can such large asymmetries be prevented or at least mitigated using standard macroeconomic policy instruments? Clearly, the common interest rate set by the ECB at the area-wide level hardly responds to asymmetric developments in the periphery and hence can provide no stabilization in face of country-specific shocks. Exchange rate devaluation, a solution used on several occasions in the pre-EMU period to re-align competitiveness within Europe, is also no longer an option once in the euro area. Finally, the fiscal policy is limited by well-known political economy constraints and implementation lags.

In this paper we check if appropriately designed macroprudential policy can provide more stability in the euro area periphery. To this end we set up a two-country DSGE model with housing frictions in the spirit of Iacoviello (2005) and a banking sector similar to Gerali et al. (2010). In this model, borrowers face a binding collateral constraint, i.e. their debt cannot exceed a certain fraction of their housing stock. As regards the banking sector setup, the key frictions are monopolistic competition and costly deviation from bank capital requirements.[1]

We use this model to investigate the effectiveness of two policy instruments, adjusted

[1]There is a growing number of papers incorporating bank capital into DSGE models. See e.g. Benes et al. (2010), Dib (2010), Gertler and Karadi (2011) and Meh and Moran (2010).

countercyclically in response to output and credit fluctuations. One is defined as the maximum loan-to-value (LTV) ratio for mortgage loans and has been used as a stabilization tool in Hong Kong. The second instrument, mostly known from the Basel Committee Recommendations, is the minimal capital adequacy (CA) ratio imposed on commercial banks.

Our main findings can be summarized as follows. First, both macroprudential policies are able to lower the amplitude of output fluctuations in the periphery. However, in this respect, a countercyclical LTV policy ranks much better than its CA counterpart. Second, macroprudential policy is particularly efficient at offsetting housing market and (common) monetary policy shocks, i.e. those types of disturbances that have been found to be important drivers of the observed divergences within the euro area. Third, only decentralized macroprudential policy can be successful. Setting its instruments at the area-wide level lowers output volatility in the periphery only marginally.

Our paper is related to a growing literature looking at the performance of various macroprudential policy rules. Lambertini et al. (2011) consider a news driven model of the housing market and find that a countercyclical LTV rule responding to credit growth can stabilize the economy better than the interest rate. Funke and Paetz (2012) examine LTV rules in a New Keynesian model for Hong Kong and argue that a non-linear rule, responding only to very high changes in property prices performs better than a standard Taylor-like one. Based on experiments with three macroeconomic models, Angelini et al. (2011) report substantial stabilization gains from a countercyclical CA rule introduced by the Basel III reform package. Christensen et al. (2011) develop a DSGE model with banks and bank capital, finding desirable stabilization properties of countercyclical bank leverage regulation in response to financial shocks and a lower efficiency of such a rule after technology shocks. Darracq-Pariés et al. (2011) estimate a DSGE model with financial frictions affecting both households and firms using the euro area data, concluding that a countercyclical bank capital regulation can provide a strong support to macroeconomic stabilization, but also lead to excessive volatility in bank balance sheets. However, none of the papers reviewed above discuss macroprudential policy in the context of a heterogeneous monetary union.

The rest of the paper is structured as follows. Section two describes the model and section three its calibration. Section four discusses the transmission mechanisms of the two macroprudential policy instruments. Section five presents our main quantitative results. Section six concludes.

2 Model

We consider a two country DSGE model with collateral constraints modeled as in Iacoviello (2005). These two countries form a monetary union. We call one of them the core and the other the periphery. Measure ω of agents reside in the periphery and $\omega^* = 1 - \omega$ in the core. Both economies are populated by patient households (who save in equilibrium) and impatient households (who borrow in equilibrium), as well as producers of consumption goods, housing and intermediate goods. Union-wide monetary policy is conducted according to a Taylor rule, while macroprudential policy instruments can be adjusted at a country level. In this paper we employ the following notational convention: variables without an asterisk refer to the periphery, while variables with an asterisk pertain to the core. Since both countries have a symmetric structure, we describe the problems of agents in the periphery only.

2.1 Households

In each economy there are two types of households indexed by ι on a unit interval: patient $\iota \in P \equiv [0, \omega_P]$ and impatient $\iota \in I \equiv (\omega_P, 1]$.[2] Hence, the measure of patient agents is ω_P, while that of impatient households is $\omega_I = 1 - \omega_P$.

2.1.1 Patient households

Patient households work $n_{P,t}$, accumulate housing $\chi_{P,t}$, consume $c_{P,t}$ and deposit savings in the banking sector $D_{P,t}$ at the interbank rate R_t.[3] We also assume that they own physical capital k_P (fixed at an aggregate level), which they rent to firms at a rate $R_{k,t}$, as well as all firms and banks in the economy, which pay them dividends $\Pi_{P,t}$.

Patient households maximize

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta_P^t \left[\varepsilon_{u,t} \frac{(c_{P,t}(\iota) - \xi_c c_{P,t-1})^{1-\sigma_c}}{1-\sigma_c} + \varepsilon_{u,t} \varepsilon_{\chi,t} A_\chi \frac{(\chi_{P,t}(\iota) - \xi_\chi \chi_{P,t-1})^{1-\sigma_\chi}}{1-\sigma_\chi} - A_n \frac{n_{P,t}(\iota)^{1+\sigma_n}}{1+\sigma_n} \right] \right\} \tag{1}$$

subject to the budget constraint

$$\begin{aligned} P_t c_{P,t}(\iota) + P_{\chi,t}(\chi_{P,t}(\iota) - (1-\delta_\chi)\chi_{P,t-1}(\iota)) + D_t(\iota) \leq \\ \leq W_{P,t}(\iota) n_{P,t}(\iota) + R_{k,t} k_P + R_{t-1} D_{P,t-1}(\iota) + \Pi_{P,t} \end{aligned} \tag{2}$$

where P_t, $P_{\chi,t}$ and $W_{P,t}$ are, respectively, the price of consumption goods, the price of housing and the patient households' nominal wage. Moreover, β_P denotes the patient agents' discount rate, while A_χ and A_n are the weights of housing and labor in utility. The inverse of the intertemporal elasticity of substitution in consumption is denoted by σ_c, that in housing by

[2] We employ the following notational convention: all variables denoted with a subscript P or I are expressed per patient or impatient household, respectively, while all other variables are expressed per all households. For example, k denotes per capita capital and since only patient households own capital, capital per patient households is equal to $k_P = k/\omega_P$.

[3] We calibrate the model so that patient households save and never borrow. Therefore, to simplify notation, we eliminate credits (which they would not take anyway) from their budget constraint. Similarly, we eliminate deposits from impatient households' budget constraint (7).

σ_χ, while σ_n is the inverse Frisch elasticity of labor supply. Housing stock depreciates at a rate δ_χ. Consumption and housing services are subject to external habit persistence ξ_c and ξ_χ, respectively. There are two preference shocks, both following an AR(1) process: (i) an intertemporal preference shock $\varepsilon_{u,t}$, with persistence ρ_u and standard deviation of innovations σ_u; and (ii) a housing preference shock $\varepsilon_{\chi,t}$, with persistence ρ_χ and standard deviation of innovations σ_χ.

2.1.2 Impatient households

Impatient households optimize by choosing consumption $c_{I,t}$, housing services $\chi_{I,t}$ and labor supply $n_{I,t}$. They maximize the following lifetime utility function

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta_I^t \left[\varepsilon_{u,t} \frac{(c_{I,t}(\iota) - \xi_c c_{I,t-1})^{1-\sigma_c}}{1-\sigma_c} + \varepsilon_{u,t}\varepsilon_{\chi,t} A_\chi \frac{(\chi_{I,t}(\iota) - \xi_\chi \chi_{I,t-1})^{1-\sigma_\chi}}{1-\sigma_\chi} - A_n \frac{n_{I,t}(\iota)^{1+\sigma_n}}{1+\sigma_n} \right] \right\} \tag{3}$$

Impatient households discount the future utility flows more heavily than patient households, hence their discount factor β_P is strictly smaller than β_I. This makes them natural borrowers. In particular, we assume that each impatient household ι can take differentiated loans $L_{I,t}(\iota, j)$ from retail banks indexed by $j \in [0,1]$. These loans are aggregated according to the following formula

$$L_{I,t}(\iota) = \left[\int_0^1 L_{I,t}(\iota, j)^{\frac{1}{\mu_L}} dj \right]^{\mu_L} \tag{4}$$

where μ_L determines the elasticity of substitution between loan varieties. Access to credit is subject to the following collateral constraint

$$R_{L,t} L_{I,t}(\iota) \leq m_{\chi,t} E_t \{P_{\chi,t+1}\} (1-\delta_\chi) \chi_{I,t}(\iota) \tag{5}$$

where $m_{\chi,t}$ is the LTV ratio set by the macroprudential authority, and $R_{L,t}$ is the interest rate on loans, defined as

$$R_{L,t} = \left[\int_0^1 R_{L,t}(j)^{\frac{1}{1-\mu_L}} dj \right]^{1-\mu_L} \tag{6}$$

The budget constraint of impatient households takes the following form

$$P_t c_{I,t}(\iota) + P_{\chi,t}(\chi_{I,t}(\iota) - (1-\delta_\chi)\chi_{I,t-1}(\iota)) + \int_0^1 R_{L,t-1}(j) L_{I,t-1}(\iota, j) dj \leq$$
$$\leq W_{I,t}(\iota) n_{I,t}(\iota) + L_{I,t}(\iota) \tag{7}$$

where $W_{I,t}$ denotes the impatient households' nominal wage.

From the household problem we get the following demand for differentiated loans taken from retail bank j

$$L_{I,t}(j) = \Big(\frac{R_{L,t}\,(j)}{R_{L,t}}\Big)^{\frac{\mu_L}{1-\mu_L}} L_{I,t} \tag{8}$$

where, in equilibrium, $L_{I,t}(\iota, j) = L_{I,t}(j)$ and $L_{I,t}(\iota) = L_{I,t}$ for all $\iota \in I$.

2.1.3 Labor market

Both patient and impatient households supply monopolistically distinct labor services to competitive aggregators, who transform them into a homogenous labor input according to the following formula

$$n_t = \left[\omega_P^{\frac{1}{\phi_n}} n_{P,t}^{\frac{\phi_n - 1}{\phi_n}} + \omega_I^{\frac{1}{\phi_n}} n_{I,t}^{\frac{\phi_n - 1}{\phi_n}}\right]^{\frac{\phi_n}{\phi_n - 1}} \tag{9}$$

where

$$n_{P,t} = \left[\frac{1}{\omega_P}\int_0^{\omega_P} n_{P,t}(\iota)^{\frac{1}{\mu_w}} d\iota\right]^{\mu_w} \tag{10}$$

$$n_{I,t} = \left[\frac{1}{\omega_I}\int_0^{\omega_I} n_{I,t}(\iota)^{\frac{1}{\mu_w}} d\iota\right]^{\mu_w} \tag{11}$$

In the above formulas, ϕ_n is the elasticity of substitution between labor supplied by the two types of households, while μ_w determines the elasticity of substitution between individual labor varieties.

We assume that wages for both types of households $W_{P,t}$ and $W_{I,t}$ are sticky. In each period, with probability $1-\theta_w$ each household receives a Calvo signal to reoptimize her wages. Otherwise, wages are indexed according to $\pi_{\zeta_w,t} = \zeta_w \pi_{t-1} + (1-\zeta_w)\pi$, where $\pi_t \equiv P_t/P_{t-1}$ and π denote inflation and its steady state level, respectively, while ζ_w controls the degree of wage indexation to past inflation.

We assume perfect risk sharing across households of the same type. As a result, wage stickiness does not create additional heterogeneity in consumption and housing choices between the agents.

2.2 Producers

In our economy there are several types of firms, all owned by patient households. Consumption and housing producers use intermediate goods to produce consumption and housing goods, respectively. Monopolistically competitive intermediate goods producers produce differentiated goods by employing capital and labor.

2.2.1 Consumption good producers

Perfectly competitive consumption good producers purchase domestic and foreign varieties of differentiated intermediate goods $c_H(i)$ and $c_F(i)$ to produce a homogeneous good according to the following technology

$$c_t = \Big((1-\eta_H)^{\frac{1}{\phi_c}} c_{F,t}^{\frac{\phi_c-1}{\phi_c}} + \eta_H^{\frac{1}{\phi_c}} c_{H,t}^{\frac{\phi_c-1}{\phi_c}}\Big)^{\frac{\phi_c}{\phi_c-1}} \tag{12}$$

where

$$c_{H,t} = \Big(\int_0^1 c_{H,t}(i)^{\frac{1}{\mu_c}} di\Big)^{\mu_c} \tag{13}$$

$$c_{F,t} = \Big(\int_0^1 c_{F,t}(i)^{\frac{1}{\mu_c}} di\Big)^{\mu_c} \tag{14}$$

In the formulas above, η_H determines the home bias in consumption, ϕ_n is the elasticity of substitution between domestic and foreign consumption goods, while μ_w determines the elasticity of substitution between differentiated intermediate goods.

2.2.2 Housing producers

In each period, perfectly competitive housing goods producers purchase undepreciated housing from the previous period and produce new housing stock according to the following formula

$$\chi_t = (1-\delta)\,\chi_{t-1} + \varepsilon_{i\chi,t}\Big(1 - S_\chi\Big(\frac{i_{\chi,t}}{i_{\chi,t-1}}\Big)\Big) i_{\chi,t} \tag{15}$$

where $i_{\chi,t}$ stands for housing investment, produced only with domestic intermediate inputs

$$i_{\chi,t} = \Big(\int_0^1 i_{\chi,t}(i)^{\frac{1}{\mu_\chi}} di\Big)^{\mu_\chi} \tag{16}$$

and $\varepsilon_{i\chi,t}$ denotes a housing investment specific technology shock, which follows an AR(1) process with persistence $\rho_{i\chi}$ and standard deviation of innovations $\sigma_{i\chi}$. We assume that housing investment adjustment cost is given by $S_\chi\Big(\frac{i_{\chi,t}}{i_{\chi,t-1}}\Big) = \frac{\kappa_\chi}{2}\Big(\frac{i_{\chi,t}}{i_{\chi,t-1}} - 1\Big)^2$, where $\kappa_\chi > 0$.

2.2.3 Intermediate goods producers

Intermediate goods producers, indexed by i, combine labor and capital with the following technology

$$c_{H,t}(i) + \frac{1-\omega}{\omega} c^*_{H,t}(i) + i_{\chi,t}(i) = z_t k(i)^\alpha n_t(i)^{1-\alpha} \tag{17}$$

where z_t denotes a productivity shock that follows an AR(1) process with persistence ρ_z and standard deviation of innovations σ_z. They operate in a monopolistically competitive environment and set their prices according to the Calvo scheme. In each period, each producer i receives with probability $1-\theta$ a signal to reoptimize her price. Otherwise, prices are indexed according to $\pi_{\zeta,t} = \zeta\pi_{t-1} + (1-\zeta)\pi$, where ζ controls the degree of indexation to past inflation.

2.3 Banking

Following Gerali et al. (2010), in our economy banks consist of two branches, wholesale and retail, both functioning independently from each other. The wholesale branch operates in a competitive environment, but is subject to capital requirements. This introduces a wedge between the lending and borrowing rates. An additional component of the spread is due to monopolistic competition in the retail branch.

2.3.1 Wholesale banking

In our economy, bank capital $K_{b,t}$ accumulates from proceeds $J_{b,t}$ of both wholesale and retail branches. We assume that a constant fraction ω_b of $J_{b,t}$ is retained in the wholesale branch and the rest is paid to shareholders (in our case patient households)

$$K_{b,t} = (1 - \delta_b)K_{b,t-1} + \omega_b J_{b,t} \tag{18}$$

where δ_b is the bank capital depreciation rate, aimed at capturing the use of resources in the banking activity.

A wholesale branch takes loans in the domestic interbank market $\tilde{L}_{Hb,t}$ at the rate R_t and in the foreign interbank market $\tilde{L}_{Fb,t}$ at the policy rate adjusted for risk premium $\varrho_t R_t^*$,[4] and uses them together with bank capital to finance loans $L_{b,t}$ extended to retail banks at a rate $R_{Lb,t}$

$$L_{b,t} = \tilde{L}_{Hb,t} + \tilde{L}_{Fb,t} + K_{b,t} \tag{19}$$

Moreover, we impose a quadratic costs ψ_t (parametrized by κ_b) on wholesale banks for deviating from the target capital to assets ratio υ_t, which we assume to be one of the macro-prudential policy instruments

$$\psi_t(L_{b,t}, K_{b,t}) = \frac{\kappa_b}{2}\left(\frac{K_{b,t}}{L_{b,t}} - \upsilon_t\right)^2 K_{b,t} \tag{20}$$

The wholesale branch goal is to maximize the discounted sum of real cash flows, taking

[4] The risks premium evolves according to the following formula $\varrho_t = 1 + \xi\left(\exp\left(\frac{d_t}{y_t} - \frac{d}{y}\right) - 1\right)$, where d_t and y_t, as well as their steady state values d and y are defined later. Perfect substitutability between domestic and foreign interbank market loans implies the following relationship: $R_t = \varrho_t R_t^*$. Hence, the presence of risk premium drives a wedge between the interbank rate in the core and its counterpart in the periphery. The risk premium is introduced only to render the model stationary. In our calibration we set ξ to a very small value so that the difference between R_t and R_t^* is negligible.

the interest rates as given[5]

$$E_0 \left\{ \sum_{t=0}^{\infty} \frac{\Lambda_{0,t+1}^P}{P_{t+1}} \left[R_{Lb,t} L_{b,t} - R_t \tilde{L}_{Hb,t} - \varrho_t R_t^* \tilde{L}_{Fb,t} - \psi(L_{b,t}, K_{b,t}) \right] \right\} \tag{21}$$

subject to (18), (19) and (20). The first order condition of the above problem is

$$R_{Lb,t} = R_t - \kappa_b \left(\frac{K_{b,t}}{L_{b,t}} - v_t \right) \left(\frac{K_{b,t}}{L_{b,t}} \right)^2 \tag{22}$$

Hence, costly deviation from the capital adequacy ratio results in a spread between the wholesale lending rate and the interbank rate.

2.3.2 Retail banking

Retail banks operate in a monopolistically competitive environment and set their interest rates $R_{L,t}(j)$ to maximize

$$(R_{L,t+1}(j) - R_{Lb,t}) L_{I,t}(j) \tag{23}$$

subject to the demand for loans from impatient households (8) (note that $L_{b,t}(j) = \omega_I L_{I,t}(j)$).

By solving the banks' problem, we obtain that the retail lending rate is a markup on the wholesale lending rate

$$R_{L,t} = \mu_L R_{Lb,t} \tag{24}$$

2.4 Macroprudential policy

The macroprudential authority aims at stabilizing output fluctuations using one of two simple feedback rules. She can either set the LTV ratio according to

$$m_{\chi,t} = (1-\gamma_m) m_\chi + \gamma_m m_{\chi,t-1} - (1-\gamma_m)\gamma_{my} \left(\frac{y_t}{y} - 1 \right) + \varepsilon_{m,t} \tag{25}$$

or the capital adequacy ratio with the following rule

$$v_t = (1-\gamma_v) v + \gamma_v v_{t-1} + (1-\gamma_v)\gamma_{vy} \left(\frac{y_t}{y} - 1 \right) + \varepsilon_{v,t} \tag{26}$$

In the formulas above, m_χ is the steady state LTV ratio, ν denotes the steady state capital requirement, γ_m and γ_ν control the degree of instrument smoothing, γ_{my} and $\gamma_{\nu y}$ determine the size of each instrument's reaction to deviations of total output y_t from its steady state level y while $\varepsilon_{m,t}$ and $\varepsilon_{v,t}$ are i.i.d. macroprudential policy shocks.

[5]Note that, since banks are owned by patient households, they discount their profits with $\Lambda_{0,t} = \beta^t u_{c,P,t}/u_{c,P,0}$, where $u_{c,P,t}$ denotes the derivative of patient households' instantaneous utility with respect to $c_{P,t}$.

2.5 Closing the model

2.5.1 GDP and Balance of Payments

We define the aggregate output (GDP) as

$$y_t \equiv c_{H,t} + c^*_{H,t}\frac{1-\omega}{\omega} + i_{\chi,t} \tag{27}$$

and the law of motion of real net foreign debt, defined as $d_t \equiv (\tilde{L}_{Fb,t} - \frac{1-\omega}{\omega}\tilde{L}^*_{Hb,t})/P_t$, can be written as

$$d_t = P_{F,t}c_{F,t} - \frac{1-\omega}{\omega}P^*_{H,t}c^*_{H,t} + \varrho_{t-1}R^*_{t-1}d_{t-1} \tag{28}$$

where$P^*_{H,t}$ and $P_{F,t}$ denote the price of, respectively, exports and imports of the periphery.

2.5.2 Monetary policy

We assume that the monetary authority reacts to union-wide variables, i.e. it sets the policy rate according to the following Taylor rule

$$\frac{R^*_t}{R^*} = \left(\frac{R^*_{t-1}}{R^*}\right)^{\gamma^*_R}\left[\left(\frac{\tilde{\pi}^*_t}{\tilde{\pi}^*}\right)^{\gamma^*_\pi}\left(\frac{\tilde{y}^*_t}{\tilde{y}^*}\right)^{\gamma^*_y}\right]^{1-\gamma^*_R} e^{\varepsilon^*_{R,t}} \tag{29}$$

where

$$\tilde{y}^* \equiv \omega y_t + (1-\omega)y^*_t$$
$$\tilde{\pi}^*_t \equiv (\pi_t)^\omega(\pi^*_t)^{1-\omega}$$

Here, γ^*_π and γ^*_y control the strength of policy rate response to inflation and output, respectively, while γ^*_R controls the degree of interest rate smoothing. The variables without time subscripts denote their respective steady state values and $\varepsilon^*_{R,t}$ is an i.i.d. monetary policy shock with a standard deviation σ^*_R.

2.5.3 Market clearing

We impose a standard set of market clearing conditions. Housing market clearing implies

$$\omega_P\chi_{P,t} + \omega_I\chi_{I,t} = \chi_t \tag{30}$$

and the consumption good resource constraint is

$$\omega_P c_{P,t} + \omega_I c_{I,t} = c_t \tag{31}$$

Factor markets clear when

$$\int_0^1 k_t(i)di = \omega_P k_P \tag{32}$$

$$\int_0^1 n_t(i)di = n_t \tag{33}$$

Finally, we have market clearing for loans

$$L_{b,t} = \omega_I \int_0^1 L_{I,t}(j)dj \tag{34}$$

Note that there is no corresponding market clearing for deposits since they are cleared by open market operations necessary to keep the interbank rate R_t at the target level.

3 Calibration

3.1 Structural parameters

This paper's focus is on a small member of a currency union facing stabilization challenges due to asymmetric shocks. To keep the exposition transparent, in our calibration we abstract from any structural heterogeneity within the union. More specifically, in our calibration the core and periphery differ only in size and shock realizations. The calibrated values of structural parameters are summarized in Table 1. Throughout, the unit of time is one quarter.

We set the relative size of the periphery to 1%, which roughly corresponds to the GDP share in the euro area of such countries like Greece, Ireland or Portugal. This calibration also implies that the core is essentially a closed economy, following a self-oriented monetary policy. The share of home-made goods in the periphery's consumption basket is set to 0.7, consistently with the average import content of private consumption estimated in Bussie‘re et al. (2011) for the euro area member states. Correcting this figure for the relative country size as in Sutherland (2005) implies the import share in the core's consumption of 0.003.

Households' preferences are calibrated in line with the literature. The discount factors for patient and impatient households are set to 0.99 and 0.975, respectively, similarly to Iacoviello and Neri (2010). The inverse of the intertemporal elasticity of substitution in consumption and housing, as well as the inverse of the Frisch elasticity of labor supply are all set to 2, as it is common in the macro literature. The degree of habit formation in consumption and housing are both calibrated at 0.7. The steady-state LTV ratio is set to 0.75.

We choose the same steady-state markups in the labor and product markets of 20%.

As in Coenen et al. (2008), the elasticity of substitution between domestic and imported consumption goods is calibrated at 1.5, while that between labor of patient and impatient households at 6.[6] The capital share in output is set to a standard value of 0.3.

While calibrating nominal rigidities, we follow closely Christoffel et al. (2008). The Calvo probabilities for wages, domestic prices and export prices are set to 0.75, 0.9 and 0.75, respectively. The corresponding indexation parameters are all calibrated at 0.5. The elasticity of the residential investment adjustment cost is set to 30. This value is substantially larger than estimated by Lombardo and McAdam (2012), but proved crucial in matching the relative volatility of residential investment. The sensitivity of the risk premium is fixed at 0.001, which ensures that foreign debt is stabilized at zero in the long run without substantially affecting the model's short-run dynamics.

The steady-state target ratio of bank capital to loans is set to 0.1, roughly in line with the average capital adequacy ratios maintained by European commercial banks. The share of retained profits in the banking sector is calibrated at 0.85. This implies a dividend payout ratio that is lower than the EU average over the period 2000-2008 reported by Onali (2012). However, a more conservative dividend policy looks more likely in the aftermath of the financial crisis. The bank capital adjustment cost curvature is set to 10, consistently with the estimates in Gerali et al. (2010).

As regards the monetary policy feedback rule, we assume a standard set of parameters, i.e. interest rate smoothing equal to 0.9, the long-run response to inflation of 2 and that to output equal to 0.15. This parametrization is roughly consistent with estimated DSGE models for the euro area. The steady state inflation rate is set to 0.5% quarterly, in line with the ECB inflation target.

Several parameters are calibrated to match a few key steady state ratios, reported in Table 3, using the euro area 1995-2011 averages as the targets.[7] We fix the housing weight in utility at 2.34 to match the steady state housing stock to output ratio of 2.32. We assume that the housing stock depreciates at 1% quarterly, which implies the long-run residential investment share in output equal to 9.4%. The weight of impatient agents is calibrated at 0.55 to match the steady state mortgage debt to output ratio of 76%. Setting the physical capital stock to 6.5 and labor weight in utility to 880 allows us to match the long-run capital-output ratio of 2 and the share of time spent at work of 33%. Following Coenen et al. (2008), we calibrate the transfers from patient to impatient households such that the steady state

[6] To be specific, Coenen et al. (2008) distinguish between Ricardian and rule-of-thumb consumers, the latter having no access to financial markets.

[7] Data on interest rates and national accounts are taken from Eurostat. Consistently with the model setup, which abstracts from government spending and business investment, as well as assumes balanced trade in the steady state, we define the empirical counterpart of output not as total GDP, but as the sum of private consumption and residential investment. Data on mortgage loans and the housing stock come from the ECB SDW.

per capita consumption of the latter is not more than 25% lower than that of the former. The markup in financial intermediation is calibrated to fit the average spread between the lending rate and the policy rate of 190 bp annually. Finally, fixing the bank capital depreciation rate at 0.048 ensures that the bank capital to loans ratio is exactly on target in the steady state.

3.2 Stochastic properties

Business cycle fluctuations in our model monetary union are driven by nine stochastic shocks. These include four pairs of region-specific shocks to productivity, preferences, relative housing preferences and housing investment technology, all modeled as first-order autoregressive processes, and one common monetary shock, assumed to be white noise. For simplicity, we assume that the inertia and volatility of shocks of a given type do not differ between the core and periphery. However, given the paper's focus on imbalances within a currency union, we assume that shocks are uncorrelated across the two regions.

Our calibration of the shock processes is summarized in Table 2. Our aim was to match the standard moments of the euro area data and to be at the same time consistent with the empirical literature. We assume a standard value of 0.95 for the inertia of technology shocks. Following Darracq-Pariés et al. (2011), housing preference shocks are assumed to be substantially more persistent. The same applies to the other pair of preference shocks, which helps in matching a positive correlation between consumption and residential investment observed in the data. The standard deviations of all shocks are broadly consistent with the estimated DSGE models for the euro area.

The results of the moment matching are summarized in Table 4. The model is quite successful in matching the volatilities of the main macro-categories. In particular, it gets the standard deviations of consumption, residential investment and loans more or less right. The model somewhat underestimates the volatility of house prices and overestimates that of inflation and the mortgage interest rate. Except for loans and inflation, the inertia implied by our calibration is also broadly in line with the data. The model does a somewhat worse job at matching the comovement between the main variables: it generates too little positive correlation of consumption with residential investment, real house prices and mortgage loans, while implying too negative correlation between consumption and the lending rate or inflation. Overall, given the model's simplicity and a relatively small number of shocks, its ability to match the key moments can be considered satisfactory.

As a last step of the model validation, we discuss the role it assigns to individual shocks in driving business cycle fluctuations. The variance decomposition results for the core are reported in Table 5. Due to its small size, shocks hitting the periphery do not have any significant effect on the rest of the monetary union. According to the model, consumption in the core is mainly driven by preference shocks, with an important role of productivity shocks.

The latter also drive a significant share of fluctuations in residential investment. However, it is the two housing market shocks (housing preference and residential investment specific) that account for the bulk of movements in this variable. Housing market shocks are also important for loans, but it is the monetary policy shock that explains most of the variance. Investment specific shocks are crucial in generating fluctuations in real house prices. Finally, productivity shocks account for the bulk of movements in inflation and the lending rate. We note that many of these implications are broadly consistent with the VAR evidence reported in Musso et al. (2011). This concerns in particular the dominant role of housing market shocks in driving residential investment and real house prices.

Turning to the variance decomposition for the periphery (see Table 6), our model assigns a substantial role to shocks originating abroad. This does not apply to residential investment, which is driven almost entirely by domestic disturbances. At the other extreme, domestic shocks play very little role in explaining fluctuations in the periphery's inflation and credit cost.

4 The effects of macroprudential policy

In this section we discuss how our macroprudential policy tools work. To this end, on Figure 2 we present impulse response functions to shocks to the macroprudential policy rules (25) and (26). The policy rule parameters are fixed at values chosen in accordance with our findings described in Section 5. More specifically, we choose policies lying at the identified efficient policy frontiers, characterized by relatively low instrument change volatility but already able to lower output volatility. Of course, the latter is meant in relative terms, since, as we explain later, the CA policy is not able to substantially reduce output fluctuations anyway. In particular, we set $\gamma_m = 0.9$, $\gamma_{my} = -2$, $\gamma_v = 0.975$ and $\gamma_{vy} = 0.9$.

The choice of specific rules is clearly arbitrary as, in contrast to monetary policy rules, there is no evidence on how macroprudential policymakers behave. Our experiments with various parameter sets show that the shape of the impulse responses is relatively immune to changes of the coefficients on output deviation. In contrast, it clearly depends on the autoregressive parameters, with higher values generating more persistent responses. Our baseline parametrization implies modestly high autoregression, though still lower than that found in the literature (for instance Angelini et al. (2010) propose $\gamma_v = 0.999$). The reason, as explained in detail in Section 5, is the extremely high volatility of the instrument implied by very persistent rules.

Let us begin with the LTV policy. A negative shock to the LTV ratio implies a tightening of lending standards for impatient households. These have to cut back borrowing and hence reduce consumption and the housing stock. Lower demand for housing drives its price down, amplifying the initial shock as the value of collateral declines. As both consumption and residential investment decline, so does output. Since the periphery has a negligible weight in the common monetary policy objectives, the interest rate barely moves and hence does not help to stabilize the economy.

The working of the CA policy is somewhat more nuanced. A positive shock to the required CA ratio means that banks initially face a penalty for not fulfilling the requirement. This is transmitted to impatient households via higher lending rates and results in a tightening of their collateral constraint. As a consequence, households have to cut back on borrowing and reduce housing and consumption demand. The price of housing falls, strengthening the initial shock. As a result housing investment, output and inflation decline.

5 Simulations and results

We are now ready to use our model for simulation purposes. We proceed in several steps. As a starting point we show the performance of our small (peripheral) economy under the assumption of not participating in the common currency area. The country runs independent monetary policy under a floating exchange rate. Next, we fix the exchange rate and assume monetary policy is taken over by the common central bank. While the latter reacts formally to area-wide output and inflation, given our baseline calibration where the small economy constitutes only 1% of the currency area, its reactions are almost completely determined by the performance of the large (foreign) economy. This means that the small economy looses protection against asymmetric shocks provided by monetary policy and exchange rate adjustment. Further on, we turn on macroprudential policy in the peripheral economy and check, whether it is able to make up for the loss of independent monetary policy in the environment of asymmetric shocks. Finally, we check whether independent (decentralized) macroprudential policy can be substituted by an area-wide policy.

One important caveat is related to the precise design of macroprudential rules. While the functional form and parametrization of monetary policy rules has been researched in detail, not much is known about macroprudential rules. Since experience of supervisors does not offer any guidance yet, we decided to present a broad range of results in the form of policy frontiers. We define our policy trade-off space as consisting of the variability of output and of the change (first difference) of the respective policy instrument. This can be seen as an analogue to the more familiar case of monetary policy, which faces trade-offs between the variability of output, inflation and the interest rate adjustment. In contrast to monetary policy, macroprudential supervision is supposed to use instruments specific to the performance of bank credit with the objective of stabilizing cyclical developments. However, similarly to monetary authorities they seem unlikely to allow for too much variability of their instruments.

In order to present the trade-off and potential gains from introducing macroprudential policy we conduct stochastic simulations (with shocks as described in Section 3) and run a grid search over various parameters of the macroprudential rules (25) and (26). In particular in case of the LTV rule we allow γ_m to vary between 0 and 0.999 and γ_{my} to vary between -1000 and 0. In case of the rule for capital requirements γ_v is allowed to change from 0 to 0.999 and $\gamma_{\nu y}$ from 0 to 2000. Next, we find the efficient policy frontier, by selecting the points that envelope our results towards the origin. We make sure that our grid covers the whole efficient frontiers.

Here, another important caveat arrises. It turns out that for both policies highly persistent rules formed a large part of the frontiers. However, such rules generate enormous volatility of the instruments despite moderate volatility of their adjustments. Hence, when presenting the frontiers we limited the volatility of the instruments. In particular, for the LTV instrument we draw three frontiers, for which the standard deviation of $m_{\chi,t}$ is limited by 2.5%, 5% and 7.5% respectively. Similarly, for the CA policy we draw frontiers for policies that do not raise the standard deviation of v_t above 1%, 2% and 3%.

Figure 3 depicts the policy frontiers for the LTV policy together with the level of output volatility under independent monetary policy. The upper left point of each frontier denotes inactive macroprudential policy. Moving along the frontiers increases the variance of the instrument change (macroprudential policy becomes more active) and, up to a certain point, reduces the variance of output.

The main conclusions from the Figure are as follows. First, joining the monetary union raises volatility of output from 1.70% to 1.99%. This is clearly the consequence of substituting monetary policy that reacts to domestic developments with one that reacts (mainly) to foreign ones.[8] Second, substituting independent monetary policy with macroprudential policy can help stabilizing the economy. To what extent it is possible to compensate for the loss of the flexible exchange rate and independent monetary policy depends on the accepted volatility of the instrument and its adjustment. Not allowing for LTV volatility to exceed 5% one cannot beat independent monetary policy. However, with a more volatile instrument (up to 7.5%) and its adjustment ($\sigma_{\Delta m_\chi} \gtrsim 0.5\%$) independent monetary policy can be beaten.

Let us now move to the second policy instrument ν. Its working is described on Figure 4. While the pattern looks similar, the details differ substantially from the previous policy. CA policy is able to lower output volatility as well, but its effectiveness is much lower. For instance even with volatility of the instrument caped at 3%, output volatility can be decreased only by 0.02 percentage points. Under our limiting assumptions it is not possible

[8] At this point one thing should be made clear in order to avoid misinterpretation of the results. Our stochastic environment does not include shocks that directly affect the exchange rate (e.g. risk premium shocks) and that possibly disappear after adopting the common currency. For this reason in our model joining the union is unequivocally detrimental for output variability, while in real life the net outcome is *ex ante* unclear.

to make up for the loss of independent monetary policy. It should be noted that our result seems to be in stark contrast with the finding in Angelini et al. (2010), who report that CA policy can be effective. However, in their effective policy rule $\gamma_v = 0.999$. As a result the instrument is probably extremely volatile despite a decent standard deviation of its change.

While our key objective was to reduce output volatility, we are also interested in how our policies affect other important variables. In Table 7 we present standard deviations for key variables in the case of monetary union with and without macroprudential policies. The underlying simulations assume the same set of shocks as above and the same policy rule parameters as selected to draw impulse responses in Section 4. These policies are also marked with bold circles on Figures 3 and 4. The table shows that our policies have relatively benign side effects. For most variables the standard deviation either remains unchanged or is reduced compared to the no-policy case. The only exception are mortgage loans whose variability increases in the case of LTV policy. This, however is understandable, since for this policy the instrument volatility transmits immediately to loan volatility via the collateral constraint equation.

Our next experiment checks whether macroprudential policy is able to trade off some shocks better than others. This is an important question in the debate on euro area imbalances, since it can be presumed that asymmetric interest rate or housing shocks could have played an important role in driving the imbalances. To answer this question we run stochastic simulations with one shock turned on at a time. Doing this we concentrate on shocks specific to the peripheral economy. Figures 5-6 present the efficient policy frontiers for LTV and CA policies respectively.[9] LTV policy is most efficient at trading off shocks related to the housing market (housing preference and investment specific) and to monetary policy. CA policy is best for housing preference shocks, although, as described before, overall this policy can reduce volatilities to a lesser extent than LTV policy. Both policies do a particularly bad job in stabilizing the economy after productivity shocks. These findings strengthen our conclusion that macroprudential policy seems well designed to deal with the kind of asymmetries and imbalances that plague the euro area.

Our final experiment aims at checking how well common macroprudential policy would work as compared to decentralized policy. To this end we conduct two grid searches with all shocks turned on assuming the same macroprudential policy for the whole euro area (i.e. a common rule that reacts to area-wide developments) and independent policies in the core and periphery. The results (policy frontiers for volatilities in periphery) are depicted on Figure 7. It is clear that common macroprudential policy fares much worse then the decentralized one.

[9]For this and the next experiment we only show the case where standard deviations of $m_{\chi,t}$ and v_t are capped by 5% and 2% respectively.

For both instruments common policy is able to lower output volatility only slightly. The comparison with independent macroprudential policy is particularly striking in case of the LTV instrument, which, if applied on a decentralized basis is relatively efficient and looses all its power when used for area-wide policy. The intuition behind this result is an analogue to monetary policy. Area wide policy reacts mainly to developments in its core and nearly ignores business cycle fluctuations specific to its (small) periphery.

6 Conclusions

In this paper we ask the question whether macroprudential policy can contribute to stabilizing a monetary union hit by asymmetric shocks. Our question is directly motivated by the imbalances that have arisen since the creation of the euro area between its "core" and "peripheral" members. To this end we construct a dynamic, stochastic general equilibrium model of two regions forming a monetary union. In addition to standard features of a new-Keynesian model our framework features independently regulated banking sectors that grant loans to households subject to collateral constraints.

Next we run a number of simulations, showing how the peripheral economy behaves under various policy assumptions. In particular, we test two types of macroprudential policy (one oriented at regulating the Loan-to-value ratio and one focused on the capital adequacy ratio) and check whether they can stabilize the economy when independent monetary policy is lost. Additionally, we consider the case of common macroprudential policy and show how it changes the outcome for the periphery. Finally, we test whether macroprudential policy is particularly efficient at stabilizing the economy hit by particular shocks.

Our findings are as follows. First, the two macroprudential policies are able to lower output volatilities in the periphery. However, while the LTV policy is even able to beat independent monetary policy (without macroprudential policy), the CA policy fares relatively poorly. Importantly, macroprudential policy targeted at stabilizing output does not do much harm to other important macrovariables. Second, macroprudential policy is particularly efficient at trading-off monetary policy shocks and shocks related to the housing market. Since these shocks are the usual suspects behind the asymmetric developments between core and periphery of the euro area, this conclusion strengthens our case for macroprudential policy as a stabilizing tool. However, (this being our third conclusion), if macroprudential policy is to prevent desynchronization of business cycles between the core and periphery it must be decentralized. Common macroprudential policy lowers output volatility in periphery only marginally.

All in all, we find that macroprudential policy can potentially play an important role in preventing the emergence of imbalances between members of a monetary union. The main prerequisite is, however, that the policy be applied on a decentralized basis. Common policy does not solve the problem.

References

Andrés, Javier, Samuel Hurtado, Eva Ortega, and Carlos Thomas (2010) 'Spain in the euro: a general equilibrium analysis.' *SERIEs* 1(1), 67–95

Angelini, Paolo, Andrea Enria, Stefano Neri, Fabio Panetta, and Mario Quagliariello (2010) 'Pro-cyclicality of capital regulation: is it a problem? How to fix it?' Questioni di Economia e Finanza (Occasional Papers) 74, Bank of Italy, Economic Research Department, October

Angelini, Paolo, Laurent Clerc, Vasco Cúrdia, Leonardo Gambacorta, Andrea Gerali, Alberto Locarno, Roberto Motto, Werner Roeger, Skander Van den Heuvel, and Jan Vlcek (2011) 'Basel iii: Long-term impact on economic performance and fluctuations.' BIS Working Papers 338, Bank for International Settlements, February

Benes, Jaromir, Michael Kumhof, and David Vavra (2010) 'Monetary policy and financial stability in emerging market economies: an operational framework.' mimeo, International Monetary Fund

Blanchard, Olivier (2007) 'Adjustment within the euro. The difficult case of Portugal.' *Portuguese Economic Journal* 6(1), 1–21

Bussie'Bre, Matthieu, Giovanni Callegari, Fabio Ghironi, Giulia Sestieri, and Norihiko Yamano (2011) 'Estimating trade elasticities: Demand composition and the trade collapse of 2008-09.' NBER Working Papers 17712, National Bureau of Economic Research, Inc, December

Christensen, Ian, Césaire Meh, and Kevin Moran (2011) 'Bank leverage regulation and macroeconomic dynamics.' Technical Report

Christoffel, Kai, Günter Coenen, and Anders Warne (2008) 'The new area-wide model of the euro area - a micro-founded open-economy model for forecasting and policy analysis.' Working Paper Series 944, European Central Bank, September

Coenen, Günter, Peter McAdam, and Roland Straub (2008) 'Tax reform and labour-market performance in the euro area: A simulation-based analysis using the new area-wide model.' *Journal of Economic Dynamics and Control* 32(8), 2543–2583

Darracq-Pariés, Matthieu, Christoffer Kok Sorensen, and Diego Rodriguez-Palenzuela (2011) 'Macroeconomic propagation under different regulatory regimes: Evidence from an estimated dsge model for the euro area.' *International Journal of Central Banking* 7(4), 49–113

Dib, Ali (2010) 'Banks, credit market frictions, and business cycles.' Technical Report

ECB (2003) 'Inflation differentials in the euro area: potential causes and policy implications.' Technical Report, European Central Bank, September

Funke, Michael, and Michael Paetz (2012) 'A dsge-based assessment of nonlinear loan-to-value policies: Evidence from hong kong.' BOFIT Discussion Papers 11/2012, Bank of Finland, Institute for Economies in Transition, May

Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico M. Signoretti (2010) 'Credit and banking in a DSGE model of the euro area.' *Journal of Money, Credit and Banking* 42(s1), 107–141

Gertler, Mark, and Peter Karadi (2011) 'A model of unconventional monetary policy.' *Journal of Monetary Economics* 58(1), 17–34

Honohan, Patrick, and Anthony J. Leddin (2006) 'Ireland in EMU - more shocks, less insulation?' *The Economic and Social Review* 37(2), 263–294

Iacoviello, Matteo (2005) 'House prices, borrowing constraints, and monetary policy in the business cycle.' *American Economic Review* 95(3), 739–764

Iacoviello, Matteo, and Stefano Neri (2010) 'Housing market spillovers: Evidence from an estimated DSGE model.' *American Economic Journal: Macroeconomics* 2(2), 125–64

in't Veld, Jan, Andrea Pagano, Rafal Raciborski, Marco Ratto, and Werner Roeger (2012) 'Imbalances and rebalancing scenarios in an estimated structural model for spain.' mimeo, European Commission

Lambertini, Luisa, Caterina Mendicino, and Maria Teresa Punzi (2011) 'Leaning against boom-bust cycles in credit and housing prices.' Working Papers 201101, Center for Fiscal Policy, Swiss Federal Institute of Technology Lausanne, March

Lombardo, Giovanni, and Peter McAdam (2012) 'Financial market frictions in a model of the euro area.' Working Paper Series 1423, European Central Bank, February

Meh, Césaire A., and Kevin Moran (2010) 'The role of bank capital in the propagation of shocks.' *Journal of Economic Dynamics and Control* 34(3), 555–576

Musso, Alberto, Stefano Neri, and Livio Stracca (2011) 'Housing, consumption and monetary policy: How different are the us and the euro area?' *Journal of Banking & Finance* 35(11), 3019–3041

Onali, Enrico (2012) 'Moral hazards, dividends, and risk in banks.' Bangor Business School Working Paper 12/001, Bangor Business School

Sutherland, Alan (2005) 'Incomplete pass-through and the welfare effects of exchange rate variability.' *Journal of International Economics* 65(2), 375–399

Tables and figures

Table 1: Calibration - parameters

Parameter	Value	Description
β_P, β_P^*	0.99	Discount factor, patient HHs
β_I, β_I^*	0.975	Discount factor, impatient HHs
δ_χ, δ_χ^*	0.01	Housing stock depreciation rate
ω_I, ω_I^*	0.55	Share of impatient HHs
A_χ, A_χ^*	2.43	Weight on housing in utility function
A_n, A_n^*	880	Weight on labor in utility function
σ_c, σ_c^*	2	Inverse of intertemporal elasticity of substitution in consumption
σ_χ, σ_χ^*	2	Inverse of intertemporal elasticity of substitution in housing
σ_n, σ_n^*	2	Inverse of Frisch elasticity of labor supply
ξ_c, ξ_c^*	0.7	Degree of external habit formation in consumption
ξ_χ, ξ_χ^*	0.7	Degree of external habit formation in housing
θ_w, θ_w^*	0.75	Calvo probability for wages
ζ_w, ζ_w^*	0.5	Indexation parameter for wages
μ_w, μ_w^*	1.2	Steady state labor markup
ϕ_n, ϕ_n^*	6	Elasticity of substitution btw. labor of patient and impatient HHs
t, t^*	0.51	Real transfers from patient to impatient HHs
μ, μ^*	1.2	Steady state product markup
θ_H, θ_F^*	0.9	Calvo probability for domestic prices
θ_F, θ_H^*	0.75	Calvo probability for export prices
ζ_H, ζ_F, ζ_H^*, ζ_F^*	0.5	Indexation parameter for prices
α, α^*	0.3	Output elasticity with respect to physical capital
k, k^*	6.5	physical capital stock per capita
κ_χ, κ_χ^*	30	Housing investment adjustment cost
μ_L, μ_L^*	1.0047	Loan markup
m_χ, m_χ^*	0.75	Steady state LTV ratio
ν, ν^*	0.1	Steady state target bank capital to loans ratio
κ_b, κ_b^*	10	Curvature of capital requirement penalty function
ω_b, ω_b^*	0.85	Share of retained profits in the banking sector
δ_b, δ_b^*	0.048	Bank capital depreciation rate
π, π^*	1.005	Steady state inflation
ξ	0.001	Elasticity of risk premium wrt. foreign debt
γ_R	0.9	Interest rate smoothing in Taylor rule
γ_π	2	Response to inflation in Taylor rule
γ_π	0.15	Response to output in Taylor rule
ω	0.01	Share of periphery in monetary union
η_c	0.7	Share of domestic goods in consumption basket (periphery)
$\eta_c^* = \omega(1-\eta_c)/(1-\omega)$	0.003	Share of imported goods in consumption basket (core)
ϕ_c, ϕ_c^*	1.5	Elasticity of substitution btw. home and foreign goods

Table 2: Calibration - stochastic shocks

Parameter	Value	Description
ρ_z, ρ_z^*	0.95	Productivity shock - autocorrelation
σ_z, σ_z^*	0.0065	Productivity shock - standard deviation
ρ_u, ρ_u^*	0.99	Preference shock - autocorrelation
σ_u, σ_u^*	0.013	Preference shock - standard deviation
ρ_χ, ρ_χ^*	0.99	Housing preference shock - autocorrelation
σ_χ, σ_χ^*	0.008	Housing preference shock - standard deviation
ρ_i, ρ_i^*	0.95	Investment specific shock - autocorrelation
σ_i, σ_i^*	0.011	Investment specific shock - standard deviation
σ_R	0.0013	Monetary shock - standard deviation

Table 3: Steady state ratios

Steady state ratio	Value
Import to output ratio (periphery)	0.27
Import to output ratio (core)	0.003
Residential investment to output ratio	0.094
Capital-output ratio (annual)	2.0
Hours worked	0.33
Housing wealth to output ratio (annual)	2.32
Debt to output ratio (annual)	0.76
Bank capital to loans ratio	0.1
Spread (annualized)	0.019
Relative consumption of impatient HHs	0.77

Table 4: Moment matching - core

Variable	Standard dev.		Autocorrelation		Corr. with cons.	
	Data	Model	Data	Model	Data	Model
Consumption	2.25	2.07	0.97	0.98	1.00	1.00
Residential investment	6.97	6.99	0.97	0.99	0.81	0.26
Mortgage loans	5.51	5.41	0.98	0.83	0.89	0.29
Real house prices	3.94	3.18	0.98	0.93	0.65	0.33
Mortgage interest rate	0.30	0.42	0.98	0.96	-0.07	-0.76
Inflation	0.28	0.39	0.32	0.97	0.19	-0.59

Note: All variables are quarterly euro area aggregates for the period 1996-2011. Consumption is defined as real final consumption expenditure of households, residential investment is real gross fixed capital formation in dwellings, inflation is the quarterly change in HICP, while mortgage interest rate is quarterly interest on housing loans to households. All these variables are taken from Eurostat. Real house prices are defined as residential property prices of new and existing houses and flats, while mortgage loans are defined as outstanding amounts of lending for house purchase. Both series come from the ECB SDW and are deflated by HICP. Trending variables (consumption, residential investment, mortgage loans and real house prices) are expressed as log-deviations from linear trends.

Table 5: Variance decomposition - core

Variable \ Shock	Productivity	Preference	Housing pref.	Inv. specific	Monetary
Consumption	20.1	63.4	1.5	2.5	12.5
Residential investment	42.4	3.4	30.5	23.3	0.4
Mortgage loans	3.2	0.8	17.4	26.8	51.8
Real house prices	21.0	0.2	4.9	58.8	15.2
Mortgage interest rate	69.8	12.7	0.2	2.2	15.1
Inflation	69.4	24.9	0.1	0.4	5.2

Table 6: Variance decomposition - periphery

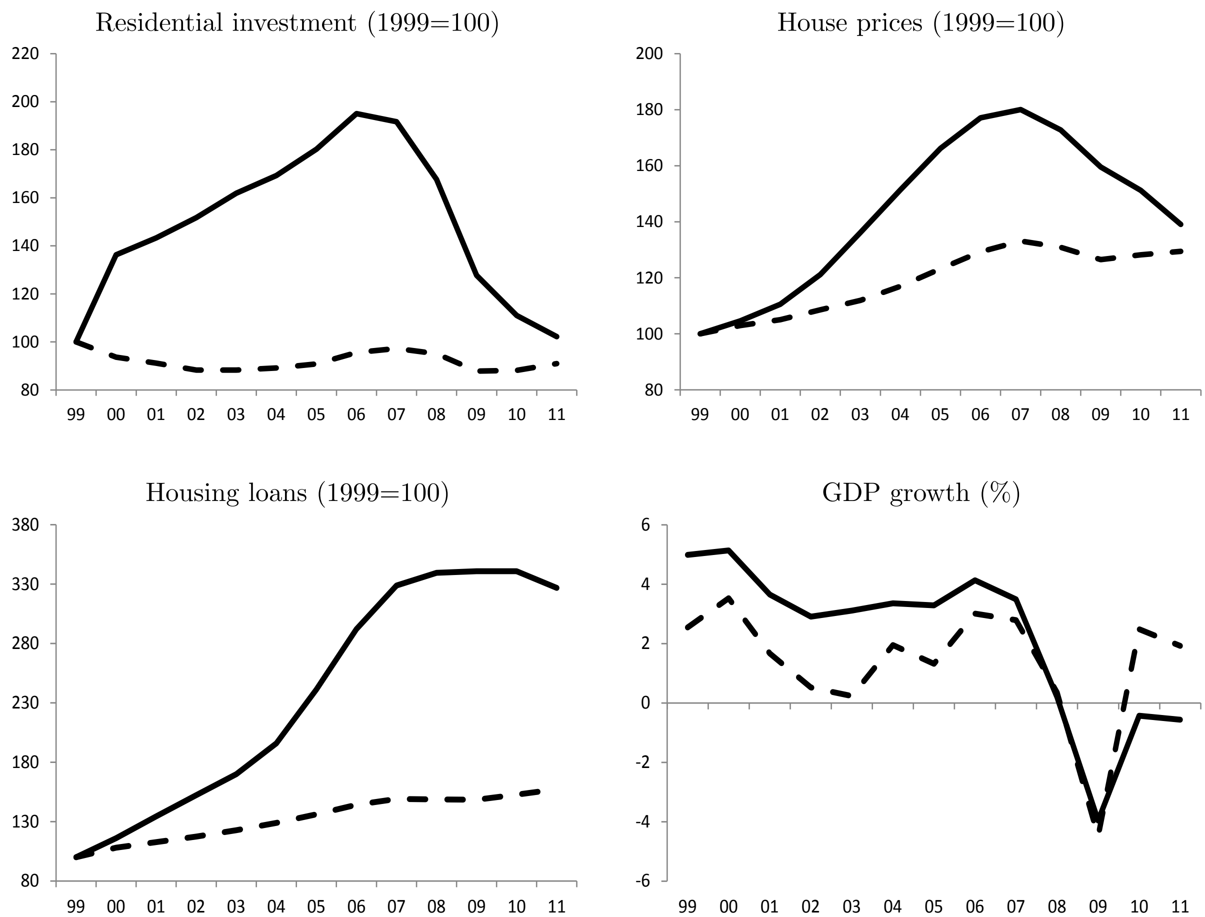
Variable \ Shock	Productivity	Preference	Housing pref.	Inv. specific	Foreign
Consumption	28.9	32.8	1.5	1.5	35.3
Residential investment	29.6	0.6	31.1	32.1	6.6
Mortgage loans	2.3	2.2	19.4	19.4	56.7
Real house prices	3.2	0.6	6.7	52.8	36.7
Mortgage interest rate	0.2	0.1	0.1	0.2	99.4
Inflation	5.9	0.1	0.0	0.1	93.9

Table 7: Effects of macroprudential policy on business cycle in the periphery

Variable	Monetary union		
	No policy	LTV policy	CA policy
Output	1.99	1.86	1.98
Consumption	1.69	1.69	1.69
Residential investment	7.25	7.23	7.07
Mortgage loans	5.59	6.81	5.55
Real house prices	3.15	3.12	3.13
Mortgage interest rate	0.42	0.42	0.42
Inflation	0.38	0.38	0.38
Target LTV	0.00	3.13	0.00
Change in target LTV	0.00	0.21	0.00
Target CA	0.00	0.00	1.00
Change in target CA	0.00	0.00	0.04

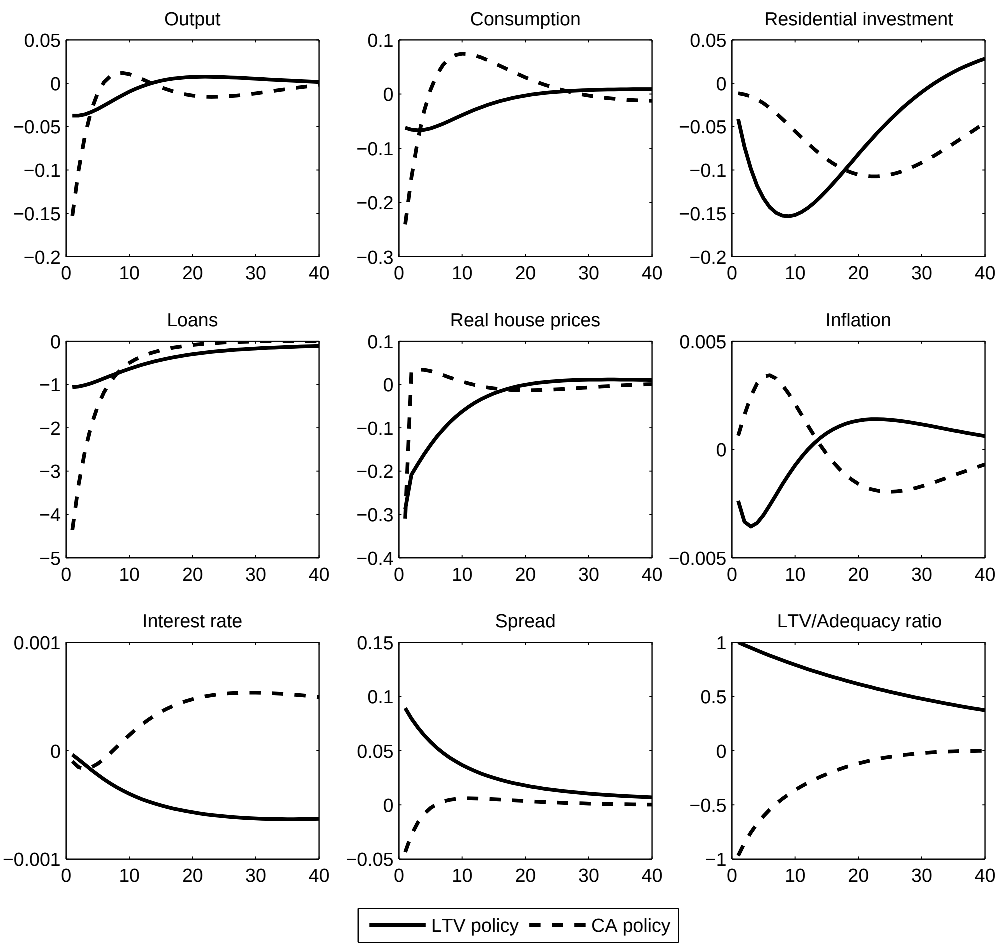
Note: All variables are expressed in per cent. The macroprudential policy rules are parametrized as in the baseline case ($\gamma_m = 0.9$, $\gamma_{my} = -2$, $\gamma_v = 0.975$, $\gamma_{vy} = 0.9$).

Figure 1: Stylized facts on imbalances in the euro area



Note: Dashed lines - core euro area members (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, Netherlands), solid lines - peripheral euro area members (Greece, Ireland, Portugal and Spain). For each country, GDP is real gross domestic product (source: Eurostat), residential investment is real gross fixed capital formation in dwellings (source: Eurostat), house prices are residential property prices of new and existing houses and flats (source: BIS), while housing loans are defined as outstanding amounts of lending for house purchase (source: ECB SWD). The last two series are deflated by HICP (source: Eurostat). The aggregates for both regions are calculated as sums (residential investment, loans and GDP) or GDP-weighted averages (house prices).

Figure 2: Impulse responses to macroprudential policy shocks



Note: All variables are expressed in per cent. The macroprudential policy rules are parametrized as in the baseline case ($\gamma_m = 0.9$, $\gamma_{my} = -2$, $\gamma_v = 0.975$, $\gamma_{vy} = 0.9$).

Figure 3: Efficient policy frontier for LTV policy (composition of shocks)

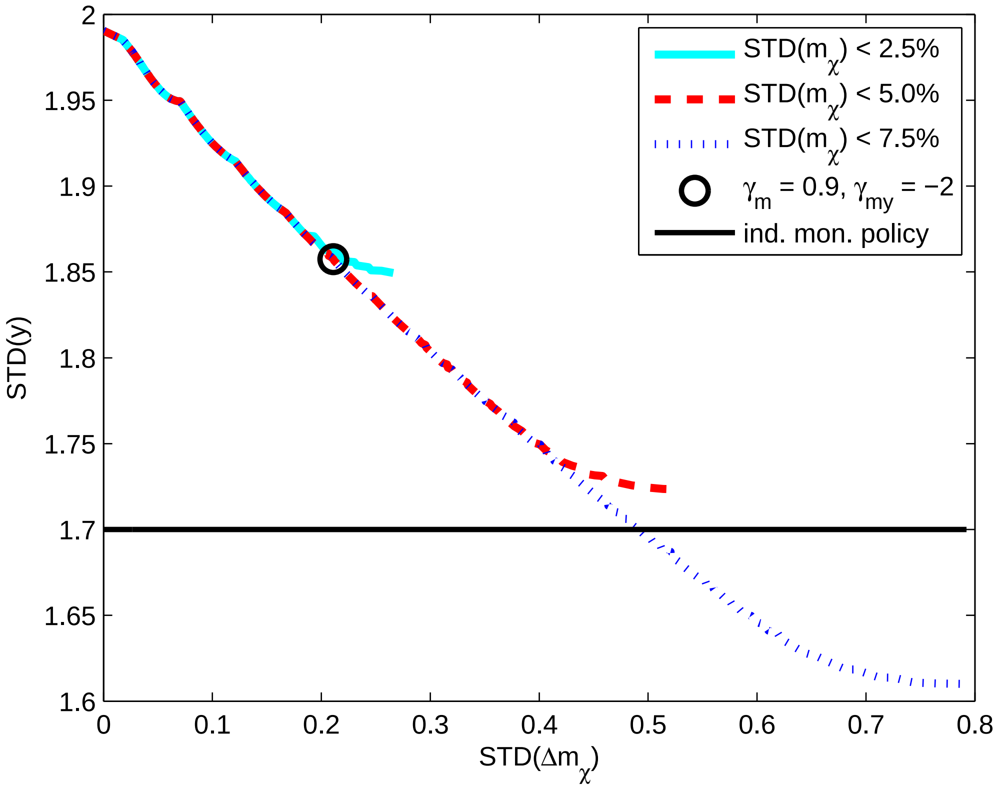


Figure 4: Efficient policy frontier for CA policy (composition of shocks)

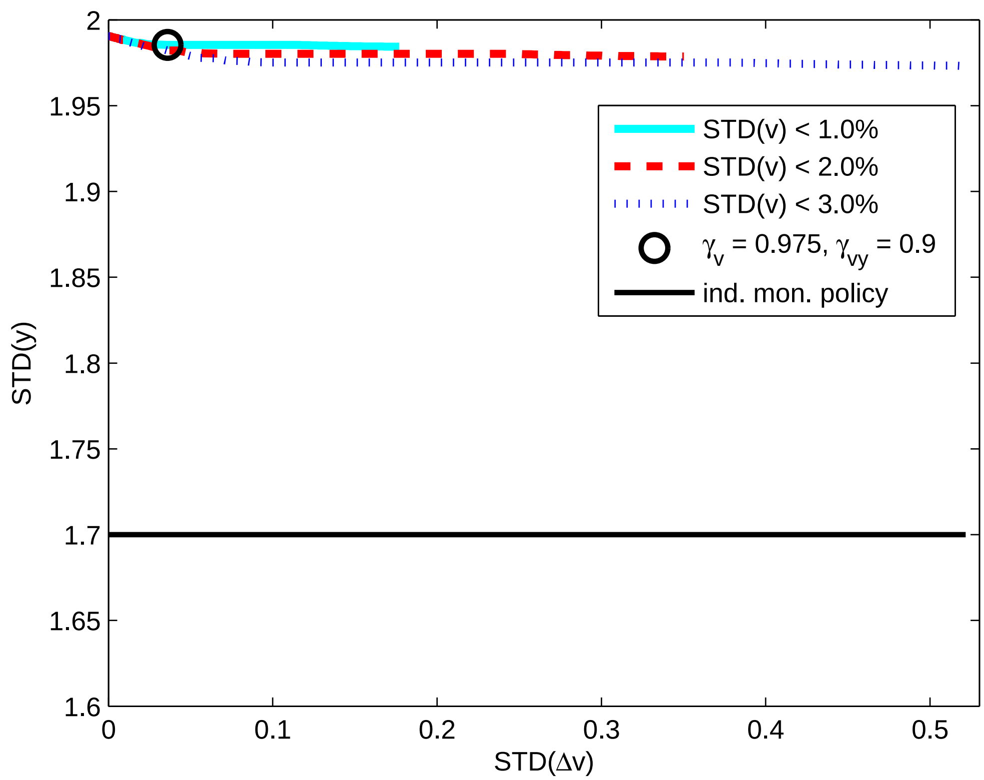


Figure 5: Efficient policy frontiers for LTV policy under various shocks

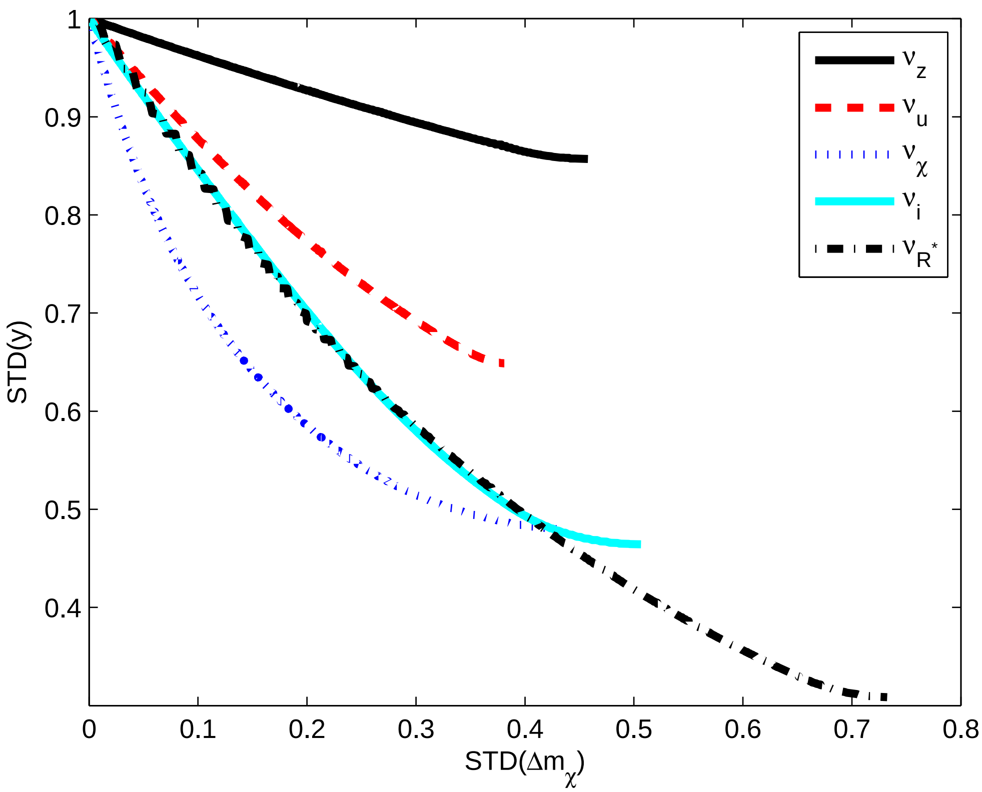


Figure 6: Efficient policy frontiers for CA policy under various shocks

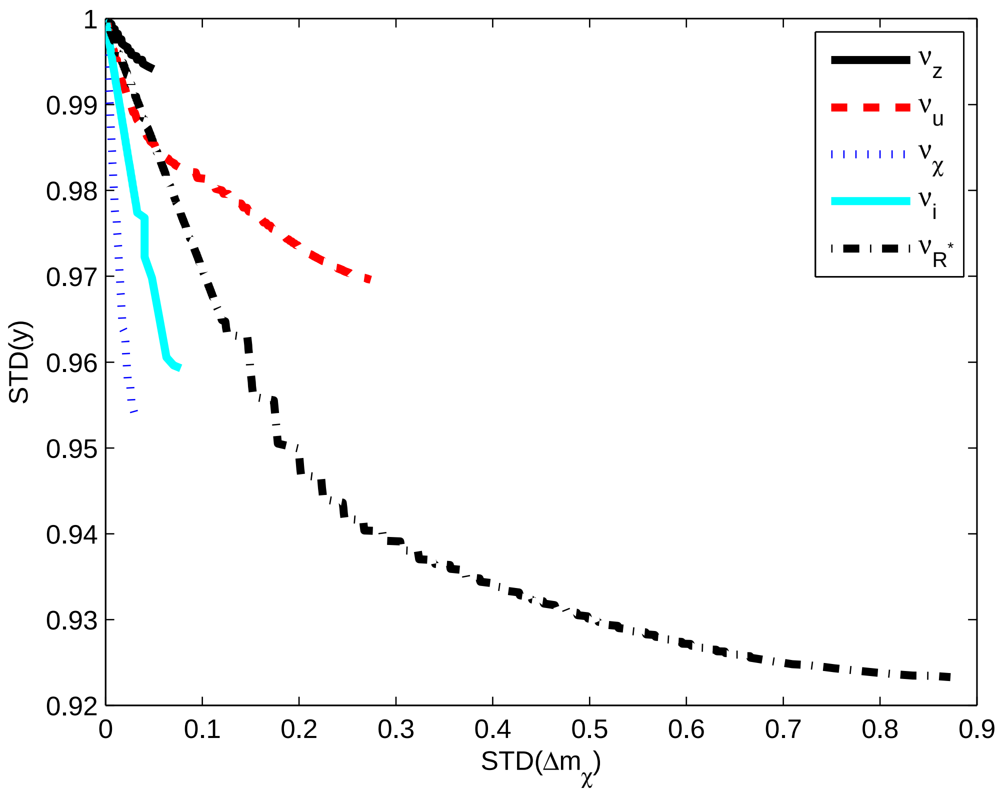


Figure 7: Efficient policy frontiers for common and independent macroprudential policies