Could the boom-bust in the eurozone's periphery have been prevented? *

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Abstract

Boom-bust cycles in the eurozone periphery almost toppled the common currency and recent experience suggests that they may return soon. We check whether monetary or macroprudential policy could have prevented the periphery's violent boom and bust after the euro adoption. We estimate a DSGE model for the two euro area regions, core and periphery, and conduct a series of historical counterfactual experiments in which monetary and macroprudential policy follow optimized rules that use area-wide welfare as the criterion. We show that common monetary policy could have better stabilized output in both regions, but not the housing market or the periphery's trade balance. In contrast, region-specific macroprudential policy could have substantially smoothed the credit cycle in the periphery and reduced the build-up of external imbalances.

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1 Introduction

The boom and bust cycle in the peripheral economies of the euro area is one of the most dramatic (but also most interesting) experiences in the recent economic history of developed countries. It started relatively innocently in the form of increasing demand and inflation pressure in selected countries of the common currency area. Over time, however, it evolved into a fully-fledged boom in the housing market, drew current accounts and international investment positions into deeply negative territories and, after property markets collapsed, triggered an economic, banking and fiscal crisis that almost toppled the common currency.

This episode has been extensively described in the literature (see e.g. Blanchard and Giavazzi 2002; Brzoza-Brzezina 2005; Honohan and Leddin 2006; Blanchard 2007; Fagan and Gaspar 2007; in't Veld et al. 2012; Rabanal and Sanjani 2015). We summarize it briefly in Figure 1, which plots the time series of output, net exports, housing loans and house prices in the core (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, Netherlands) and periphery (Greece, Ireland, Portugal and Spain) of the euro area. It is clear that the boom-bust cycle was restricted to the latter region and was particularly stark in the housing market. Our main goal is to check whether policy, be it monetary or macroprudential, could have prevented such a scenario.

We do not build on empty ground. The existing literature has already pointed to macroprudential policy as a possible solution to the problem of asymmetries in a monetary union. Obviously, common monetary policy cannot deal with asymmetric shocks, especially if they affect a relatively small part of the common currency area (the GDP share of the affected peripheral members only slightly exceeds 15%). However, a properly designed macroprudential policy could in principle complement monetary policy, as long as the asymmetric developments show up in areas where such policy can be effective. Since the boom-bust in the eurozone periphery was largely concentrated in the residential property market, the literature has mainly focused on the potential gains that can be achieved with adjustments in the macroprudential policy instruments related to housing mortgages.

Quint and Rabanal (2014) study the optimal mix of monetary and macroprudential policies in the euro area and find that the introduction of a rule affecting credit spreads would help in reducing macroeconomic volatility and hence in improving EMU-wide welfare. Brzoza-Brzezina et al. (2015) conclude that macroprudential policy using the loan-to-value (LTV) ratio as an instrument can substantially improve welfare in the euro area member countries affected by asymmetric shocks, provided that it is implemented at a national rather than union-wide basis. Rubio (2014) develops this finding further and shows that the outcomes depend on the source of the observed heterogeneity between the member states, with potential welfare gains achievable when the asymmetries originate in the housing market. Our paper is also related to the vast literature that asseses macroprudential policy without explicitly modeling a monetary union (see e.g. Darracq-Pariés et al. (2011); Lambertini et al. (2013); Claessens (2014)).

While all these papers show a clear direction for future policies, they do not necessarily give a clear answer to the question stated in this paper's title. This is because their conclusions are based on stochastic simulations applied to a typical business cycle environment. However, as we confirm in our analysis, the series of shocks that hit the eurozone periphery was quite special in terms of sign and size. For this reason, we focus on the particular period when the boom developed and then turned into bust. Our results are thus based on historical counterfactual simulations for the period since the eurozone was created. Moreover, while designing such experiments it is crucial to account for potential structural heterogeneity between the core and peripheral countries as this may lead to different responses of key macroaggregates even in response to common shocks. Therefore, we base our conclusions on an estimated model where the two regions of the euro area are not only hit by asymmetric shocks, but also are allowed to differ in average leverage as well as nominal and real rigidities. Indeed, we find that these structural differences make the periphery more prone to boom-bust cycles originating in the housing market.

Given the pronounced role of the housing market in the recent eurozone crisis, and our focus on counterfactual simulations with alternative monetary and macroprudential policy adjustments, our modeling strategy is relatively clear-cut. We construct a New Keynesian two-region DSGE model featuring a housing market, real and nominal frictions, and common monetary policy. The model is then estimated using macroeconomic data for the two areas of the eurozone. Our estimation confirms a pronounced role of housing markets in driving the boom in the periphery and its larger vulnerability.

Next, we conduct a series of counterfactual simulations. Our evaluation is based on social welfare function. We begin by checking whether common monetary policy could have prevented the boom-bust. To this end we generate counterfactual scenarios with monetary policy rule parameters optimized such that area-wide welfare in stochastic equilibrium is maximized. We show that such policy could have stabilized output in both regions of the monetary union quite well. However, its ability to affect housing loans or the trade balance is very limited. In contrast, macroprudential policy could have significantly smoothed the credit cycle in the periphery. It also appears as a promising way of limiting the build-up of external imbalances in this relatively more vulnerable region.

The rest of the paper is structured as follows. In Section 2 we present the model, and in Section 3 we document its estimation and stochastic properties. Section 4 presents historical shock decompositions and discusses how differences in the economic structure make the periphery more prone to boom-bust cycles. In section 5 we describe the counterfactual simulations. Section 6 concludes.

2 Model

We construct a two-region DSGE framework with collateral constraints modeled as in Iacoviello (2005). These two regions, called core and periphery, form a monetary union. 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 final goods, housing and intermediate goods. Union-wide monetary policy is conducted according to a Taylor rule, while macroprudential policy instruments can be adjusted at the regional level.

In what follows, variables and parameters without an asterisk refer to the periphery, while those with an asterisk refer to the core. Variables without time subscripts denote their respective steady state values. Since both regions 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 $\iota \in I \equiv (\omega_P, 1]$.[1] 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 discount the future with factor β_P and optimize by choosing consumption $c_{P,t}$, housing services $\chi_{P,t}$ and labor supply $n_{P,t}$. They set their own nominal wages $W_{P,t}$ in a monopolistically competitive environment and deposit savings $D_{P,t}$ in the banking sector, repaid with interest rate R_t known in advance. We assume that patient households own all capital, as well as all shares of firms and banks in the economy. Thus, they receive rent $R_{k,t}$ from owned capital[2] k_P and dividends $\Pi_{P,t}$. They also pay two lump sum taxes, one as a fixed redistributive transfer to impatient households τ_P and the other to finance government consumption τ_t.

A ι-th representative patient household maximizes its expected utility

[1] 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 $k_P = k/\omega_P$.

[2] We assume that the capital stock is fixed at the aggregate level.

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

subject to the budget constraint

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

where ξ_c measures the degree of external habit persistence in consumption, A_χ and A_n are the weights of housing and labor in utility, σ_c denotes the inverse of intertemporal elasticity of substitution in consumption, σ_n is the inverse Frisch elasticity of labor supply, and δ_χ is the rate of housing depreciation. There are two preference shocks – an intertemporal preference shock $\varepsilon_{u,t}$ and a housing preference shock $\varepsilon_{\chi,t}$, both following independent AR(1) processes. Finally, prices of consumption and housing are denoted as P_t and $P_{\chi,t}$. In what follows, prices written with lower case letters are expressed in real terms, relative to the CPI index P_t.

While estimating and simulating the model, following Justiniano et al. (2015) we assume that the utility of the housing services flow $\nu(\chi_{P,t})$ is such that it implies a rigid housing demand of patient households at the level χ_P. This assumption implies that there is no reallocation of houses across the two types of households, which can be motivated by some housing market segmentation, as argued by Landvoigt et al. (2015). It is also consistent with the argument by Geanakoplos (2010) that prices are determined by marginal agents.

2.1.2 Impatient households

Impatient households discount the future with factor $\beta_I < \beta_P$ and optimize by choosing consumption $c_{I,t}$, housing services $\chi_{I,t}$ and labor supply $n_{I,t}$. They set their nominal wages $W_{I,t}$ and acquire loans $L_{I,t}$ from the banking sector, charged with interest rate $R_{L,t}$ known in advance. Access to credit is constrained by the value of collateral. While impatient households pay a tax financing government spending just as patient households, they also receive a redistributive lump sum transfer τ_I.

A ι-th representative impatient household maximizes its expected utility

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

where ξ_χ and σ_χ denote the degree of external habit persistence and the inverse of intertemporal elasticity of substitution in housing, respectively. This optimization is subject to the budget constraint

$$P_t c_{I,t}\left(\iota\right) + P_{\chi,t}\left[\chi_{I,t}\left(\iota\right) - \left(1-\delta_\chi\right)\chi_{I,t-1}\left(\iota\right)\right] + R_{L,t-1} L_{I,t-1}\left(\iota\right) + \tau_t \leq W_{I,t}\left(\iota\right) n_{I,t}\left(\iota\right) + L_{I,t}\left(\iota\right) + \tau_I \tag{4}$$

and the collateral constraint on credit

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

where $m_{\chi,t}$ is the LTV ratio set by the macroprudential authority.

2.1.3 Labor market

The differentiated labor services of patient and impatient households are purchased by competitive aggregators who transform them to standardized labor services n_t using the following technology

$$n_t = \left[\omega_P^{\frac{1}{\phi_n}} n_{P,t}^{\frac{\phi_n - 1}{\phi_n}} + \omega_I^{\frac{1}{\phi_n}} n_{I,t}^{\frac{\phi_n - 1}{\phi_n}}\right]^{\frac{\phi_n}{\phi_n - 1}}, \tag{6}$$

where

$$n_{P,t} = \left[\frac{1}{\omega_P}\int_0^{\omega_P} n_{P,t}\left(\iota\right)^{\frac{1}{\mu_w}} \mathrm{d}\iota\right]^{\mu_w} \quad \text{and} \quad n_{I,t} = \left[\frac{1}{\omega_I}\int_0^{\omega_I} n_{I,t}\left(\iota\right)^{\frac{1}{\mu_w}} \mathrm{d}\iota\right]^{\mu_w}. \tag{7}$$

In the formulas above, ϕ_n measures the elasticity of substitution between patient and impatient labor, and μ_w denotes households' markup over the competitive wage level.

Nominal wages set by the households are sticky as in the Calvo scheme, and within each period only a fraction $1-\theta_w$ of them receives a signal to reoptimize. Others update their wages according to $\pi_{\zeta_w,t} = \zeta_w \pi_{t-1} + \left(1-\zeta_w\right)\pi$, where $\pi_t \equiv P_t/P_{t-1}$ is CPI inflation, π is its steady state level, and ζ_w is the weight of past inflation in the wage indexing scheme. We assume that households share risk perfectly within each type, either through large families or through access to complete markets for Arrow-Debreu securities. Thus, wage stickiness does not translate into consumption and housing stock heterogeneity.

2.2 Producers

There are three types of producers in the economy – final goods, housing and intermediate goods producers. All of them are owned by patient households. The first two types of producers operate in perfectly competitive markets and use only intermediate goods as inputs, which in turn are produced by monopolistically competitive sector that employs capital and labor.

2.2.1 Final goods producers

Final goods producers purchase domestic $f_{H,t}$ and foreign $f_{F,t}$ intermediate goods varieties and produce a homogenous final good according to the following technology

$$f_t = \left[\eta_H^{\frac{1}{\phi_f}} f_{H,t}^{\frac{\phi_f - 1}{\phi_f}} + (1 - \eta_H)^{\frac{1}{\phi_f}} f_{F,t}^{\frac{\phi_f - 1}{\phi_f}} \right]^{\frac{\phi_f}{\phi_f - 1}}, \tag{8}$$

where

$$f_{H,t} = \left[\int_0^1 f_{H,t}(i)^{\frac{1}{\mu_t}} \, \mathrm{d}i \right]^{\mu_t} \quad \text{and} \quad f_{F,t} = \left[\int_0^1 f_{F,t}(i)^{\frac{1}{\mu_t}} \, \mathrm{d}i \right]^{\mu_t}. \tag{9}$$

In the above formulas, η_H reflects the home bias in consumption, ϕ_f is the elasticity of substitution between domestic and foreign intermediates, and μ_t is an AR(1) markup shock.

2.2.2 Housing producers

Aggregate housing stock χ_t in the economy evolves according to

$$\chi_t = (1 - \delta_\chi)\, \chi_{t-1} + \varepsilon_{i\chi,t} \left[1 - S_\chi \left(\frac{i_{\chi,t}}{i_{\chi,t-1}} \right) \right] i_{\chi,t}, \tag{10}$$

where $\varepsilon_{i\chi,t}$ is an AR(1) investment technology shock, $i_{\chi,t}$ denotes investment in housing and

$$S_\chi \left(\frac{i_{\chi,t}}{i_{\chi,t-1}} \right) = \frac{\kappa_\chi}{2} \left(\frac{i_{\chi,t}}{i_{\chi,t-1}} - 1 \right)^2$$

is the investment adjustment cost function, with $\kappa_\chi > 0$.

Investment results from optimal choices made by perfectly competitive housing producers who acquire domestic intermediate goods and combine them into homogeneous housing investment good

$$i_{\chi,t} = \left[\int_0^1 i_{\chi,t}\left(i\right)^{\frac{1}{\mu_t}} \,\mathrm{d}i \right]^{\mu_t}. \tag{11}$$

2.2.3 Intermediate goods producers

Monopolistically competitive intermediate goods producers indexed by i employ capital and labor to produce output according to the Cobb-Douglas production technology, with $\varepsilon_{z,t}$ denoting an AR(1) productivity shock and α denoting the capital share of output. Output is supplied to domestic final goods producers, foreign final goods producers, and domestic housing producers.

$$f_{H,t}\left(i\right) + \frac{1-\omega}{\omega} f_{H,t}^{*}\left(i\right) + i_{\chi,t}\left(i\right) = \varepsilon_{z,t} k\left(i\right)^{\alpha} n_t\left(i\right)^{1-\alpha}. \tag{12}$$

All firms set their prices independently for the domestic and foreign markets according to the Calvo scheme. Both markets have their own price reoptimization probabilities, denoted respectively by $1-\theta_H$ and $1-\theta_F$. While not being allowed to reoptimize, firms update prices according to $\pi_{\zeta H,t} = \zeta_H \pi_{t-1} + \left(1-\zeta_H\right)\pi$ in the domestic market and $\pi_{\zeta F,t}^{*} = \zeta_F \pi_{t-1}^{*} + \left(1-\zeta_F\right)\pi^{*}$ in the foreign market, with ζs controlling the weights of past inflation in the indexation schemes.

2.3 Closing the model

2.3.1 GDP, net exports and balance of payments

Real gross domestic product at market prices y_t is defined as the sum of private and government consumption, investment in housing and net exports nx_t,

$$y_t = f_t + p_{i_{\chi},t} i_{\chi,t} + nx_t, \tag{13}$$

where

$$nx_t = \frac{1-\omega}{\omega} q_t p_{H,t}^{*} f_{H,t}^{*} - p_{F,t} f_{F,t} + \varepsilon_{row,t}. \tag{14}$$

In the equation above, $q_t = P_t^{*}/P_t$ stands for the real exchange rate and $\varepsilon_{row,t}$ is a net exports shock from the rest of the world, which we assume to affect only the periphery.

Real net foreign debt $\tilde{d}_t$ is given by

$$\tilde{d}_t = -nx_t + \frac{R_{t-1}}{\pi_t}\tilde{d}_{t-1}, \tag{15}$$

where $\varrho_t \equiv 1 + \xi\left[\exp\left(\tilde{d}_t/y_t\right) - 1\right]\varepsilon_{\xi,t}$ is a risk premium factor that depends on the international investment position of a country, with $\xi > 0$. A risk premium shock $\varepsilon_{\xi,t}$ is included to account for the pre-euro interest rate differential between the core and periphery.

2.3.2 Banking sector

Banks collect deposits from patient households (potentially also from foreign ones) and then lend the funds to impatient households, setting the lending rate in a monopolistically competitive manner.

A j-th bank maximizes profits, evaluated using the marginal utility of patient households' future consumption

$$E_t \left\{ \beta_P \frac{u^c_{P,t+1}}{P_{t+1}} \left[R_{L,t}(j) L_t(j) - R_t D_t(j) - \varrho_t R^*_t D^*_t(j) \right] \right\}, \tag{16}$$

subject to

$$L_t(j) = D_t(j) + D^*_t(j), \tag{17}$$

where $L_t(j)$, $D_t(j)$ and $D^*(j)$ denote j-th bank's real loans, domestic deposits and foreign deposits, respectively.

The differentiated loans are aggregated according to the following formula

$$\omega_I L_{I,t} = \left[\int_0^1 L_t(j)^{\frac{1}{\mu_{L,t}}} \mathrm{d}j \right]^{\mu_{L,t}}, \tag{18}$$

where $\mu_{L,t}$ is the stochastic AR(1) markup for loans. The above considerations imply that all banks charge the same lending rate $R_{L,t} = \mu_{L,t} R_t$, and that the following uncovered interest rate parity holds $R_t = \varrho_t R^*_t$.

2.3.3 Fiscal and monetary policy

The fiscal authority collects lump sum taxes τ_t to finance government consumption g_t, which on average amounts to $\bar{g}$ share of GDP. The government spending is subject to an AR(1) shock $\varepsilon_{g,t}$ so that

$$\tau_t = g_t = \bar{g} \cdot y_t \cdot \varepsilon_{g,t}. \tag{19}$$

The monetary authority sets the short term interest rate reacting to union-wide variables according to a Taylor-like formula

$$\frac{R^*_t}{R^*} = \left(\frac{R^*_{t-1}}{R^*} \right)^{\gamma^*_R} \left[\left(\frac{\tilde{\pi}^*_t}{\tilde{\pi}^*} \right)^{\gamma^*_\pi} \left(\frac{\tilde{y}^*_t}{\tilde{y}^*} \right)^{\gamma^*_y} \right]^{1-\gamma^*_R} \varepsilon^*_{R,t}, \tag{20}$$

where γ^*_R controls the degree of interest rate smoothing, $\varepsilon^*_{R,t}$ is a white noise monetary policy shock, while γ^*_π and γ^*_y control the strength of policy rate response to area-wide inflation and output

$$\tilde{\pi}_t^* \equiv (\pi_t)^{\omega} (\pi_t^*)^{1-\omega} \quad \text{and} \quad \tilde{y}_t^* \equiv \omega y_t + (1-\omega) y_t^* \tag{21}$$

2.3.4 Macroprudential policy

The macroprudential authority may set the LTV ratio according to

$$\frac{m_{\chi,t}}{m_{\chi}} = \left(\frac{l_t}{l}\right)^{\gamma_{ml}} \left(\frac{p_{\chi,t}}{p_{\chi}}\right)^{\gamma_{mp}}. \tag{22}$$

In the formula above, m_{χ} is the steady state LTV ratio and parameters γ_{ml} and γ_{mp} determine the strength of reaction to deviations of, respectively, real loans l_t and real house prices $p_{\chi,t}$ from their steady state values.

2.3.5 Market clearing

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

$$\omega_P \chi_{P,t} + \omega_I \chi_{I,t} = \chi_t \tag{23}$$

Consumption of both types of households together with government consumption must be equal to final goods supply

$$\omega_P c_{P,t} + \omega_I c_{I,t} = c_t \quad \text{and} \quad c_t + g_t = f_t \tag{24}$$

Finally, capital and labor markets clear

$$\int_0^1 k_t(i)\, \mathrm{d}i = \omega_P k_P \quad \text{and} \quad \int_0^1 n_t(i)\, \mathrm{d}i = n_t \tag{25}$$

3 Calibration and estimation

3.1 Calibration

As it is standard in the literature, we calibrate most of the parameters affecting the model's steady state equilibrium.[3] We use as targets the averages of key macroeconomic proportions observed in the data over the period 1995-2014. The values of all calibrated parameters are presented in Table 1 and the targeted steady state ratios are reported in Table 2.

[3] While solving for the steady state we fix the housing stock owned by patient households χ_P to 8.24 and χ_P^* to 7.31, which are the values that would be obtained if we asummed that their housing utility is of the same form as that characterizing impatient agents, i.e. $\nu(\chi_{P,t}) = \frac{(\chi_{P,t}(\iota) - \xi_{\chi}\chi_{P,t-1})^{1-\sigma_{\chi}}}{1-\sigma_{\chi}}$.

Our model features two regions: the periphery consisting of Greece, Ireland, Portugal and Spain, and the core consisting of Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and the Netherlands. We calibrate the size of the periphery to 16.8%, which corresponds to the average share of this region in the euro area GDP for the period covered by our analysis. We set the share of home-made goods in the periphery's consumption basket at 0.7, which is consistent with the estimates of Bussiere et al. (2013) for the euro area member states. Adjusting this number for the relative size of the two regions leads to the corresponding share in the core of 0.06. The share of impatient households is calibrated at 0.675 in the periphery and at 0.5 in the core, which allows us to match the debt to annual GDP ratio in these two regions of 0.70 and 0.52, respectively.

Since in the data we neither see strong evidence of long-term differences between the core and periphery as regards the remaining steady state ratios, nor the observed heterogeneity is important for our main results, we keep the rest of our calibration symmetric across the two regions. The share of government spending in GDP is fixed at 0.25. We calibrate the weight of housing and labor in utility function using the following formulas $A_\chi = 1.67 \cdot (1-\xi_\chi)^{\sigma_\chi} (1-\xi_c)^{\sigma_c}$ and $A_n = 35.1 \cdot (1-\xi_c)^{-\sigma_c}$. This guarantees that, irrespective of the degree of habit formation that we estimate, the housing wealth to GDP ratio equals 1.78 and the hours worked equal 0.33. As in Coenen et al. (2008), we assume that the elasticity of substitution between domestic and imported goods equals 1.5, and the elasticity of substitution between labor of patient and impatient households equals 6. In the steady state, markups in the labor and product markets are all set to 20%, and the capital share in output is fixed at 0.3.

We set the discount factor applied by patient households to 0.998 to match the annual real interest rate in the euro area of 0.8%. The discount factor of impatient agents is calibrated at 0.983 to match the share of residential investment in GDP of 7%. As it is standard in the literature, we fix the inverse of the intertemporal elasticity of substitution in consumption and housing, as well as the inverse of the Frisch elasticity for labor supply at 2. We assume that each quarter 1% of housing depreciates. We set the LTV ratio to a conventional level of 0.75. Transfers from patient to impatient households are calibrated at 0.25 so that the steady state per capita consumption of impatient agents equals 0.7-0.8 of per capita consumption of patient agents, similarly to Coenen et al. (2008). Loan markups are calibrated at 0.0047 to match annual spreads in the euro area of 0.019. The steady state inflation rate is set to 2% annually.

3.2 Data and prior assumptions

We estimate the model using time series covering the period 1995q1-2012q3, giving us $T = 71$ quarterly observations.[4] The data we use in simulations run to 2015q1, but we decided to exclude the period during which the zero lower bound (ZLB) constraint on the eurozone's nominal interest rates was binding.[5]

We use the following seven pairs of data series for the core and periphery: real GDP less non-residential investment, real private consumption, real residential investment, real housing loans, real house prices, HICP inflation and interest on housing loans. We also treat as observable the euro money market rate and its pre-euro value in the periphery,[6] as well as the periphery's net exports relative to GDP. This gives us in total seventeen observed time series.[7]

To estimate the model we use Bayesian methods. The prior and posterior distribution characteristics for structural parameters and shocks are presented, respectively, in Tables 3 and 4. Our priors are based on the previous literature. We set the prior mean for the Calvo probabilities at 0.75, which is consistent with the empirical estimates of average price duration reported by Álvarez et al. (2006). The prior distribution for indexation parameters and habits are all centered around the standard value of 0.5. We set the prior mean of the investment adjustment cost parameter to 30, which is close to the value used in Brzoza-Brzezina et al. (2015). The prior mean of the debt elasticity of risk premium is set to 0.005, which is a value that stabilizes foreign debt at zero without affecting much the short term model dynamics.

The prior means for the monetary policy rule are set to standard values used in the literature. For lack of evidence on the monetary policy bias towards one of the regions, while estimating our model we use population weights for aggregates defined by equations (21).

[4] Since the HICP index is not available before 1996, our inflation and real house price series start in 1996q1. Data on housing loans and interest on housing loans are available as from 1997q3. While estimating the model we use the Kalman filter to fill in these missing observations.

[5] Hirose and Inoue (2015) show that including a ZLB period while estimating a model without explicit modeling this constraint may lead to biased parameter estimates. This bias increases with the duration of the ZLB period.

[6] The difference between these two money market rates is non-zero only before the eurozone creation. The reason for including data on this pre-euro interest spread in estimation is to capture the effects of interest rate convergence among the prospective euro area members before 1999. in't Veld et al. (2012) identify this process as an important driver of the lending boom in the periphery.

[7] The national accounts series, HICP inflation and money market rates come from Eurostat. House prices are defined as residential property prices of new and existing houses and flats and come from the BIS Long-term series on nominal residential property prices and ECB SDW. Housing loans are defined as outstanding amounts of lending for house purchase and were taken from the ECB SDW. The lending interest rate is quarterly interest on housing loans to households taken from the ECB SDW. All variables are seasonally adjusted. House prices and lending for house purchase are expressed in real terms using HICP. The national accounts series and real loans were divided by population size. Before estimation, GDP, its components, real house prices and loans were transformed into growth rates and subsequently demeaned.

Since macroprudential policy was not used in the euro area during the period covered by our sample, the feedback parameters showing up in equation (22) are both set to zero so that the LTV ratio is constant. All of these monetary and macroprudential policy parameters will be subject to optimization while constructing our counterfactual simulations described later in the text.

Our model is driven by seventeen stochastic shocks. These include the pairs of productivity, time preference, housing preference, price, wage and loan markups, as well as government expenditure shocks in the core and periphery. Additionally, we have a common monetary policy shock, a shock to the periphery's net exports and a risk premium shock accounting for the interest rate differential between the two regions prior to euro creation. All shocks are modeled as first-order autoregressive processes, except for the monetary policy shock that is assumed to be white noise.

We set the prior means of shock inertia to 0.7, with fairly large standard deviations. The prior distributions of shock volatilities are centered around 0.01. A smaller prior mean of 0.001 is assumed for shocks affecting the interest rates (i.e. monetary policy, loan markup and risk premium shocks), consistently with the previous literature.

3.3 Estimation results

We estimate the model using Dynare version 4.4.3. The posterior mode in the first pass is obtained with the CMA-ES procedure,[8] while the second pass uses Christopher Sims' optimization routine. We next run the Metropolis-Hastings algorithm with two blocks, each consisting of 250,000 replications. Convergence was confirmed by a set of diagnostic tests proposed by Brooks and Gelman (1998). Finally, the posterior distributions are approximated using the second half of the draws.

As can be seen from Tables 3 and 4, our dataset is informative about all of the estimated parameters, except for habits in housing, price indexation in imports, and feedback parameters in the monetary policy rule. The posterior modes are broadly consistent with earlier estimates in the literature obtained for the euro area. We find some evidence of structural heterogeneity between the two regions of the monetary union, with the degree of nominal and real rigidities usually higher in the periphery. This is particularly true for the residential investment adjustment cost and, to a lesser extent, habits in consumption and wage stickiness. As regards the estimates of processes driving stochastic shocks, they are usually more inertial and more volatile in the periphery, consistently with larger business cycles observed in that region.

In Tables 5 and 6 we present the forecast error variance decompositions for the core and

[8] Andreasen (2010) shows that the CMA-ES algorithm outperforms Simulated Annealing and Nelder-Mead algorithms in finding the 'true' parameters of DSGE models with many estimated parameters.

the periphery implied by our model and evaluated at the posterior mean of the estimated parameters. For the sake of clarity, we collect the shocks into groups. It is clear that local housing market shocks are more important in the periphery, where they account for more than a half of fluctuations in GDP and its components, as well as in housing loans and house prices. The contribution of these shocks in the core is also substantial, but smaller than that of other domestic demand and supply shocks, except for residential investment and house prices. As expected, the periphery is much more influenced by shocks originating from abroad than the core. In particular, foreign shocks drive most of the observed fluctuations in the periphery's cost of housing loans.

4 Inspecting heterogeneity between the core and periphery

4.1 Historical shock decomposition

Before we conduct our counterfactual simulations, we analyze the role of exogenous shocks in driving key macroeconomic variables in the periphery. Figure 2 documents the historical shock decomposition of this region's GDP, net exports, housing loans and house prices. It is clear that housing market shocks were the main drivers of imbalances observed in the periphery over the analyzed timespan. The dominance of these shocks is especially pronounced in the case of housing loans and house prices, where the impact of other shocks is almost negligible. Before the residential property market collapsed in 2007, the housing preference shock was highly positive, driving all four variables away from the long-run equilibrium. Housing supply shocks acted as a countervailing force, dampening investment and GDP, and boosting house prices. After 2007, housing demand waned, which might be tentatively associated with the flight of foreign property investors from peripheral housing market towards safer assets. In this period, housing supply shocks were slowing down the collapse of house prices, which moderated the effects of the collateral losses.

Foreign shocks helped to dampen the cyclical fluctuations in the periphery's GDP while deepening the current account imbalance and had only minuscule effects on the housing market. Consistently with the previous literature, the build-up of external imbalances in the periphery was also largely driven by the pre-euro interest rate convergence. On the other hand, domestic supply shocks contributed to the dismal economic performance after 2007. Domestic demand shocks acted hand in hand with housing demand shocks, amplifying the cycle in the analyzed period. Monetary policy shocks reduced the slump in economic activity until the interest rate hit the zero lower bound.

4.2 Is the periphery more vulnerable to housing booms?

We have seen in Figure 1 that while the periphery experienced a massive boom-bust cycle, the macroeconomic developments in the core over the same period did not significantly deviate from a typical business cycle. As we have already mentioned, this reflects to a large extent the fact that shocks hitting the periphery were much larger and more persistent. However, our estimation also shows that not only shock properties, but also some of the structural parameters differ significantly across the two regions, pointing to stronger nominal and real rigidities in the periphery. A natural way of evaluating whether this structural heterogeneity makes the periphery more vulnerable than the core is to compare the reactions of these two economic areas to common disturbances.

As an illustration we use a common housing demand shock ($\varepsilon_{\chi,t} = \varepsilon^*_{\chi,t}$), which we choose because of its dominant role in driving the boom-bust cycle in the periphery documented above. In this exercise, the inertia of this shock is assumed to be the same in the two regions and equal to that estimated for the core. The impulse responses are plotted in Figure 3. If structural parameters were the same in the core and periphery, we should see no difference between the two reactions. This is clearly not the case. Since house supply is more rigid in the periphery (housing investment responds more sluggishly), house prices in this region increase by much more than in the core. As credit must be secured with housing collateral, its expansion in the periphery is initially weaker, but after a year markedly stronger than in the core. These differences in the propagation through the housing and credit market have aggregate demand consequences. As a result, GDP in the periphery increases more than in the core, and a part of excess demand in this region is satisfied from abroad so that the current account balance deteriorates. Overall, it is clear that even if both regions of the euro area were hit by the same housing preference shocks, the reaction of output, house prices, credit and external balance would be stronger in the periphery.

5 Counterfactual policy experiments

Our model is now ready to conduct a series of simulations that are aimed to answer the question whether monetary or macroprudential policy could have, to a substantial degree, prevented the boom-bust in the eurozone periphery. We first look at union-wide monetary policy, taking as given the fact that countries form a monetary union. Hence, the question what would have happened under independent monetary regimes is not asked in this study. Next we look at country-specific macroprudential policy, i.e. we allow the LTV ratios to be adjusted differently in the core and periphery. In this respect, we draw on the previous literature that demonstrated that such region-specific policy is much more effective in fighting asymmetric shocks than imposing the same LTV ratios in both regions.

A crucial question is how to evaluate the success of a policy. The boom-bust was a highly multidimensional experience - it affected output, credit, house prices, current accounts and a number of other important macrovariables. A standard measure to evaluate policies is welfare, and we use this criterion while designing our counterfactual policies. However, we are also aware that our model does not feature several aspects of reality that may be of interest from the policymaker's perspective and that would ultimately (if accounted for) also affect welfare. Sovereign or banking sector defaults, as well as their macroeconomic consequences could serve as a useful example. For this reason, we also evaluate our policies looking at other indicators that concerned economists and policymakers during the boom-bust episode, like credit volatility or current account imbalances.

5.1 Monetary and macroprudential policy transmission

Before we present the counterfactual simulations, we provide a brief explanation of how macroprudential and monetary policies work in our model. Figure 4 presents the effects of a positive macroprudential policy shock in the peripheral economy, in which the LTV ratio is assumed to follow a simple AR(1) process with autoregression equal to 0.9. A hike in the LTV ratio boosts credit, which in turn raises demand for both consumption goods and housing. Residential investment responds with a lag, therefore real house prices increase. The central bank reacts by raising the interest rate, but only marginally as the share of the periphery in the union is small.

The effects of a contractionary monetary policy shock are presented in Figure 5, for two cases. The solid lines show the responses under constant LTV ratio while the dashed lines depict the case of active macroprudential policy. In the latter case, the LTV ratios in both regions react to credit and house prices as in rule (22), with the feedback coefficients optimized as described below. An increase in the interest rate results in a decline in GDP and inflation. Absent response from the macroprudential authority, this leads to a fall in credit and house prices, amplifying the contraction. However, if macroprudential policy is active, the LTV ratio and hence credit go up, which dampens the fall in GDP. The initial decrease in house prices is also reduced, but it takes them longer to return to the steady state level.

5.2 Optimized monetary policy

We first examine if common monetary policy, optimized in a way maximizing union-wide welfare could have significantly changed the boom-bust scenario observed after the euro creation. To this end, we set γ_R^* in the monetary policy rule (20) to the estimated value and search for optimal values of the feedback parameters γ_π^* and γ_y^*. To be precise, we find the parameter values that maximize the second order approximation to the euro-wide welfare function defined as follows (see Rubio, 2011):

$$U_t \equiv \omega \left[\omega_P(1-\beta_P)U_{P,t} + \omega_I(1-\beta_I)U_{I,t}\right] + (1-\omega)\left[\omega_P^*(1-\beta_P^*)U_{P,t}^* + \omega_I^*(1-\beta_I^*)U_{I,t}^*\right] \quad (26)$$

Next, we generate a counterfactual path for the economy, starting from 4q1998 (i.e. just before the creation of the euro area), based on the welfare maximizing Taylor rule parameters.

Figure 6 presents the historical and counterfactual paths for a selection of variables. The policy has a clear stabilizing impact on GDP in the core and (somewhat less) in the periphery. The paths for inflation are modified as well, although here the stabilizing effect is somewhat less visible. More importantly, however, the policy has only a negligible impact on credit or net exports. Table 7 presents welfare gains on the counterfactual path relative to the historical path, both extended into the future assuming no further shocks.[9] As can be seen, monetary policy was able to raise welfare for all types of agents, with highest gains pertaining to impatient households in the periphery. However, as already mentioned, these gains do not seem to go in line with a clear improvement with respect to the boom-bust developments.

Given the mixed findings using the welfare criterion, we also experiment with policies that explicitly target selected variables specific to the boom-bust cycle: house prices and credit. The findings (not shown in figures) are not very encouraging – common monetary policy is not able to modify the historical paths of the targeted variables in any meaningful way. All of these policies have also only a negligible impact on the periphery's trade balance.

5.3 Optimized macroprudential policy

Following the previous findings in the literature, we focus on region-specific macroprudential policy. More precisely, we optimize four feedback parameters γ_{ml}, γ_{mp}, γ_{ml}^*, γ_{mp}^* from rule (22) and its core counterpart, not restricting them to be pairwise equal between the two regions. As before, we use the euro-wide welfare criterion given by equation (26). We have also constrained the set of outcomes such that the standard deviation of the macroprudential instrument (LTV ratio) is below 0.15 for each region, which guarantees that it remains within a reasonable range in our counterfactual scenarios.

Figure 7 shows the counterfactual paths of key macrovariables under such policy, assuming that its implementation begins in 4q1998. It is clear that agents in this model prefer to hold less credit at the onset of the crisis. A negative consequence of active macroprudential policy is that it generates short-lived and shallow recessions, which may be interpreted as a result

[9] Welfare gains are calculated as follows. First, we extend the historical and counterfactual paths for an infinite horizon, assuming that no further shocks arrive after the end of our sample. Next, for both paths we calculate the discounted sums of period utilities for both types of agents of the two eurozone regions. The gains reported in Table 7 are expressed as steady state consumption equivalents. The area-wide gain is calculated as a weighted average using the shares of each type of agent in the eurozone population.

of "popping" credit bubbles. Active policy also reduces the build-up of external imbalances, as evidenced by the counterfactual behavior of net exports.

The welfare impact of active macroprudential policy is reported in Table 7. For our historical sample, welfare effects are almost ubiquitously positive, with negligible welfare losses for patient households, and significant gains for impatient ones. The overall welfare gain is clearly positive and larger than that obtained with optimized monetary policy.

As before, we have also experimented with macroprudential policies directly aimed at stabilizing loans, house prices and the external balance. The policies attempting to stabilize loans and net exports generate similar paths to those obtained using our welfare criterion. This suggests that attempting to stabilize these indicators approximates welfare-based policies reasonably well. In contrast, targeting the euro-wide house price index has greatly destabilizing effects on other variables, especially in the core economy. This result may serve as a warning that attempting to stabilize certain variables, often treated as macroprudential policy targets, may have dire consequences for the overall economic performance.

5.4 Optimized monetary-macroprudential policy mix

In the previous two experiments, we have examined the effects of optimized monetary and macroprudential policies separately. We now look at the outcomes that could be achieved if these policies are implemented in a coordinated way. More specifically, we optimize the Taylor rule parameters γ_π^* and γ_y^* and four macroprudential policy rule coefficients γ_{ml}, γ_{mp}, γ_{ml}^* and γ_{mp}^* jointly to maximize euro-wide welfare function (26).

Figure 8 compares the historical and counterfactual paths for a selection of variables while Table 7 reports the resulting welfare gains. Overall, the outcomes are very similar to the case of optimized macroprudential policy alone, with slightly larger welfare gains for impatient agents, especially in the periphery. As regards the counterfactual paths, output in both regions appears to be smoother if monetary policy helps macroprudential authorities to optimally stabilize the euro area. However, most of the gains in welfare, as well as reduction in credit cycle and external imbalances, could have been achieved by macroprudential policy without the need to modify monetary policy.

6 Conclusions

In this paper we ask whether policy - be it monetary or macroprudential - could have prevented the boom-bust cycle that plagued the euro area periphery. We draw on the literature that documented - albeit in stochastic simulations - that macroprudential policy can be relatively successful in stabilizing real and financial variables in a small region of the monetary union affected by asymmetric shocks. Our exercise is different in the sense that, instead of concentrating on a typical business cycle, we focus on the historical experience of the euro area. Our simulations are applied to the period 1998q4-2015q1, which covers the build-up and correction of imbalances in the euro area.

Our simulations are based on a two-country DSGE model estimated using euro area (core and periphery) data. We find that the imbalances were driven mainly by shocks related to the housing market in the periphery. We also show that this region is more vulnerable to boom-bust cycles originating in this sector because of the more rigid structure of the economy. Next we check whether common monetary policy could have prevented the boom-bust. We find that optimal monetary policy could have stabilized somewhat the business (GDP) cycle in the periphery, however the remaining variables typical for the boom-bust episode (house prices, loans, net exports) remain unaffected. In this respect, region-specific macroprudential policy does a much better job, smoothing not only output, but also the credit cycle and reducing the build-up of external imbalances in the periphery.

It should be stressed that, while focusing on the past, this study does not have just a historical flavor. The recent experience of Ireland, where by 2015q3 house prices increased by 33% from its post-crisis low achieved in 2013q1 (source: BIS) suggests that the problem of asymmetric housing market developments may soon reappear.

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Tables and figures

Table 1: Calibration - parameters

Parameter	Value	Description
β_P, β_P^*	0.998	Discount factor, patient HHs
β_I, β_I^*	0.983	Discount factor, impatient HHs
δ_χ, δ_χ^*	0.01	Housing stock depreciation rate
ω_I	0.675	Share of impatient HHs in periphery
ω_I^*	0.5	Share of impatient HHs in core
A_χ, A_χ^*	1.67	Weight on housing in utility function (see footnote 5)
A_n, A_n^*	35.1	Weight on labor in utility function (see footnote 5)
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
μ_w, μ_w^*	1.2	Steady state wage markup
ϕ_n, ϕ_n^*	6	Elasticity of substitution btw. labor of patient and impatient HHs
τ_I, τ_I^*	0.25	Real transfers from patient to impatient HHs
μ, μ^*	1.2	Steady state product markup
α, α^*	0.3	Output elasticity with respect to physical capital
k, k^*	6.7	physical capital stock per capita
μ_L, μ_L^*	1.0047	Loan markup
m_χ, m_χ^*	0.75	Steady state LTV ratio
π, π^*	1.005	Steady state inflation
ξ	0.001	Elasticity of risk premium wrt. foreign debt
ω	0.168	Share of periphery in monetary union
η_H	0.70	Share of domestic goods in consumption basket (periphery)
$\eta_H^* = \frac{\omega}{1-\omega}(1-\eta_H)$	0.06	Share of imported goods in consumption basket (core)
ϕ_f, ϕ_f^*	1.5	Elasticity of substitution btw. home and foreign goods

Table 2: Steady state ratios

Steady state ratio	Value
Import to GDP ratio (periphery)	0.27
Import to GDP ratio (core)	0.06
Government spending to GDP ratio	0.25
Residential investment to GDP ratio	0.07
Capital-GDP ratio (annual)	2.0
Hours worked	0.33
Housing wealth to GDP ratio (annual)	1.78
Debt to GDP ratio (annual, periphery)	0.70
Debt to GDP ratio (annual, core)	0.52
Spread (annualized)	0.019

Table 3: Prior and posterior distribution: structural parameters

Parameter	Prior distribution			Posterior distribution		
	type	Mean	St. Dev.	Mode	Mean	St. Dev.
ξ_c	beta	0.50	0.20	0.82	0.82	0.03
ξ_c^*	beta	0.50	0.20	0.73	0.77	0.05
ξ_χ	beta	0.50	0.20	0.46	0.45	0.25
ξ_χ^*	beta	0.50	0.20	0.59	0.52	0.32
θ_w	beta	0.75	0.05	0.84	0.83	0.03
θ_w^*	beta	0.75	0.05	0.78	0.78	0.04
ζ_w	beta	0.50	0.20	0.79	0.67	0.16
ζ_w^*	beta	0.50	0.20	0.80	0.72	0.15
κ_χ	norm	30.0	10.0	23.0	22.8	2.90
κ_χ^*	norm	30.0	10.0	9.12	9.42	1.26
θ_H	beta	0.75	0.05	0.91	0.91	0.02
θ_F^*	beta	0.75	0.05	0.91	0.91	0.01
θ_F	beta	0.75	0.05	0.83	0.84	0.03
θ_H^*	beta	0.75	0.05	0.80	0.78	0.04
ζ_H	beta	0.50	0.20	0.14	0.23	0.10
ζ_F^*	beta	0.50	0.20	0.21	0.34	0.13
ζ_F	beta	0.50	0.20	0.40	0.48	0.25
ζ_H^*	beta	0.50	0.20	0.44	0.47	0.27
ξ	beta	0.005	0.002	0.002	0.002	0.00
γ_R^*	beta	0.90	0.05	0.89	0.88	0.01
γ_π^*	norm	1.70	0.10	1.51	1.59	0.12
γ_y^*	beta	0.125	0.005	0.03	0.06	0.01

Table 5: Variance decomposition - core

Variable \ Shock	Housing demand	Housing supply	Other demand	Other supply	Monetary	Foreign
GDP-I	25.8	7.8	27.2	21.8	12.3	5.1
Consumption	27.4	13.3	29.9	18.9	9.6	0.8
Residential investment	31.3	57.3	5.6	4.3	0.9	0.6
Mortgage loans	20.9	27.5	7.9	38.7	2.0	3.0
Real house prices	43.4	17.8	6.5	20.6	10.9	0.8
Mortgage interest rate	1.6	0.7	31.3	33.7	24.3	8.5
Inflation	0.4	0.2	4.9	89.8	1.9	2.9

Note: The shock groupings are as follows. Housing preference, housing investment and monetary policy shocks that hit the core have their own groups called 'Housing demand', 'Housing supply' and 'Monetary', respectively. 'Other demand' group collects the core's time preference, loan markup and government spending shocks. Technology and product markup shocks of the core populate 'Other supply' group. 'Foreign' group aggregates all shocks originating in the periphery, including the risk premium and rest of the world net exports shocks.

Table 4: Prior and posterior distribution: shocks

Parameter	Prior distribution			Posterior distribution		
	type	Mean	St. Dev.	Mode	Mean	St. Dev.
ρ_u	beta	0.70	0.10	0.74	0.71	0.07
ρ_u^*	beta	0.70	0.10	0.95	0.84	0.06
ρ_χ	beta	0.70	0.10	0.98	0.98	0.01
ρ_χ^*	beta	0.70	0.10	0.97	0.96	0.01
$\rho_{i\chi}$	beta	0.70	0.10	0.77	0.76	0.03
$\rho_{i\chi}^*$	beta	0.70	0.10	0.57	0.54	0.05
ρ_z	beta	0.70	0.10	0.36	0.37	0.06
ρ_z^*	beta	0.70	0.10	0.21	0.21	0.05
ρ_{μ_L}	beta	0.70	0.10	0.92	0.91	0.03
$\rho_{\mu_L}^*$	beta	0.70	0.10	0.88	0.87	0.03
ρ_μ	beta	0.70	0.10	0.84	0.80	0.05
ρ_μ^*	beta	0.70	0.10	0.70	0.64	0.09
ρ_g	beta	0.70	0.10	0.89	0.88	0.04
ρ_g^*	beta	0.70	0.10	0.90	0.89	0.03
ρ_ξ	beta	0.70	0.10	0.97	0.97	0.01
ρ_{nx}	beta	0.70	0.10	0.93	0.93	0.02
σ_u	invg	0.01	Inf	0.13	0.14	0.02
σ_u^*	invg	0.01	Inf	0.05	0.06	0.01
σ_χ	invg	0.01	Inf	0.17	0.19	0.02
σ_χ^*	invg	0.01	Inf	0.08	0.10	0.02
$\sigma_{i\chi}$	invg	0.01	Inf	0.23	0.24	0.04
$\sigma_{i\chi}^*$	invg	0.01	Inf	0.12	0.13	0.02
σ_z	invg	0.01	Inf	0.05	0.05	0.00
σ_z^*	invg	0.01	Inf	0.03	0.03	0.00
σ_R^*	invg	0.001	Inf	0.001	0.001	0.00
σ_{μ_L}	invg	0.001	Inf	0.001	0.001	0.00
$\sigma_{\mu_L}^*$	invg	0.001	Inf	0.001	0.001	0.00
σ_μ	invg	0.01	Inf	0.06	0.07	0.02
σ_μ^*	invg	0.01	Inf	0.07	0.09	0.02
σ_g	invg	0.01	Inf	0.02	0.02	0.00
σ_g^*	invg	0.01	Inf	0.01	0.01	0.00
σ_ξ	invg	0.001	Inf	0.001	0.001	0.00
σ_{nx}	invg	0.01	Inf	0.005	0.005	0.00

Table 6: Variance decomposition - periphery

Variable \ Shock	Housing demand	Housing supply	Other demand	Other supply	Monetary	Foreign
GDP-I	41.2	17.3	7.2	13.3	4.4	16.7
Consumption	47.6	22.5	9.1	12.8	2.2	5.9
Residential investment	31.2	65.1	0.6	2.2	0.1	0.9
Mortgage loans	43.9	17.4	2.3	30.3	0.3	5.9
Real house prices	55.1	22.7	4.2	10.8	2.0	5.2
Mortgage interest rate	1.1	0.6	18.8	5.3	20.5	53.8
Inflation	0.3	0.3	0.3	93.9	0.9	4.4

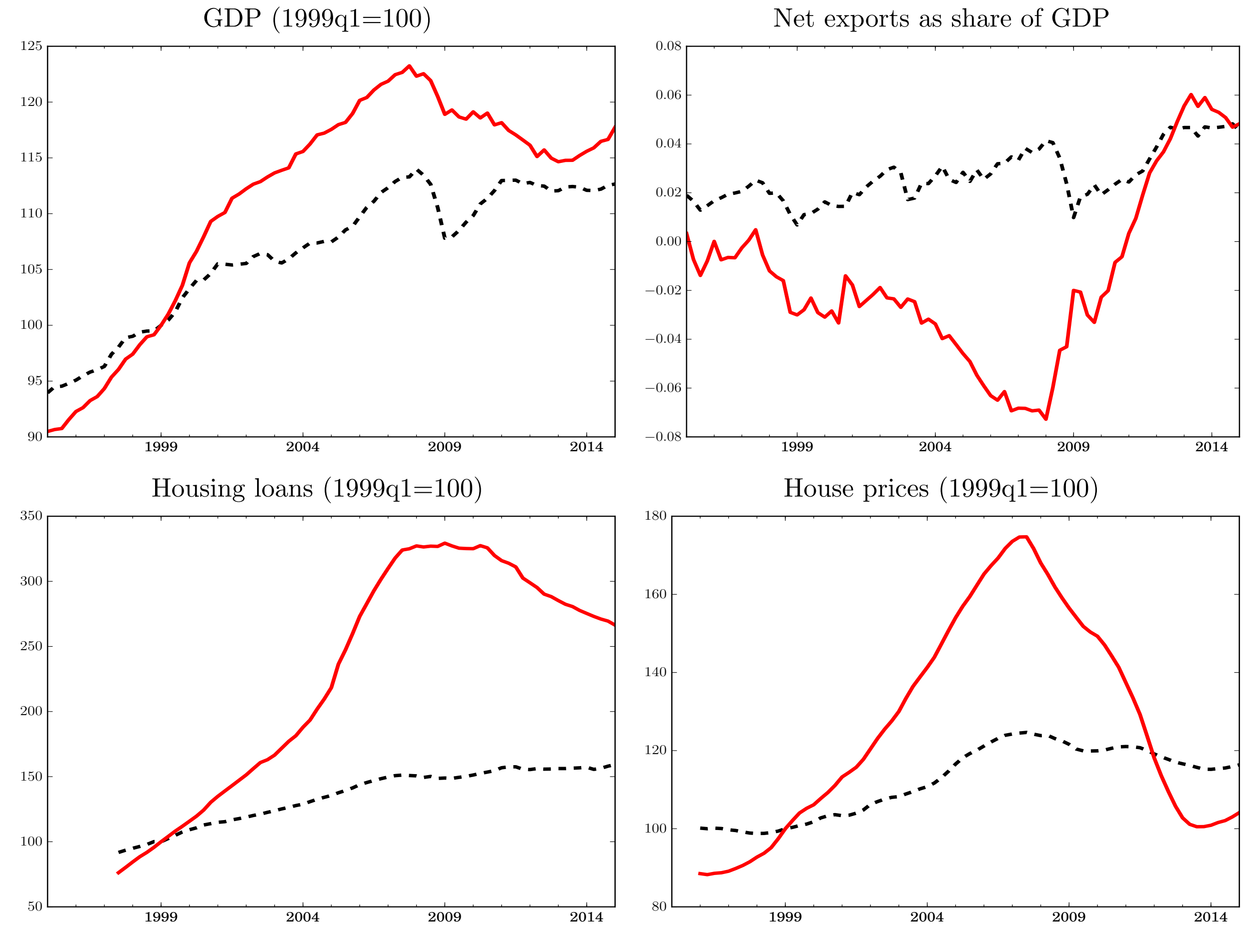
Note: The shock groupings are as follows. Housing preference, housing investment and monetary policy shocks that hit the periphery have their own groups called 'Housing demand', 'Housing supply' and 'Monetary', respectively. 'Other demand' group collects the periphery's time preference, loan markup and government spending shocks. Technology and product markup shocks of the periphery populate 'Other supply' group. 'Foreign' group aggregates all shocks originating outside of the periphery, as well as the risk premium and rest of the world net exports shocks.

Table 7: Welfare effects of optimized policies

Agent \ Policy	Monetary policy	Macroprudential policy	Both policies
Patient (periphery)	0.00	-0.00	-0.00
Impatient (periphery)	0.40	1.12	1.20
Patient (core)	0.00	-0.00	-0.00
Impatient (core)	0.26	0.24	0.26
All agents	0.16	0.23	0.24

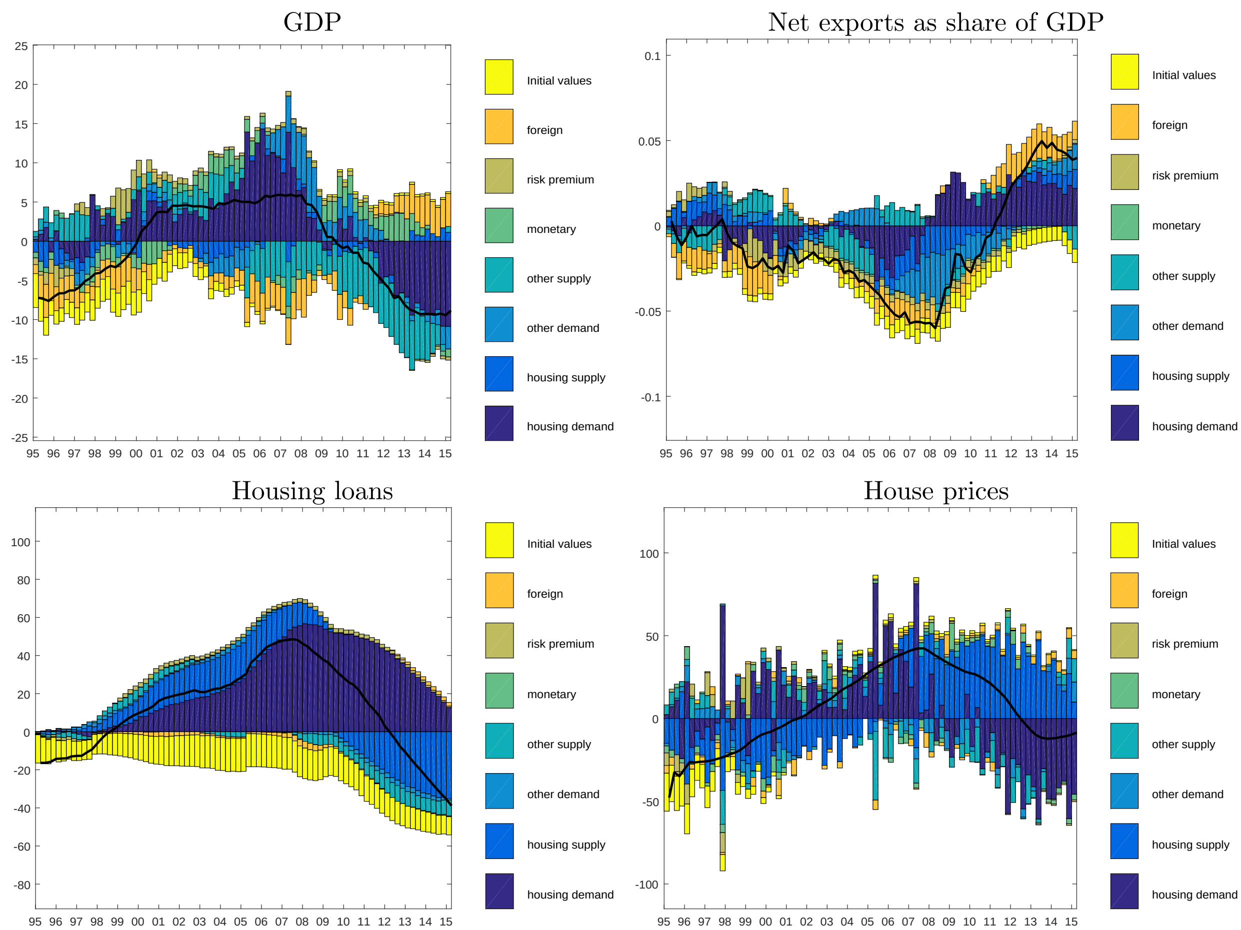
Note: The table presents the welfare gains on the counterfactual path over the historical path. Gains are expressed in percent of steady state consumption.

Figure 1: Stylized facts on imbalances in the euro area



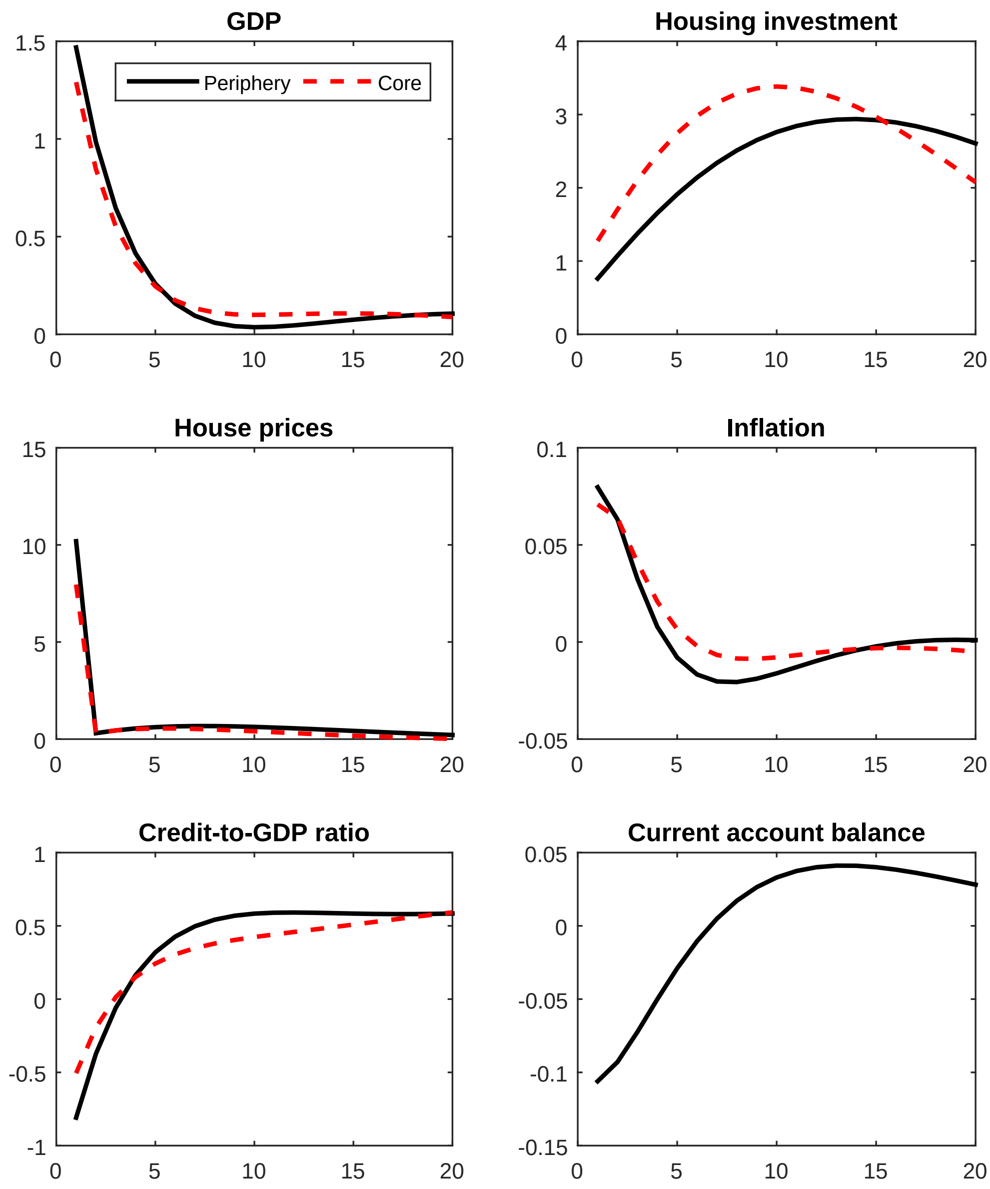
Note: Black dashed lines - core euro area members (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, Netherlands), red solid lines - peripheral euro area members (Greece, Ireland, Portugal and Spain). For each country, GDP is real gross domestic product (source: Eurostat), net exports as share of GDP is real net exports divided by real GDP (source: Eurostat), house prices are residential property prices of new and existing houses and flats (source: ECB SDW and 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 (GDP, net exports and loans) or GDP-weighted averages (house prices). Aggregated GDP and loans are divided by total population (source: Eurostat) in the respective country groups.

Figure 2: Historical shock decomposition in the periphery



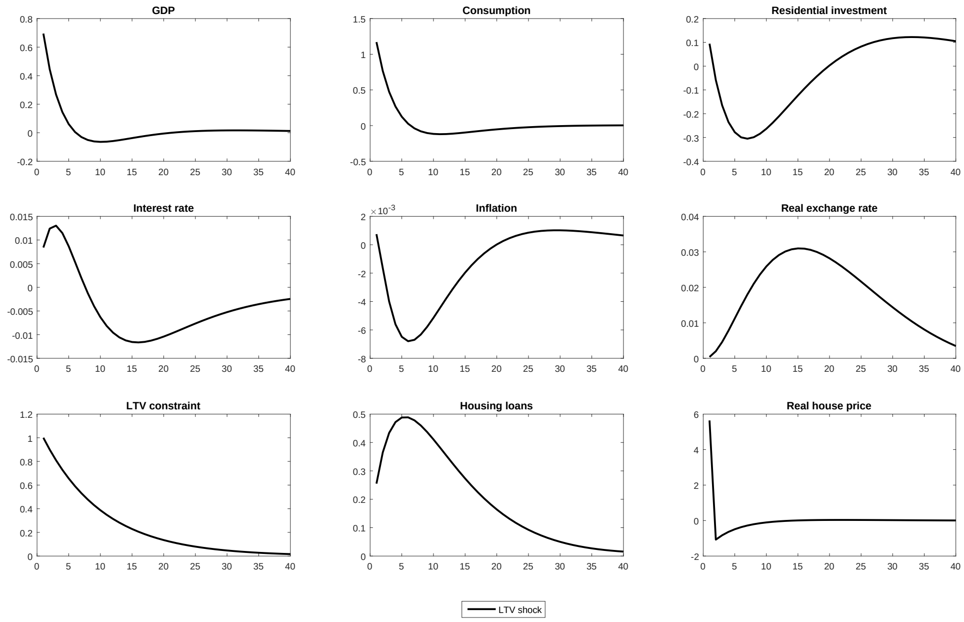
Note: All variables are expressed in percent deviations from steady state, except for net exports as share of GDP, which is in levels.

Figure 3: Impulse responses to common housing preference shock



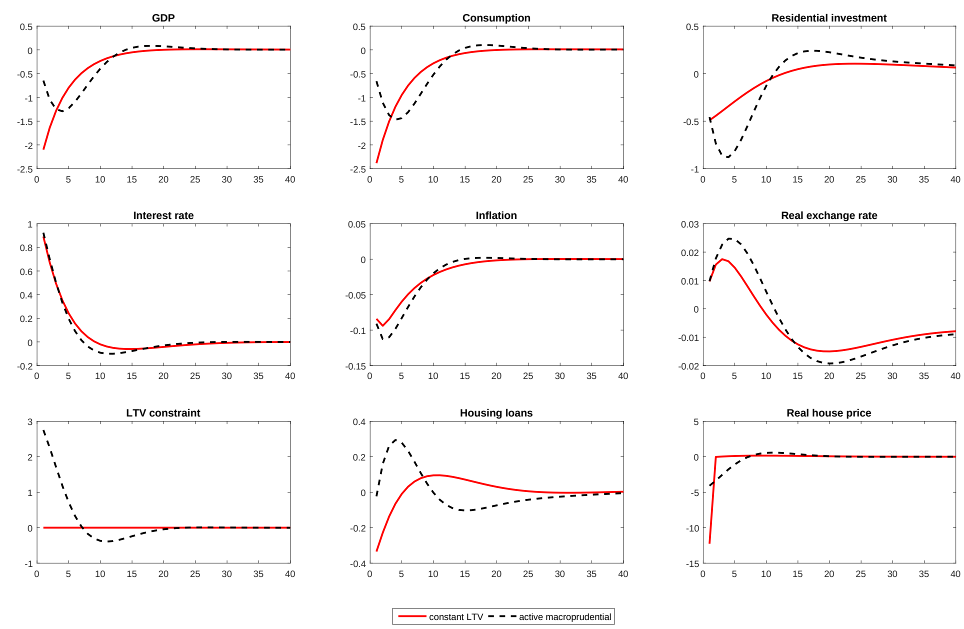
Note: All variables are expressed in percent deviations from steady state.The credit-to-GDP ratio and inflation are annualized.

Figure 4: Impulse responses to macroprudential policy shocks in the periphery



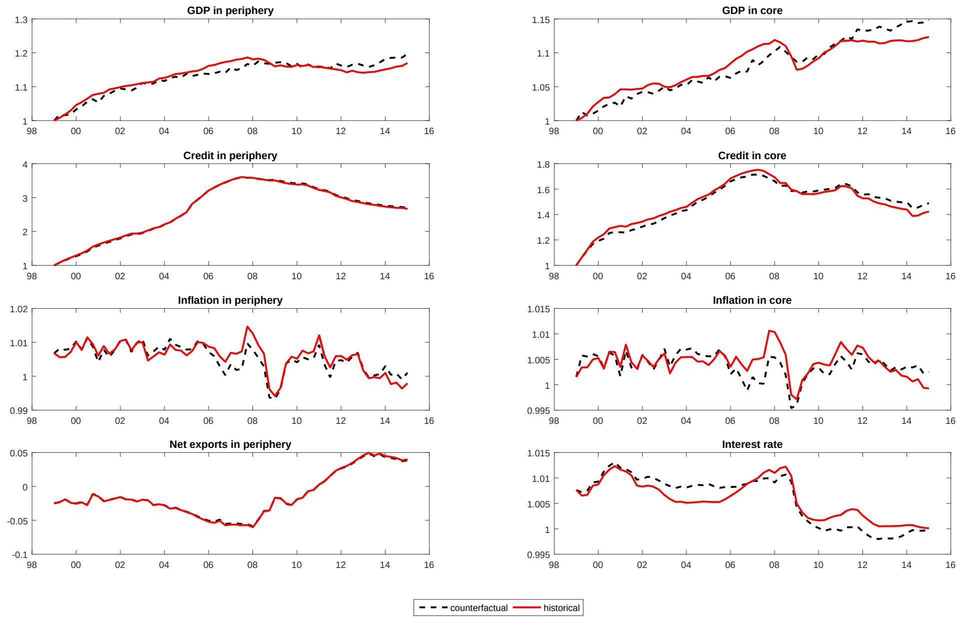
Note: All variables are expressed in percent deviations from steady state. Macroprudential rule follows a pure AR(1) process with autoregression of 0.9.

Figure 5: Impulse responses to monetary policy shocks



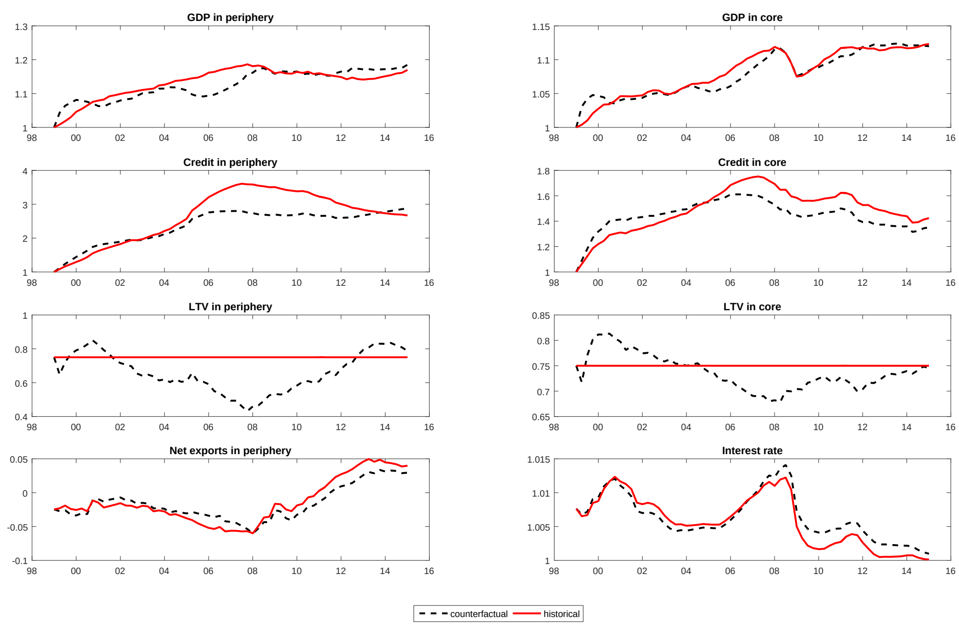
Note: All variables are expressed in percent deviations from steady state. Macroprudential policy parameters in the active scenario are: $\gamma_{ml} = -0.06$, $\gamma_{mp} = -0.90$, $\gamma^*_{ml} = -0.06$, $\gamma^*_{mp} = -0.80$.

Figure 6: Historical and counterfactual paths under optimal monetary policy maximizing welfare



Note: All variables are expressed in levels. Monetary policy parameters in the counterfactual scenario are: $\gamma_\pi^* = 1$, $\gamma_y^* = 0.36$.

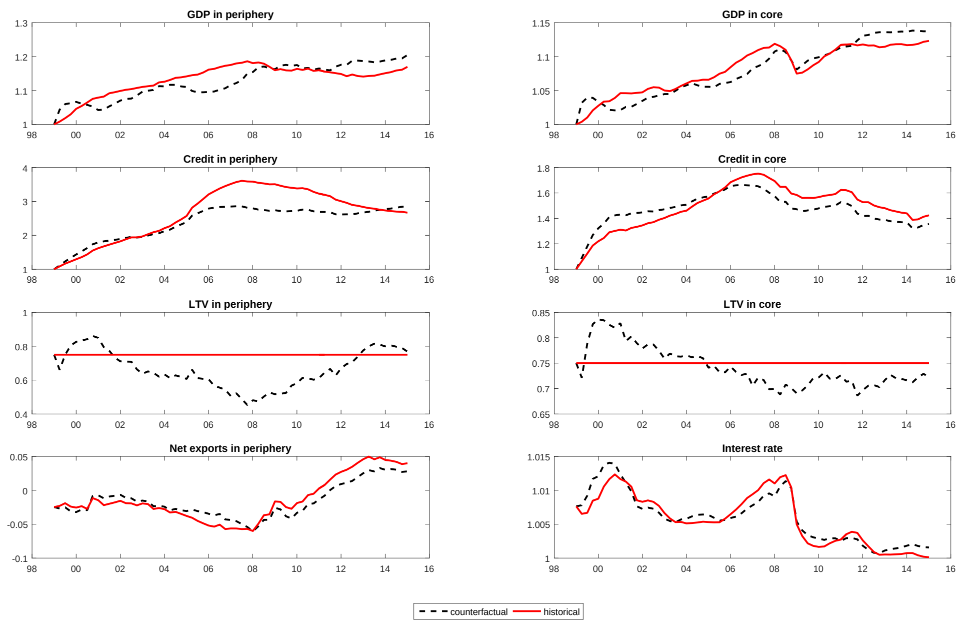
Figure 7: Historical and counterfactual paths under optimal macroprudential policy maximizing welfare



Note: All variables are expressed in levels. Macroprudential policy parameters in the counterfactual scenario are:

$\gamma_{ml} = -0.06$, $\gamma_{mp} = -0.90$, $\gamma_{ml}^* = -0.06$, $\gamma_{mp}^* = -0.80$.

Figure 8: Historical and counterfactual paths under cooperating optimal monetary and macroprudential policies maximizing welfare



Note: All variables are expressed in levels. Monetary policy parameters in the counterfactual scenario are: $\gamma_\pi^* = 1$, $\gamma_y^* = 0.26$. Macroprudential policy parameters in the counterfactual scenario are: $\gamma_{ml} = -0.05$, $\gamma_{mp} = -0.85$, $\gamma_{ml}^* = 0.00$, $\gamma_{mp}^* = -0.7$.