Global Banking and the Conduct of Macroprudential Policy in a Monetary Union

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Abstract

This paper questions the role of cross-border lending in the definition of national macroprudential policies in the European Monetary Union. We build and estimate a two-country DSGE model with corporate and interbank cross-border loans, Core-Periphery diverging financial cycles and a national implementation of coordinated macroprudential measures based on Countercyclical Capital Buffers. We get three main results. First, targeting a national credit-to-GDP ratio should be favored to federal averages as this rule induces better stabilizing performances in front of important divergences in credit cycles between core and peripheral countries. Second, policies reacting to the evolution of national credit supply should be favored as the transmission channel of macroprudential policy directly impacts the marginal cost of loan production and, by so, financial intermediaries. Third, the interest of lifting up macroprudential policymaking to the supra-national level remains questionable for admissible value of international lending between Eurozone countries. Indeed, national capital buffers reacting to the union-wide loan-to-GDP ratio only lead to the same stabilization results than the one obtained under the national reaction if cross-border lending reaches 45%. However, even if cross-border linkages are high enough to justify the implementation of a federal adjusted solution, the reaction to national lending conditions remains remarkably optimal.

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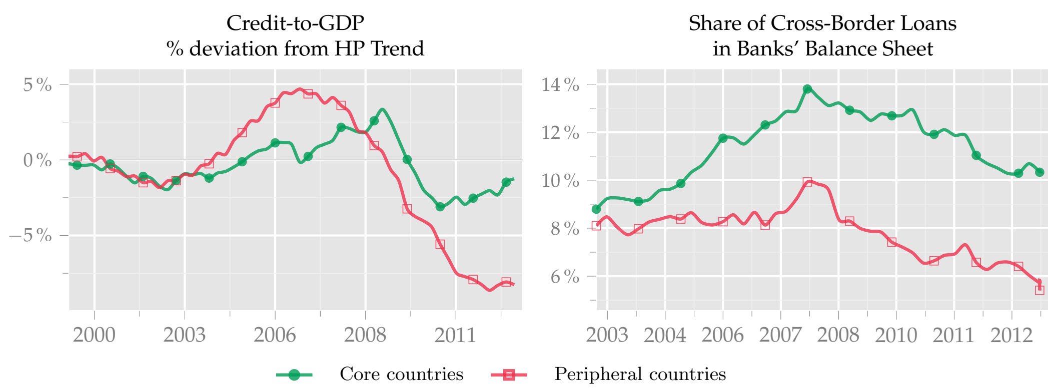
1. Introduction

The disruption of financial relations that followed the 2007 subprime crisis set the basis for the adoption of macroprudential policies in most countries.[1] In the Euro Area, the implementation of such measures remains fragmented along national lines while the coordination and internalization of cross-border spillovers are achieved through the actions of the European Systemic Risk Board (ESRB, henceforth). This federal organization accounts for two conflicting features of the Eurozone that can be approached by contrasting core and peripheral countries.[2] Panel (a) of Figure 1 shows that financial cycles (as measured by the credit to GDP ratio in percentage deviation from HP trend) remain clearly national, which militates for a decentralized definition and implementation of macroprudential measures. However, as reported in panel (b) of Figure 1, these two regions are closely linked by cross-border banking activities (as measured by the share of loans lent to a foreign agent residing in another Euro Area country) and the international spillovers of national macroprudential policies may be harmful for the monetary union. The remaining uncertainties on undesirable side-effects of self oriented macroprudential policies have thus put global banks at a central stage in the on-going debate related to the conduct of macroprudential policies.[3]



NOTE: Cross-border lending refers to any financing arrangement that crosses national borders between a domestic bank and a foreign borrower. The share of cross-border loans is computed here as the ratio between loans to euro area excluding the domestic area and the loans to euro area (i.e. cross-border loans between core countries are included in the calculation of the share of international loans). Sources: ESRB and ECB statistics.

Figure 1: Stylized facts characterizing the Eurosystem banking system: credit cycles remain clearly national while cross-border lending experienced an important growth

This paper questions how sizable cross-border lending flows should be treated in the definition of national macroprudential policies in the Euro Area. We more particularly assess whether cross-border bank lending should explicitly be considered in the setting of coordinated national

[1] In a nutshell, macroprudential policy aims at completing monetary policy to enhance the resilience of the financial system and contain the procyclicality of financial factors on activity.

[2] In the first group we aggregate data for countries with a current account surplus and low government bond yields over the sample period (Austria, Belgium, Germany, Finland, France, Luxembourg and Netherlands), while in the second group, we aggregate data for countries with a current account deficit and high government bond yields over the sample period (Spain, Greece, Ireland, Italy and Portugal).

[3] For example, regarding issues related to macroprudential policy with global banking, we refer to the IMF (2013, key issues, p31), the ESRB handbook (2014), ECB (2015, Financial Stability Review, May), Bank of England (2015, Staff Working Paper).

macroprudential measures or whether national regulators should only focus on the sole national financial stance to contribute to the financial stability of the Eurozone.

We build and estimate a two-country DSGE model that accounts for two major aspects to address the question at hands. First, we extend the setup of Poutineau and Vermandel (2015) - featuring cross-border banking on the corporate and interbank loan markets[4] - to account for bank capital regulation and thus to contrast the effectiveness of macroprudential policy from banking autarky to perfect integration. Second, in line with the actual organization of macroprudential policy,[5] we focus on the joint-optimization of macroprudential policy rules in each country using the countercyclical capital buffer (CCB, henceforth) rate as an instrument. This solution has become one of the leading facets of prudential regulation since the adoption of Basel III accords (2010) by building up a bank capital buffer during periods of excessive credit growth that can be released when systemic risks abate. The international dimension of banks offered by our setting allows us to contrast different CCB rules based on: (*i*) the federal or the national credit-to-gdp targeting, (*ii*) the loan demand (from firms) or supply (from banks) to GDP targeting, and (*iii*) the loan inflows-to-GDP ratio targeting as envisaged by Rey (2015).

The methodology employed in this paper comprises three steps. First, we build and estimate a two-country DSGE model for the Euro Area with only monetary policy (as there are no observations for an estimation of a macroprudential rule). Second, we compute the optimal policy rules (both monetary and macroprudential policy) given the estimated parameters assuming a two-stage game where monetary policy is the leader.[6] Third, we examine implications of cross-border lending on the optimal design of macroprudential rules across country members of the Eurosystem using the optimal monetary policy rule as a benchmark.

The main result of the paper suggests that self oriented macroprudential national policies reacting to the evolution of home country loan creation should be favored even with high amounts of cross-border lending flows: First, targeting a national credit-to-gdp ratio should be favored to federal averages as this rule induces better stabilizing performances in front of important divergences in credit cycles between core and peripheral countries. Second, policies reacting to the evolution of national credit supply should be favored as the transmission channel of macroprudential policy directly impacts the marginal cost of loan production and, by so, financial intermediaries. Third, the interest of lifting up macroprudential policymaking to the supra-national level remains questionable for admissible value of international lending between Eurozone countries. Indeed, national capital buffers reacting to the union-wide loan-to-GDP ratio only lead to the same stabilization results than the one obtained under the national reaction if cross-border lending reaches 45%. However, even if cross-border linkages are high enough to justify the implementation of a federal adjusted solution, the reaction to national lending conditions remains remarkably optimal.

Additionally, we outline some particularities regarding the conduct of macroprudential poli-

[4]In this paper, we omit the mortgage market and concentrate on corporate and interbank loans. Given the insignificant size of cross-border housing loans in the portfolio of banks (the share of cross-border loans is below 1% in the Euro Area according to ECB internal data), this omission does not seem to be important for the analysis conducted here.

[5]We refer to Carboni et al. (2013) for a discussion regarding the macroprudential policy mandate in the Euro Area shared between European Central Bank and the Single Supervisory Mechanism, national competent authorities and coordinated by the European Systemic Risk Board.

[6]A important branch of the literature analyzed the interaction between monetary policy and financial stability, a topic not covered in the paper as we concentrate here on interactions between national prudential authorities. We refer to Woodford (2012) for a summary of policy challenges and results offered by the existing literature concerning the role of monetary policy in providing financial stability.

cies for peripheral countries. We find that adjusting the macroprudential instrument to capital inflows-to-GDP is a promising tool for these countries that have experienced a large amount of loan inflows. Furthermore, disentangling the demand/supply of credit has implications for macroprudential policymaking as it is preferable to target credit suppliers for core countries and borrowers for peripheral economies.

Our approach is partly related to a set of papers examining macroprudential measures in the Eurozone with a closed economy setup. Notably, Darracq-Pariès et al. (2011) and Angelini et al. (2014) build a DSGE model of the Eurozone close to Gerali et al. (2010) with both corporate and housing credit markets and evaluate the optimal mix between monetary and macroprudential policy using loss functions. As a key contribution to the literature, they suggest that time-varying capital requirements can improve macroeconomic stability by supporting monetary policy actions. Our analysis can thus be considered as an extension to these papers, by accounting for the heterogeneity between Euro Area participants and the existence of national macroprudential policies with cross-border spillovers.

Our paper also contributes to macroprudential policy analysis in open economies. As an example, Quint and Rabanal (2014) account for financial asymmetries between participating countries and focus on the interaction between financial and housing cycles without considering cross-border flows between countries. By omitting cross-border lending, they naturally find that there are no important spillover effects of regulation from one member state to another via an estimated two-country DSGE model of the Eurozone. Additionally, Jeanne (2014) employs a static open economy model to evaluate the effectiveness of macroprudential and capital control measures. Contrary to Quint and Rabanal (2014), he finds that these prudential policies generate important global spillovers even with international coordination.

The paper is organized as follows: Section 2 describes the financial sector of the model. Section 3 takes the model to the data. Section 4 discusses the performance of macroprudential policy. Section 5 provides a sensitivity analysis to assess the robustness of our results. Section 6 concludes.

2. The financial sector

The economy is composed of two countries of unequal size and populated by households, firms and banks. This first section describes the banking component of the model while the rest of the framework (standard to the literature) is presented in appendix.

2.1. The financial sector in a nutshell

Figure 2 provides a broad picture of the financial sector and summarizes its interaction with the rest of the economy. Banks engage in interbank lending/borrowing relations and provide corporate loans to entrepreneurs and deposit services to households. Authorities affect the decisions of the banking sector through monetary and macroprudential policies.

To introduce an interbank market, we assume that banks are heterogenous in terms of liquidity. This feature gives rise to an interbank market where liquid banks provide interbank loans to both home and foreign banks. This feature is line with the current European banking system characterized by banks relying on wholesale fundings as illustrated by Giannone et al. (2012). In our setup, the distinction between liquid and illiquid banks lies in the direct access of liquid banks to ECB fundings which allow intra-financial sector flows between financial intermediaries.[7]

[7]This assumption is empirically motivated: in the Eurosystem, only a fraction of the 2500 banks participates

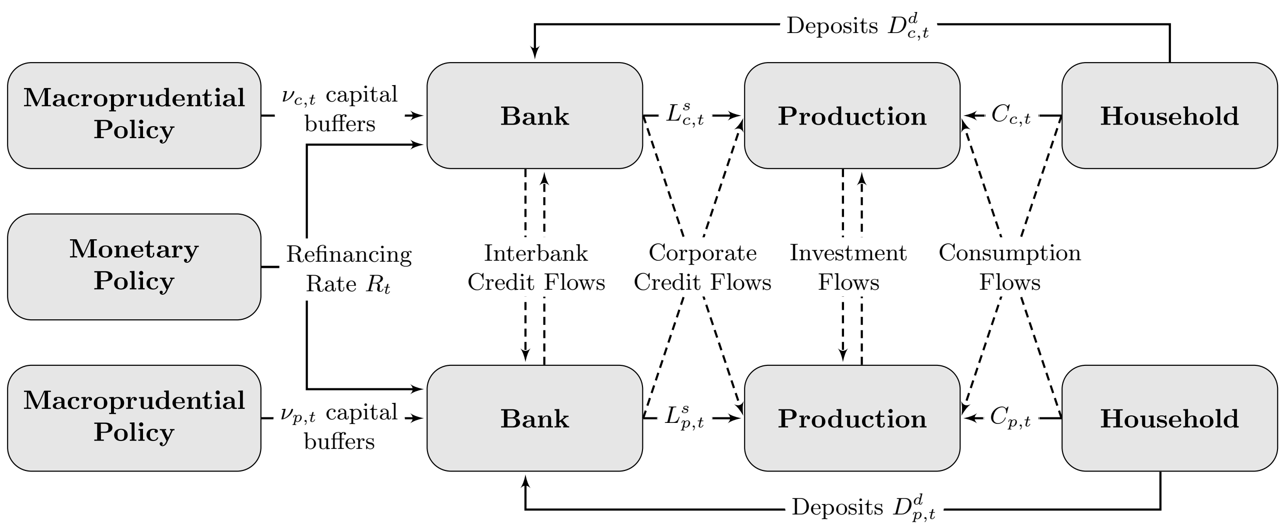


Figure 2: Macroprudential policy and cross-border banking in a New Keynesian Framework

Extending this assumption to an international perspective, illiquid banks can borrow from both domestic and foreign liquid banks, which gives rise to cross-border interbank lending flows. The decision of the banking system regarding the provision of deposit services to households and loans to the corporate sector affects the rest of the economy through the setting of deposit and lending interest rates.[8] In line with the EMU situation, we do not consider cross-border deposit nor cross-border lending to households. The international flow of loans between economies is thus a consequence of interbank liquidity provision and borrowing choices undertaken by entrepreneurs (following a comparison between the relative interest rates of domestic and foreign corporate loans).

This paper adopts a macroeconomic perspective to focus on the effect of cross-border lending on the conduct of macroprudential policy in a heterogeneous monetary union. As a consequence, the financial sector is combined with a standard two-country DSGE model accounting for short run rigidities in goods prices and nominal wages. In what follows, we outline the main assumptions regarding the functioning of the financial sector that are deemed necessary to improve both the tractability of the analysis and the estimation of the many behavioral parameters of the DSGE structure. Some modelling choices have been done in line with the DSGE literature that contrast with a more standard description of the behavior of the banking sector as summarized by Freixas and Rochet (2008) and VanHoose (2009). As in the initial contribution of Gerali et al. (2010), this macro superstructure is augmented with a highly simplified banking model. A host of assumptions should be invoked that effectively splinter a bank's decisions into independent choices about different portions of its balance sheet.[9]

regularly to the bidding process in main refinancing operations of the ECB while the others rely on interbank funding.

[8]For tractability reasons we assume that even if banks differ in their ability to raise funds from the central bank, their loan and deposit supply decisions remain homogenous after aggregation. In a real life situation, illiquid banks may face more difficulties in attracting households deposits requiring banks to set higher deposit rates to compensate their default risk. Regarding corproate loans provision, the tighter funding constraint of illiquid may diminish their loan supply compared to liquid banks.

[9]First, portfolio separation holds (Baltensperger (1980) and Santomero (1984)), which means (Sealey and Lindley (1977) and Sealey (1985)) that a number of assumptions have been invoked. For instance, either shareholder

This paper extends Poutineau and Vermandel (2015) to account for deposit decisions and for macroprudential consideration in the balance sheets of financial intermediaries. The stickiness in both deposit and loan interest rates is a key ingredient of the framework. The setting of interest rate mimics the way other sticky nominal variables such as prices and wages are set in the model by adopting a Calvo-type mechanism. This device, shared by most DSGE models with a banking sector, partly contrasts with the literature developed from the banking industry perspective. Indeed, most of the banking literature has, following Flannery (1982) original work on deposits as quasi-fixed factors, focused on intertemporal quantity adjustment costs. It is also worth noting that the substantial banking literature on this topic has proposed alternative ways of approaching this question, including Cosimano and Van Huyck (1989), Cosimano (1987, 1988), and Elyasiani et al. (1995) and Abo-Zaid (2015). Furthermore, sluggish and even asymmetric variations in bank retail rates have been documented in the empirical literature as in Van Leuvensteijn et al. (2013) through imperfect competition among banking systems, while Kopecky and Van Hoose (2012) rely on intertemporal quantity adjustment costs together with imperfect competition to explain such observations. The adoption of a Calvo mechanism combined with monopolistic competition has been employed here in a macro-perspective for credit and deposit interest rates, as this solution allows us to consider the sluggishness in the adjustment of all the nominal variables of the economy (prices, wages and interest rates) through the estimation of a "Calvo lottery parameter".

As a second major noticeable difference from Poutineau and Vermandel (2015), we account for endogenous leverage of financial intermediaries, thus reflecting the riskiness in the balance sheet of banks. We use time-varying capital requirements as the macroprudential instrument. As underlined by Angelini et al. (2014), capital buffers have taken a center stage in the ongoing debate on regulatory reform and have become one of leading facet of macroprudential regulation. Specifically in the European Union, a number of macro-prudential policy instruments including countercyclical buffers are embedded in the legislative texts transposing the Basel III regulatory standards into EU law.[10] To account for this compulsory macroprudential instrument, we borrow the modelling device of Darracq-Pariès et al. (2011) and Angelini et al. (2014) by assuming that each type of bank must pay a quadratic cost when its risk weighted assets ratio deviates from the time-varying ratio fixed by the macroprudential authority in country i according to the systemic risk arising within the financial system. The decision to penalize banks for keeping equity-capital positions below the official benchmark is easy to understand, as undercapitalized banks make the banking sector more fragile and in turn subject to bank runs (Diamond and Rajan (2001)). Symmetrically, the decision to impose costs on banks for having equity-capital positions above the required levels may be understood in a macroeconomic perspective: by keeping more equity capital levels than required by the official regulation, the banking sector diverts resources and, in turn, creates credit rationing for both entrepreneurs and illiquid banks. This may create lower

unanimity is assumed for all banks in the model, or risk neutrality has been assumed to render shareholder unanimity a non-issue. In addition, it must be assumed that banks' costs of real resources utilized in their operations are separable from resource costs for others of the banks' assets and liabilities at during each period and across periods if interperiod adjustment costs are taken into account. Finally, banks must have access to a market in which they can both borrow and lend at exactly the same interest rate. Only when all such assumptions are invoked, it is legitimate for each bank to be able to make separable decisions about balance-sheet choices as assumed in this model.

[10] Namely the new Capital Requirements Directive (CRD IV) and the Capital Requirements Regulation (CRR). We refer to Carboni et al. (2013) for a discussion regarding the macroprudential policy mandate in the Euro Area shared between ECB/SSM, national competent authorities and coordinated by the ESRB.

than desired banking activity, reduce investment in the economy and incur inefficiencies.[11]

2.2. Interbank relations

In each country the banking system consists of two distinct branches: a continuum of monopolistic banks and financial packers. Monopolistic banks provide different types of loans and deposit services and set interest rates on a Calvo basis. The financial intermediary is a CES packer that produces one homogenous loan and deposit service.[12] A share λ of banks is illiquid *(i.e.* credit constrained), while the remaining share of banks 1-λ is liquid and supplies interbank loans to illiquid banks.

The representative share λ of illiquid banks b in country i has the following balance sheet,

$$L^s_{i,t} = IB^H_{i,t} + BK^{ill}_{i,t} + D_{i,t} + liab^{ill}_{i,t}, \tag{1}$$

where $L^s_{i,t}$ is the loan supply of borrowing banks, $IB^H_{i,t}$ is the interbank loans supplied by liquid banks subject to external habits, $BK^{ill}_{i,t}$ is the bank capital, $D_{i,t}$ are deposit services to households and $liab_{i,t}$ are other liabilities in the balance sheet of the bank that are not considered in the model.[13] To close the model, we assume that the cost of these liabilities is set by the central bank through its refinancing rate. We suppose that the demand for interbank funds are subject to external habits at a degree h^B_i where $IB^H_{i,t} = IB^d_{i,t} - h^B_i(IB^d_{i,t-1} - \overline{IB}^d_i)$. These habits captures the empirical autocorrelation of interbank funding. In addition, these habits are empirically documented in the interbank network literature: Finger et al. (2014, 2015) find at a bank level that bilateral links between banks are persistent as banks heavily rely on well-established business relations, thus exhibiting some habits in borrowing/lending decisions.

The one-period stream of profits of the b-th illiquid bank is given by:

$$\begin{aligned}\Pi^{ill}_{i,t} = &\left[1 - \mu^B\left(1 - \mathbb{E}_t\left\{\eta_{i,t+1}\right\}\right)\right]\left(1 + R^L_{i,t}\right)L^s_{i,t} - \left(1 + R^D_{i,t}\right)D_{i,t} - \left(1 + P^{IB}_{i,t}\right)IB^H_{i,t} \\ &- \left(1 + R_t\right)liab^{ill}_{i,t} - F\left(rwa^{ill}_{i,t} - \upsilon_{it}\right)BK^{ill}_{i,t},\end{aligned} \tag{2}$$

where $\mu^B \in [0,1]$ denotes the loss-given-default (*i.e.* the percentage of the amount owed on a defaulted loan that the bank is not able to recover), $1 - \mathbb{E}_t\left\{\eta_{i,t+1}\right\}$ is the expected average default

[11] Van den Heuvel (2008) finds using a general equilibrium model that increasing capital requirements induces high welfare costs in terms of unconditional consumption, suggesting that capital requirements should be lower than in the current adequacy framework. Clerc et al. (2015) highlight the presence of a tradeoff using a financial accelerator model between too high and too low capital requirements.

[12] The financial packer acts as a loan and deposit bundler in a perfectly competitive market. Banks supply differentiated types b of deposits $D_{i,t}(b)$ and loans $L^s_{i,t}(b)$ bundled by financial packers. Their packing technology for deposit services and loans reads as, $D^d_{i,t} = [(1/n_i)^{1/\epsilon_D}\mathcal{G}(D_{i,t}(b)^{(\epsilon_D-1)/\epsilon_D})]^{\epsilon_D/(\epsilon_D-1)}$, and $L^d_{i,t} = [(1/n_i)^{1/\epsilon_L}\mathcal{G}(L^s_{i,t}(b)^{(\epsilon_L-1)/\epsilon_L})]^{\epsilon_L/(\epsilon_L-1)}$. It maximizes profits, $R^D_{i,t}D^d_{i,t} + R^L_{i,t}L^d_{i,t} - \mathcal{G}(R^D_{i,t}(b)D_{i,t}(b)) - \mathcal{G}(R^L_{i,t}(b)L^s_{i,t}(b))$, subject to their two technology curves. Here, $L^d_{i,t}$ is the loans demand from home and foreign entrepreneurs, $D^d_{i,t}$ is the deposit services demand from domestic households and $\mathcal{G}(.)$ is the aggregator function. Deposits and loans are imperfect substitute with elasticity of substitution $\epsilon_D < -1$ and $\epsilon_L > 1$. The corresponding demand functions associated from the previous problem are, $D_{i,t}(b) = (1/n_i)(R^D_{i,t}(b)/R^D_{i,t})^{-\epsilon_D}D^d_{i,t}$ and $L^s_{i,t}(b) = (1/n_i)(R^L_{i,t}(b)/R^L_{i,t})^{-\epsilon_L}L^d_{i,t}$. The aggregate price index of all varieties in the economy is given by, $R^D_{i,t} = [(1/n_i)\mathcal{G}(R^D_{i,t}(b)^{1-\epsilon_D})]^{1/(1-\epsilon_D)}$ and $R^L_{i,t} = [(1/n_i)\mathcal{G}(R^L_{i,t}(b)^{1-\epsilon_L})]^{1/(1-\epsilon_L)}$.

[13] We suppose that they follow an exogenous $AR(1)$ shock process $\varepsilon^B_{i,t}$ such that, $liab_{i,t} = e^{\varepsilon^B_{i,t}}\overline{liab}_i$, this shock captures some aggregate movements in the funding constraint araising from the wholesale funding market, see for instance Pérignon et al. (2017) for an analysis of liquidity runs on the French unsecured market of certificates of deposits.

rate of the bank's home and foreign customers,[14] $R_{i,t}^{D}$ is deposit rate, $P_{i,t}^{IB}$ is the borrowing cost on the interbank, R_t the interest rate set by the central bank and $F_i(\cdot)$ denotes the capital requirement cost function. This cost function is taken from Gerali et al. (2010) and is defined as $F_i(x) = 0.5\chi^k x^2$ where $\chi^k \geq 0$ is the cost of capital adequacy framework paid in term of bank capital.[15] This cost function is a shortcut that makes bank capital more costly than any source of financing, and allows in turn to mimic the response of credit rates and credit to a capital requirement tightening consistently with empirical evidence (see for instance Fraisse et al. (2013) for an empirical measure of this elasticity). When the bank capital-to-risky-asset ratio $rwa_{i,t}^{ill}$ is below the policy target v_{it}, the bank is penalized by regulatory rules that affect the borrowing rates in the monetary union and in turn damage output. This penalization replicates the market discipline imposed by investors on low capitalized banks, forcing the latter to boost their retained earnings though higher credit rates. The risk is evaluated through fixed weights on assets, based on the type of the borrowers (1 for corporate exposure and 0.20 for interbank exposure between OECD banks as defined in Basel accords) as defined in Basel I accords. Since illiquid banks are only exposed to corporate risk, the risk weighted assets ratio is given by $rwa_{i,t}^{ill} = BK_{i,t}^{ill}/L_{i,t}^{s}$. In addition, the financial intermediary has access to domestic and foreign interbank loans to meet its balance sheet. The modelling device to introduce international borrowing is analogous to trade channels through a CES as in Poutineau and Vermandel (2015) and Brzoza-Brzezina et al. (2015). The total amount borrowed by the representative bank reads as follows:

$$IB_{i,t}^{d} = \left(\left(1-\alpha_i^{IB}\right)^{1/\xi} \left(IB_{hi,t}^{d}\right)^{(\xi-1)/\xi} + \left(\alpha_i^{IB}\right)^{1/\xi} \left(IB_{fi,t}^{d}\right)^{(\xi-1)/\xi} \right)^{\xi/(\xi-1)}, \tag{3}$$

where parameter $\xi > 0$ is the elasticity of substitution between domestic and foreign interbank funds, α_i^{IB} represents the percentage of cross-border interbank loan flows in the monetary union and $IB_{hi,t+1}^{d}$ (resp. $IB_{fi,t+1}^{d}$) the amount of domestic (resp. foreign) loans demanded by borrowing bank b in country i. This existence of an home bias on the interbank market is empirically motivated, Fricke and Lux (2015) find, using Italian bank-level data, that Italian banks tend to trade with each other rather than with foreign banks, in particular after the financial turmoil. More broadly in the literature of finance, the home bias in portfolio was first documented by French and Poterba (1991).

The total cost incurred by illiquid banks to finance interbank loans, $1 + P_{i,t}^{IB}$, is thus defined according to the CES aggregator:

$$1 + P_{i,t}^{IB} = \left(\left(1-\alpha_i^{IB}\right)(1+R_{h,t}^{IB})^{1-\xi} + \alpha_i^{IB}(1+R_{f,t}^{IB})^{1-\xi}\right)^{1/(1-\xi)}, \tag{4}$$

where $1 + R_{h,t}^{IB}$ (resp. $1 + R_{f,t}^{IB}$) is the cost of loans obtained from home (resp. foreign) banks in country i. Finally following Gerali et al. (2010), the bank capital accumulation process of illiquid

[14] To simplify both the steady state and the log-linear version of the model, the bank default expectation regarding entrepreneurs' projects is defined by a geometric average of home and foreign surviving rates of entrepreneurs, $\eta_{i,t} = (\eta_{h,t}^{E})^{1-\alpha_h^L}(\eta_{f,t}^{E})^{\alpha_j^L}\overline{\overline{\eta}}^{\alpha_h^L-\alpha_j^L}$ where $\eta_{i,t+1}^{E}$is the default rate of entrepreneurs operating in country $i \in \{c,p\}$. The expression $\overline{\overline{\eta}}^{\alpha_h^L-\alpha_j^L}$ ensures the detesministic steady state remains symmetric between Core and Periphery without affecting the dynamic of the model up to a first order approximation.

[15] The quadratic nature of this cost has been discussed in the previous subsection.

banks ($BK^{ill}_{i,t}$) is determined by:

$$BK^{ill}_{i,t} = \left(1 - \delta^{ill}_{i}\right) \Pi^{ill}_{i,t-1}, \tag{5}$$

where $\delta^{ill}_i \in [0,1]$ measures resources used in managing bank capital and conducting the overall banking intermediation activity and is determined endogenously by the steady state of the model. Given the functional form of $F_i(\cdot)$, the first order condition on loans which determines the marginal cost of supplying an additional unit of loans to home and foreign entrepreneurs is:

$$1 + MC^{ill}_{i,t} = \frac{1 + P^{IB}_{i,t} + \chi^k \left(\upsilon_{it} - rwa^{ill}_{i,t}\right)\left(rwa^{ill}_{i,t}\right)^2}{1 - \mu^B \left(1 - \mathbb{E}_t \left\{\eta_{i,t+1}\right\}\right)}. \tag{6}$$

From this equation, we observe that an increase (reduction) in the CCB rate $\upsilon_{i,t}$ (risk weighted assets ratio $rwa^{ill}_{i,t}$) imposes on banks to accumulate more equity via retained earnings through a rise in credit rates. Parameter χ^k determines the elasticity of interest rates to capital regulation change.[16] During phases of expansion, banks have incentives to increase their leverage away from the target in order to boost their profits. This risk taking by banks is addressed in our model though the cost function that forces banks to control their capital structure.

The fraction $1-\lambda$ of remaining liquid banks has the following balance sheet:

$$L^s_{i,t} + IB^s_{i,t} = L^{ECB}_{i,t} + BK^{liq}_{i,t} + D_{i,t} + liab^{liq}_{i,t}, \tag{7}$$

where $L^s_{i,t}$ is the lending supply to entrepreneurs, $IB^s_{i,t}$ is the supply of funds on the interbank market, $L^{ECB}_{i,t}$ is the amount of refinancing operations obtained by the liquid bank, $BK^{liq}_{i,t}$ is the amount of bank capital, $D_{i,t}$ are deposits collected from domestic households and $liab_{i,t}$ are exogenous liabilities as explained previously. The one-period profit of the bank $\Pi^{liq}_{i,t}$ is defined as:

$$\begin{aligned}\Pi^{liq}_{i,t} = {} & \left(1 - \mu^B \left(1 - \mathbb{E}_t \left\{\eta_{i,t+1}\right\}\right)\right)\left(1 + R^L_{i,t}\right) L^s_{i,t} + \left(1 + R^{IB}_{i,t}\right) IB^s_{i,t} - \left(1 + R^D_{i,t}\right) D_{i,t} \\ & - \left(1 + R_t\right) liab^{liq}_{i,t} - \left(1 + R_t\right) L^{ECB}_{i,t} - F(rwa^{liq}_{i,t} - \upsilon_{it}) BK^{liq}_{i,t}.\end{aligned} \tag{8}$$

Here, $R^{IB}_{i,t}$ is the interest rate set by liquid banks to home and foreign illiquid banks, R_t is the refinancing rate of the central bank and $F_i(\cdot)$ denotes the same Basel cost function as for illiquid banks: $F_i(x) = 0.5\chi^k x^2$. Interbank claims affect the amount of equity held by banks and are given a risk weight at 20%. The risk weighted asset ratio for liquid bank incorporating corporate and bank exposures is given by $rwa^{liq}_{i,t} = BK^{liq}_{i,t}/(L^s_{i,t} + 0.2IB^s_{i,t})$. According to the illiquid bank, bank capital of liquid banks evolves according to

$$BK^{liq}_{i,t} = (1 - \tau^{liq}_i)\Pi^{liq}_{i,t-1}, \tag{9}$$

where $\delta^{liq}_i \in [0,1]$ is similar to the illiquid bank and measures the fraction of capital used during the intermediation process that cannot be re-invested next period. The first order condition on

[16] Empirically, Fraisse et al. (2013) find at a bank level that one percentage increase in capital requirements leads to a reduction in lending by approximately 10%.

loans determining the marginal cost of loans of the liquid bank b is:

$$1 + MC_{i,t}^{liq} = \frac{1 + R_t + \chi^k \left(\upsilon_{it} - rwa_{i,t}^{liq}\right) \left(rwa_{i,t}^{liq}\right)^2}{1 - \mu^B \left(1 - \mathbb{E}_t\{\eta_{i,t+1}\}\right)}, \tag{10}$$

and the second first order condition on interbank loans determines the interbank rate set by banks operating in country i:

$$R_{i,t}^{IB} = R_t + 0.2\chi^k(\upsilon_{it} - rwa_{i,t}^{liq})(rwa_{i,t}^{liq})^2. \tag{11}$$

Here again, an increase in bank capital requirements raises the bank's cost of lending, and in turn increases both interbank and corporate interest rates. This result is consistent with standard business cycle models and is referred to the bank capital channel as in Van den Heuvel (2008), Meh and Moran (2010), Darracq-Pariès et al. (2011) and Angelini et al. (2014).

2.3. Interest rate setting

We assume that interest rates on deposits and corporate credit loans are sticky. In particular, sluggish and even asymmetric variations in bank retail rates have been documented in the empirical literature as in Kopecky and Van Hoose (2012) and Van Leuvensteijn et al. (2013) through imperfect competition among banking systems. The setting of interest rate mimics the way other sticky nominal variables such as prices and wages are set in the model. As in Darracq-Pariès et al. (2011), we introduce a Calvo model for credit rates to firms and deposit rates while the interbank rate is left flexible as banks operate under perfect competition on the interbank market. Banks must solve a two-stage problem. In the first stage, banks minimize the cost of managing their funds on a competitive input markets by computing the marginal cost of supplying an additional loan to borrowers and a deposit service to households. The computation of these marginal costs has already been performed in the previous subsection. In a second stage, they operate under monopolistic competition by applying a markup (markdown) on their commercial loan (deposit) rate, and set the interest rate on a staggered basis. Using a Calvo nominal rigidity device, each period a random fraction θ_i^L (θ_i^D) of banks is unable to update its lending (deposit) rate, $R_{i,t}^L = R_{i,t-1}^L$ ($R_{i,t}^D = R_{i,t-1}^D$), creating an imperfect transmission of monetary policy decisions to borrowers and savers living in the monetary union. The bank that it is able to modify its loan interest rate (with a constant probability $1 - \theta_i^L$) chooses $R_{i,t}^{L*}$ to maximize its expected stream of profits adjusted by the risk of default:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \left(\theta_i^L\right)^\tau \Lambda_{i,t+s} \left(1 - \mu^B \left(1 - \eta_{i,t+1+\tau}\right)\right) \left[R_{i,t}^{L*} - \exp(\varepsilon_{i,t+s}^L) MC_{i,t+s}^L\right] L_{i,t+s}^s, \tag{12}$$

where $\varepsilon_{i,t}^L$ is an *ad-hoc* markup AR(1) shock to the credit rate equation, $\theta_i^L \in [0, 1)$ is the Calvo lottery coefficient determining the degree of nominal rigidity and $MC_{i,t}^L$ is the aggregate marginal cost combining outputs from liquid and illiquid banks of country i. We aggregate loans from liquid and illiquid banks and their respective marginal costs before applying the markup for tractability purposes: this device is useful to compute a single Phillips curve as well as an unique credit rate for both liquid and illiquid banks. We borrow this shortcut procedure from Gerali et al. (2010) adapted in a different context, i.e. all banks belonging to a national banking system share the same marginal cost of production, reflecting the average liquidity degree of national banks: $1 + MC_{i,t}^L = (1 + MC_{i,t}^{ill})^\lambda (1 + MC_{i,t}^{liq})^{(1-\lambda)}$. In addition, the banking spread reflecting the level of financial distress is given by $S_{i,t}^L = (1 + R_{i,t}^L)/(1 + R_t)$.

In a similar fashion for deposit rates, assuming that it is able to modify its interest rate with a constant probability $1-\theta_i^D$, the representative bank chooses $R_{i,t}^{D*}$ to maximize its expected stream of profits, by applying a markdown on the refinancing rate of the central bank R_t:

$$\mathbb{E}_t \sum\nolimits_{\tau=0}^{\infty} \left(\theta_i^D\right)^{\tau} \Lambda_{i,t+s} \left[R_{t+s} \exp(\varepsilon_{i,t+s}^D) - R_{i,t}^{D*}\right] D_{i,t+s}, \tag{13}$$

where $\varepsilon_{i,t}^D$ is an *ad-hoc* time-varying AR(1) markdown shock to the deposit rate equation and $\theta_i^D \in [0,1)$ is the Calvo lottery parameter.

2.4. Macroprudential policy

Macroprudential policy affects the general equilibrium of the economy through the policy instrument $v_{i,t}$ that contributes to the marginal cost of commercial banks' loans. As a consequence, a macroprudential policy tightening is associated with higher lending rates, and lower bank credit growth and asset prices. We assume that the macroprudential authority sets the time-varying capital requirement $\nu_{i,t}$ according to:

$$v_{i,t} = (1-\rho_i^v)\,\bar{\nu} + \rho_i^v \nu_{i,t-1} + \phi_i(\mathcal{T}_{i,t} - \bar{\mathcal{T}}_i), \tag{14}$$

where $\rho_i^v \in [0,1)$ is the smoothing coefficient of the rule, $\mathcal{T}_{i,t}$ is the macroprudential target, $\phi_i \geq 0$ is the macroprudential weight to the target in country i and $\bar{\mathcal{T}}_i$ is the steady state of the target. In our specification, capital requirements are expected to increase when the target deviates from its steady state. The choice of the target $\mathcal{T}_{i,t}$ is a key aspect of the paper that will be discussed below.

The ESRB has developed a buffer guide to choose the CCB rate based on the credit-to-gdp gap.[17] However, the global nature of the European banking system introduces many possibilities for the definition of the credit-to-gdp ratio taken into account by national authorities. Indeed, the CCB rate may be adjusted to the credit supply (of banks) or the credit demand (of entrepreneurs),[18] either on a national or on a federal basis. Our framework with international bank flows allows us to distinguish between five operational targets as listed in Table 1.

The first set of credit targeting rules is oriented towards the supply of credit using either a federal (1.a) or a country-specific aggregate (1.b). A macroprudential policy based on credit supply aims at stabilizing lenders by focusing more on the stabilization of financial shocks hitting lenders rather than demand and supply shocks hitting borrowers. Given the scale of cross-border loans in the Eurozone, the decisions of the national supervisor has side effects on countries where a national bank has a subsidiary or branches or where this bank lends to may favor a federal definition of the ratio. Thus to handle these pecuniary externalities, we evaluate the possibility of an union-wide targeting system (1.a) against a national targeting system (1.b), the latter being expected to create more externalities (positive or negative) as it affects the foreign banking system without taking into account its financial developments.[19]

[17] Other indicators (such as early warning variables) are included in the CCB guide which are not implementable in our model.

[18] In an open economy context where banks can lend across borders, banks supply credit to both home and foreign, which creates a gap between the domestic supply and the domestic demand for loans. This distinction between demand and supply is easy to see on the market clearing conditions of interbank (Equation B.23) and corporate markets (B.22).

[19] For further discussions of these cross-border issues, we refer to Beck et al. (2016).

Table 1
Various Macroprudential Policy Schemes in terms of Target (average in the monetary union, national supply or national target) and in terms of policy stance (common or national-adjusted)

Schemes	Target
LOAN SUPPLY TARGETING	
1.a Union-wide loan supply	$\mathcal{T}_t = (L_t^s + (1-\lambda)IB_t^s)/Y_t$
1.b National loan supply	$\mathcal{T}_{i,t} = (L_{i,t}^s + \lambda IB_{i,t}^d)/Y_{i,t}$ for $i \in \{c,p\}$
LOAN DEMAND TARGETING	
2.a Union-wide loan demand	$\mathcal{T}_t = (L_t^d + \lambda IB_t^d)/Y_t$
2.b National loan demand	$\mathcal{T}_{i,t} = (L_{i,t}^d + \lambda IB_{i,t}^d)/Y_{i,t}$ for $i \in \{c,p\}$
CAPITAL INFLOWS TARGETING	
3 Capital Inflows	$\mathcal{T}_{i,t} = (L_{i,t}^d - L_{i,t}^s + \lambda IB_{i,t}^d - (1-\lambda)IB_{i,t}^s)/Y_{i,t}$ for $i \in \{c,p\}$

Note: variables without country subscript such as x_t denote union-wide averages computed as a weighted sum of each country $x_t = nx_{c,t} + (1-n)x_{p,t}$.

The second set of credit targeting rules concentrates on the demand of credit emanating from entrepreneurs.[20] The interest of a CCB rate tailored to borrowers is that it may provide more stabilization following real and nominal shocks hitting households and firms at the expense of financial shocks affecting banks. This solution seeks at internalizing the social cost of entrepreneurs' over-borrowing that may arise given their biased expectations. As this policy regime inefficiently affects foreign borrowers through cross-border lending, spillovers effects may be dampened by a federal targeting (2.a) rather than a national one (2.b).

We also evaluate the interest of adopting provisional measures to affect cross border lending directly, through targeting capital inflows in the CCB. This solution, as envisaged by Jeanne and Korinek (2010), Brunnermeier et al. (2012) and Rey (2015), is relatively similar to a capital control measure. The main insight behind this scheme would rely on the fact that persistent capital account imbalances induce financial stability risks and may have implications for the sustainability of net external asset positions. In particular since the creation in the Eurozone, global banking has experienced an explosive growth helping to fuel unsustainable credit booms in peripheral economies such as in Spain and in Ireland, followed by a sudden stop in capital inflows compensated by unconventional measures. Macroprudential policies can play a key role to contain this problem by imposing targeted regulations on banks engaged in cross-border activities. When borrowing to other European banks is increasing faster with respect to the GDP, a national authority can rise the CCB rate to affect banks' balance sheet management and reduce their exposure to international borrowing. In addition when system risks abate in one economy, leading to capital flow reversals, national authorities may release the buffer thus loosening the banks' funding constraint to address the procyclicality of capital flows.

[20] A loan demand targeting is feasible in a real life situation, the ECB already disentangles the credit demand and supply by collecting the domestic and cross-border positions of Euro area monetary financial institutions since 1999 for each participant of the monetary union. Regarding the demand side of credit markets, the bank lending survey published by the ECB on a quarterly basis provides an analysis of the driving forces of the demand of credit in the Euro Area. For the supply side, both the ECB and the BIS collect domestic and cross-border positions of euro area monetary financial institutions.

3. Estimation strategy

We fit the previous two country DSGE to Eurozone data over the sample time period 1999Q1-2013Q4 using Bayesian techniques. We estimate structural parameters and the sequence of shocks by following the seminal contributions of Smets and Wouters (2003, 2007) and Christiano et al. (2005). For a detailed description, we refer to the original papers.

3.1. Data

We split the Eurozone in two groups adopting the core-periphery dichotomy as in Quint and Rabanal (2014) and Poutineau and Vermandel (2015). Core countries gather Austria, Belgium, Germany, Finland, France, Luxembourg and Netherlands while peripheral countries include Spain, Greece, Ireland, Italy and Portugal. The model is estimated with Bayesian methods on Eurozone quarterly data over the sample period 1999Q1 to 2013Q4, which makes 60 observations for each observable variable. Concerning the transformation of series, the point is to map non-stationary data to a stationary model. Data which are known to have a trend (namely GDP, consumption, investment, corporate loan and interbank supply) or unit root are made stationary in two steps. First, we divide the sample by the population. Second, data are taken in logs and we use a first difference filtering to obtain growth rates. In addition, real variables are deflated by the HICP price index and we remove the seasonal component in the data using a multiplicative decomposition. Furthermore, we demean the data as we do not use the information contained in the observable mean. Interest rates are set on a quarterly basis by dividing them by 4. Since hours worked are not observable for the Euro Area, we adopt the same modelling strategy as Smets and Wouters (2003) to identify TFP shocks using employment as a proxy for hours worked. Employment is divided by the working population index, taken in logs and demeaned. To map employment to hours worked in our model, we introduce an auxiliary equation for each country which states that only a share $\theta_i^E \in [0,1)$ of firms is allowed to adjust its level of employment $\hat{e}_{i,t}$ to its optimal labor demand $H_{i,t}^d$:

$$\hat{e}_{i,t} = \beta \hat{e}_{i,t+1} + \left(1 - \beta\theta_i^E\right)\left(1 - \theta_i^E\right)/\theta_i^E \left(\log\left(H_{i,t}^d/\bar{H}^d\right) - \hat{e}_{i,t}\right). \tag{15}$$

The vector of observable variables reads as:

$$\mathcal{Y}_t = 100[\Delta\hat{y}_{i,t}, \hat{e}_{i,t}, \Delta\hat{c}_{i,t}, \Delta\hat{\imath}_{i,t}, \hat{\pi}_{i,t}^C, \Delta\hat{w}_{i,t}, \hat{r}_{i,t}^D, \Delta\hat{l}_{i,t}^s, \Delta\widehat{ib}_{i,t}^s, \hat{r}_t] \text{ for } i = \{c,p\}.$$

3.2. Calibration, priors and model assumptions

We fix a small number of parameters commonly used in the literature of real business cycles models which are weakly identified. The discount factor β is set at 0.99, the depreciation rate δ at 0.025, the capital share α at 0.38, the share of steady state hours worked $\bar{H}$ at 1, the spending to GDP ratio g at 24%.[21] Concerning ϵ_P and ϵ_W (the substitutability between final goods and labor), we consider the calibration at 10 as in Smets and Wouters (2007). Regarding financial parameters, we fix $\bar{N}/\bar{K}$ (the net worth to capital) ratio to 0.40 to be consistent with the observed debt-to-financial assets ratio of non-financial corporations which fluctuates between 50% and 65% since 1999. The steady state value of spreads and the bank balance sheet are calibrated on their averages observed over the sample period in the Euro Area: $\bar{R}$-$\bar{R}^D$=1.66/400, $\bar{R}^L$-$\bar{R}^D$=3.67/400,

[21] This calibration offers a consumption-to-output ratio of 55.45% (vs 57.31% in the data) and investment-to-output ratio of 20.55% (vs 20.70% in the data).

$\bar{D}/\bar{L}^s$=0.46, $\overline{rwa}$=$\bar{v}$=0.10 and $\overline{IB}^d/\bar{L}^s$=0.20. The capital regulation cost χ^k is set at 11 as in Gerali et al. (2010) to replicate the response of credit and interest rate to a capital requirement rise.

For substitution parameters for corporate and interbank loans υ and ξ as well as for the fraction of illiquid banks λ, to our knowledge there are no empirical analysis using bank level data that provides an estimation of these parameters. We rely on the previous fit exercise of Poutineau and Vermandel (2015) by calibrating λ at 0.38 and υ, ξ at 1.1. The latter calibration for substitution parameters is rather conservative by allowing very low substitution effects between home and foreign loans.[22] The quarterly share of defaulting firms' projects $1-\bar{\eta}^E$ is fixed at 0.025/4,[23] and the auditing cost μ^B at 0.10,[24] those values are very similar to Bernanke et al. (1999). We compute the parameter governing the relative size of the core area n at 0.58 as in Kolasa (2009), which is the share implied by nominal GDP levels averaged over the period 1999-2013. We calibrate symmetrically the adjustment cost on deposits χ_i^D at 0.0007 as in Schmitt-Grohé and Uribe (2003) to remove an unit root component generated by the two-country set-up. Finally, the lower bound $\omega_{\min}$ and the shape κ of the Pareto distribution are endogenously determined by the model equations assuming a risk-free economy with no spread and default, we obtain: $\omega_{\min}$=1-$\bar{N}/\bar{K}$ and κ=$\bar{K}/\bar{N}$. Our calibration delivers for the main endogenous variables the following steady state: $\bar{\omega}^C$=0.6015, ε^D=-2.41, ε^L=4.37, $\bar{r}^L$=0.0192 and $\bar{r}^K$=0.0166.

Our priors are listed in Table B.7. Overall, they are either relatively uninformative or consistent with earlier contributions to Bayesian estimations. For a majority of new Keynesian models' parameters, *i.e.* σ_i^L, h_i^C, θ_i^P, ξ_i^P, θ_i^W, ξ_i^W, θ_i^E, χ_i^I, ψ_i, ϕ^π, $\phi^{\Delta y}$ and shock processes parameters, we use the prior distributions close to Smets and Wouters (2003, 2007). Calvo probabilities for rates have the same uninformative priors as for prices/wages while loans habits are given a prior mean 0.5 with standard deviation 0.2. Our priors for openness parameters are based on their observed average over the sample period. Substitutabilities between home/foreign credit and final goods are set to 2 with standard deviations of 0.50. We set the prior for the elasticity of the external finance premium $\varkappa_i$ to a beta distribution with prior mean equal to 0.05 and standard deviation 0.02 consistent with prior information of Gilchrist et al. (2009). Finally, in order to catch up the correlation and co-movements between countries' aggregates, we estimate the cross-country correlation between structural shocks, associated priors are inspired by in Jondeau et al. (2006) and Kolasa (2009), we set the mean of the prior distribution for shock correlations between core countries and peripheral countries at 0.2 with a standard deviation at 0.2.

Finally, regarding bank capital regulation for the fit exercise, we disable the macroprudential instrument by fixing the CCB rate to its deterministic steady state value:

$$\nu_{i,t} = \bar{v}. \tag{16}$$

[22]In contrast, Brzoza-Brzezina et al. (2015) assign a value of 6 to their substitution parameter, which is rather high with respect to the literature of trade. In general, substitution parameters for goods market are rather low and usually remain between 1 and 2 as in Quint and Rabanal (2014) or Poutineau and Vermandel (2015).

[23]This is consistent with corporate default statistics from Moody's, the rating agency, which show an average default rate on (non-US) non-financial corporate bonds of 0.75% for the period 1989-2009, as shown by Darracq-Pariès et al. (2011). The other rating agency Standards & Poor's evaluates the rate of default for the period 1991-2014 to 0.58%. We consider a default rate of 0.63% which is in the ballpark of the numbers found by rating agencies.

[24]The auditing cost cannot be observed as few data on loan losses are publicly available for reasons of confidentiality. Dermine and De Carvalho (2006) find using bank level data that these costs critically depends on the size of the loans: recovery costs on smaller loans are substantially higher than on large loans, 4.1% vs. 0.9%. In addition, once the contentious department has to rely on external lawyers, the recovery costs rise to 10.4%.

This assumption is reasonable for two main reasons. First over the sample period, capital regulation has been mainly dominated by the Basel I Accords characterized by fixed capital requirement ratios. Second, even through the adoption of the Basel III Accords allows Euro Area countries to employ the countercyclical capital buffer as a shield against the build up of financial imbalances, it has not been yet employed by a participant of the monetary union.[25]

3.3. Estimation results

The methodology employed is standard to the Bayesian estimations of DSGE models.[26] Table B.7 reports estimation results which summarizes the means and the 5th and 95th percentiles of the posterior distributions while the latter are drawn in Figure B.6. According to this figure, prior and posterior distributions are relatively different showing that the data were fairly informative. Several parameters are well identified for one country but weakly for the other economy, we decide to keep these parameters in the fit exercise after checking that their weak identification does not affect our estimations (i.e. calibrating these parameters and re-estimating the model provides very similar results). While our estimates of the standard parameters are in line with the literature (see for instance Smets and Wouters (2003) and Quint and Rabanal (2014)), several observations are worth making by commenting the mean of the posterior distribution of structural parameters.

First regarding asymmetries in business and credit cycles between the core and the periphery, they are mainly driven by the standard deviation of shocks which are larger in peripheral economies. In particular, inefficiency shocks for wages and prices are more volatile in periphery which may constitute an issue in the implementation of a single monetary policy. In the same vein for macroprudential regulation, the presence of heterogenous financial shocks in terms of volatility questions the perspective of a single federal macroprudential authority.

Second turning to structural parameters, we find an important difference between countries regarding parameter θ_i^E that determines the adjustment of employment to the demand of hours worked: core countries observe a sluggish response of employment to the cycle while the mirror image is seen for periphery. Still regarding the labor market, wage rigidity and indexation parameters are also higher in core countries suggesting that core countries are farther from the optimal allocation characterized by flexible wages and prices. However this interpretation is nuanced by Galí (2013) showing that wage rigidities can, in some particular situations, play a stabilizing role for the economy. One of these particular situations exposed by Galí (2013) is a monetary policy weakly oriented toward inflation which can be observed when monetary policy has hit its lower bound. In the light of this new reinterpretation that meets the current situation of the Euro Area, wages and employment rigidities of core countries may have been stabilizing frictions since the financial crisis episode in 2009.

[25]The ESRB offers on its website an interactive map of the Euro Area on countercyclical capital buffers. To this date, only Sweden and Norway have activated the CCB rate in the European Union but both of these countries are not Euro Area participants.

[26]The posterior distribution combines the likelihood function with prior information. To calculate the posterior distribution to evaluate the marginal likelihood of the model, the Metropolis-Hastings algorithm is employed. We compute the posterior moments of the parameters using a sufficiently large number of draws, having made sure that the MCMC algorithm converged. To do this, a sample of $250,000$ draws was generated for four chains through parallelization, neglecting the first $50,000$. The scale factor was set in order to deliver acceptance rates of between 20 and 30 percent for each chain. Convergence was assessed by means of the multivariate convergence statistics taken from Brooks and Gelman (1998). We estimate the model using the dynare package of Adjemian et al. (2011). We provide in the online appendix the bayesian IRF of the model which are all fairly consistent with VAR-type models evidence.

Third, the results related to market integration are in line with the standard empirical evidence. In particular, peripheral economies are more open and dependent to the core area than the opposite, except for interbank facilities. This latter result is hard to reconcile with the empirical evidence as, before the financial crisis, peripheral economies where net recipient of interbank loans that fueled the property boom. This could be a limitation of the analysis conducted here, however by summing both the net entry of corporate and interbank loans, our model predicts that peripheral economies were net recipient of loans consistently with the historical experience of the Euro Area.

4. The performance of Macroprudential Policy

4.1. The suboptimality of the federal solution

The countercyclical capital buffer (CCB, henceforth), as defined in the Basel III accords (2010) and ESRB handbook (2014), is an instrument designed to contain the procyclicality of the financial sector. It is aimed at building up a capital buffer when threats to resilience are high or during periods of excessive credit growth and can be released when systemic risks abate. The ESRB has selected the credit-to-gdp gap as a leading indicator to signal upcoming crises that the CCB is meant to mitigate. A natural translation of the CCB's objective in our setup corresponds to the minimization of the variance of the credit-to-gdp ratio in the monetary union:[27]

$$\mathcal{L} = \sigma^2_{L/Y} + \lambda_Y \sigma^2_Y + \lambda_\nu \sigma^2_\nu, \tag{17}$$

where $\sigma^2_{L/Y}$, σ^2_Y and σ^2_ν denote respectively the unconditional variance of the credit-to-gdp ratio, output and policy tool $\nu_{i,t}$ while parameters λ_Y and λ_ν are weights on output and CCB. This *ad-hoc* loss function $\mathcal{L}$ borrowed from Angelini et al. (2014) is obtained as a weighted average of national loss functions for each area. It is defined as, $\mathcal{L} = n\mathcal{L}_c + (1-n)\,\mathcal{L}_p$, where for each country the national loss is given by, $\mathcal{L}_i = \sigma^2_{i,L/Y} + \lambda_Y \sigma^2_{i,Y} + \lambda_\nu \sigma^2_{i,\nu}$. Noticeably, as our model features an interbank market, the credit-to-gdp ratio is given by the aggregate credit supply divided by output: $ctg_{i,t}{=}(L^s_{i,t} + (1-\lambda)\, IB^s_{i,t})/Y_{i,t}$. As Angelini et al. (2014), we assume that λ_ν=0.10 and λ_Y=0, however in a robustness section we investigate whether our results are sensitive to this calibration.

Using the criterion (17), we are able to perform a similar exercise as Angelini et al. (2014) by ranking macroprudential policies selecting CCB rule's coefficients $[\rho^\upsilon_c,\rho^\upsilon_p,\phi_c,\phi_p]$ that deliver the smallest loss. We search over a four-dimensional grid over parameters ranges [0,1) for ρ^υ_i and [0,5] for ϕ_i. As a benchmark for comparing our scenarios for CCB implementation, we consider the optimal monetary policy situation characterized by the optimized Taylor rule that maximizes the welfare of households living in the monetary union. Put differently, the interaction between monetary and macroprudential policy follows a Stackelberg game where monetary policy is leader by removing nominal inefficiencies in the Euro area through the refinancing rate, followed afterward by macroprudential policy which dampens financial cycles. Optimal monetary policy is

[27] We are aware that the minimization of a loss function rather than a micro-founded welfare criterion is a limitation of our analysis. However, it is also well-known that the usual welfare criterion weakly portrays the trade-off faced by macroprudential authorities between macroeconomic and financial stabilization. A macroprudential policy maximizing the welfare index reduces inflation to the detriment of the financial system which experiences higher volatilities for credit supply and spreads. In response, Woodford (2012) employs an *ad hoc* loss function that fairly portrays the objective of macroprudential policy. Most of the literature follows Woodford's approach, such as Darracq-Pariès et al. (2011) and Angelini et al. (2014).

based on a second order approximation to equilibrium conditions of the model as in Schmitt-Grohé and Uribe (2007) using estimated parameters of Table B.7.[28] Optimal weights in the Taylor rule are respectively ρ=0.99, ϕ^{π}=4.38, $\phi^{\Delta y}$=0.5.

Finally, the minimization of the variance of the credit-to-GDP gap can be re-interpreted through an allocation problem for authorities. Entrepreneurs' distorted beliefs generate over-borrowing decisions which inefficiently amplify the cycle. By so, entrepreneurs do not internalize their contribution to the financial amplification. Authorities thus implement a capital requirement policy which can be seen as a Pigouvian tax on banks aiming at internalizing the increase of the social cost through higher lending rates to entrepreneurs.[29] Thus the financial amplification is measured here through the variance of the credit-to-GDP ratio.

We evaluate the stabilization performance of each macroprudential policy scheme by minimizing the second order loss function defined in Equation 17 subject to linear equilibrium conditions of the estimated model.

Table 2

Loss-based ranking of different macroprudential policy implementation schemes

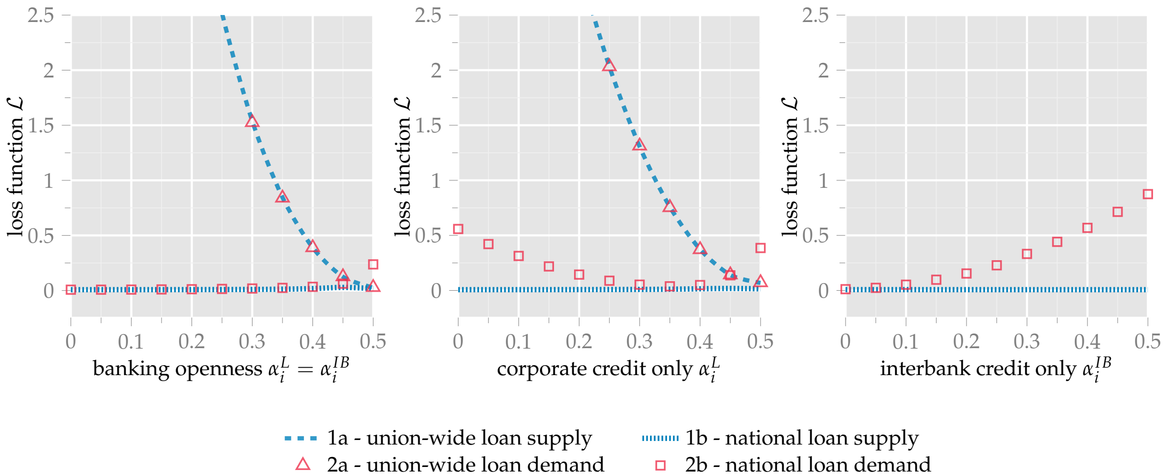
Scheme	Optimal Stances				Loss		
	ρ_c^{υ}	ϕ_c	ρ_p^{υ}	ϕ_p	$\mathcal{L}$	$\mathcal{L}_c$	$\mathcal{L}_p$
Loan Supply Targeting							
1.a Union-wide loan supply	0.59	5.2	0.28	4.6	5.4076	3.9097	7.4761
1.b National loan supply	0.96	2.2	0.91	1.97	0.0071	0.0078	0.0062
Loan Demand Targeting							
2.a Union-wide loan demand	0.46	2.64	0.49	1.25	5.4787	3.9577	7.5791
2.b National loan demand	0.16	2.55	0.96	2.79	0.67336	0.46427	0.9621
Capital Inflows Targeting							
3. Capital Inflows	0.53	2.36	0.15	0.57	19.7407	13.5852	28.241

Table 2 reports the policy stance and the stabilizing performances for each implementation scheme. The optimal stabilization of the financial system critically depends on the target selected by macroprudential authorities. Unsurprisingly, we observe a clear ranking favoring operational instruments reacting to national loan developments (schemes 1.b and 2.b) that outperforms solutions based on federal loan developments (schemes 1.a and 2.a).

A natural question is thus to determine the degree of mutual financial cross-border lending flows that should be observed to affect this main conclusion. Indeed, as underlined by Cecchetti and Tucker (2016) and Beck et al. (2016) a higher banking integration should require a common prudential standard (here, the targeting rule) applied appropriately to all parts of the financial system. As a consequence, the efficiency of federal targeting rules (*i.e.* schemes *1.a* and *2.a*) is expected to increase with the share of cross-border loans while national adjusted should be less efficient. To investigate this question, Figure 3 reports minimized loss functions for different levels

[28]In the quantitative simulation, we first search for weights attached to inflation ϕ^{π}, GDP growth $\phi^{\Delta y}$ and the smoothing degree ρ in the Taylor rule that gives the highest unconditional welfare of households from Equation B.1. Based on the grid search by 0.01 unit, we limit our attention to policy coefficients in the interval $(1, 5]$ for ϕ^{π}, $[0, 0.5]$ for $\phi^{\Delta y}$ (Schmitt-Grohé and Uribe, 2007), and in the interval $[0, 0.99]$ for ρ to speed up optimization routines. We take into account the zero-lower bound by adding a penalty term in the welfare index associated to the variance of the nominal interest rate following the calibration of Woodford (2003).

[29]We refer to Jeanne and Korinek (2013) for the implementation of macroprudential measures through a social planner problem.



NOTE: for each value of the share of foreign loans in the portfolio of entrepreneurs (denoted α_i^L) and banks (denoted α_i^{IB}), we compute the optimal macroprudential policy for four different schemes. The loss function is an average between core and periphery detailed in Equation 17. Capital inflows-adjusted policy is not reported as its loss is too high compared to alternative schemes.

Figure 3: The role of cross-border banking in the scheme ranking.

of cross-border loans. Three component are presented related to an increase in total (namely the sum of corporate and interbank) cross-border loans in the left panel, in corporate loans only in the center panel and in interbank loans only in the right panel.

We can draw three main conclusions from Figure 3. First, the interest of conducting federal based definition of the credit-to-gdp ratio unsurprisingly increases with the size of cross-border flows. As reported in the first panel, the relative interest of implementing a national adjusted rule (such as *1.b* and *2.b*) is magnified with respect to the federal adjusted rule for lower values of α_i^L and α_i^{IB}. However for values of these parameters higher than 25%, the gap in the loss function values tends to decrease significantly. Nevertheless, macroprudential rules based on a federal definition of the credit to GDP ratio becomes only interesting for a mutual cross-border lending openness lying around 45%. This figure is rather high with respect to the current value of cross-border lending, which makes this solution not optimal for the moment.

Second, this policy outcome regarding the reduction in the loss function under a federal definition of the credit-to-gdp ratio is mainly driven by the mutual openness of the corporate credit markets. As reported in the center and right panels, interbank cross-border lending credit has no noticeable impact on the relative ranking of policy solutions, while the integration of the corporate loan segment determines the slope of the decrease in the loss function under the federal solution.

Third, even if banking integration clearly enhances the stabilization performances of federal-adjusted schemes, a macroprudential solution targeting the national credit supply remains remarkably efficient with a global banking system. For the all spectrum of values of α_i^L and α_i^{IB} displayed in panels of Figure 3, CCB reaction to a national definition of the credit-to-gdp ratio determines the lowest value for the loss function. Thus, our experiments suggest that even if cross-border linkages are high enough to justify the implementation of a federal adjusted solution, the reaction to national lending conditions remains optimal.

4.2. Contrasting national solutions

As underlined in Table 2 our numerical results suggest that the best outcome for the loss function value is obtained when macroprudential policy targets the national supply of loans instead of the national demand for loans (*i.e.*, accounts for the national and foreign nature of loans contracted in the economy). The interest of targeting loan supply is easily understandable, as the transmission channel of macroprudential policy directly impacts the marginal cost of loan production and, by so, financial intermediaries. If macroprudential policy targets loan demand, this direct channel is dampened, which leads to a lower reduction of the loss function. National macroprudential policies reacting to federal averages do not target the origin of financial imbalances as regional divergences in credit cycles are too important to have a single federal target. The solution focusing on cross-border lending developments (3), is clearly dominated by all the other implementation schemes: in this case, the loss function reaches its highest value, revealing that targeting external imbalances is not appropriate as it does not take into account the financial roots of the problem.

To understand these results we simulate the dynamic responses to a negative productivity shock in core countries and a negative net wealth shock in peripheral economies.[30] We concentrate on these two shocks as they are leading drivers of the loan-to-gdp ratio that authorities aim at stabilizing through capital buffer measures.

First, Figure 4 reports the IRFs after a negative productivity shock for each CCB rule with respect to the optimal monetary policy situation. Under the benchmark of an optimal monetary policy (dashed lines), a negative home productivity shock depresses investment and activity and implies inefficient fluctuations in the credit-to-gdp ratio. This shock translates to the peripheral region through trade channels, cross-border lending, monetary policy reaction and shock correlation. The introduction of national macroprudential measures has a clear stabilizing effect for business cycles of the monetary union. The release of the buffer eases the bank capital constraint which in turn lowers credit spreads and investment fluctuations. However, the targeting regime determining the CCB rate critically affects the outcome the economy that does not experience the shock and explains the effectiveness of national credit targeting regimes over federal ones. In a federal targeting regime (1.a and 2.a), both countries react to a common average credit-to-gdp ratio which leads the foreign country to react procyclically to foreign shocks. In addition, we do not find clear differences between targeting national credit demand or supply. Finally CCB rates adjusted to capital inflows fail at providing macroeconomic stability in particular for the peripheral country. The shock in the core country generates a re-allocation of credit from core to peripheral economies and authorities in peripheral economies procyclically tighten the capital constraint which inefficiently amplifies the crisis.

Second, Figure 5 depicts the IRFs after a negative stock market shock in peripheral economies. Under the optimal monetary policy benchmark (dashed lines), this shock deteriorates the borrowing conditions of entrepreneurs, thus incurring a large decline in output and investment through the external finance premium channel. Consequently, the credit-to-gdp gap experiences a large decline inefficiently driven by the biased expectations of entrepreneurs. Our main results regarding the implementation of macroprudential measures are similar to the productivity shock. National credit targeting is preferred to a federal one as the latter exacerbates fluctuations for the country that does not experience the shock, creating a spillover effect. The same procyclical mechanism is observed for the capital inflows targeting scheme. Finally, targeting the demand or

[30] As underlined by Angelini et al. (2014), supply shocks may dominate in normal times, while financial shocks are important in exceptional times.

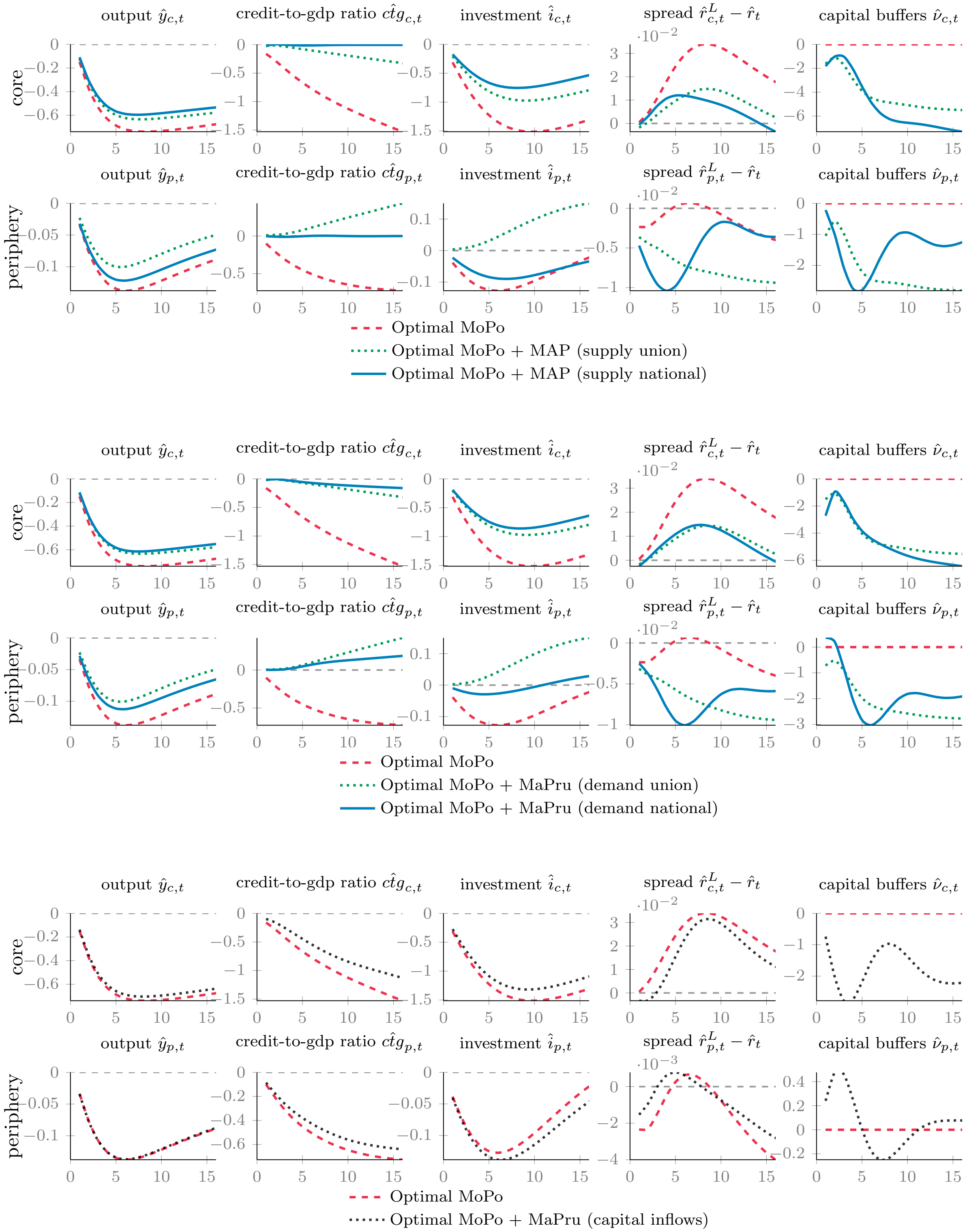


Figure 4: System response to an estimated negative productivity shock in core countries $\eta^A_{c,t}$ measured in percentage deviations from steady state under different macroprudential policy rules (domestic or union-wide supply/demand/inflows targeting).

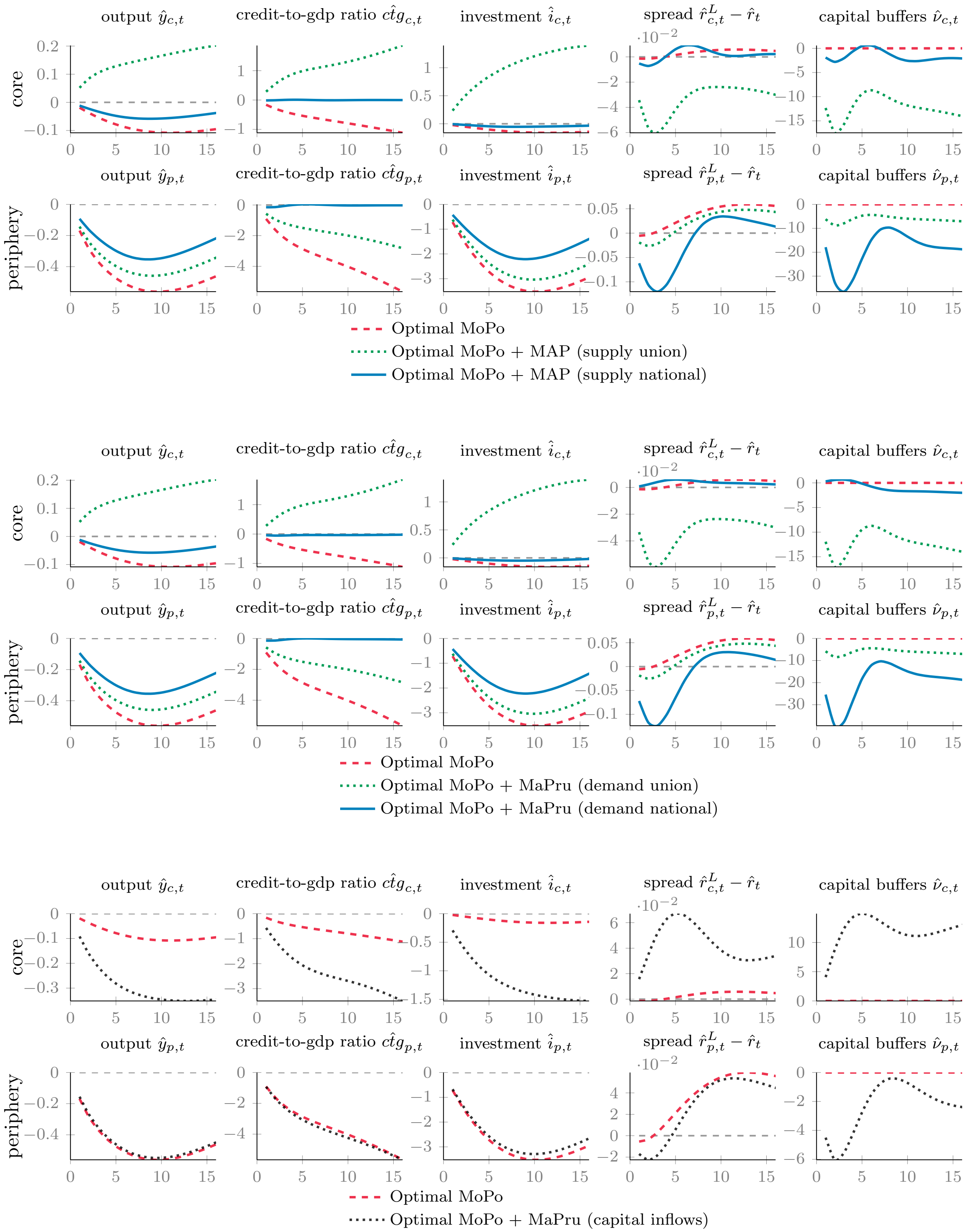


Figure 5: System response to an estimated negative firms net wealth shock in peripheral countries $\eta^N_{p,t}$ measured in percentage deviations from steady state under different CCB regulation schemes (domestic or union-wide supply/demand/inflows targeting).

supply of credit provides very similar responses.

Table 3
Macroeconomic performances of different implementation schemes in comparison to the optimal policy benchmark

	Standard deviations (%)								Correlation
	Core				Periphery				
Scheme	$\hat{y}_{c,t}$	$\hat{l}^s_{c,t}$	$i\hat{b}_{c,t}$	$\hat{s}^L_{c,t}$	$\hat{y}_{p,t}$	$\hat{l}^s_{p,t}$	$i\hat{b}_{p,t}$	$\hat{s}^L_{c,t}$	corr$(\hat{y}_{c,t}, \hat{y}_{p,t})$
Monetary Policy Only									
Benchmark	100	100	100	100	100	100	100	100	0.15
Loan Supply Targeting									
1.a Union-wide loan supply	91.57	91.95	75.11	127.47	103.88	113.45	73.86	105.96	0.15
1.b National loan supply	79.67	76.60	74.48	130.46	95.06	86.19	73.93	120.19	0.46
Loan Demand Targeting									
2.a Union-wide loan demand	91.58	92.06	75.1	127.29	103.79	112.92	73.96	105.58	0.16
2.b National loan demand	82.89	92.94	71.73	137.08	76.24	63.42	76.19	116.41	0.44
Capital Inflows Targeting									
3 Capital Inflows	93.42	138.3	73.27	156.67	96.33	79.92	88.94	90.46	0.37

Accounting for all shocks of the model, Table 3 reports the standard deviation of activity, corporate and interbank loans and interest rate spread under alternative policy schemes. We contrast our results with respect to the optimal monetary policy (without prudential regulation) to measure how the conduct of macroprudential measures have decreased/increased the standard deviation of endogenous variables for each country. This exercise measures how the stabilizing gains are distributed between countries. We also report business cycle synchronization statistics, as measured by the correlation of output between economies, to evaluate whether the scheme is able to smooth the heterogeneity between Euro Area participants.

Overall, the highest gains can be obtained by adopting macroprudential policy measures reacting to national developments in the credit-to-gdp ratio. The reaction of the macroprudential instrument to other measures of the credit-to-gdp ratio (based on either loan demand or federal averages) leads to less reduction in the standard deviation of these aggregates. However, the implementation of macroprudential policy is not a free lunch since the building up of a capital buffer mechanically increases the volatility of the spread when stabilizing the debt-to-GDP ratio.[31]

In addition, we observe a natural link between loan-to-GDP stabilization and business cycle synchronization, showing that the implementation of national-adjusted macroprudential policies smooths the heterogeneity across regions. Such a result is interesting for monetary policy makers, as the effectiveness of a single monetary policy critically depends on business cycle synchronization between monetary union participants. Thus the enhanced cycle synchronization partially solves the Euro Area's problem of a "one-size-fits-all" monetary policy.

Contrasting the national demand and national supply targeting solutions, we find that their effectiveness are clearly different according to the country considered. As an example, the supply side oriented policy fits the situation of core economies, while the one oriented towards the demand of credit meets the situation of peripheral economies in terms of macroeconomic stabilization. Core

[31] The variability of the lending spread is a leading indicator of financial distress, Woodford (2012) sets its stabilization as an objective for monetary policy making with financial frictions.

countries should thus focus on the stabilization of its banks while peripheral economies should stabilize its borrowers. Having asymmetric targets between regions of the Eurozone could be an interesting perspective to implement stabilization policies.

Finally the capital inflows targeting solution fits well peripheral economies that were net recipient of foreign claims before the 2009 crisis. However, this policy is harmful for core countries, affected by an increase in the volatility of loans and of the credit spread. Over the sample time period, core countries were net exporter of loans by fueling property booms in peripheral economies through interbank lending, this capital outflow involves an inefficient and durable reduction of the CCB rate enhancing the volatility of credit domestically. While capital controls appears to be a promising tool for Periphery, it is clearly unsuited to countries experiencing capital outflows.

5. Additional sensitivity analysis

This section assesses the robustness of our results with respect to some key parameters of the model and to the nature of shocks encountered in the economy.

5.1. Loss function calibration

Table 4
Sensitivity analysis of scheme ranking to different calibrated parameters

		Euro area loss $\mathcal{L}$				
		1.a	1.b	2.a	2.b	3
Loss output stabilization	$\lambda_y = 0$	5.4076	0.0071	5.4787	0.67336	19.7407
	$\lambda_y = 5$	6.0138	0.4063	5.9196	1.0906	16.7659
	$\lambda_y = 10$	6.5325	0.8036	6.5119	1.5042	20.8989
Loss policy instrument	$\lambda_\nu = 0$	5.4063	0.0004	5.5147	0.66152	19.9706
	$\lambda_\nu = 5$	5.7099	0.28443	5.7186	0.97562	20.1045
	$\lambda_\nu = 10$	5.9328	0.53581	5.9252	1.1936	20.4273
Loan substitutability	$\nu, \xi = 0$	5.5082	0.0072	5.4190	0.67025	19.7962
	$\nu, \xi = 5$	5.5206	0.0068	5.5392	0.6914	20.2309
	$\nu, \xi = 10$	5.5372	0.0067	5.5298	0.7056	20.9558
Share of core countries	$n = 0.4$	5.5641	0.0069	5.5485	0.0868	19.0729
	$n = 0.5$	5.6804	0.0069	5.7378	0.3138	19.7849
	$n = 0.6$	5.4134	0.0071	5.4053	0.78181	20.2335
Flexible interest rates	$\theta_i^L = 0$	5.9139	0.0058	5.8096	0.65304	17.8474
	$\theta_i^D = 0$	5.8987	0.0074	5.8685	0.66579	16.6966
	$\theta_i^L = \theta_i^D = 0$	5.9067	0.0059	5.8446	0.66382	21.3504

NOTE: λ_y and λ_ν denote respectively weights on output and policy tool volatilities in the macroprudential loss function, ν is the substitution degree between home and foreign credit varieties and n denotes the share of core countries in terms of real GDP in the euro area. Losses are evaluated using the average of core and peripheral countries volatilities.

First, Table 4 reports the sensitivity analysis of the main results to the calibrated value of some underlying parameters. The first experiments focus on the weight parameters of the loss function of macroprudential authorities. As reported, the ranking of policies remain unaffected by the value of these parameters. An increase in the policymakers preferences for output (denoted λ_y) or the penalization of the variance of capital requirements (denoted λ_ν) increases the loss. Turning to structural parameters (namely the degree of substitutability between different varieties of loans ν and n the share of core countries in the monetary union) the sensitivity analysis does not alter the ranking of macroprudential decisions. As observed, an increase in the size of the core countries' group has opposite results on the value of the loss, depending on the dimension of the credit-to-gdp ratio that is taken into account in the reaction of macroprudential policy. The loss decreases for schemes based on a reaction to national loan developments while it increases when the macroprudential instrument reacts to the federal value of the ratio. However, the gap between the loss values remain so high that the ranking between national and federal solutions is left unaffected. Regarding the nominal rigidities on interest rates, thus reflecting the imperfect pass-through of both monetary and macroprudential policies, disabling this nominal friction does not affect the ranking too.

5.2. Nature of shocks

Table 5

Robustness check: optimal monetary and macroprudential Policies conditional on shocks

		Monetary Policy			Macroprudential Policy				Union	Loss Core	Periph
Scheme		ρ	ϕ^{π}	$\phi^{\Delta y}$	ρ_c^{υ}	ϕ_c	ρ_p^{υ}	ϕ_p	$\mathcal{L}_u$	$\mathcal{L}_c$	$\mathcal{L}_p$
					Supply Shocks						
1.a	Union-wide loan supply	0.94	5	0.5	0.82	0.30	0.41	3.86	1.3139	0.95417	1.8107
1.b	National loan supply	0.94	5	0.5	0.95	2.72	0.86	2.58	0.0027	0.0041	0.0007
2.a	Union-wide loan demand	0.94	5	0.5	0.90	3.54	0.39	0.50	1.3189	0.95679	1.819
2.b	National loan demand	0.94	5	0.5	0.46	2.49	0.48	2.46	0.065797	0.04746	0.091119
3	Capital Inflows	0.94	5	0.5	0.81	3.63	0.43	0.98	1.9538	1.5535	2.5065
					Demand Shocks						
1.a	Union-wide loan supply	0.99	1	0.5	0.66	3.07	0.62	2.16	0.20432	0.14956	0.27993
1.b	National loan supply	0.99	1	0.5	0.94	2.52	0.64	2.52	0.0035	0.0039	0.0029
2.a	Union-wide loan demand	0.99	1	0.5	0.58	2.61	0.39	2.37	0.2051	0.1504	0.2806
2.b	National loan demand	0.99	1	0.5	0.05	2.35	0.80	2.69	0.7980	0.5139	1.1903
3	Capital Inflows	0.99	1	0.5	0.76	3.68	0.08	0.41	12.7015	11.5068	14.3513
					Financial Shocks						
1.a	Union-wide loan supply	0	1.48	0.5	0.15	1.60	0.24	3.35	0.5895	0.4308	0.8086
1.b	National loan supply	0	1.48	0.5	0.92	2.21	0.94	1.66	0.0023	0.0014	0.0035
2.a	Union-wide loan demand	0	1.48	0.5	0.06	1.94	0.26	3.58	0.5900	0.4301	0.8107
2.b	National loan demand	0	1.48	0.5	0.98	1.72	0.85	1.37	0.0054	0.0038	0.0077
3	Capital Inflows	0	1.48	0.5	0.30	0.47	0.96	4.63	2.6168	2.1119	3.3141

Note: each group of shocks is composed of core and peripheral shocks and their associated cross-correlation. Supply shocks group gathers productivity shocks $\eta_{i,t}^{A}$; Demand shocks group gathers spending $\eta_{i,t}^{G}$, preferences $\eta_{i,t}^{U}$ and investment $\eta_{i,t}^{I}$; Financial shocks gathers collateral crunch $\eta_{i,t}^{N}$, riskiness $\eta_{i,t}^{Q}$ and deposit cost-push $\eta_{i,t}^{D}$ innovations.

Second, Table 5 reports the sensitivity analysis of the main results to the nature of shocks encountered in the economy. We distinguish between supply (productivity shocks), demand (gathering public spending shocks, preference shocks and investment shocks) and financial shocks (gathering shocks on the collateral of corporate lending, on riskiness of investment projects and cost push shocks on deposit). As underlined by Angelini et al. (2014), supply and demand shocks may dominate in normal times, while financial shocks are important in exceptional times. For each shock, we contrast the consequences of adopting one of the macroprudential scheme adopted for the definition of the credit-to-gdp ratio (1a to 3). As observed, the relative ranking of the policy scheme is not altered by the nature of shocks encountered in the economy, as the solution based upon the reaction of authorities to the fluctuations in the national loan supply to GDP dominates all the other possibilities. However, the value of the loss fluctuates and it is higher for financial shocks. Furthermore, a closer look at the macroprudential parameters shows that the nature of the shock affects the contemporaneous policy stance of regional authorities. As observed, for real shocks, the contemporaneous reaction of core countries authorities tends to be higher for supply shocks while peripheral countries are more reactive for demand shocks. This latter feature is also observed for exceptional times.

5.3. Structural financial asymmetries

Table 6
Sensitivity analysis of scheme ranking to financial structural asymmetries

		Euro area loss $\mathcal{L}$				
		1.a	1.b	2.a	2.b	3
Benchmark		5.4076	0.0071	5.4787	0.67336	19.7407
Firms rate of default	$1-\bar{\eta}_p^E = 0.0125$	6.6312	0.0078	6.6535	0.58638	22.6661
Share of illiquid banks	$\lambda_p = 0.48$	6.0702	0.0078	6.3512	1.9242	21.7665
Corporate net wealth-to-assets ratio	$\bar{N}_p/\bar{K}_p = 0.2$	7.4030	0.0070	7.3528	0.55023	22.8376
Bank leverage ratio	$\overline{BK}_c/\bar{A}_c = 0.06$	6.5421	0.0163	6.5513	0.64037	19.651

Third, we investigate whether structural asymmetries affect the ranking of the model, results are reported in Table 6. In the benchmark setup developed in the paper, we assumed that most of the endogenous variables in the deterministic steady state were symmetric between countries. However this assumption is questionable, in particular regarding the asymmetries in the financial sector which may be an important feature for macroprudential policymaking. As a first exercise, we examine whether the symmetry assumption on the default rate of entrepreneurs matters for the scheme ranking. Since we cannot observe the default rate of entrepreneurs, we use as a proxy the share of non-performing loans in the balance sheet of banks in BankScope database. We find that the share of non-performing loans is on average twice higher in Periphery and calibrate the defaulting share of entrepreneurs accordingly. We find that this structural asymmetry does not affect the ranking, however we observe a small reduction of the gap between the demand-adjusted and the supply-adjusted macroprudential policy. We also investigate the implications of cross-country heterogeneity in the share of illiquid banks operating in the interbank market. We proxy this parameter through the number of banks borrowing on the unsecured money market provided by Garcia-de Andoain et al. (2014). We find that on average the share of banks borrowing on the interbank market is 25% higher in Periphery, we calibrate λ_P accordingly in our model. The new ranking obtained from the new set of simulations show no important difference, except for the national demand solution which becomes less efficient in stabilizing the credit-to-gdp ratio. We also investigate the implication of asymmetric steady state leverages of firms and of banks between countries. Core countries observed a lower net-worth-to-asset ratio than Peripheral economies for firms,[32] we take this feature into account by calibrating $\bar{N}_p/\bar{K}_p$ at 20% as in Italy. For banks, we use the ECB's Risk Assessment Indicators (RAI) and find that Core banks are less capitalized on average, in particular because of Belgium, Germany and Netherlands's low equity to assets ratios. We calibrate the leverage ratio of core banks to 6% to incorporate this structural asymmetry and run the simulations. We observe no clear ranking change under these two asymmetries. Overall, these robustness exercises confirm that these structural aspects

[32]There is a clear asymmetry between Core and Peripheral countries in terms of debt-to-financial assets ratios. For instance, France had a ratio of 40%, Germany 60% and Netherlands 60% while Italy had 80% and Spain 60%.

does not affect the ranking as second order statistics minimized in the loss function are rather independent of structural asymmetries.

6. Conclusion

This paper shows that international lending flows have mixed effects on the optimal conduct of macroprudential policy in the Eurozone. Contrasting alternative rules for countercyclical capital buffers, our results suggest that targeting a national credit-to-gdp ratio should be favored to federal averages as this rule induces better stabilizing performances in terms of output and loan volatility. The important divergences in credit cycles between core and peripheral countries reported in the data require a national orientation of macroprudential policy tailored to domestic financial developments. Our results have also underlined the reduced interest of lifting up macroprudential policymaking to the supra-national level. Indeed, national capital buffers reacting to the union-wide loan-to-GDP ratio lead to the same stabilization results than the one obtained under the national reaction when mutual cross-border lending reaches 45%. However, even if cross-border linkages are high enough to justify the implementation of a federal adjusted solution, the reaction to national lending conditions remarkably remains optimal. In addition, we find that adjusting the macroprudential instrument to capital inflows is a promising tool for countries experiencing loans inflows.

The analysis of cross-border lending on the conduct of macroprudential policy is a burgeoning research area. In this paper we focused on countercyclical capital buffers, and an interesting question for future research is to evaluate how this result favoring self-oriented macroprudential measures may be affected by the choice of alternative macroprudential instruments. The construction of an original welfare index, that features a trade-off between macroeconomic and financial stability, could be a next step of research. Finally, the analysis of the CCB rate through a Ramsey allocation problem could also be part of a future research agenda.

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Appendix A. Data sources

Gross domestic product: millions of national currency, current prices, quarterly levels, seasonally adjusted - *sources Eurostat.* **Private final consumption expenditure:** millions of national currency, current prices, quarterly levels, seasonally adjusted - *sources Eurostat.* **Gross**

fixed capital formation: millions of national currency, current prices, quarterly levels, seasonally adjusted - *sources Eurostat*. **GDP deflator:** Deseasonalized using a multiplicative decomposition - *sources Eurostat*. **Loans to Non-Financial corporations:** Index of Notional Stocks, Total maturity, Euro area (changing composition) counterpart, Deseasonalized using a multiplicative decomposition, monthly data (aggregated to get quarterly data) - *sources ECB (internal backcasted series)*. **Loans to MFIs:** Index of Notional Stocks, Total maturity, Euro area (changing composition) counterpart, Deseasonalized using a multiplicative decomposition, monthly data (aggregated to get quarterly data) - *sources ECB (internal backcasted series)*. **Borrowing cost:** monthly (taken in average to get quarterly data), Credit and other institutions (MFI except MMFs and central banks); Loans up to 1 year; BS counterpart sector: Non-Financial corporations (S.11); Outstanding amount - *sources ECB (internal backcasted series)*. **Deposit rate:** monthly (taken in average to get quarterly data), Firms and Households; - *sources ECB (internal backcasted series)*. **Money market rates:** money market interest rates, one year maturity, quarterly data - *sources Eurostat*.

Appendix B. The non-banking part of the model

We extend the model of Poutineau and Vermandel (2015) to account for the conduct of macroprudential policy in an heterogenous monetary union such as the Euro Area. Our model describes a monetary union made of two asymmetric countries $i \in \{c, p\}$ (where c is for core and p for periphery). Each part i of the monetary union is of a relative size n_i.[33] As shown in Figure 2, each country is populated by consumers, intermediate and final producers, entrepreneurs, capital suppliers and a banking system. Regarding the conduct of macroeconomic policy, we assume national fiscal authorities and a common central bank. The implementation of the macroprudential policy is left open, and will be discussed below in another section. Our model is confronted to the data using Bayesian econometrics and it encompasses several sources of rigidities to enhance its empirical relevance. The set of real rigidities accounts for consumption habits, investment adjustment costs and loan demand habits. Regarding nominal rigidities, we account for stickiness in final goods prices and loan interest rates.

Appendix B.1. Households and labor unions

The preferences of the j^{th} household are given by:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^{\tau} \exp(\varepsilon^U_{i,t+s}) \left(\log \left(C_{i,t+s} - h^C_i \mathcal{C}_{i,t-1+s} \right) - \frac{\chi_i}{(1+\sigma^H_i)} H^{1+\sigma^H_i}_{i,t+s} \right), \tag{B.1}$$

where $\mathbb{E}_t$ denotes the expectation operator, $\beta \in (0, 1)$ is the discount factor, parameter $\sigma^H_i > 0$ shapes the utility function of the j^{th} household associated to hours worked $H_{i,t}$. The consumption index $C_{i,t}$ is subject to external habits with degree $h^C_i \in [0; 1)$ with $\mathcal{C}_{i,t-1}$ the aggregate lagged consumption, while $\chi_i > 0$ is a shift parameter allowing us to pin down the steady state amount of hours worked. The discount factor is affected by a time-preference shock $\varepsilon^U_{i,t}$ following an AR(1) stochastic process that exogenously changes the household's intertemporal allocation of consumption over the cycle.

[33] Normalizing the size of the monetary union to unity, the relative size of the core are is n and the relative size of the peripheral area is $1 - n$.

Household j^{th} period budget constraint is given by:

$$w_{i,t}^{h}H_{i,t}+D_{i,t-1}^{d}\frac{\left(1+R_{i,t-1}^{D}\right)}{(1+\pi_{i,t}^{C})}+\Pi_{i,t}=C_{i,t}+D_{i,t}^{d}+t_{i,t}+p_{i,t}AC_{i,t}^{D}. \tag{B.2}$$

The income of the representative household is made of labor income with the desired real wage $w_{i,t}^{h}$,[34] interest payments for deposit services $D_{i,t}^{d}$ and real earnings $\Pi_{i,t}$ from shareholdings of firms and unions. The interest rate is deflated by the consumer price inflation rate $1+\pi_{i,t}^{C}=P_{i,t}^{C}/P_{i,t-1}^{C}$. The representative household spends this income on consumption, deposits and tax payments for a real amount of $t_{i,t}$. Finally, we assume that the household has to pay quadratic adjustment costs to buy new deposits,[35] these costs are paid in terms home goods with relative price $p_{i,t}=P_{i,t}/P_{i,t}^{C}$ where $P_{i,t}$ is the production price index of home produced goods while $P_{i,t}^{C}$ is the consumption price index. Households consume both home and foreign goods and their corresponding consumption basket follows a standard CES function:

$$C_{i,t}=\left(\left(1-\alpha_{i}^{C}\right)^{1/\mu}C_{hi,t}^{(\mu-1)/\mu}+\left(\alpha_{i}^{C}\right)^{1/\mu}C_{fi,t}^{(\mu-1)/\mu}\right)^{\mu/(\mu-1)}, \tag{B.3}$$

where parameter $\mu>0$ is the elasticity of substitution between domestic and foreign final goods and $\alpha_{i}^{C}\in[0,1/2]$ measures the fraction of goods bought abroad. The corresponding price index is, $P_{i,t}^{C}=(\left(1-\alpha_{i}^{C}\right)P_{h,t}^{1-\mu}+\alpha_{i}^{C}P_{f,t}^{1-\mu})^{1/(1-\mu)}$.

Households delegate the wage negotiation process to unions. Households provide differentiated labor types, sold by labor unions to perfectly competitive labor packers who assemble them in a CES aggregator and sell the homogenous labor to intermediate firms.[36] Unions negotiate the real margin between the real desired wage of households $w_{i,t}^{h}$ and the real marginal product of labor $W_{i,t}/P_{i,t}^{C}$. Using a Calvo wage nominal rigidity device, each period a random fraction θ_{i}^{W} of unions is unable to re-negotiate a new wage. Assuming that the trade union is able to modify its wage with a probability $1-\theta_{i}^{W}$, the j^{th} union chooses the nominal optimal wage $W_{i,t}^{*}$ to maximize its expected sum of profits:

$$\mathbb{E}_{t}\sum_{s=0}^{\infty}\left(\theta_{i}^{W}\right)^{s}\Lambda_{i,t+s}\left[\frac{W_{i,t}^{*}}{P_{i,t+\tau}^{C}}\prod_{k=1}^{s}\left(1+\pi_{i,t+k-1}^{C}\right)^{\xi_{i}^{W}}-\exp(\varepsilon_{i,t+s}^{W})w_{i,t+s}^{h}\right]H_{i,t+s}, \tag{B.4}$$

where $\Lambda_{i,t+\tau}$ is household's stochastic discount factor, $\varepsilon_{i,t}^{W}$ is an *ad-hoc* wage-push shock to the real wage equation following an AR(1) process which captures exogenous fluctuations in the wage margin negotiated by unions and affects in turn the productivity of the economy.

[34] As explained below, the desired wage is negotiated by a trade union.

[35] This cost is almost neutral on the dynamic of the model and is necessary to remove an unit root component which is standardly induced by the international nature of our model. See Schmitt-Grohé and Uribe (2003) for an extensive discussion and solutions regarding this issue. The functional form we choose is: $AC_{i,t}^{D}(j)=0.5\chi_{D}(D_{i,t}^{d}(j)-\bar{D}_{i})^{2}/\bar{D}_{i}$, where $\bar{D}_{i}$ is the steady state level of deposits and $\chi_{D}>0$ is the cost parameter.

[36] Labor packers are perfectly competitive and maximize profits, $W_{i,t}H_{i,t}^{d}-\mathcal{G}(W_{i,t}(j)H_{i,t}(j))$, under their packing technology constraint, $H_{i,t}=[(1/n_{i})^{1/\epsilon_{W}}\mathcal{G}(H_{i,t}(j)^{(\epsilon_{W}-1)/\epsilon_{W}})]^{\epsilon_{W}/(\epsilon_{W}-1)}$. Here, $W_{i,t}$ is the production price, $H_{i,t}^{d}$ is the labor demand and ϵ_{W} is a substitution parameter. The first order condition which determines the optimal demand for the j^{th} labor type is, $H_{i,t}(j)=(1/n_{i})(W_{i,t}(j)/W_{i,t})^{-\epsilon_{W}}H_{i,t}^{d}$, $\forall j$. Thus the aggregate wage index of all labor types in the economy emerges from the zero-profit condition: $W_{i,t}=[(1/n_{i})\mathcal{G}(W_{i,t}(j)^{1-\epsilon_{W}})]^{1/(1-\epsilon_{W})}$.

Appendix B.2. Firms

Intermediate firms produce differentiated goods, decide on labor and capital inputs on a perfectly competitive inputs market and set prices according to the Calvo model. The i^{th} firm has the following Cobb-Douglas technology:

$$Y_{i,t} = \exp(\varepsilon^{A}_{i,t}) \left(K^{u}_{i,t}\right)^{\alpha} \left(H^{d}_{i,t}\right)^{1-\alpha}, \tag{B.5}$$

where $Y_{i,t}$ is the standard production function that combines (utilized) physical capital $K^{u}_{i,t}$, labor demand $H^{d}_{i,t}$ to household and (exogenous) technology $\varepsilon^{A}_{i,t}$. Intermediate firms solve a two-stage problem. In the first stage, taking the real input prices $w_{i,t}$ and $z_{i,t}$ as given, firms rent inputs $H^{d}_{i,t}$ and $K^{u}_{i,t}$ in a perfectly competitive factor market in order to minimize costs subject to the production constraint (B.5) to determine the real marginal cost $mc_{i,t}$.

In the second-stage, the intermediate firm i sets prices according to a Calvo mechanism. Each period firm i is not allowed to re-optimize its price with probability θ^{P}_{i} but price increases by $\xi^{P}_{i} \in [0;1)$ with respect to the previous period's rate of price inflation, $P_{i,t} = (1+\pi_{i,t-1})^{\xi^{P}_{i}} P_{i,t-1}$. The i^{th} firm allowed to modify its selling price with a probability $1-\theta^{P}_{i}$ chooses $P^{*}_{i,t}$ to maximize its discounted sum of profits:

$$\mathbb{E}_t \sum\nolimits_{s=0}^{\infty} \left(\theta^{P}_{i}\right)^{s} \Lambda_{i,t+s} \left[\frac{P^{*}_{i,t}}{P^{C}_{i,t+s}} \prod_{k=1}^{s} (1+\pi_{i,t+k-1})^{\xi^{P}_{i}} - \exp(\varepsilon^{P}_{i,t+s}) mc_{i,t+s} \right] Y_{i,t+s}, \tag{B.6}$$

where $\varepsilon^{P}_{i,t}$ is an *ad-hoc* cost-push shock to the inflation equation following an AR(1) process which captures exogenous inflation pressures.

Once goods are produced and prices are set, final firms act as goods packers: they combine differentiated goods to produce the homogenous final good sold mainly to households.[37]

Appendix B.3. Entrepreneurs

The capital required by the intermediate firm in the production process is financed by an entrepreneur that belongs to the same business unit i. The balance sheet of the i^{th} entrepreneur is given by:

$$q_{i,t} K_{i,t} = L^{H}_{i,t} + N_{i,t}. \tag{B.7}$$

Defining $Q_{i,t}K_{i,t}$ as the amount of capital to be financed by entrepreneur i, $q_{i,t} = Q_{i,t}/P^{C}_{i,t}$ is the real shadow value of capital goods. This quantity $q_{i,t}K_{i,t}$ is financed by the entrepreneur through two means: its net wealth $N_{i,t}$ and the real amount borrowed from the banking system, $L^{H}_{i,t+1}$. Formally, loan demands are subject to external habits as follows: $L^{H}_{i,t} = L^{d}_{i,t} - h^{L}_{i}(L^{d}_{i,t-1} - \bar{L}^{d}_{i})$ with the habit degree $h^{L}_{i} \in [0,1)$, $L^{d}_{i,t-1}$ the aggregate average level of loans of the previous period and $\bar{L}^{d}_{i}$ the steady state stock of loans.[38] Empirically, firms and banks operating in the

[37] Goods packers are perfectly competitive and maximize profits, $P_{i,t}Y^{d}_{i,t} - \mathcal{G}(P_{i,t}(i)\,Y_{i,t}(i))$, under their packing technology constraint, $Y^{d}_{i,t} = [(1/n_i)^{1/\epsilon_P} \mathcal{G}(Y_{i,t}(i)^{(\epsilon_P-1)/\epsilon_P})]^{\epsilon_P/(\epsilon_P-1)}$. Here, $P_{i,t}$ is the production price, $Y^{d}_{i,t}$ is the aggregate demand (or the resource constraint) and ϵ_P is a substitution parameter. The first order condition which determines the optimal demand for the i^{th} good is, $Y_{i,t}(i) = (1/n_i)(P_{i,t}(i)/P_{i,t})^{-\epsilon_P} Y^{d}_{i,t}$, $\forall i$. Thus the aggregate price index of all varieties in the economy emerges from the zero-profit condition: $P_{i,t} = [(1/n_i)\mathcal{G}(P_{i,t}(i)^{1-\epsilon_P})]^{1/(1-\epsilon_P)}$.

[38] In the estimation exercise, we use the total stock of loans, they are of different maturities implying a strong autocorrelation. Simply by introducing loan demand habits, taking into account the high autocorrelation of loans

Euro Area choose longer debt maturities than the standard one-period contract usually used in real business cycle models. Then the term $h_i^L L_{i,t-1}^d$ allows for slow adjustment over time of the balance sheet constraint, to capture the idea that in practice borrowers do not readjust their outstanding amount of loans every quarter. This approach of introducing slow adjustment of credit is close to Iacoviello (2015), employed here in a context of a financial accelerator model. During phases of recession characterized by asset price collapses of $q_{i,t}$, this friction prevents the total stock of loans to fall at the same rate as the price of financial assets, thus making credit less procyclical consistently with empirical evidence. Since these habits don't directly affect the first order condition of the entrepreneur (as the overall problem of the entrepreneur can be expressed in terms of physical capital directly), their implications on entrepreneurs' profits is rather minor but large for financial intermediary facing a persistent demand for loans.

To introduce corporate cross-border lending, we follow Poutineau and Vermandel (2015) and Brzoza-Brzezina et al. (2015) by adopting a CES function that bundles domestic and foreign loans offered by banks operating in the monetary union:[39]

$$L_{i,t}^d = \left(\left(1-\alpha_i^L\right)^{1/\upsilon}\left(L_{hi,t}^d\right)^{(\upsilon-1)/\upsilon} + \left(\alpha_i^L\right)^{1/\upsilon}\left(L_{fi,t}^d\right)^{(\upsilon-1)/\upsilon}\right)^{\upsilon/(\upsilon-1)}. \tag{B.8}$$

Here, parameter $\upsilon \geq 0$ is the elasticity of substitution between domestic and foreign interbank funds, $\alpha_i^L \in [0, 1/2]$ represents the percentage of cross-border interbank loan flows in the monetary union and $L_{hi,t}^d$ (resp. $L_{fi,t}^d$) the amount of domestic (resp. foreign) loans demanded by borrowing entrepreneurs living in country i. As a consequence, the borrowing cost is a CES aggregate of home and foreign credit rates defined as: $1+P_{i,t}^L = ((1-\alpha_i^L)(1+R_{h,t}^L)^{1-\upsilon} + \alpha_i^L(1+R_{f,t}^L)^{1-\upsilon})^{1/(1-\upsilon)}$.

Regarding financial frictions, we reinterpret the financial accelerator *à la* Bernanke et al. (1999) from a banking perspective in order to have state-contingent lending rates needed to introduce macroprudential measures.[40] To do so, we follow the modelling device of Poutineau and Vermandel (2015) that provides a micro-foundation for the financial accelerator mechanism relying on biased expectations of entrepreneurs instead of a standard moral hazard problem. The investment projects undertaken by the entrepreneur are risky and differ with respect to their individual returns. To model individual riskiness, we borrow from Bernanke et al. (1999) and assume that each project has an individual return equal to $\omega\left(1+R_{i,t}^k\right)$, *i.e.* that the aggregate return of investment projects in the economy $1+R_{i,t}^k$ is multiplied by a random value ω. The representative entrepreneur conducts a mass ω of diversified investment projects and the profit of the ω^{th} investment project is given by:

$$\Pi_{i,t}^E(\omega) = \omega\mathbb{E}_t\left\{1+R_{i,t+1}^k\right\} q_{i,t}K_{i,t}(\omega) - \left(1+P_{i,t}^L\right)L_{i,t}^H(\omega), \tag{B.9}$$

becomes tractable easily and does not change the steady state of the model. For instance in 1999, loans with a maturity above one year represented 64% of the outstanding stock of loans in the Eurosystem.

[39] Kollmann et al. (2011) provides a complementary way of introducing cross-border lending through global banks. However, this approach assumes a perfect credit market intregration between Euro participants that is not consistent with the data. Alternatively, Dedola and Lombardo (2012) introduce cross-border loans through a portfolio problem that requires a second order approximation to the policy function, which poses an issue when putting the model to the data.

[40] The pathbreaking contribution of Bernanke et al. (1999) focuses on the demand side of credit market through a moral hazard problem but neglects its supply side and in turn the possibility to introduce macroprudential measures that could affect the macroeconomic outcome. Their model is closed assuming that lending rates are pre-determined.

In order to acquire a loan, entrepreneurs have to engage in a financial contract before the realization of ω.[41] After engaging in the financial contract, entrepreneurs recognize *ex post* the value of $\omega^C_{i,t}$ which separates the default space ($\omega < \omega^C_{i,t}$) from the space of gains ($\omega \geq \omega^C_{i,t}$). Thereby the *ex post* threshold separating the default space from the profitable space is computed trough the zero profit condition on Equation B.9:

$$\omega^C_{i,t}\left(1+R^k_{i,t}\right)q_{i,t-1}K_{i,t-1} = \left(1+P^L_{i,t-1}\right)L^H_{i,t-1}. \tag{B.10}$$

Following Helpman et al. (2004), we adapt the Pareto distribution to model the productivity of firms in a financial context. Investment projects are drawn from a Pareto distribution $\omega \sim \mathcal{P}(\kappa)$ with support $\omega \in [\omega_{\min}, +\infty)$ where $\kappa > 1$ is the shape parameter and $\omega_{\min} > 0$ is the lower bound of the distribution. Given the characteristics of the distribution, it is possible to compute the share of profitable projects, denoted $\eta^E_{i,t} = (\omega_{\min}/\omega^C_{i,t})^\kappa$, and their aggregate value, $\bar{\omega}_{i,t} = \kappa/(\kappa-1)\omega^C_{i,t}$.[42] When the entrepreneur is underwater with an investment project value below the cost of credit, she endogenously defaults on her loan and abandons her investment project.

To introduce a financial accelerator mechanism, we assume that entrepreneurs have short term distorted expectations regarding the aggregate profitability of their aggregate investment projects $\bar{\omega}_{i,t}$, thus creating a financial friction in the economy with dynamic properties close to Bernanke et al. (1999). The perceived *ex ante* value of profitable projects $\bar{\omega}_{i,t+1}$ is defined by the CES function:[43]

$$g\left(\bar{\omega}_{i,t+1}\right) = \bar{\omega}_i^{1/(1-\varkappa_i)}\left(\bar{\omega}_{i,t+1}\right)^{\varkappa_i/(\varkappa_i-1)}, \tag{B.11}$$

where $\varkappa_i \in [0,1)$ is the elasticity of the external finance premium and $\bar{\omega}_i$ is the steady state of $\bar{\omega}_{i,t+1}$. During phases of expansion characterized by high aggregate returns above the the steady state $\bar{\omega}_{i,t+1} > \bar{\omega}_i$, entrepreneurs' forecasts regarding the aggregate profitability are optimistic with $g\left(\bar{\omega}_{i,t+1}\right) > \bar{\omega}_{i,t+1}$. In contrast for low expected realizations of $\bar{\omega}_{i,t+1}$ below its steady state, entrepreneurs tend to hold pessimistic expectations about their returns with $g\left(\bar{\omega}_{i,t+1}\right) < \bar{\omega}_{i,t+1}$. Finally in steady state, there is no expectation bias, $g\left(\bar{\omega}_i\right) = \bar{\omega}_i$.[44] Any shock driving financial returns above or below the steady state will trigger an acceleration of the business cycles through these biased expectations for $\varkappa_i > 0$.

Aggregating all profitable investment projects (i.e. above $\omega^C_{i,t}$) that the entrepreneur does not abandon, it chooses a capital value of $K_{i,t}$ that maximizes its profit (before the realization of ω)

[41] The individual return ω is also referred as an idiosyncratic shock in the financial accelerator literature. The debt contract is conclude before the idiosyncratic shock is recognized which generates unexpected losses for the entrepreneurs and lenders.

[42] Using the characteristics of the Pareto distribution $F(\omega)$, the distribution of stochastic investment projects ω has a positive support, is independently distributed (across entrepreneurs and time) with unitary mean $E[\omega] = 1$, and density function $f(\omega)$. Investment projects above the cut-off value, $\omega > \omega^C_{i,t}$, have positive profits $\Pi^E_{i,t}(\omega) \geq 0$ which allows entrepreneurs to repay its loans to the bank. The share of profitable projects $1 - F(\omega)$ is computed as, $\eta^E = \Pr\left[\omega \geq \omega^C\right] = \int_{\omega^C}^{\infty} f(\omega)\mathrm{d}\omega = (\omega_{\min}/\omega^C)^\kappa$ while the conditional expectation of ω when entrepreneur's project is gainful is, $\eta^E\bar{\omega} = \int_{\omega^C}^{\infty}\omega f(\omega)\,d\omega$ with $\bar{\omega} = E\left[\omega|\omega \geq \omega^C\right] = \frac{\kappa}{\kappa-1}\omega^C$.

[43] There is a rich literature providing evidence that entrepreneurs are more optimistic compared to the general population; for some recent studies see, e.g., Landier and Thesmar (2009), Puri and Robinson (2013), Dawson and Henley (2013).

[44] It is important to stress that function $g\left(\bar{\omega}_{i,t+1}\right)$ only affects expected returns of $\mathbb{E}_t\left\{\bar{\omega}_{i,t+1}\right\}$, while for *ex post* values (*e.g.*, $\bar{\omega}_{i,t}$ and $\bar{\omega}_{i,t-1}$) the entrepreneur recorgnizes the true value of her return.

defined as:

$$\Pi^E_{i,t} = \mathbb{E}_t \left\{ \eta^E_{i,t+1} \left[g\left(\bar{\omega}_{i,t+1}\right) \left(1 + R^k_{i,t+1}\right) q_{i,t} K_{i,t} - \left(1 + P^L_{i,t}\right) L^H_{i,t} \right] \right\}. \tag{B.12}$$

Taking the first order condition combined with Equation B.10, the financial accelerator principle emerges through the external finance premium expression:

$$\frac{1 + R^k_{i,t+1}}{1 + P^L_{i,t}} = \frac{1}{\bar{\omega}_i} \left[\frac{\kappa}{\kappa - 1} \left(1 - \frac{N_{i,t}}{q_{i,t} K_{i,t}}\right) \right]^{\varkappa_i}. \tag{B.13}$$

Up to a first order, $\hat{r}^k_{i,t+1} - \hat{p}^L_{i,t} \simeq \varkappa_i(\hat{q}_{i,t} + \hat{k}_{i,t} - \hat{n}_{i,t})$, the spread is a positive function to the capital-to-net wealth ratio. Under this assumption, the balance sheet of borrowers affects the borrowing conditions and magnifies the financial cycle. The size of the accelerator is determined by the degree of bias $\varkappa_i$ of borrowers.

Finally, the law of motion of the net wealth is given by profit obtained at the end of period t-1:

$$N_{i,t} = \left(1 - \delta^E\right) \Pi^E_{i,t-1} \exp(\varepsilon^N_{i,t}), \tag{B.14}$$

where $\delta^E \in [0,1]$ is the net wealth decay that is related to the default rate of entrepreneur (endogenously determined in steady state) and $\varepsilon^N_{i,t}$ is an AR(1) shock to the net wealth of entrepreneurs which captures exogenous variations in stock prices and the demand for loans.

Appendix B.4. Capital goods producers

The capital producer rents and refurbishes the capital stock used by intermediate firms and financed by the entrepreneurs on a competitive market. The law of motion of physical capital is determined by:

$$K_{i,t} = \left(1 - S((\exp(\varepsilon^I_{i,t}) I_{i,t}/I_{i,t-1})\right) I_{i,t} + (1 - \delta) K_{i,t-1}, \tag{B.15}$$

where $\varepsilon^I_{i,t}$ is a stochastic process which captures exogenous changes in asset price fluctuations and the adjustment cost function taken from Smets and Wouters (2007) reads as: $S(x_t){=}\chi^I_i(x_t - 1)^2$ with $\chi^I_i \geq 0$ is the adjustment cost. In addition, investment is composed of domestic and foreign goods summarized by a CES function:

$$I_{i,t} = (\left(1 - \alpha^I_i\right)^{1/\mu} I^{(\mu-1)/\mu}_{hi,t} + \left(\alpha^I_i\right)^{1/\mu} I^{(\mu-1)/\mu}_{fi,t})^{\mu/(\mu-1)}, \tag{B.16}$$

where parameter μ is the elasticity of substitution between domestic and foreign goods in investment and α^I_i measures the degree of investment diversification in the monetary union between home and foreign countries. The corresponding price index of investment is, $P^I_{i,t} = (\left(1 - \alpha^I_i\right) \left(P_{h,t}\right)^{1-\mu} + \alpha^I_i \left(P_{f,t}\right)^{1-\mu})^{1/(1-\mu)}$.

The representative capital supplier chooses $I_{i,t}$ to maximize its real discounted profits:

$$\max_{\{I_{i,t}\}} \mathbb{E}_t \sum\nolimits_{s=0}^{\infty} \Lambda_{i,t+s} \left(q_{i,t+s} \left(1 - S(\exp(\varepsilon^I_{i,t}) I_{i,t}/I_{i,t-1})\right) - p^I_{i,t+s}\right) I_{i,t+s}, \tag{B.17}$$

where $q_{i,t} = Q_{i,t}/P^C_{i,t}$ stands for the real shadow value of investment goods and $p^I_{i,t} = P^I_{i,t}/P^C_{i,t}$ is the relative price of investment goods.

Finally regarding capital utilization, the optimal rate of utilization is given by:[45]

$$a'(u_{i,t}) = Z_{i,t}, \quad \text{with } a(u_{i,t}) = \bar{Z}(u_{i,t}-1) + 0.5\psi_i/(1-\psi_i)\bar{Z}(u_{i,t}-1)^2, \tag{B.18}$$

where $\psi_i \in (0,1)$ is the elasticity of utilization costs with respect to capital inputs. As in Smets and Wouters (2003, 2007), capital requires one period to be settled so that utilized capital is defined as, $K^u_{i,t} = u_{i,t}K_{i,t-1}$.

Appendix B.5. Monetary and fiscal policy

National governments finance public spending by charging lump-sum taxes to households $t_{i,t}$. The total amount of taxes finance public spending without contracting public debt such that the public budget is always balanced. As in Smets and Wouters (2003, 2007), the level of spending $G_{i,t}$ is exogenously determined as a constant fraction of output $g\bar{Y}\exp(\varepsilon^G_{i,t})$, where $g\bar{Y}$ is the fix component and $\varepsilon^G_{i,t}$ is the time-varying component of spending that follows a standard AR(1) shock process. Parameter $g \in [0,1)$ is the steady state spending-to-GDP ratio. It is important to mention that we omit seigniorage revenues that could be given to fiscal authorities as their inclusion generates an explosive path of deposits.[46] This could be a limitation of our model, however Leeper (1991) indicates seigniorage represents a small fraction of government revenues for developed economies thus showing that its omission does not seem to be important for the analysis conducted here.

Concerning federal monetary policy, the general expression of the interest rule implemented by the monetary union central bank follows the linear rule:

$$R_t - \bar{R} = \rho\left(R_{t-1} - \bar{R}\right) + (1-\rho)\left(\phi^\pi \pi^C_t + \phi^{\Delta y}(Y_t - Y_{t-1})\right) + \varepsilon^R_t, \tag{B.19}$$

where ε^R_t is a monetary policy shock common to the monetary union members, $\phi^\pi \geq 1$ is the inflation target parameter, $\phi^{\Delta y}$ is the GDP growth target. As monetary policy responds to the aggregate evolution of inflation and activity in the monetary union, recall that $\pi^C_t = n_c\pi^C_{c,t} + n_p\pi^C_{p,t}$ and $Y_t = n_cY_{c,t} + n_pY_{p,t}$.

Appendix B.6. Stochastic shock processes

To be in line with the benchmark model of Smets and Wouters (2003) for the Euro Area, all our random processes follows an AR(1) specification. Each part of the Eurozone includes 10 country-specific shocks for $s = \{A, G, U, I, P, W, N, D, B, L\}$ such that:

$$\varepsilon^s_{i,t} = \rho^s_i \varepsilon^s_{i,t-1} + \eta^s_{i,t} \text{ with } \eta^s_{i,t} \sim N(0, \sigma^s_i). \tag{B.20}$$

Finally both part of the monetary union are affected by a common monetary policy shock in Equation B.19 defined as, $\varepsilon^R_t = \rho^R\varepsilon^R_{t-1} + \eta^R_t$ with $\eta^R_t \sim N(0,\sigma^R)$. Markups shocks for $m = \{P, W, D\}$ are normalized to one, as implicitly assumed in Smets and Wouters (2003), by dividing their stochastic innovations η^m_{it} by the elasticity of the linear New Keynesian Phillips curve, (1-$\beta\theta^m_i$)(1-θ^m_i)/θ^m_i.

[45] When households do not take capital supply decisions, the optimal capital utilization is determined by, $\max_{u_{i,t}}\left(Z_{i,t}u_{i,t} - a(u_{i,t})\right)K_{i,t}$.

[46] This assumption is common for recent macroeconomic models as underlined by Curdia and Woodford (2011). We refer to Gerali et al. (2010) or Adam (2011) for macro-models without seignioriage.

Appendix B.7. Aggregation and market clearing

The general equilibrium of the model is set as follows. After (i) aggregating all agents and varieties in the economy, (ii) imposing market clearing for all markets, (iii) substituting the relevant demand functions, (iv) normalizing the total size of the monetary union $(n_c + n_p = 1)$ such that the size of the core area is n and the peripheral area size is $1 - n$, we get the general equilibrium conditions of the model. We can express the aggregation function of variable $X_t(x)$ as: $\mathcal{G}(X_{i,t}(x)) = \int_0^n X_{i,t}(x)\mathrm{d}x$ for $i = c$ and $\mathcal{G}(X_{i,t}(x)) = \int_n^1 X_{i,t}(x)\mathrm{d}x$ for $i = p$.

Thus, replacing the demand functions of foreign and home goods (consumption and investment), we finally obtain the home final goods market equilibrium:

$$\begin{aligned}
Y_{c,t}/\Delta^P_{c,t} = & \left(1-\alpha^C_c\right)\left[P_{c,t}/P^C_{c,t}\right]^{-\mu} C_{c,t} + \left(1-\alpha^I_c\right)\left[P_{c,t}/P^I_{c,t}\right]^{-\mu} I_{c,t} \\
& + (1-n)/n\left(\alpha^C_p\left[P_{c,t}/P^C_{p,t}\right]^{-\mu} C_{p,t} + \alpha^I_p\left[P_{c,t}/P^I_{p,t}\right]^{-\mu} I_{p,t}\right) \\
& + a\left(u_{c,t}\right) K_{c,t-1} + g\bar{Y}\exp(\varepsilon^G_{c,t}) + AC^D_{c,t}\ ,
\end{aligned} \tag{B.21}$$

where $\Delta^P_{i,t} = \mathcal{G}\left(P_{i,t}(i)/P_{i,t}\right)^{-\epsilon_P}$ denotes the price dispersion term, which is induced by the assumed nature of price stickiness.

Concerning the corporate loan market, recall that entrepreneurs borrow to domestic and foreign banks with varieties b produced by liquid illiquid banks, leading to the following equilibrium for each country:

$$\begin{aligned}
L^s_{c,t}/\Delta^L_{c,t} = & \left(1-\alpha^L_c\right)\left[(1+R^L_{c,t})/(1+P^L_{c,t})\right]^{-\nu} L_{c,t} \\
& + n/(1-n)\alpha^L_p\left[(1+R^L_{c,t})/(1+P^L_{p,t})\right]^{-\nu} L_{p,t},
\end{aligned} \tag{B.22}$$

where $\Delta^L_{i,t}$ is the credit rate dispersion term.

Turning to the interbank market, the perfect competition involves no interest rate dispersion between loan varieties. It clears when the following condition between liquid banks and home and foreign illiquid banks holds:

$$\begin{aligned}
IB^s_{c,t}(1-\lambda)/\lambda = & \left(1-\alpha^{IB}_c\right)\left[(1+R^{IB}_{c,t})/(1+P^{IB}_{c,t})\right]^{-\xi} IB^d_{c,t} \\
& + n/(1-n)\alpha^{IB}_p\left[(1+R^{IB}_{c,t})/(1+P^{IB}_{p,t})\right]^{-\xi} IB^d_{p,t}
\end{aligned} \tag{B.23}$$

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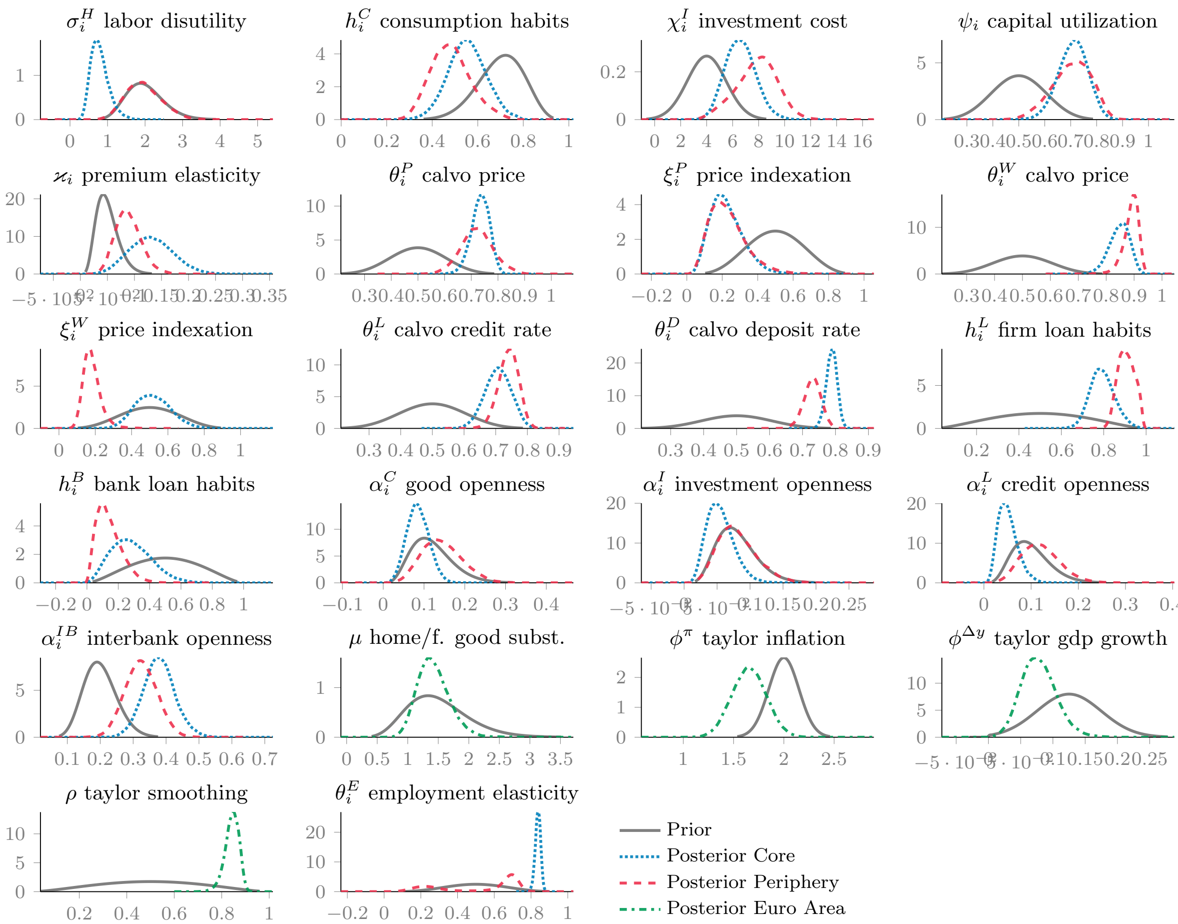

Figure B.6: Prior and posterior distributions of structural parameters.

Table B.7
Prior and Posterior distributions of structural parameters and shock processes.

	Parameter	Prior distributions	Posterior distribution [5%:95%]					
		Shape[mean;std]	CORE		PERIPHERY		EURO	
		SHOCK STANDARD DEVIATIONS						
σ_i^A	Productivity	$\mathcal{IG}$[0.10,2.00]	0.82	*[0.64:1.00]*	0.79	*[0.43:1.11]*	-	
σ_i^G	Government spending	$\mathcal{IG}$[0.10,2.00]	1.43	*[1.20:1.65]*	1.39	*[1.15:1.63]*	-	
σ_i^U	Preferences	$\mathcal{IG}$[0.10,2.00]	1.24	*[0.76:1.73]*	1.52	*[0.98:2.06]*	-	
σ_i^I	Investment costs	$\mathcal{IG}$[0.10,2.00]	2.55	*[1.83:3.26]*	2.57	*[1.78:3.47]*	-	
σ_i^P	Firms markup	$\mathcal{IG}$[0.10,2.00]	0.10	*[0.06:0.14]*	0.29	*[0.17:0.41]*	-	
σ_i^W	Unions markup	$\mathcal{IG}$[0.10,2.00]	0.45	*[0.33:0.57]*	0.71	*[0.58:0.85]*	-	
σ_i^N	Firms net wealth	$\mathcal{IG}$[0.10,2.00]	0.36	*[0.28:0.45]*	0.37	*[0.26:0.47]*	-	
σ_i^D	Deposit markdown	$\mathcal{IG}$[0.10,2.00]	0.30	*[0.23:0.37]*	0.64	*[0.48:0.79]*	-	
σ_i^B	Bank liabilities	$\mathcal{IG}$[0.10,2.00]	5.89	*[4.63:7.10]*	9.75	*[7.95:11.57]*	-	
σ_i^L	Credit markup	$\mathcal{IG}$[0.10,2.00]	2.31	*[1.78:2.81]*	2.09	*[1.61:2.57]*	-	
σ^R	Monetary policy	$\mathcal{IG}$[0.10,2.00]	-		-		0.09	*[0.07:0.10]*
		SHOCK PROCESS AR(1)						
ρ_i^A	Productivity	$\mathcal{B}$[0.50,0.20]	0.98	*[0.97:0.99]*	0.96	*[0.91:1.00]*	-	
ρ_i^G	Government spending	$\mathcal{B}$[0.50,0.20]	0.87	*[0.82:0.93]*	0.63	*[0.44:0.82]*	-	
ρ_i^U	Preferences	$\mathcal{B}$[0.50,0.20]	0.29	*[0.08:0.49]*	0.82	*[0.67:0.96]*	-	
ρ_i^I	Investment costs	$\mathcal{B}$[0.50,0.20]	0.79	*[0.70:0.88]*	0.68	*[0.50:0.90]*	-	
ρ_i^P	Firms markup	$\mathcal{B}$[0.50,0.20]	0.99	*[0.99:1.00]*	0.76	*[0.54:0.95]*	-	
ρ_i^W	Unions markup	$\mathcal{B}$[0.50,0.20]	0.49	*[0.21:0.77]*	0.16	*[0.02:0.30]*	-	
ρ_i^N	Firms net wealth	$\mathcal{B}$[0.50,0.20]	0.86	*[0.81:0.90]*	0.91	*[0.87:0.95]*	-	
ρ_i^D	Deposit markdown	$\mathcal{B}$[0.50,0.20]	0.88	*[0.84:0.93]*	0.90	*[0.84:0.95]*	-	
ρ_i^B	Bank liabilities	$\mathcal{B}$[0.50,0.20]	0.94	*[0.90:0.99]*	0.96	*[0.93:0.99]*	-	
ρ_i^L	Credit markup	$\mathcal{B}$[0.50,0.20]	0.71	*[0.55:0.86]*	0.68	*[0.54:0.82]*	-	
ρ^R	Monetary policy	$\mathcal{B}$[0.50,0.20]	-		-		0.36	*[0.25:0.48]*
		INTERNATIONAL SHOCK CORRELATION						
$corr_t^A$	Productivity	$\mathcal{N}$[0.20,0.20]	-		-		0.20	*[0.01:0.40]*
$corr_t^G$	Government spending	$\mathcal{N}$[0.20,0.20]	-		-		0.13	*[-0.06:0.33]*
$corr_t^U$	Preferences	$\mathcal{N}$[0.20,0.20]	-		-		0.07	*[-0.12:0.26]*
$corr_t^I$	Investment costs	$\mathcal{N}$[0.20,0.20]	-		-		0.45	*[0.28:0.63]*
$corr_t^P$	Firms markup	$\mathcal{N}$[0.20,0.20]	-		-		0.28	*[0.10:0.47]*
$corr_t^W$	Unions markup	$\mathcal{N}$[0.20,0.20]	-		-		0.24	*[0.08:0.42]*
$corr_t^N$	Firms net wealth	$\mathcal{N}$[0.20,0.20]	-		-		0.33	*[0.15:0.51]*
$corr_t^D$	Deposit markdown	$\mathcal{N}$[0.20,0.20]	-		-		0.68	*[0.56:0.81]*
$corr_t^B$	Bank liabilities	$\mathcal{N}$[0.20,0.20]	-		-		0.00	*[-0.21:0.22]*
$corr_t^L$	Credit markup	$\mathcal{N}$[0.20,0.20]	-		-		0.81	*[0.72:0.90]*
		STRUCTURAL PARAMETERS						
σ_i^H	Labour disutility	$\mathcal{G}$[2.00,0.50]	0.79	*[0.41:1.15]*	1.96	*[1.17:2.73]*	-	
h_i^C	Consumption habits	$\mathcal{B}$[0.70,0.10]	0.55	*[0.42:0.69]*	0.48	*[0.34:0.62]*	-	
θ_i^P	Calvo price	$\mathcal{B}$[0.50,0.10]	0.72	*[0.67:0.78]*	0.72	*[0.62:0.82]*	-	
ξ_i^P	Price indexation	$\mathcal{B}$[0.50,0.15]	0.22	*[0.08:0.37]*	0.23	*[0.07:0.38]*	-	
θ_i^W	Calvo wage	$\mathcal{B}$[0.50,0.10]	0.85	*[0.79:0.91]*	0.89	*[0.85:0.93]*	-	
ξ_i^W	Wage indexation	$\mathcal{B}$[0.50,0.15]	0.51	*[0.35:0.67]*	0.18	*[0.10:0.25]*	-	
θ_i^E	Employment elasticity	$\mathcal{B}$[0.50,0.10]	0.84	*[0.81:0.86]*	0.52	*[0.18:0.74]*	-	
θ_i^L	Calvo credit rate	$\mathcal{B}$[0.50,0.10]	0.71	*[0.64:0.78]*	0.74	*[0.69:0.79]*	-	
θ_i^D	Calvo deposit rate	$\mathcal{B}$[0.50,0.10]	0.79	*[0.76:0.81]*	0.73	*[0.69:0.77]*	-	
χ_i^I	Investment costs	$\mathcal{N}$[0.50,1.50]	6.59	*[4.63:8.41]*	7.83	*[5.08:10.3]*	-	
ψ_i	Utilization elasticity	$\mathcal{B}$[0.50,0.10]	0.71	*[0.62:0.80]*	0.70	*[0.58:0.82]*	-	
$\varkappa_i$	External finance elasticity	$\mathcal{B}$[0.05,0.02]	0.13	*[0.06:0.19]*	0.09	*[0.05:0.13]*	-	
h_i^L	Loan demand habits	$\mathcal{B}$[0.50,0.20]	0.79	*[0.70:0.89]*	0.91	*[0.85:0.97]*	-	
h_i^B	Interbank habits	$\mathcal{B}$[0.50,0.20]	0.28	*[0.07:0.48]*	0.14	*[0.02:0.26]*	-	
α_i^C	Goods market openness	$\mathcal{B}$[0.12,0.05]	0.08	*[0.04:0.13]*	0.14	*[0.07:0.22]*	-	
α_i^I	Inv. market openness	$\mathcal{B}$[0.08,0.03]	0.05	*[0.02:0.09]*	0.08	*[0.03:0.13]*	-	
α_i^L	Credit market openness	$\mathcal{B}$[0.10,0.04]	0.05	*[0.02:0.08]*	0.12	*[0.05:0.18]*	-	
α_i^B	Interbank openness	$\mathcal{B}$[0.20,0.05]	0.38	*[0.30:0.46]*	0.32	*[0.24:0.4]*	-	
μ	Substitutability goods	$\mathcal{G}$[1.50,0.50]	-		-		1.42	*[0.99:1.83]*
ρ	MPR smoothing	$\mathcal{B}$[0.50,0.20]	-		-		0.84	*[0.80:0.89]*
ϕ^π	MPR inflation	$\mathcal{N}$[2.00,0.15]	-		-		1.65	*[1.37:1.92]*
$\phi^{\Delta y}$	MPR GDP growth	$\mathcal{N}$[0.12,0.05]	-		-		0.08	*[0.03:0.12]*
	Marginal log-likelihood				-1199.2			

NOTE: $\mathcal{IG}$ denotes the Inverse Gamma distribution, $\mathcal{B}$ the Beta, $\mathcal{N}$ the Normal, $\mathcal{G}$ the Gamma.