The Effects of an Homogenous Unconventional Monetary Policy on a Financially Heterogeneous Monetary Union (Preliminary version)*

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Abstract

This paper provides a two-country DSGE model to analyze the consequences of homogenous non-conventional monetary policy decisions on an heterogeneous monetary union. In our setting heterogeneity arises endogenously from an occasionally binding credit constraint that generates a regional credit disruption in the peripheral part of the union. Our main results are twofold: First, we find that cross border lending plays an ambiguous role for transmitting a regional financial stress arising in the periphery to the global EMU level as it affects national situations in opposite directions. For the calibrated value adopted in our setting we find that it improved the global situation of the eurozone. Second, we find that the conduct of credit policy unambiguously improves the situation of the monetary union, albeit with differing consequences on national economies. Unsurprisingly, a homogenous credit policy leads to a second best situation with respect to unconventional policy measures targeting directly national situations in terms of financial stress. However, we find that most of the difference disappear for a value of cross-border lending neighboring 30% of total loan distribution at the monetary union level.

1 Introduction

The 2007 financial crisis had a strong overall impact on the eurozone, furthermore unveiling the size of financial heterogeneity between members. As reported by Ciccarelli et al (2013), a considerable degree of country heterogeneities has been observed at the disaggregated level in terms of credit developments, financial fragility of borrowers and lenders, sovereigns and real activity. This heterogeneous environment has framed the transmission of the unconventional monetary policy decisions, adopted by the ECB since the onset of the crisis to avoid a crude disruption of the European credit market .

Considering the Eurozone as a whole, the ECB mostly focused on union-wide macroeconomic and financial developments while neglecting the aforementioned national heterogeneities. As underlined by Buriel and Galesi (2017), even if the macroeconomic and financial effects of the ECB's unconventional monetary policies between 2007 and 2015 have had beneficial effects on aggregate output and inflation, a substantial degree of heterogeneity has been observed between the 19 countries participating to the European Monetary Union (EMU). In particular, they find that countries with less fragile banking systems benefited the most from unconventional monetary policies

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in terms of output gains while the effects were smaller in those countries which were mostly affected by the crisis such as Portugal, Greece and Spain.

The aim of this paper is to analyze the heterogeneous consequences of homogenous unconventional policy measures undertaken by the ECB to fight the financial disruption that affected the eurozone at the beginning of the crisis. We provide a two country DSGE model that accounts for cross border lending relations as a major source of spillovers between eurozone members. In line with the stylized facts, we describe a situation where some peripheral countries of the monetary union were mostly affected by an initial stress. This phenomenon - that arises endogenously following exogenous financial shocks - is characterized by a lending disruption implying a fall in loan distribution and a sharp increase in interest rate spreads needed to balance the loan market. In our setting this credit disruption is transmitted to the rest of the eurozone through cross border bank relations. On the policy side we combine a conventional monetary policy based on the steering of a short run interest rate with a state dependent credit policy aiming at providing liquidity to the banking sector to avoid a disruption in credit supply. We assess the global macroeconomic and welfare consequences of the unconventional part of monetary policy by contrasting its effects to a first best situation where credit policy action would have been conducted owing the particular situation of each part of the eurozone.

To build this model, we draw on different strands of the literature. First, regarding the modeling of financial factors, we extend the paper of Cargoët and Poutineau (2018) - that provides a mechanism explaining the endogenous creation of financial disruption in loan creation - to a two country world. This model contrasts normal times (where financial frictions give rise to an accelerator phenomenon on investment) with crisis times as described by Gertler and Karadi (2011). Our extension of the financial accelerator mechanism to a two country framework is based on Dedola, Karadi and Lombardo (2013). We approach heterogeneity in the eurozone in a standard way by distinguishing between core and peripheral countries - the latter group encompassing major stressed countries. On the policy side, we combine conventional and unconventional monetary policy instruments. Conventional monetary policy is described as a simple interest rule in the spirit of Taylor (1993) while unconventional policy is based on Gertler and Karadi (2011) and is related to a situation where the provision of loans falls short with respect to loan demand. As in Cargoët and Poutineau (2018) the length of this policy action is endogenously determined in the model.

Our analysis mostly focuses on two related questions regarding the consequences of applying homogenous unconventional monetary policy measures on an heterogeneous group of countries sharing a common currency. First, we assess how the financial connection of national banking systems - through cross border lending flows - shapes the transmission of asymmetric financial and real shocks. Second we evaluate the effect of a credit policy, using the benchmark of a first best situation where policy actions could target each country's financial system independently.

As a theoretical contribution our analysis underlines the ambiguous role of cross border lending for transmitting a regional financial stress arising in the periphery to the global EMU level, as it affects national situations in

opposite directions. For countries affected by a financial disruption it improves the situation through the import of loans while it deteriorates the situation of countries that were initially not affected directly by a financial disruption. Owing to these opposite national reactions, the net effect of cross border lending on union wide aggregates rests on an optimal degree of loan market integration. However, we find that there exists an optimal level of financial integration for which the net effects of financial shocks are minimized for the Eurozone as whole.

As a policy contribution our analysis studies the heterogeneous effects of an homogenous policy on an heterogeneous monetary union. We find that the conduct of credit policy unambiguously improves the situation of the monetary union, albeit with differing consequences on core and peripheral economies. Unsurprisingly, we find that in most situations, a common credit policy leads to a second best situation with respect to unconventional policy measures targeting directly national situations in terms of financial stress.

The rest of the paper is organized as follows: Section 2 presents the background of the paper. Section 3 presents the baseline component of the model. Section 4 describes the financial component of the model. Section 5 analyses the transmission of financial and supply shocks between countries depending on the size of cross border bank relations. Section 6 discusses the conduct of unconventional monetary policy and assess the consequences coming from the heterogeneous situation of participating countries. Section 7 concludes.

2 Background of the paper

2.1 Stylized facts and Institutional background

Figure 1 reports the value of the Composite Indicator of Systemic Stress (CISS) published by the ECB (see Holo et al, 2012), for 7 main eurozone countries (France, Germany, Greece, Ireland, Italy, Portugal, Spain) between January 2000 and December 2017.[1] As underlined by the sharp rise of this index in 2007 the financial crisis that originated in the United States transmitted quickly and sharply to the eurozone as a whole. However, after a few quarters, this index began to decrease significantly for France and Germany, while increasing furthermore for countries belonging to the periphery of the eurozone.

The period of high financial stress between September 2007 and June 2009 corresponds to the bank crisis. During this period, banks suffered strong losses in the asset part of their balance sheet, so they dramatically decreased both the amount of loans granted to the non banking sector and their interbank lending, which created a vicious circle of financial stress increase and loan shortages until the massive intervention of the ECB. The second period of high financial stress that began in september 2009 corresponds to the sovereign debt crisis phase. Having suffered high public deficits in the first period of the financial crisis, as their governments had to borrow massively in order to

[1]The CISS captures the systemic dimension of financial instability. It is composed of 5 stress subindexes on 5 market segments, each of one targeting a different channel by which the funds of savers are reallocated to borrowers. The segments include: (1) money market; (2) bond market; (3) equity market; (4) financial intermediaries; (5) foreign exchange markets. The aggregation takes into account the time-varying cross-correlations between the subindices, in the same way that portfolio risk is computed from individual asset risks. As a result, the CISS puts more weight on situations in which stress prevails in several market segments at the same time.

address the real consequences of the bank crisis, european countries were subject to a serious increase of their debt ratio. As a consequence, confidence on their debt sustainability began to drop, increasing their difficulties to raise funds at an affordable cost, thus creating another vicious circle on public debt this time.

Two groups of countries clearly emerge from Figure 1. Although core and peripheral countries seem to have suffered the initial phase of the financial crisis (i.e the bank crisis) with a similar strength, financial stress during the debt crisis period that followed directly the bank crisis in september 2009 was clearly much more pronounced for peripheral countries. Indeed, suffering from a weakest financial sector, peripheral governments had to raise more funds as they faced higher deficits following the bank crisis, which increased their debt ratio more than those of core countries, thus introducing a real asymmetry in their respective ability to raise funds.

The heterogenous situation of eurozone countries can further be illustrated by Figure 2. In line with Gertler and Karadi (2011), we can approach the financial stress in a concrete manner through the spread between the short-term interest rate on loans to corporations and the main refinancing operation rate. During the financial crisis, the banking sector shortened loan supply for liquidity reasons, thus introducing a disconnection between policy and market rates. Figure 2 displays a mean of this interest-rate spread for the two groups of countries considered before, between january 2003 and december 2017. During the bank crisis period, we observe an increase in the spread for both core and peripheral countries: As financial stress increased, banks restricted their supply of loans, which induced an increase in the cost of credit to adjust the credit demand with the decreasing supply. In periods of very high financial stress, we observe a growing decorrelation between the policy rates and the market rates, under which conventional monetary policy tools become ineffective.

During the first period of the financial crisis (i.e the bank crisis), the increase in the interest rate spread was symmetric for core and peripheral countries, reflecting the symmetric increase in financial stress between this two groups already observed in Figure 1. However, in september 2009 we observe a growing asymmetry between core spreads, stabilized, and peripheral spreads, continuing to increase. The asymmetric path of interest rate spreads reflects the asymmetric effects of the debt crisis between the two groups of countries. Indeed, as peripheral countries, subject to a higher debt ratio, encountered difficulties to raise funds at an affordable price, the resulting financial stress had also an impact on the availability of credit to firms, which leaded to an increase of the interest rate spread characterized by high levels of financial stress in the EMU countries, which generated loan shortages that strongly affected real economy. However, some countries were far more affected than others.

Even if the ECB maintained a conventional monetary policy based on short run interest rate control until 2014, it introduced unconventional monetary measures at the onset of the financial crisis partly in reaction to this decorrelation between interest rate on loans and the policy rate, which decreased the efficiency of conventional monetary policy tools. Decisions of the ECB can be divided into three categories: The large-scale asset purchases programmes (quantitative easing), the lending facilities, and the forward guidance. Figure 3 represents the evolution of the European Central Bank's balance sheet and its components between january 2000 and december 2017. It

clearly appears from the figure that the two main sources of the wide increase in the ECB's balance sheet since 2008 are the lending to euro area credit institutions related to monetary policy operations, and the purchase of securities from euro residents.

The strong increase in securities of euro residents held by the ECB is a consequence of the expanded asset purchase programme (APP) undertaken since July 2009. This expanded asset purchase programme includes a variety of asset purchase programmes under which public and private sector securities are purchased, in order to inject liquidity into the banking system. In the beginning of 2018, assets held by the ECB as part of the APP are public sector securities (for the biggest part), corporate bonds, asset-backed securities and covered bonds. Lending to euro area credit institutions related to monetary policy operations encompasses both short term refinancing operations (main refinancing operations) and longer-term refinancing operations (LTROs). The strong increase of lending to credit institutions is a consequence of the large increase in LTROs since 2007, used by the European Central Bank as a monetary policy tool to offer long-term funding at attractive conditions to banks in order to stimulate bank lending to the real economy. Credit policy in this model is largely inspired by Gertler and Karadi (2011), and is more suited to capture the large scale asset purchase programme than it is to capture LTROs, so we will focus on the APP component of the ECB's quantitative easing.

The ECB adapted its monetary policy to introduce unconventional tools, but maintained a key element of its status, namely to operate in a way that considers the EMU as an homogenous region despite the clear heterogeneous situation of countries belonging to the eurozone. As a consequence, asset purchases for monetary policy purposes are always equally divided between the different eurozone's countries, forbidding the ECB to locally adjust its policy to country specific economic and financial factors.

2.2 Relation to the literature

Our analysis evaluates the conduct of unconventional monetary policy decisions in a monetary union with an heterogenous financial situation using a two country DSGE model. In this model the financial crisis affects initially a part of the monetary union - the peripheral countries - and transmits to the other part of the monetary union - the core countries - through cross border banking spillovers. As the existing literature offers multiple modeling solutions regarding three key aspects of the analysis - the crisis experiment, the cross border banking relations and the nature of the unconventional monetary policy - we had to make choices so as to keep the model simple to assess the question at hands while capturing the main features of the problem.

First, the crisis experiment corresponds to a credit disruption in one part of the monetary union - the peripheral country group - following a financial shock affecting the soundness of the banking system. This crisis situation implies a sharp increase in lending rate required to balance the local credit market is contrasted with "normal times" where lending rates are set on the basis of the official policy rate and the amount of loans is determined by the need of the producing sector of the economy. In normal times the financial part of the model corresponds to the

BGG (1999) model, with an accelerator phenomenon for entrepreneurs. In crisis times, our model accounts for the situation described by Gertler and Karadi (2011) and the amount of loans provided to the economy is constrained by the reduced resources of the banking system. The length of the crisis is endogenously determined in our model. This focus is in line with Foerster (2015), who uses a Markov-Switching DSGE model with fixed transition probabilities between crisis and non-crisis regimes. However, we do not impose a fixed probability of transition between regimes (that would make the length of the crisis exogenous), but we combine two opposite regimes along the lines of Cargoët and Poutineau (2018) using the approach of transitory binding constraints introduced in Guerrieri and Iacoviello (2015).

Second we consider the transmssion of the financial crisis from peripheral to core countries through the cross border bank lending channel. This channel played a critical role during the international transmission of the crisis in the eurozone (Cicarelli and al. (2013)) revealing a troubled aspect of financial integration. The existing literature provides different ways for modelling this aspect. Dedola et al. (2013) show how financial integration makes bank balance sheet constraints highly correlated across countries. They account for cross border banking relations both for the assets component and for the liabilities component (deposits). However, building on the evidence conveyed by Poutineau and Vermandel (2015), we abstract for the deposit side and concentrate on cross border lending between banks and entrepreneurs. To keep the model tractable we leave aside interbank liquidity aspects covered in the model of Poutineau and Vermandel (2015) and we only concentrate on cross border investment loans. We only concentrate on cross border lending at the entrepreneur level by outlining the channel of transmission to investment and activity, that penalized the eurozone. In contrast, Schwanenbeck (2017) concentrates on the interbank market which allows him to assess two aspects of unconventional monetary policy, depending on the level of intervention.

Third, turning to the conduct of unconventional policy we extend the approach of Cargoët and Poutineau (2018) to the open economy. We consider that such policy measures are only transitory and are related to the particular situation of the financial sector traped in a quantitative disruption of loan supply. Putting aside its transitory nature, the solution adopted to describe the unconventional policy decision is standard to the literature and is similar to Gertler and Karadi (2011) and Dedola et al. (2013). Unconventional monetary policy is modelled as an expansion of Central Bank credit intermediation needed to offset a disruption of private financial intermediation and improve the economic situation.

3 Baseline model

We consider a two-country model of a monetary union. Each economy is populated by households, intermediate and final firms and capital suppliers. As in Gertler and Karadi (2011), households are made of workers and bankers (workers supply labor to firms, consume and save, while bankers manage financial intermediaries), firms are made of intermediate and final sectors (the intermediate sector produces intermediate goods using capital and labor,

while final firms produce final goods by combining intermediate goods and set sticky prices for these goods that are consumed by households and invested by intermediate firms), capital is provided by capital suppliers. The role of entrepreneurs will be presented in the next section (financial part of the model).

3.1 Households

The number of households in each economy is normalized to 1. The representative household $j \in [0,1]$ in economy i is made of two parts: a fraction $(1-f_i)$ of the household consumes, supply labor services and saves, while a fraction f_i acts as a banker. Each period a fraction $(1-\theta_i)$ of bankers (thus $(1-\theta_i)f_i$ individuals) become workers while an equivalent number of workers become bankers, to maintain a constant proportion between the two components. New bankers are endowed with an initial amount of wealth. We define $C_{i,t}(j) = \left[\left(1-\alpha_i^C\right)^{\frac{1}{\mu_i^C}} \left(C_{i,h,t}(j)\right)^{\frac{\mu_i^C-1}{\mu_i^C}} + \left(\alpha_i^C\right)^{\frac{1}{\mu_i^C}} \left(C_{i,f,t}(j)\right)^{\frac{\mu_i^C-1}{\mu_i^C}}\right]^{\frac{\mu_i^C}{\mu_i^C-1}}$ as the consumption bundle of household j from country i, with $C_{i,h,t}(j) = \left(1-\alpha_i^C\right)\left(\frac{P_{h,t}}{P_{i,t}^C}\right)^{-\mu_i^C} C_{i,t}(j)$ the consumption of home good and $C_{i,f,t}(j) = \alpha_i^C \left(\frac{P_{f,t}}{P_{i,t}^C}\right)^{-\mu_i^C} C_{i,t}(j)$ the consumption of foreign good by the household j from country i. α_i^C is the degree of home bias in the decisions of consumption from households of country i (with $\alpha_h^C = 1-\alpha_f^C < \frac{1}{2}$), μ_i^C is the elasticity of substitution between consumption goods, and $P_{i,t}^C = \left[\left(1-\alpha_i^C\right)P_{h,t}^{1-\mu_i^C} + \alpha_i^C P_{f,t}^{1-\mu_i^C}\right]^{\frac{1}{1-\mu_i^C}}$ is the aggregate price for consumption goods, with $P_{h,t}$ (resp. $P_{f,t}$) the price of the home (resp. foreign) good.

Following Dedola, Karadi and Lombardo (2012), we consider two types of risk-free assets: deposits ($D_{i,t}(j)$), held by banks and bonds $B_{i,t}(j)$ traded between the households of each country, in zero net supply ($B_{h,t}+B_{f,t}=0$). Defining $H_{i,t}(j)$ as the supply of labour, we can write the welfare of the representative household as,

$$\max_{\{C_{i,t+\tau}(j),H_{i,t+\tau}(j),D_{i,t+1+\tau}(j)\}} \sum_{\tau=0}^{+\infty} \beta^\tau \left[\ln(C_{i,t+\tau}(j) - h_i C_{i,t+\tau-1}(j)) - \chi_i^C \frac{1}{1+\varphi_i} H_{i,t+\tau}(j)^{1+\varphi_i}\right]. \tag{1}$$

He maximizes its welfare subject to a budget constraint,

$$P_{i,t}^C C_{i,t}(j) + D_{i,t+1}(j) + B_{i,t+1}(j) + AC_{i,t}^B(j) = W_{i,t}^h(j) H_{i,t}(j) + T_{i,t} + R_t\left(D_{i,t}(j) + B_{i,t}(j)\right), \tag{2}$$

where $B_{i,t+1}(j)$ is the amount of international bonds subscribed by household j at the end of period t, $W_{i,t}^h(j)$ the nominal wage, $T_{i,t}$ the total amount of net transfers received in period t, and $AC_{i,t}^B(j) = \frac{\varkappa_i^B}{2}\left(B_{i,t+1}(j) - B_i(j)\right)$ are the quadratic adjustment costs the household has to pay to buy new bonds (Schmitt-Grohé and Uribe, 2003), with $B_i(j)$ the steady state level of bonds held by household j. We define $\Pi_{i,t+1}^C = \frac{P_{i,t+1}^C}{P_{i,t}^C}$ as the gross inflation rate on the economy. FOC can be combined to get,

$$\beta \frac{E_t[\Lambda_{i,t,t+1}(j) R_{t+1}]}{1+\varkappa_i^B\left(B_{i,t+1}(j) - B_i(j)\right)} = \Pi_{i,t+1}^C, \tag{3}$$

$$\varrho_{i,t}(j)W^h_{i,t}(j) = \chi^C_i H_{i,t}(j)^{\varphi_i}, \tag{4}$$

with,

$$\varrho_{i,t}(j) = \frac{1}{C_{i,t}(j) - h_i C_{i,t-1}(j)} - \frac{\beta h_i}{E_t[C_{i,t+1}(j)] - h_i C_{i,t}(j)}, \tag{5}$$

$$\Lambda_{i,t,t+1}(j) = \frac{\varrho_{i,t+1}(j)}{\varrho_{i,t}(j)}. \tag{6}$$

where $\varrho_t(j)$ is the marginal utility of consumption. 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. Each representative union is related to an household $j \in [0;1]$. Each household provides a differentiated type of labor $H_{i,t}(j)$. The aggregated amount of labor in the economy $H_{i,t}$ is defined as,

$$H_{i,t} = \left[\int_0^1 H_{i,t}(j)^{(\varepsilon^W_i - 1)/\varepsilon^W_i} dj\right]^{\varepsilon^W_i/(\varepsilon^W_i - 1)}, \tag{7}$$

where ε^W_i is the elasticity of substitution. The demand for an individual type of labor is defined as,

$$H_{i,t}(j) = \left(\frac{W^h_{i,t}(j)}{W_{i,t}}\right)^{-\varepsilon^W_i} H_{i,t}, \tag{8}$$

where $W^h_{i,t}(j)$ is the wage for labor of type j and,

$$W_{i,t} = \left[\int_0^1 W^h_{i,t}(j)^{1-\varepsilon^W_i} dj\right]^{1/(1-\varepsilon^W_i)}. \tag{9}$$

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. In line with Calvo (1983), assuming that the labor union is able to modify its wage with a probability $1 - \theta^W_i$, it chooses the optimal wage $W^*_{i,t}(j)$ to maximize its expected sum of profits: Wage stickiness arises from the fact that each labor union cannot adjust immediately nominal wages. We assume that each labor union is able to choose an optimal wage $W^{h*}_{i,t}(j)$ with probability $(1-\theta^W_i)$ while the remaining of workers have their wage indexed on the previous period $\left(\Pi_{i,t} = \frac{P_{i,t}}{P_{i,t-1}}\right)$. The labor union thus maximizes,

$$\max_{\{W^*_{i,t}(j)\}} E_t \sum_{\tau=0}^{+\infty} (\theta^W_i)^\tau \beta^\tau \Lambda_{i,t,t+\tau}(j) \left[\frac{W^{h*}_{i,t}(j)}{P_{i,t+\tau}} \prod_{k=1}^{\tau} \left(\Pi_{i,t+k-1}\right)^{\gamma^{pw}_i} - \frac{W^h_{i,t}(j)}{P_{i,t+\tau}}\right] H_{i,t+\tau}(j), \tag{10}$$

subject to, $H_{i,t+\tau}(j) = \left(\frac{W^{h*}_{i,t}(j)}{W_{i,t+\tau}} \prod_{k=1}^{\tau} \left(\Pi_{i,t+k-1}\right)^{\gamma^{pw}_i}\right)^{-\varepsilon^W_i}$, with γ^{pw}_i featuring the indexation parameter. The FOC

that governs the dynamics of the nominal wage is,

$$E_t \sum_{\tau=0}^{+\infty} (\theta_i^W)^\tau \beta^\tau \Lambda_{i,t,t+\tau}(j) \left[\frac{W_{i,t}^{h*}(j)}{P_{i,t+\tau}} \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma_i^{pw}} - \frac{\varepsilon_i^W}{\varepsilon_i^W - 1} \frac{W_{i,t}^h(j)}{P_{i,t+\tau}} \right] H_{i,t+\tau}(j) = 0, \tag{11}$$

where $\frac{\varepsilon_i^W}{\varepsilon_i^W - 1}$ is the mark up on the labor market.

3.2 Firms and capital suppliers

The productive sector of each country combines intermediate firms, final firms and capital suppliers. Intermediate firms produce differentiated goods i, choose labor and capital inputs, and set prices according to the Calvo model. Final goods producers act as a consumption bundler by combining national intermediate goods to produce the homogenous final good[2]. Capital suppliers rent and refurbish the capital stock used by intermediate firms and financed by the entrepreneurs on a competitive market.

The representative intermediate firm $i \in [0, 1]$ from country i, produces,

$$Y_{i,t}^s(i) = e^{\varepsilon_{i,t}^a} (U_{i,t}(i) K_{i,t}(i))^{\alpha_i} H_{i,t}(i)^{1-\alpha_i}, \tag{12}$$

where $Y_{i,t}^S(i)$ is the production function of the intermediate good that combines capital $K_{i,t}(i)$, labor $H_{i,t}(i)$ and technology $e^{\varepsilon_{i,t}^A}$ (an $AR(1)$ productivity shock). Intermediate goods producers solve a two-stages problem. In the first stage, taking the real input prices $W_{i,t}$ and $Z_{i,t}^k$ as given, firms rent inputs $H_{i,t}(i)$ and $K_{i,t}(i)$ in a perfectly competitive factor markets in order to minimize costs subject to the production constraint. They pay a cost $\Phi(U_{i,t}(i))$ for using capital that is affected to entrepreneurs through the $R_{i,t}^k$. In equilibrium this marginal cost of using capital $(\Phi'(U_{i,t}(i)))$ is equal to the marginal return of capital denoted $Z_{i,t}^k$ [3]. The marginal cost of production is thus,

$$MC_{i,t}^E(i) = \alpha_i^{-\alpha_i} (1-\alpha_i)^{\alpha_i - 1} (Z_{i,t}^k)^{\alpha_i} {W_{i,t}}^{1-\alpha} \left(e^{\varepsilon_{i,t}^a} \right)^{-1}. \tag{13}$$

The average rate of capital profitability is,

$$\frac{R_{i,t+1}^k}{1 + \varkappa_i^B (B_{i,t+1}(j) - B_i(j))} = \frac{[MC_{i,t+1}^E \alpha_i \frac{Y_{i,t+1}^s}{K_{i,t+1}} + (1 - \delta_{i,c}) Q_{i,t+1} - \Phi(U_{i,t+1})]}{Q_{i,t}}, \tag{14}$$

with $\delta_{i,c}$ is the depreciation parameter.

[2]Final good producers are perfectly competitive and maximize profits, $P_{i,t} Y_{i,t}^D - \int_0^1 P_{i,t}(i) Y_{i,t}^S(i) \mathrm{d}i$ (with $P_{i,t}(i)$ the price of good i), subject to the production function $Y_{i,t}^D = (\int_0^1 Y_{i,t}^S(i)^{(\epsilon_i^E - 1)/\epsilon_i^E} \mathrm{d}i)^{\epsilon_i^E/(\epsilon_i^E - 1)}$. We find the intermediate demand functions associated with this problem are, $Y_{i,t}^S(i) = (P_{i,t}(i)/P_{i,t})^{-\epsilon_i^E} Y_{i,t}^D$, $\forall i$ where $Y_{i,t}^D$ is the aggregate demand.

[3]Following Poutineau et Vermandel (2015), we define $\Phi(U_{i,t}) = \frac{1-\Psi_i}{\Psi_i} \bar{Z} [e^{\frac{\Psi_i}{1-\Psi_i}(U_{i,t}-1)} - 1]$. Thus, we get $Z_{i,t}^k = \Phi'(U_{i,t}) = \bar{Z}_i e^{\frac{\Psi_i}{1-\Psi_i}(U_{i,t}-1)}$.

Each firm i fixes sets the price of $Y^s_{i,t}(i)$ according to a Calvo mechanism. Each period firm i is not allowed to re optimize its price with probability θ^E_i. Thus, only a fraction $(1-\theta^E_i)$ of final firms is able to set the optimal price $P^*_{i,t}(i)$, other prices being partially indexed on the inflation rate. The optimization program of the representative intermediate firm is thus,

$$\max_{\left\{P^*_{i,t}(i)\right\}} E_t \sum_{\tau=0}^{\infty} \left(\theta^E_i\right)^{\tau} \beta^{\tau} \Lambda_{i,t,t+\tau} \left[P^*_{i,t}(i) \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma^{pe}} - MC^E_{i,t+\tau}(i) \right] Y^s_{i,t+\tau}(i), \tag{15}$$

where $\gamma^{pe}_i < 1$ is the indexation parameter. The First order condition is given by,

$$\sum_{\tau=0}^{\infty} \left(\theta^E_i\right)^{\tau} \beta^{\tau} \Lambda_{i,t,t+\tau} \left[P^*_{i,t}(i) \prod_{k=1}^{\tau} (\Pi_{i,t+k-1})^{\gamma^{pe}} - \frac{\varepsilon^E_i}{\varepsilon^E_i - 1} MC^E_{i,t+\tau}(i) \right] Y^s_{i,t+\tau}(i) = 0. \tag{16}$$

where $\frac{\varepsilon^E_i}{\varepsilon^E_i - 1}$ is the mark up on the final good market.

Capital suppliers are homogenous and distributed over a continuum normalized to one. The representative capital supplier q acts competitively to supply a quantity $K_{i,t+1}(q)$ of capital. Investment is costly, *i.e.* the capital supplier pays an adjustment cost function $f\left(\frac{I_{n,i,t+\tau}(q)+\bar{I}_i(q)}{I_{n,i,t+\tau-1}(q)+\bar{I}_i(q)}\right) = \frac{\eta^I_i}{2}\left(\frac{I_{n,i,t}(q)+\bar{I}_i(q)}{I_{n,i,t-1}(q)+\bar{I}_i(q)} - 1\right)^2$ on new investment $I_{n,i,t}(q) \equiv I_{i,t}(q) - \delta(U_{i,t})K_{i,t}(q)$ (with $\delta(U_{i,t})K_{i,t}(q)$ the depreciated capital). They provide a capital amount of $Q_{i,t}(q)K_{i,t+1}(q)$ by buying the non depreciated capital to entrepreneurs $(1-\delta(U_{i,t}))K_{i,t+1}(q)$ and investing $I_{i,t}(q) = \left[\left(1-\alpha^I_i\right)^{\frac{1}{\mu^I}} \left(I_{i,h,t}(q)\right)^{\frac{\mu^I-1}{\mu^I}} + \left(\alpha^I_i\right)^{\frac{1}{\mu^I}} \left(I_{i,f,t}(q)\right)^{\frac{\mu^I-1}{\mu^I}}\right]^{\frac{\mu^I}{\mu^I-1}}$, with price of investment $P^I_{i,t} = \left(1-\alpha^I_i\right) P^{1-\mu^I}_{h,t} + \alpha^I_i P^{1-\mu^I}_{f,t}$. We have $I_{i,h,t}(q) = \left(1-\alpha^I_i\right)\left(\frac{P_{h,t}}{P^I_{i,t}}\right)^{-\mu^I} I_{i,t}(q)$ and $I_{i,f,t}(q) = \alpha^I_i \left(\frac{P_{f,t}}{P^I_{i,t}}\right)^{-\mu^I} I_{i,t}(q)$. The representative capital supplier thus maximizes,

$$\max_{\{I_{n,i,t+\tau}(q)\}} E_t \sum_{\tau=0}^{\infty} \theta^{\beta}_{i,t+\tau} \Lambda_{i,t,t+1+\tau} \left[(Q_{i,t+\tau}(q)-1) I_{n,i,t+\tau}(q) - f\left(\frac{I_{n,i,t+\tau}(q)+\bar{I}_i(q)}{I_{n,i,t+\tau-1}(q)+\bar{I}_i(q)}\right)\left(I_{n,i,t+\tau}(q)+\bar{I}_i(q)\right)\right] \tag{17}$$

The first order condition associated to this program defines the renting price of capital,

$$\begin{aligned} Q_{i,t}(q) &= 1 + f\left(\frac{I_{n,i,t+i}(q)+\bar{I}(q)}{I_{n,i,t+i-1}(q)+\bar{I}(q)}\right) + \frac{I_{n,i,t+i}(q)+\bar{I}(q)}{I_{n,i,t+i-1}(q)+\bar{I}(q)} f'\left(\frac{I_{n,i,t+i}(q)+\bar{I}(q)}{I_{n,i,t+i-1}(q)+\bar{I}(q)}\right) \\ &\quad - E_t\left[\beta\left(C_{i,t}\right)\Lambda_{i,t,t+1}\left(\frac{I_{n,i,t+i}(q)+\bar{I}(q)}{I_{n,i,t+i-1}(q)+\bar{I}(q)}\right)^2 f'\left(\frac{I_{n,i,t+i}(q)+\bar{I}(q)}{I_{n,i,t+i-1}(q)+\bar{I}(q)}\right)\right] \end{aligned} \tag{18}$$

4 Financial relations and general equilibrium

4.1 Loan market equilibrium in a nutshell

Loan demand emanates from entrepreneurs. The representative entrepreneur $e \in [0,1]$ from country i finances the capital renting of intermediate firms with their wealth and loans. As in Poutineau and Vermandel (2015), in period t, this entrepreneur conducts a great number of heterogeneous projects with total value $Q_{i,t}K_{i,t+1}(e)$, where $Q_{i,t}$ is the price of capital and $K_{i,t+1}(e)$ is the amount of capital financed. These projects are financed by his net wealth $N^E_{i,t}(e)$ and by loans contracted from the banking system $L^D_{i,t}(e)$. The balance sheet of the representative entrepreneur is determined by, $Q_{i,t}K_{i,t+1}(e) = N^E_{i,t}(e) + L^D_{i,t}(e)$, with the value of capital he finances proportional to his net wealth, $Q_{i,t}K_{i,t+1}(e) = \phi^E_{i,t}(e)N^E_{i,t}(e)$, while the entrepreneur's loan demand is defined as, $L^D_{i,t}(e) = (\phi^E_{i,t}(e) - 1)N^E_{i,t}(e)$, where variable $\phi^E_{i,t}(e)$ is a borrowing accelerator à la Bernanke et al (1999), defined as, $\phi^E_{i,t}(e) \equiv \left[1 - \frac{\kappa_i - 1}{\kappa_i}\left(\frac{\mathbb{E}_t\left[R^k_{i,t+1}\right]}{P^L_{i,t}}\frac{\gamma_i^{1-\chi^E_i}}{e^{\varepsilon^{opt}_{i,t}}}\right)^{\frac{1}{\chi^E_i}}\right]^{-1}$, where γ_i is as scale parameter, κ_i is a shape parameter of the Pareto law on investment projects, and $\varepsilon^{opt}_{i,t}$ is an $AR(1)$ shock on entrepreneurs optimism[4]. The size of the borrowing accelerator is determined by the external finance premium $\frac{\mathbb{E}_t\left[R^k_{i,t+1}\right]}{P^L_{i,t}}$, with elasticity χ^E_i.

Loan supply emanates from banks. The representative bank $b \in [0,1]$ from country i operates in a regime of monopolistic competition to provide deposits and credit services to households and firms. Each period, the bank collects deposits $D_{i,t+1}(b)$ from its own country's households, remunerated at the risk free nominal interest rate R_t (as we consider a monetary union situation, the nominal interest rate is common between the two economies), and supplies loans $L^S_{i,t}(b)$ to both domestic and foreign entrepreneurs at a rate $R^L_{i,t}(b)$. In providing resources to their national banking system, households are faced with a problem of moral hazard. As in Gertler and Karadi (2011), banks may decide to divert a fraction $\lambda_{i,t}$ of their resources and transfer this back to the household of which it is a member. Depositors can force the intermediary to go bankrupt and they recover the remaining fraction $(1 - \lambda_{i,t})$ of assets. We assume that $\lambda_{i,t} = \lambda_i e^{\varepsilon^{\lambda}_{i,t}}$, with $\varepsilon^{\lambda}_{i,t} \sim AR(1)$. The representative financial intermediary $b \in [0,1]$ from country i provides loans to both domestic and foreign entrepreneurs using resources obtained from the deposits of country i households $D_{i,t+1}(b)$ and from its net wealth $N^B_{i,t}(b)$, so its balance sheet is determined by, $L^S_{i,t}(b) = N^B_{i,t}(b) + D_{i,t+1}(b)$, with $L^S_{i,t}(b)$ the amount of loans supplied by the bank.[5] Banks from each country are subject to an occasionally binding credit constraint on the maximum amount they can lend ($L^{S\max}_{i,t}(b)$). Indeed, because of the agency problem between households and banks, households will only agree to put deposits at the bank in a limited amount (an amount that does not trigger the diversion incentive from the bank), thus defining a maximum amount of loans ($L^{S\max}_{i,t}(b)$) banks can not exceed. This maximum amount is determined as a function of their net wealth and a lending accelerator $\phi^B_{i,t}(b)$ as, $L^S_{i,t}(b)^{\max} = \phi^B_{i,t}(b)N^B_{i,t}(b)$.

Cross border lending affects this part of the model. Loan demand is such that accounting for cross border

[4] More details about the compution of the borrowing accelerator are provided in the appendix.

[5] As in the original setting of Gertler and Karadi (2011), banks are owned by households (see the next section) and the landlord of the bank cannot put deposits in his bank.

lending, the total amount of loans contracted by the representative entrepreneur is,

$$L_{i,t}^{D}(e) = \left[\left(1-\alpha_i^L\right)^{\frac{1}{\mu_i^L}} \left(L_{i,h,t}^{D}(e)\right)^{\frac{\mu_i^L-1}{\mu_i^L}} + \left(\alpha_i^L\right)^{\frac{1}{\mu_i^L}} \left(L_{i,f,t}^{D}(e)\right)^{\frac{\mu_i^L-1}{\mu_i^L}} \right]^{\frac{\mu_i^L}{\mu_i^L-1}}. \tag{19}$$

$L_{i,t}^{D}(e)$ is defined as a CES bundle of loans purchased from both domestic banks ($L_{i,h,t}^{D}(e)$) and foreign banks ($L_{i,h,t}^{D}(e)$)[6], with α_i^L featuring a home bias ($\alpha_h^L = 1-\alpha_f^L < \frac{1}{2}$), parameter μ_i^L is the elasticity of substitution between domestic and foreign loans and $ToT_t \equiv \frac{P_{f,t}}{P_{h,t}}$ is the terms of trade between the two economies ($P_{h,t}$ (resp. $P_{f,t}$) is the price level in the domestic (resp. foreign) economy). Variable $R_{h,t}^{L}(e)$ (resp. $R_{f,t}^{L}(e)$) is the cost of loans obtained by entrepreneur e from domestic (resp. foreign) banks, and,

$$P_{h,t}^{L}(e) = \left[\left(1-\alpha_h^L\right) R_{h,t}^{L}(e)^{1-\mu_h^L} + \alpha_h^L \left(\frac{ToT_{t+1}}{ToT_t} R_{f,t}^{L}(e) \right)^{1-\mu_h^L} \right]^{1/(1-\mu_h^L)},$$

is the total cost of loans for a domestic entrepreneur e.[7] At the equilibrium on the loan market, the total loan supply in the economy i is equal to the total loan demand addressed to the economy i,

$$L_{i,t}^{S} = L_{h,i,t}^{D} + L_{f,i,t}^{D}, \tag{20}$$

with $L_{h,i,t}^{D}$ the loan demand from domestic entrepreneurs to the economy i and $L_{f,i,t}^{D}$ the loan demand from foreign entrepreneurs to the economy i.[8]

[6]Loans purchased by a domestic entrepreneur e from domestic (resp. foreign) banks write $L_{h,h,t}^{D}(e) = \left(1-\alpha_h^L\right)\left(\frac{R_{h,t}^{L}(e)}{P_{h,t}^{L}(e)}\right)^{-\mu_h^L} L_{h,t}^{D}(e)$ (resp. $L_{h,f,t}^{D}(e) = \alpha_h^L\left(\frac{\frac{ToT_{t+1}}{ToT_t}R_{f,t}^{L}(e)}{P_{h,t}^{L}(e)}\right)^{-\mu_h^L} L_{h,t}^{D}(e)$), while loans purchased by a foreign entrepreneur e from domestic (resp. foreign) banks write $L_{f,h,t}^{D}(e) = \left(1-\alpha_f^L\right)\left(\frac{\frac{ToT_t}{ToT_{t+1}}R_{h,t}^{L}(e)}{P_{f,t}^{L}(e)}\right)^{-\mu_f^L} L_{f,t}^{D}(e)$ (resp. $L_{f,f,t}^{D}(e) = \alpha_f^L\left(\frac{R_{f,t}^{L}(e)}{P_{f,t}^{L}(e)}\right)^{-\mu_{if}^L} L_{f,t}^{D}(e)$)

[7]Conversely, $P_{f,t}^{L}(e) = \left[\left(1-\alpha_f^L\right)\left(\frac{ToT_t}{ToT_{t+1}}R_{h,t}^{L}(e)\right)^{1-\mu_f^L} + \alpha_f^L R_{f,t}^{L}(e)^{1-\mu_f^L}\right]^{1/(1-\mu_f^L)}$ is the total cost of loans for a foreign entrepreneur e.

[8]At the equilibrium on the loan market, total credit supply in the economy i is a bundle of loans supplied by individual banks in this economy: $\frac{L_{i,t}^{S}}{\Delta_{i,t}^{L}} = \left[\int_0^1 L_{i,t}^{S}(b)^{(\epsilon_i^B-1)/\epsilon_i^B} db\right]^{\epsilon_i^B/(\epsilon_i^B-1)}$, with ϵ_i^B the elasticity of substitution between loans and $\Delta_{i,t}^{L} = \int_0^1 (R_{i,t}^{L}(b)/R_{i,t}^{L})^{-\epsilon_{i,t}^B/(\epsilon_{i,t}^B-1)} db$ the dispersion term for interest rates on loans. The demand of loans adressed to each bank individually is $L_{i,t}^{S}(b) = \left(\frac{R_{i,t}^{L}(b)}{R_{i,t}^{L}}\right)^{-\epsilon_i^B} L_{i,t}^{S}$, where $R_{i,t}^{L} = \left[\int_0^1 R_{i,t}^{L}(b)^{1-\epsilon_i^B} db\right]^{1/(1-\epsilon_i^B)}$ is the agregate cost of loans in the economy.

In this model, we consider flexible interest rates on loans, so $R_{i,t}^{L}(b) = R_{i,t}^{L}$, and $\Delta_{i,t}^{L} = 1$. If the incentive constraint is checked, the total amount of loans intermediated by the banking system depends on the quantity of loans demanded by both home and foreign entrepreneurs.

4.2 Normal times vs crisis times

Financial troubles affect the equilibrium of the market through a quantitative constraint on loan availability to entrepreneurs. In providing deposits to the banking system, households face a moral hazard problem. This moral hazard problem may lead depositors to shrink the quantity of resources needed by the banking system. This, in turn, induces quantitative restrictions in the provision of loans from banks to entrepreneurs. For lenders to be willing to supply funds to the banker, the following incentive constraint must be satisfied, $V_{i,t}(b) \geq \lambda_{i,t} L^S_{i,t}(b)$, where $V_{i,t}(b)$ is the expected discounted intertemporal profit of the bank in all his remaining periods of activity. The constraint states that households accept to hold deposits $D_{i,t+1}(b)$ at the bank only until they reach a maximum amount of deposits for which the bank is indifferent between continuing his activity of lender and going into bankruptcy by diverting a fraction $\lambda_{i,t}$ of his resources $L^S_{i,t}(b) = N^B_{i,t}(b) + D_{i,t+1}(b)$ normally used for lending.[9]In "normal times", financial intermediaries are not constrained and they have enough resources to meet the quantity of loans demanded by both home and foreign entrepreneurs (i.e., $L^D_{h,i,t} + L^D_{f,i,t} \leq L^{S,\max}_{i,t}$). In "crisis times", banks have trouble to get enough resources to create as much loans as demanded by entrepreneurs (either because of a drop in the amount of deposits or a decrease in their capital value following an adverse financial shock), and restrict their supply of loans to $L^{S,\max}_{i,t}$. In this situation the notional demand for loans emanating from entrepreneurs is not met. So the situation on each country's credit market can be summarized by the following system,

$$\begin{cases} L_{i,t} \leq L^{S,\max}_{i,t} & \text{if } \; L^{D,n}_{i,t} \leq L^{S,\max}_{i,t} \text{ (normal times)}, \\ L_{i,t} = L^{S,\max}_{i,t} & \text{if } \; L^{D,n}_{i,t} > L^{S,\max}_{i,t} \text{ (crisis times)}, \end{cases} \tag{21}$$

where $L^{D,n}_{i,t}$ is the notional demand for loans, i.e. the sum of demands for loans from both domestic and foreign entrepreneurs that would be observed in the economy i if there was no credit constraint, and $L_{i,t}$ is the effective quantity of credit in the economy at the equilibrium on the credit market, i.e. the quantity that meets $L^S_{i,t} = L^D_{h,i,t} + L^D_{f,i,t}$. If the notional loan demand from entrepreneurs is smaller than the maximal amount of loans banks can offer, then the quantity of loans in the economy is not constrained. If the notional loan demand from entrepreneurs is higher than the maximal amount of loans banks can offer, then the quantity of loans in the economy becomes constrained.

In normal times, the incentive constraint is checked and the banking system has no trouble to get resources from households to create loans. In this interior solution, the total amount of loans intermediated on country i by the banking system depends on the quantity of loans demanded by domestic entrepreneurs ($L^D_{h,i,t}$) and foreign entrepreneurs ($L^D_{f,i,t}$). The setting of the loan interest rate for the representative bank b of country h in normal times is intended to maximize the expected profit of the bank that takes into account the possibility of domestic and foreign entrepreneurs to fail to pay back their loans, with respective probabilities $(1 - E_t\left[\eta^E_{h,t+1}\right])$ and $(1 - E_t\left[\eta^E_{f,t+1}\right])$,

[9]More details about this constraint are provided in the next subsection.

$$R^L_{h,t}(b) = \frac{\epsilon^B_h}{\epsilon^B_h - 1} MC^B_{h,t}(b) = \frac{\epsilon^B_h}{\epsilon^B_h - 1} \frac{1}{1-\tau^B_h} \frac{R_t}{\left(E_t\left[\eta^E_{h,t+1}\right] - \left(E_t\left[\eta^E_{h,t+1}\right] - E_t\left[\eta^E_{f,t+1}\right]\right)\Xi_{h,t}\right)}, \quad (22)$$

$$R^L_{f,t}(b) = \frac{\epsilon^B_f}{\epsilon^B_f - 1} MC^B_{f,t}(b) = \frac{\epsilon^B_f}{\epsilon^B_f - 1} \frac{1}{1-\tau^B_f} \frac{R_t}{\left(E_t\left[\eta^E_{f,t+1}\right] - \left(E_t\left[\eta^E_{f,t+1}\right] - E_t\left[\eta^E_{h,t+1}\right]\right)\Xi_{f,t}\right)}, \quad (23)$$

where $MC^B_{h,t}(b)$ is the marginal cost of creating new loans[10], ϵ^B_i is the elasticity of substitution between different types of loans, $\Xi_{f,t} \equiv \frac{L^D_{h,f,t}(b)}{L^D_{h,f,t}(b)+L^D_{f,f,t}(b)} = \left(\frac{1-\alpha^L_h}{\alpha^L_h}\left(\frac{P^L_{h,t}}{P^L_{f,t}}\frac{ToT_{t+1}}{ToT_t}\right)^{-\mu^L_f}\frac{Q_{f,t}K_{f,t+1}-N^E_{f,t}}{Q_{h,t}K_{h,t+1}-N^E_{h,t}}+1\right)^{-1}$ is the share of loan demand from domestic entrepreneurs to the foreign bank b on the total loan demand to the foreign bank b, and τ^B_f a tax set by the social planner of country f on the revenue of the bank. In normal times the amount of loans in country i is determined by loan demand from both home and foreign entrepreneurs given the interest rate set by the banking system of country i. Imposing symmetry between all entrepreneurs and between all banks, and defining $L^D_{h,i,t}$ (resp. $L^D_{f,i,t}$) as the total amount of loans demanded by home (resp. foreign) entrepreneurs to banks of country i, the quantity of loans supplied in the whole country i is $L^S_{i,t} = L^D_{h,i,t} + L^D_{f,i,t}$. Calling $L_{i,t}$ the total amount of loans circulating in the economy i and using the expression of the loan demand **??**, we can write,

$$L_{h,t} = L^S_{h,t} = (1-\alpha^L_h)\left[\frac{R^L_{h,t}}{P^L_{h,t}}\right]^{-\mu^L_h}(\phi^E_{h,t}-1)N^E_{h,t} + \left(1-\alpha^L_f\right)\left[\frac{\frac{ToT_t}{ToT_{t+1}}R^L_{h,t}}{P^L_{f,t}}\right]^{-\mu^L_h}(\phi^E_{f,t}-1)N^E_{f,t}, \quad (24)$$

$$L_{f,t} = L^S_{f,t} = \alpha^L_h\left[\frac{\frac{ToT_{t+1}}{ToT_t}R^L_{f,t}(e)}{P^L_{h,t}(e)}\right]^{-\mu^L_h}(\phi^E_{h,t}-1)N^E_{h,t} + \alpha^L_f\left[\frac{R^L_{f,t}(e)}{P^L_{f,t}(e)}\right]^{-\mu^L_h}(\phi^E_{f,t}-1)N^E_{f,t}, \quad (25)$$

The crisis is driven by exogenous shocks that affect the ability of the banking system to create loans. This shortage of resources in an economy can come either from less deposits or from a collapse in the capital value of the banking system. In an open economy situation, a financial crisis in one economy can come either from shocks on the financial sector on the economy itself, or from shocks on the other country, through international transmission channels. Since the resource constraint of banks bites, the amount of loans created in economy i corresponds to $L^{S,\max}_{i,t}$. The computation of this loan ceiling $L^{S,\max}_{i,t}$ follows Gertler and Karadi (2011). Here, $L^S_{i,t}(b) = L^S_{i,t}(b)^{\max} = \phi^B_{i,t}(b)N^B_{i,t}(b)$, where $\phi^B_{i,t}(b) \equiv \frac{\eta_{i,t}(b)}{\lambda_{i,t}-\nu_{i,t}(b)}$ features the lending accelerator.

In this situation, the interest rate on loans ($R^L_{i,t}$) becomes a jump variable determined at the market level to force demand to equalize loan supply. Imposing symmetry between all entrepreneurs and between all banks, $R^L_{i,t}$

[10]More details regarding the computation of bank marginal cost are provided on the Appendix B.

solves,

$$\phi^B_{h,t}N^B_{h,t} = (1-\alpha^L_h)\left[\frac{R^L_{h,t}}{P^L_{h,t}}\right]^{-\mu^L_h}(\phi^E_{h,t}-1)N^E_{h,t} + \left(1-\alpha^L_f\right)\left[\frac{\frac{ToT_t}{ToT_{t+1}}R^L_{h,t}}{P^L_{f,t}}\right]^{-\mu^L_h}(\phi^E_{f,t}-1)N^E_{f,t}, \quad (26)$$

$$\phi^B_{f,t}N^B_{f,t} = \alpha^L_h\left[\frac{\frac{ToT_{t+1}}{ToT_t}R^L_{f,t}(e)}{P^L_{h,t}(e)}\right]^{-\mu^L_h}(\phi^E_{h,t}-1)N^E_{h,t} + \alpha^L_f\left[\frac{R^L_{f,t}(e)}{P^L_{f,t}(e)}\right]^{-\mu^L_h}(\phi^E_{f,t}-1)N^E_{f,t} \quad (27)$$

with,

$$\phi^B_{i,t} \equiv \frac{\eta_{i,t}}{\lambda_{i,t}-\nu_{i,t}}, \quad (28)$$

$$N^B_{h,t} = \frac{\theta_h\left(1-\tau^B_h\right)\left[\left(\eta^E_{h,t}R^L_{h,t-1}-\frac{1}{1-\tau^B_h}R_{t-1}\right)-R^L_{h,t-1}\left(\eta^E_{h,t}-\eta^E_{f,t}\right)\Xi_{h,t-1}\right]L^S_{h,t-1}+R_{t-1}N^B_{h,t-1}}{e^{\varepsilon^{N^B}_{h,t}}} + \omega_h L^S_{h,t-1}, \quad (29)$$

$$N^B_{f,t} = \frac{\left(1-\tau^B_f\right)\left[\left(\eta^E_{f,t}R^L_{f,t-1}-\frac{1}{1-\tau^B_h}R_{t-1}\right)-R^L_{f,t-1}\left(\eta^E_{f,t}-\eta^E_{h,t}\right)\Xi_{f,t-1}\right]L^S_{f,t-1}+R_{t-1}N^B_{f,t-1}}{e^{\varepsilon^{N^B}_{f,t}}} + \omega_f L^S_{f,t-1}, \quad (30)$$

$$\phi^E_{i,t+1} \equiv \left[1-\frac{\kappa_i-1}{\kappa_i}\left(\frac{E_t\left[R^k_{i,t+1}\right]}{R^L_{i,t}}\gamma_i^{1-\chi^E_i}\right)^{\frac{1}{\chi^E_i}}\right]^{-1}, \quad (31)$$

$$N^E_{i,t+1} = \left(1-\tau^E_i\right)\Pi^E_{i,t}. \quad (32)$$

$\left(\theta_h\left[\left(\left(1-\tau^B_h\right)\eta^E_{h,t}R^L_{h,t-1}-R_{t-1}\right)-\left(1-\tau^B_h\right)R^L_{h,t-1}\left(\eta^E_{h,t}-\eta^E_{f,t}\right)\Xi_{h,t-1}\right]L^S_{h,t-1}+R_{t-1}N^B_{h,t-1}\right)/e^{\varepsilon^{N^B}_{h,t}}$ is the aggregate net wealth of home bankers that already existed at period $t-1$, and $\omega_h L^S_{h,t-1}$ is the aggregate net wealth of new home bankers, with $\frac{\omega_h}{1-\theta_h}$ the fraction of the total final period assets of exiting bankers at period $t-1$ ($(1-\theta_h)L^S_{h,t-1}$) transferred by the households to the new bankers.[11]

4.3 Loan market tightness

The previous information can be simply summarized thanks to the computation of a tightness indicator. In crisis times, loan market tightness can be measured as follows: The interest rate that balances the loan market can be written as $R^L_{i,t}$ with,

$$R^L_{i,t} = \frac{\epsilon^B_i}{\epsilon^B_i-1}\frac{1}{1-\tau^B_i}\frac{R_t+\zeta_{i,t}}{E_t\left[\eta^E_{i,t+1}\right]}, \quad (33)$$

where $\zeta_{i,t}>0$ measures the tightness of country i loan market.[12] Defining $R^{L,S}_{i,t}$ as the shadow value of the loan interest rate, i.e. the value that the loan interest rate would have taken if the banks were not subject to a financial

[11] Gertler and Karadi (2011) use this way to close the system.

[12] See Appendix B for more details in the computation of the interest rate on loans from a maximization program of bank's profit with an occasionally binding constraint on their leverage ratio.

constraint we get,

$$R_{i,t}^{L} - R_{i,t}^{L,S} = \frac{\epsilon_i^B}{\epsilon_i^B - 1} \frac{1}{1-\tau_i^B} \frac{R_t + \zeta_{i,t}}{E_t\left[\eta_{i,t+1}^E\right]} - \frac{\epsilon_i^B}{\epsilon_i^B - 1} \frac{1}{1-\tau_i^B} \frac{R_t}{E_t\left[\eta_{i,t+1}^E\right]}. \tag{34}$$

Rearranging this expression, the tightness of the loan market, $\zeta_{i,t}$, is defined as,

$$\zeta_{i,t} = \frac{\epsilon_i^B - 1}{\epsilon_i^B} \left(1-\tau_i^B\right) E_t\left[\eta_{i,t+1}^E\right] (R_{i,t}^{L} - R_{i,t}^{L,S}). \tag{35}$$

To summarize, in normal times, $\zeta_{i,t} = 0$, as the interest rate that balances the loan market corresponds to the interest rate that would have prevailed without the existence of the credit constraint (i.e., $R_{i,t}^{L,S} = R_{i,t}^{L}$). In crisis times, $\zeta_{i,t} > 0$, as the tightness of the loan market is proportional to the interest rate spread between the interest rate on loans that balances loan supply and demand and the interest that would have been set by the banking system without the credit constraint. This variable will be used as an indicator to characterize the situation of the loan market and the policy to be adopted (either conventional for $\zeta_{h,t} = \zeta_{f,t} = 0$, or otherwise combining conventional and unconventional measures).

4.4 Macroeconomic policies and general equilibrium

Fiscal policy is assumed exogenous in our setting, i.e. $G_{i,t} = G_i e^{\varepsilon_{i,t}^g}$ with, G_i the steady state level of public spending and $\varepsilon_{i,t}^g \sim AR(1)$ representing a public spending shock in period t, that affects the resource constraint of the economy,

$$Y_{i,t}^D = C_{h,i,t} + C_{f,i,t} + I_{h,i,t} + I_{f,i,t} + G_{i,t} + \tau_i Q_{i,t} K_{i,t+1} \tag{36}$$

As in Gertler and Karadi (2011), $\tau_i Q_{i,t} K_{i,t+1}$ measures inefficiencies related to the cost of implementing a credit policy (assumed less efficient than loan creation by financial intermediaries, where τ_i is an inefficiency parameter if the central bank intermediates funds directly). Capital accumulation is defined according to,

$$K_{i,t} = (1 - \delta(U_{i,t}))K_{i,t-1} + I_{i,t}. \tag{37}$$

The common central bank follows a standard Taylor rule policy, taking into account inflation and output gaps from the two countries,

$$R_t = \frac{1}{\bar{\beta}} \left(\Pi_{h,t}\Pi_{f,t}\right)^{\phi_\pi} \left(\frac{Y_{h,t}}{Y_{h,t-1}} \frac{Y_{f,t}}{Y_{f,t-1}}\right)^{\phi_y} \varepsilon_t^r, \tag{38}$$

Where $\varepsilon_t^r \sim N\left(0, \sigma_{\varepsilon^r}\right)$ is a conventional monetary policy shock. There is no persistence in the interest rate fixation, as we consider that in a crisis situation the central bank does react in a flexible way to the economic conditions it faces.

Finally, the dynamic of the current account for the domestic country ($CA_{h,t} = -CA_{f,t}$) is defined as,

$$CA_{h,t} = C_{h,h,t} + Inv_{h,h,t} - C_{f,h,t} - Inv_{f,h,t} \tag{39}$$

In the model, we have two countries, 10 AR(1) shocks such that $\varepsilon^s_{i,t} = \rho^s_i \varepsilon^s_{i,t} + \eta^s_{i,t}$, for $s \in \{\lambda, a, g, opt, cons\}$ and $i \in \{h, f\}$, where ρ^s_i is the autoregressive parameter and $\eta^s_{i,t}$ is normally distributed, and 3 normally distributed shocks $\varepsilon^{N^B}_{i,t}$ for $i \in \{h, f\}$, and ε^r_t. The general equilibrium combines a sequence of quantities $\{Q_t\}^{\infty}_{t=0}$ and a sequence of prices $\{P_t\}^{\infty}_{t=0}$, such that, for a given sequence of shocks $\{S_t\}^{\infty}_{t=0}$ and conditional on the monetary policy: (i) For a given sequence of prices $\{P_t\}^{\infty}_{t=0}$, the sequence $\{Q_t\}^{\infty}_{t=0}$ satisfies first-order conditions of households, entrepreneurs, firms, capital producers and financial intermediaries; (ii) For a given sequence of quantities $\{Q_t\}^{\infty}_{t=0}$, the sequence $\{P_t\}^{\infty}_{t=0}$, guarantees the equilibrium on all markets**.**

5 Crisis experiment

In this section, we calibrate the model and we evaluate the macroeconomic effects of transitory shortages in bank lending, for both core and peripheral countries.[13]

5.1 Calibration and steady state

The calibration of the model is summarized in Table 1. We borrow most parameter values from Poutineau and Vermandel (2015) and Gertler and Karadi (2011). The value chosen for the model's parameter should meet two requirements: First, the steady state of the model should correspond to normal times (i.e., it should lie in the non saturated lending region that corresponds to a normal working of the loan market); Second, this steady state should be close enough to a loan shortage situation thus allowing for the possibility of a transitory lending shortage at the outcome of admissible values for financial and real shocks. This feature is important to generate crisis times in the economy so as to provide the pre requisite for unconventional policy measures.

Most parameters are calibrated following Poutineau and Vermandel (2015). This is the case of the weight of capital in the production function α, the depreciation rate of capital δ_c, the portfolio adjustment costs $\varkappa^B$, the ratio of government spending on GDP G/Y, the steady state labor supply H, the steady state interest rate spread $R^L - R$, the probability of reimbursement of firms in the steady state η^E, the Taylor coefficients on inflation ϕ_π and output ϕ_y, the openness on goods market $\alpha^C_h = 1 - \alpha^C_f$ and investment market $\alpha^I_h = 1 - \alpha^I_f$, the elasticity of substitution between core and peripheral consumption goods μ^C and between core and peripheral loans μ^L (the elasticity of substitution between core and peripheral investment goods μ^I is calibrated as μ^C), the consumption habit parameter h, the shape parameter of the marginal cost of using capital Ψ, the labor supply elasticity φ, the

[13] To get a four regime model (normal times and financial crisis, for both core and peripheral countries), we use the method developped by Guerrieri and Iacoviello (2015). The authors show how to approximate a nonlinear model by computing the matrices of several linear models with close steady states, thus creating what they call a piecewise linear model, close to the nonlinear one.

Parameter	h	f	Definition
β	0.99		discount factor
δ_c	0.02		depreciation rate of capital
α	0.25		weight of capital in the production function
H	1/3		steady state labor supply
$\varkappa^B$	0.0007		portfolio adjustment costs
G/Y	0.24		ratio of government spending on GDP
LEV	1.5		leverage ratio at the steady state
$R^L - R$	0.0248/4		steady state interest rate spread
ε^E	4.167		elasticity of substitution between goods varieties
ε^B	100		elasticity of substitution between varieties of loans
ε^W	10		elasticity of substitution between varieties of labour
η^E	0.995		probability of reimbursement of firms in the steady state
θ	0.972		survival rate of bankers
ω	0.002		transfer parameter towards new bankers
η^I	0.06		scale parameter on investment costs
ϕ_π	1.85		Taylor coefficient on inflation
ϕ_y	0.15		Taylor coefficient on output
τ	0.001		inefficiency parameter for government spending
λ	0.681		share of deposit in the steady state
v	10		credit policy parameter
$\alpha_h^C = 1 - \alpha_f^C$	0.17		openness on goods market
$\alpha_h^I = 1 - \alpha_f^I$	0.06		openness on investment market
μ^C	4.43		elasticity of substitution between core and peripheral consumption goods
μ^I	4.43		elasticity of substitution between core and peripheral investment goods
μ^L	2.02		elasticity of substitution between core and peripheral loans
h	0.32	0.57	consumption habit parameter
Ψ	0.66	0.68	shape parameter of the marginal cost of using capital
φ	0.59	0.66	labor supply elasticity
θ^E	0.56		price rigidity parameter
γ^{pe}	0.07	0.08	price indexation parameter
θ^W	0.67	0.6	rigidity parameter on wages
γ^{pw}	0.46	0.36	indexation parameter on wages
χ^E	0.05	0.08	bias parameter on entrepreneur expectations
ρ^λ	0.95		shock autocorrelation (banking risk perception)
ρ^a	0.95		shock autocorrelation (productivity)
ρ^g	0.95		shock autocorrelation (public spending)
ρ^{cons}	0.95		shock autocorrelation (consumption)
ρ^{opt}	0.95		shock autocorrelation (optimism)

Table 1: Calibration of parameters

price rigidity parameter θ^E and rigidity parameter on wages θ^W, the price indexation parameter γ^{pe} and indexation parameter on wages γ^{pw}, and the bias parameter on entrepreneur expectations χ^E. Interest rates on loans are fully flexible.

Parameters related to the dynamics of the banking system are calibrated following Gertler and Karadi (2011). This is the case of the survival rate of bankers θ, the transfer parameter towards new bankers ω, the credit policy parameter v and the inefficiency parameter for government spending τ. The discount factor β is also calibrated following Gertler and Karadi (2011).

The elasticity of substitution between goods varieties ε^E, varieties of loans ε^B and varieties of labour ε^W, that have no values in Poutineau and Vermandel (2015) and Gertler and Karadi (2011) because this models are declared in log deviation form, are calibrated as in Cargoët and Poutineau (2017). Following Cargoët and Poutineau (2017), the rest of our parameters is calibrated in order to meet our requirements regarding the characteristics of the steady state that should correspond to normal times and be close enough to a loan shortage situation: The steady state value of the diversion parameter is set to $\lambda = 0.685$, and the steady state value of the leverage ratio ($LEV = N^E/K$) is set to 1.5. Finally, shock persistency parameters are given as follows: $\rho_i^{\lambda} = 0.95, \rho_i^{a} = 0.95, \rho_i^{g} = 0.8, \rho_i^{opt} = 0.9, \rho_i^{cons} = 0.8$.

5.2 Cross border lending and the international transmission of financial troubles

We study the effects of asymmetric financial and supply shocks affecting the peripheral part of the monetary union. This perspective aims at capturing the heterogeneity of eurozone members following the transmission of the subprime crisis into the eurozone and the fragility of countries belonging to this group. We assess the national and global impact effects of this shocks depending on the size of cross border lending relations between core and peripheral countries.

5.2.1 Loan market fragmentation

We first evaluate how the possibility of a financial disruption in one part of the monetary union affects the aggregate situation of the union under a conventional monetary policy. We study the responses of the model assuming loan market fragmentation (we set $\alpha_h^L = 1 - \alpha_f^L = 0$).

Figure 4 depicts the consequences of a 5% negative realization of $\varepsilon_{f,t}^{\lambda}$ that can be understood as a sudden loss of confidence from peripheral bank depositors (i.e peripheral households) following an increase in the perceived incentive of peripheral banks to divert assets. This decreases the amount of deposits peripheral banks are able to use for loan creation. This shock is similar to the financial shock considered in Dedola, Karadi and Lombardo (2013). For the peripheral countries, this shock creates a quantitative disruption of lending in the economy.[14] As depicted by the grey area the loan shortage situation lasts for 10 periods, and implies a sharp increase in the interest

[14] In this figure, we contrast 2 versions of the model. In the version that neglects the possibility of quantitative shortage of loan supply, this shock has no effect on the variables of the model, see Cargoet and Poutineau (2017).

rate on peripheral loans to contain loan demand. The increase in the interest rate on loans faced by entrepreneurs reflects the scarcity of loans in the economy. As reported in the figure, even if the lending shortage lasts for a limited number of periods, it has sizable consequences for the rest of the analysis: The rise in the interest rate spread decreases investment, activity and inflation. The policy reaction (a decrease in the policy rate) tends to dampen the effect in the following periods so the economy slowly goes back to equilibrium. This effect, already documented in Poutineau and Cargoët (2017), is affected by international trade: The decrease in peripheral goods prices leads to more export towards the core countries, which should require, marginally more production and thus would marginally increase the loan shortage in the peripheral countries.

This shock affects core countries along two opposite channels. On the international part, as prices diminish in the peripheral countries, the core countries terms of trade deteriorate, which in turn leads to a decrease in core countries exports while peripheral exports increase. The current account of the core countries deteriorates. At the same time, the accommodating conventional monetary policy undertaken by the central bank in reaction to the decrease in activity and prices in the peripheral countries affects positively activity in the core countries. As reported in the graphs, this positive effect clearly overcomes the negative consequences of the core countries current account deficit. Thus we observe a net increase in the core GDP, but a decrease in core inflation.

Figure 5 reports the consequences of a 5% negative realization of $\varepsilon_{f,t}^{N^B}$ which can be understood as a sudden depreciation of peripheral banks' assets. Due to the close nature of the two shocks, we observe almost the same results as for the shock on $\varepsilon_{f,t}^{\lambda}$, the only difference lying on the size of those effects, approximately three times lower for the shock on banks' assets (first period log-deviation decrease in peripheral GDP is equal to $1.8e^{-2}$ for the confidence shock against $6e^{-3}$ for the shock on banks' assets). This difference in the size of effects comes from the multiplicative impact of $\lambda_{f,t}$ on the maximum quantity of resources $(D_{f,t+1} + N_{f,t}^{B})$ peripheral banks are allowed to keep to avoid a fund diversion.

Figure 6 reports the consequences of a negative peripheral productivity shock (i.e. a 5% decrease of $\varepsilon_{f,t}^{a}$). To assess the amplifying features of a loan shortage, we contrast the IRFs obtained ignoring this phenomenon (in dotted lines) with the financial disruption case. Ignoring the quantitative shortage of loans, we find standard results since, as widely documented in the literature, this shock leads to a slump in activity while it increases inflation in the peripheral countries. As capital productivity decreases so does investment. Monetary policy reaction induces an interest rate increase to fight inflation, which in turn affects the interest rate on loans. As reported, the interest rate on loans increases more than the policy rate, as the shock leads also to a decrease in investment profitability, which in turn increases the risk premium correction of banks.

The possibility of a transitory lending constraint (plain line) clearly deteriorates the adjustment of the economy. Even if the quantitative shortage lasts only for 4 periods, it amplifies the negative impact of the shock and reinforces its persistency on the main aggregates. As reported, it takes more time for the economy to recover. The negative productivity shock affects the profitability of entrepreneurs projects which, in turn, reduces the net wealth of the

banking system, and the resources (and so the bank deposits) of households (Cargoët and Poutineau, 2017). These two elements create a shortage in the supply of loans that reinforces the initial negative effect of the shock on investment and activity. Following the decrease in loan supply, the interest rate spread needed to balance the loan market increases sharply which leads to a deeper impact of the real shock on both investment and activity. The further effect on activity and investment due to the loan shortage requires a lower increase of the central bank interest rate. Inflation increases less, while activity loss is higher which dampens the authorities reaction with regard to the standard DSGE model.

To get a clear insight of the consequences of the shock on the core part of the monetary union, it is worthwhile to distinguish the consequences coming from trade integration (that further deteriorates the situation of the periphery) from those coming from the consequences of the reaction of the central bank.

As usually documented in the literature, the negative productivity shock leads to decrease in peripheral GDP, while leading to an increase in peripheral inflation. Ignoring financial disruption, this increases the terms of trade (which decreases peripheral export and deteriorates both the peripheral current account and furthermore reinforces the decrease in activity. Due to the loan shortage, the profitability of peripheral entrepreneur projects and the number of profitable projects decrease furthermore, which in turn decreases banks' net wealth in the peripheral countries and further saturates the credit constraint. Thus the drop in peripheral activity is higher. In the core countries, the improvement in the terms of trade increases the current account surplus which increases both GDP and Inflation. However the saturation of the credit constraint in the peripheral countries dampens this effect, as it affects negatively peripheral demand (and thus core exports). Thus the credit constraint in the peripheral countries affects negatively activity in the core part of the monetary union, so that the net increase of core activity is smaller than the one observed without the binding financial constraint.

The reaction of the central bank partly dampens the shock. Following the drop in the interest rate, the binding of the financial constraint decreases. The increase in the interest rate is smaller than the one observed without the financial constraint. Because of the limited increase of the interest rate, the interest rate spread decrease is limited which translates into a smaller decrease of the banking return and thus makes the constraint looser and marginally reduces the output drop.

5.2.2 Loan market integration

We now study the impact of cross border lending on the consequences of asymmetric financial and supply shocks in the monetary union, owing to the possibility of financial disruption on the credit market.

Figure 7 depicts the consequences of a 5% decrease in $\varepsilon^{\lambda}_{f,t}$, based on different levels of mutual openness on the loan market. As observed, the possibility of cross border lending has a dampening effect on the peripheral adjustment as it makes the credit constraint looser than in the autarkic situation. Entrepreneurs are now able to purchase a fraction of their loans to core banks, so when the peripheral countries are in a situation of financial

disruption, loan demand shifts from peripheral banks to core banks, which lightens the stress in peripheral credit market (as reported, the cost variable $\zeta_{f,t}$ decreases). The more the financial openness, the fewer the stress on the peripheral credit market and the less are the peripheral credit costs increased. This, in turn, dampens the initial recession and deflation on the peripheral countries.

Conversely, cross border lending deteriorates the situation of the core country. Indeed, as the demand of core loans increases, both from peripheral entrepreneurs who are not able to borrow from peripheral banks anymore and from core entrepreneurs that previously borrowed in the other part of the monetary union, the credit constraint on the core countries becomes binding, which generates a net increase on loans' interest rates, and thus a recession.

As the international connection of the financial system smoothes the effects of financial disruption between the two croups of countries, it has union wide consequences on the aggregates of the monetary union averages. As reported, the effect of an increase in loan market integration is non linear on global recession. Even if recession reaches its maximum for the autarkic situation, perfect integration does not correspond either to the best situation. The baseline calibration adopted in the model ($\alpha_h^L = 0.09$) leads to a better outcome. Due to the underlying value of parameters, we find an optimal level of cross border lending around $\alpha_h^L = 0.29$ when taking into account the variance of the GDP in the entire zone following a shock on $\varepsilon_{f,t}^{\lambda}$. Indeed, for a very low value of financial integration, the marginal positive effect of a 1% increase in α_h^L will be much higher for the peripheral countries than the marginal negative effect on the core countries. Conversely, for a very high value of financial integration, the marginal effect of a 1% increase in α_h^L will cause much more damages in the core countries than it will resolve in the peripheral countries. The length of the constrained period in the peripheral countries is only marginally affected by the choice of α_h^L.

Figure 8 reports the consequences of a 5% decrease in $N_{f,t}^B$, for different levels of financial integration. Once again, the effects are quite similar to those of the confidence shock, the difference lying on the relative size of those effects. However, when testing for different degrees of financial integration, it appears that the magnitude of the macroeconomic effects of the shock on $\varepsilon_t^{N_f^B}$ is not sufficient to trigger the bidding of the financial constraint for the core countries through spillover effects, except of course for a perfect financial integration ($\alpha^L = 0.5$).

Figure 9 reports the effect of cross border lending on the international transmission of negative productivity shock in the peripheral economy. As observed, the degree of cross border lending does not have a significant effect on the real and price adjustment in the eurozone. The main effect is observed on the amount of loan contracted in the eurozone, without affecting noticeably the real equilibrium. This outcome comes from the fact that cross border lending affects the financial consequences of the shock, not the real ones.

6 Credit policy

Our model generates a transitory disruption of lending coming from a worsening of the balance sheet of financial intermediaries. The Central Bank is able to dampen the consequences of shocks on the provision of loans using a credit policy. In this section, we follow Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) by assuming that the central bank proceeds to direct lending measures. Part of the initial unconventional policy measures implemented by the ECB can be associated to direct lending measures, as they eased the credit conditions for the private sector. We evaluate the consequences of such measures according to a state dependent perspective, assuming that they are stopped once the shortage situation ends.

A main challenge of our paper is to assess the degree of inequalities created by such a policy conveyed by the ECB to react to average financial stress in the Euro-area. To this aim, we assess the effect of a homogenous credit policy and we contrast it with policy decisions implemented in relation with the national financial situation of member countries. This allows us to assess the heterogeneous reaction of countries, depending on both their underlying parameters and the situation related to the regional and national financial stress (since, as reported in the previous section, financial disruption can be of different magnitude and length between countries)

6.1 The nature of Credit policy

To assess the way a homogenous credit policy affects both the aggregate and the national situations in the eurozone, we compare two outcomes. We consider as a benchmark a heterogeneous policy that would lead to a first best solution of the problem. We suppose that at the onset of a crisis, the central bank injects credit in response to movements in credit spreads in each economy proportionally to its degree of financial stress measured by $\zeta_{i,t}$. The total amount of loans available to entrepreneurs in each thus becomes,

$$L_{i,t}^{S} = L_{i,t}^{Sp} + L_{i,t}^{Sg}, \tag{40}$$

with $L_{i,t}^{Sp} = L_{i,t}^{S\max} = \phi_{i,t}^{B} N_{i,t}^{B}$, is the loan supply of the private sector, as the initial shock triggers the binding of the credit constraint for country i, and $L_{i,t}^{Sg}$ is the quantity of loans supplied by the central bank. As in Gertler and Karadi (2011), there is no agency problem between the central bank and its creditors because it can commit to always honoring its debt.[15] We assume that the central bank offers loans proportionally to the quantity of total assets offered in the economy,

$$L_{i,t}^{Sg} = \psi_i L_{i,t}^{S}, \tag{41}$$

[15] We refer the reader to the discussion provided in Gertler and Karadi (2011).

with $0 < \psi_{i,t} < 1$, is the credit policy variable. In this situation, the bank's accelerator is,

$$L_{i,t}^{S} = \frac{\phi_{i,t}^{B}}{1-\psi_{i,t}} N_{i,t}^{B}. \tag{42}$$

As in Gertler and Karadi (2011), $\phi_{i,c,t}^{B} \equiv \frac{\phi_{i,t}^{B}}{1-\psi_{i,t}}$, so $\phi_{i,c,t}^{B} > \phi_{i,t}^{B}$, i.e., the credit policy reinforces the leverage effect on bank's capitalization in the economy.

However, in contrast with Gertler and Karadi (2011), we link the implementation of a credit policy to a situation of lending shortage coming from financial intermediaries. We assume that the size of this policy is proportional to the quantity of missing loans in the economy that suffers the shock. As we outlined above the rise in the interest rate of loans is symptomatic of the financial distress in the economy and the size of credit shortage in the core countries (resp. peripheral countries) can be approached by the value of $\zeta_{h,t}$ (resp. $\zeta_{f,t}$),

$$\zeta_{h,t} = \frac{\epsilon_{h}^{B}-1}{\epsilon_{h}^{B}} \left(1-\tau_{h}^{B}\right) \left(E_t\left[\eta_{h,t+1}^{E}\right] - \left(E_t\left[\eta_{h,t+1}^{E}\right] - E_t\left[\eta_{f,t+1}^{E}\right]\right) \Xi_{h,t}\right) \left(R_{h,t}^{L} - R_{h,t}^{L,S}\right), \tag{43}$$

$$\zeta_{f,t} = \frac{\epsilon_{f}^{B}-1}{\epsilon_{f}^{B}} \left(1-\tau_{f}^{B}\right) \left(E_t\left[\eta_{f,t+1}^{E}\right] - \left(E_t\left[\eta_{f,t+1}^{E}\right] - E_t\left[\eta_{h,t+1}^{E}\right]\right) \Xi_{f,t}\right) \left(R_{f,t}^{L} - R_{f,t}^{L,S}\right), \tag{44}$$

which serves as a proxy to measure the size of financial disruption in the economy.

Thus, for the heterogeneous credit policy, we link the credit policy parameter to this indicator of market stress, according to,

$$\psi_{h,t} = v_h \zeta_{h,t}, \tag{45}$$

$$\psi_{f,t} = v_f \zeta_{f,t}, \tag{46}$$

with v_i a scale parameter. For low degrees of financial integration, the credit constraint does not transmit to the core countries, so there is no financial stress in the core financial system ($\zeta_{h,t} = 0$), and $\psi_{h,t} = 0$.

According to its status, the ECB conducts monetary policy actions taking into account the average situation in the monetary union. Thus, the credit policy rule is related to an average level of financial disruption between the two country, and is operated as a purchase of the same quantity of assets in each country. The credit policy rule for each country is defined as,

$$\psi_{h,t} = \psi_{f,t} = v \frac{\zeta_{h,t} + \zeta_{f,t}}{2}, \tag{47}$$

so for each country i, the equality $L_{i,t}^{S} = \frac{\phi_{i,t}^{B}}{1-\psi_{i,t}} N_{i,t}^{B}$, with $\psi_{i,t} \neq 0$, holds.

6.2 Impulse response functions

Here we study the consequences of different types of credit policies on the dampening of the initial shock, and on the magnitude and length of the financial disruption event for both countries. We fix the degree of financial openness to our benchmark calibration $\alpha_h^L = 1 - \alpha_f^L = 0.09$.

Figure 10 reports the consequences of a transitory credit policy following a negative shock on $\lambda_{f,t}$. As observed, the net macroeconomic effects of credit policy is clearly positive. Credit policy unambiguously reduces the magnitude of the crisis (as measured by variable $\zeta_{f,t}$), whatever the calibration is. Independently of its specification (reacting to national or global features) this policy always leads to a better outcome than the conventional monetary policy alone.

Unsurprisingly, a credit policy taylored to the local situation of the periphery is clearly more efficient than the homogenous credit policy based on average financial developments of the monetary union. Indeed, as the homogenous credit policy is based on the average binding degree of financial constraints in the two parts of the monetary union, the magnitude of this credit policy is far less important on the peripheral financial market than the other one's. Moreover, as half of the asset purchases is directed towards the core countries, which are affected by a lower financial disruption, most of these asset purchases is useless with respect to the bank credit channel. Indeed, when the possibility of a financial disruption is totally suppressed for the core countries, there is no need to further increase the maximum value of the credit supply, because it does not affect the amount of loans in normal times (in normal times, the maximum amount of loans on the economy is only determined by the credit demand from entrepreneurs, and cost function and market power of banks). However, as in Gertler and Karadi (2011), there is no significant negative effect of expanding the Central Bank balance sheet, because the cost function associated to Central Bank credit intermediation is linear, and with cost parameter τ_i calibrated at a very low value.

One shall note that the nature of the financial shock affects the final outcome of credit policy and the international transmission of the quantitative tightening of loans.

Turning to the situation of the core countries, we get unambiguous results. For a low benchmark value of financial integration ($\alpha^L = 0.09$), the net effects of the peripheral negative financial shocks on core countries are positive, as the international effects of the transmission of the financial crisis from peripheral to core countries are not big enough to overcome the positive international spillover effects coming from an accomodating union-wide conventional monetary policy. Noticeably, since a credit policy would have a higher negative impact on core countries through as it leads to a dampening in the decrease of the policy interest rate, conducting no credit policy at the union level should be a first best policy reaction from the point of view of core countries. Accordingly since both credit policies totally erase financial disruption for core countries, the most efficient solution for the peripheral group of countries (i.e. the heterogeneous credit policy) is also the less efficient one for the core country group, as the latter takes some "advantages" of the financial disruption in the peripheral countries through the conventional monetary policy channel.

However, considering the eurozone as a whole, a "differentiated" credit policy provides better results in reducing

the impact of macroeconomic shocks. However, as ECB clearly excludes the possibility of targeting its asset purchases differently across the eurozone according to country specific factors, conducting a differentiated credit policy is definitely not an option.

Figure 11 presents the effects of a negative shock on peripheral banks' asset values $N^B_{f,t}$ along the same policy regimes. As reported, the effects are almost similar to those observed for the previous shock. Once again, the main difference with respect to the other financial shock lies on the relative size of these effects. For the benchmark calibration, the shock on peripheral banks' asset values does not trigger a binding financial constraint for core countries. Thus, a differentiated credit policy will only target peripheral country, while a homogenous credit policy will only have direct effects on the loan market of the peripheral country, with half the size of the heterogeneous credit policy.

The effects of the different credit policies in case of a shock on $\varepsilon^a_{f,t}$ are reported in Figure 12. As observed credit policies tend to reduce the magnitude of the shock with regard to a situation with no credit policy, through the decrease in the value of the binding variable of both credit constraints. However, we can hardly distinguish between the effects of the different credit policies, because as the technology shock is a real shock, the saturation of the credit constraint is not the only mechanism by which it affects the economy, so reducing the effects of the binding of the credit constraint has a proportionally lesser impact on the total effects of the shock.

6.3 Evaluating the inefficiency of homogenous credit policy

Unconventional monetary policy responds to the average loan market tightness in the monetary union. As already underlined, by reacting to average developments, the central bank does not target directly financial problems where they occur. As a consequence, such a policy can only be considered as a second best solution with respect to a credit policy reacting heterogeneously to national developments. We assess the relative inefficiency of the homogenous credit policy along two complementary indicators based on the cumulated output losses along the transitory path where the economy goes back to its steady state equilibrium after a financial shock.

First, in Figure 14 we report the cumulated core, peripheral and monetary union output losses with resepct to the steady state (ie, the cumulated log-deviation of GDP series) under the conventional and unconventional policies (distinguishing the homogenous conduct of the effective policy from the first best solution based on national credit market tighness). We report figures for values of the loan market openness ranking from 0 (no integration) to 0.5 (full integration), following a shock on peripheral banks' net worth (higher panel) and on peripheral deposits (lower panel).

Unsurprisingly, credit policy dampens output developments for all values of the cross border lending parameter for peripheral countries and the eurozone as a whole. The situation is more mixed for core countries as we observe a better performance of the conventional for very high value of cross border lending ($\alpha^L > 0.4$). As observed, at the core level a higher loan market integration slightly improves the performance of both unconventional solutions,

and the two modalities become closer at the national level for cross border lending equal to 0.3 (which corresponds to the credit market integration for which cumulated output losses move to a negative value so that a credit policy becomes beneficial). Nevertheless at the aggregate monetary union, the relative performance of heterogenous policies remains unaffected (even if the difference is small and represents an increase in output deviation of 20% for cumulated output losses with respect over a period of 40 quarters)

Second, the performance of homogenous actions can also be evaluated along a second metric balancing the average union wide effect performance with its heterogeneous consequences between core and peripheral countries. Formally Figure 15 reports values for the following ratio,

$$Ratio = \left(\frac{y_{h,t} - y_{f,t}}{\frac{y_{h,t}+y_{f,t}}{2}} \right)^2$$

for all three policy scenarios. This ratio balances the whole average performance of the policy (the denominator measures per capita average eurozone output) with the size of heterogeneity in its transmission to national economies. The square value is useful to concentrate on asymmetry while the in the monetary union. furthtermore a lower value of this ratio underlines a more homogenous impact of the policy over the monetary union countries. Finally a value equal to zero underlines an homogenous transmission of the policy stance to all eurozone countries. As for figure 14, we report values for this indicator with respect to the size of cross border lending between core and peripheral countries.

Our main findings can be stated as follows: Unsurprisingly the heterogeneity in the transmission of all policies disappears for perfect loan market integration ($\alpha^L = 0.4$). As observed unconventional policy actions provide less heterogeneity in the adjustment path of output following a financial crisis. Furthermore, the difference between the homogenous unconventional monetary policy and the first best unconventional monetary policy is not that much. As reported, the heterogenous effects of all three policies reach almost a similar value for cross border lending neighboring 30%, since the value of the computed ratio becomes almost similar.

Finally, combining Figure13 and 14, we see that if cross border lending integration increases the heterogenous policy becomes less efficient for the peripheral countries with respect to the two other policy scenarios, while we observe an opposite outcome for the core country group (in figure 14). As a consequence, the inequalities steaming from the homogenous credit policy decrease as the cross border lending parameter increases.

7 Conclusion

The main objective of this paper was to provide an analysis of the heterogeneous consequences of homogenous unconventional policy measures undertaken by the ECB to fight the initial financial disruption that affected the eurozone at the beginning of the crisis. We have introduced a two country DSGE model that accounts for cross border lending relations as a major source of spillovers between eurozone members and the possibility of financial

disruption on the loan market. On the policy side we combine a conventional monetary policy based on the steering of a short run interest rate with a state dependent credit policy aiming at providing liquidity to the banking sector to avoid a disruption in credit supply.

We find that the global macroeconomic and welfare consequences of the unconventional part of monetary policy partly rest on the size of cross border lending relations. First, cross border lending plays an ambiguous role for transmitting a regional financial stress arising in the periphery to the global EMU level as it affects core situations in opposite directions. In particular we find that there exists an optimal level of financial integration for which the net effects of financial shocks are minimized amongst the Eurozone. Second, we assess the global effect of an homogenous temporary credit policy adopted to fight financial disruption affecting one part of the monetary union. We find that the conduct of credit policy unambiguously improves the situation of the monetary union, albeit with differing consequences on national economies. When considering the bank credit channel, a differentiated credit policy (asset purchases in each country, depending on the magnitude of financial disruption in each country) is the best credit policy. The common credit policy is less efficient, because it is less adapted to the needs of each country (pointlessly high in the country where financial disruption is low, insufficient in the country where financial disruption is high). However the inequalities between core and periphery induced by a second best credit policy decrease with the degree of financial integration.

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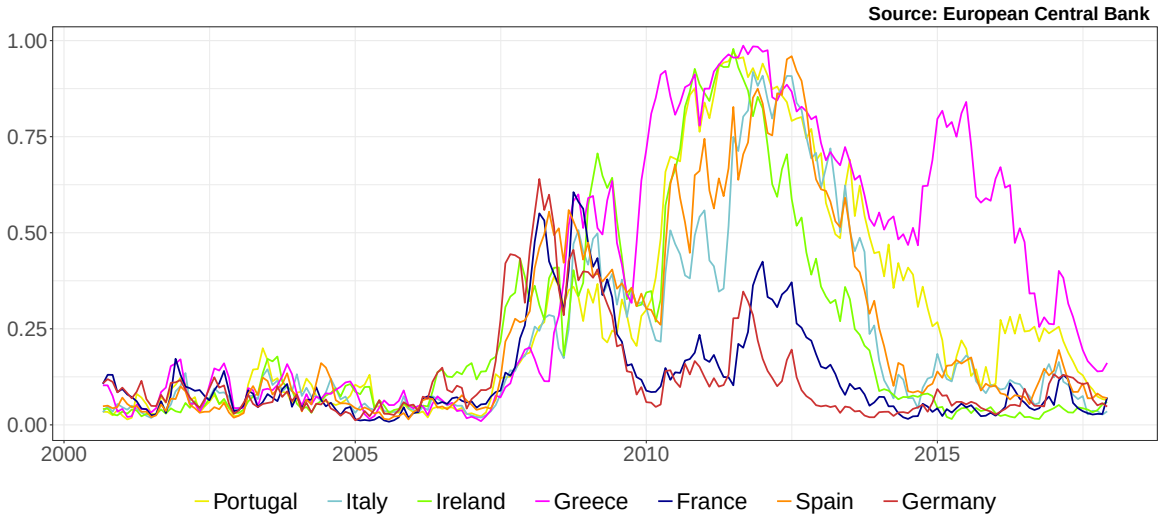

Figure 1: Composite Indicator of Systemic Stress for eurozone members

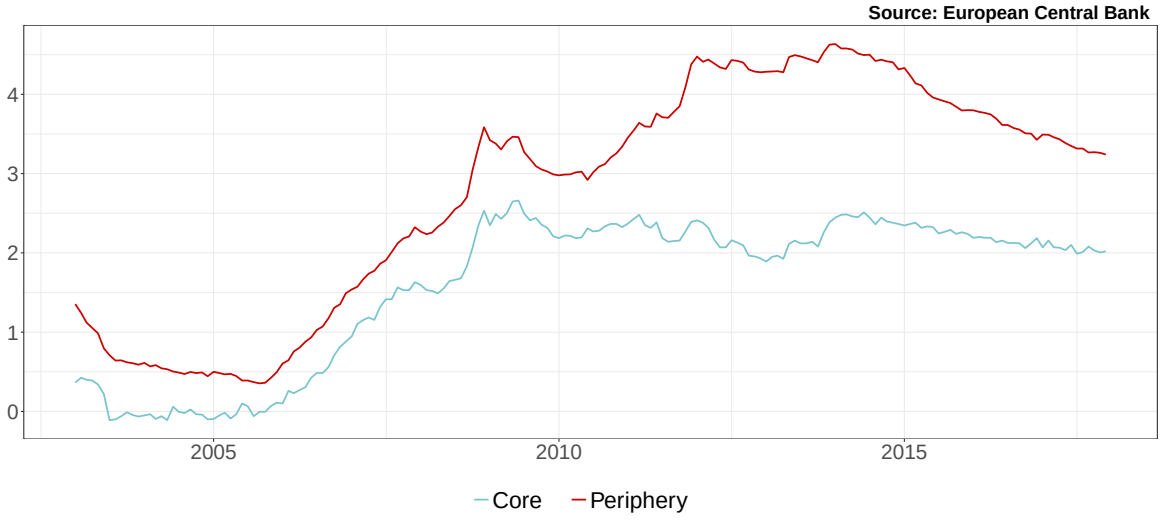

Figure 2: Interest rate spread - Core and peripheral countries

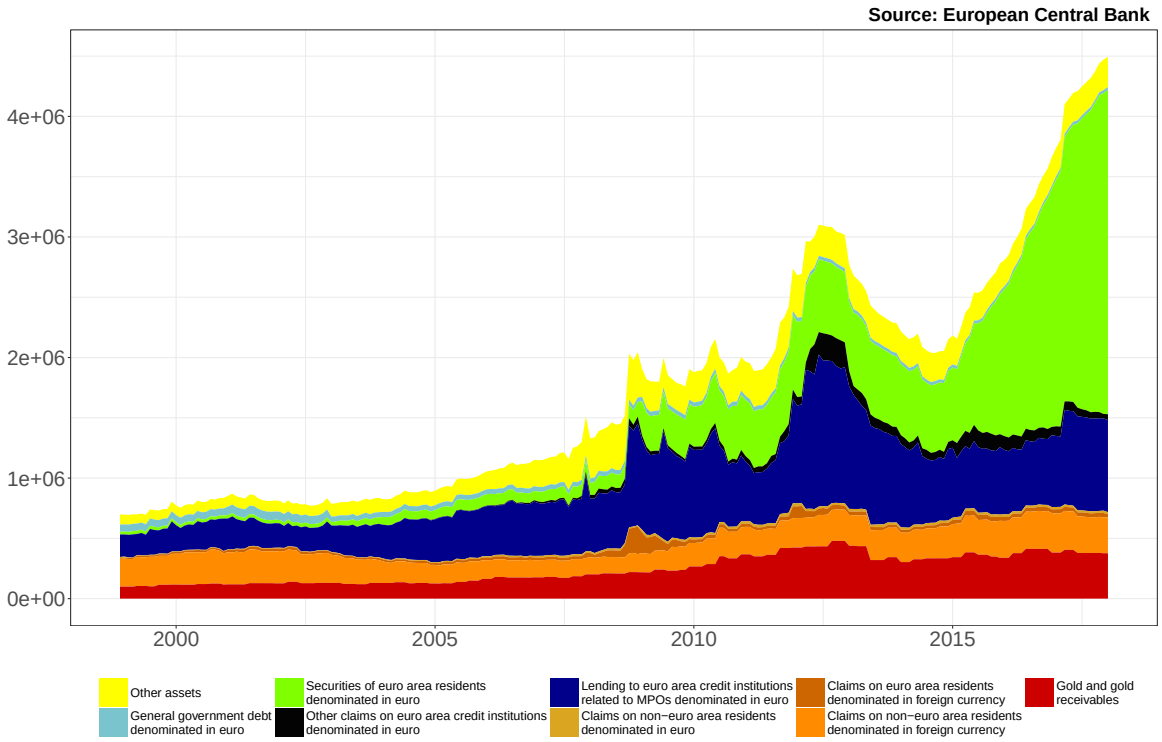

Figure 3: ECB balance sheet

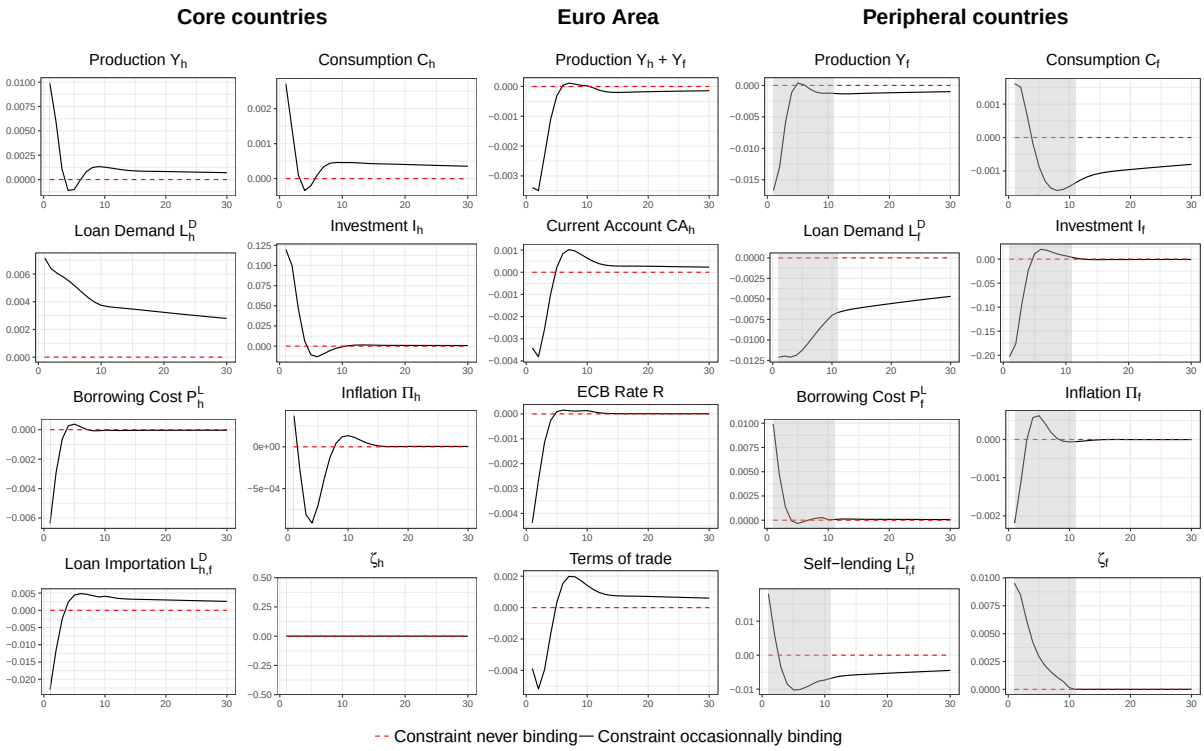

Figure 4: Shock on λ, without financial integration, response of the model with and without credit constraint

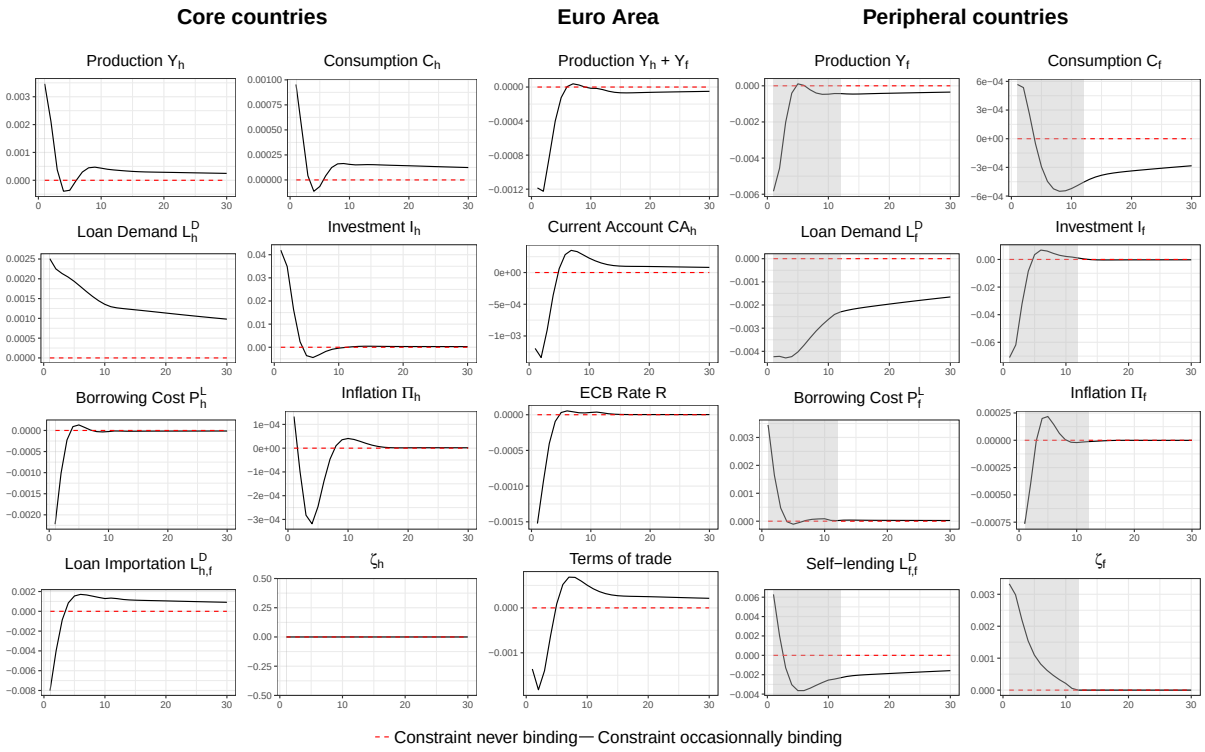

Figure 5: Shock on N^B, without financial integration, response of the model with and without credit constraint

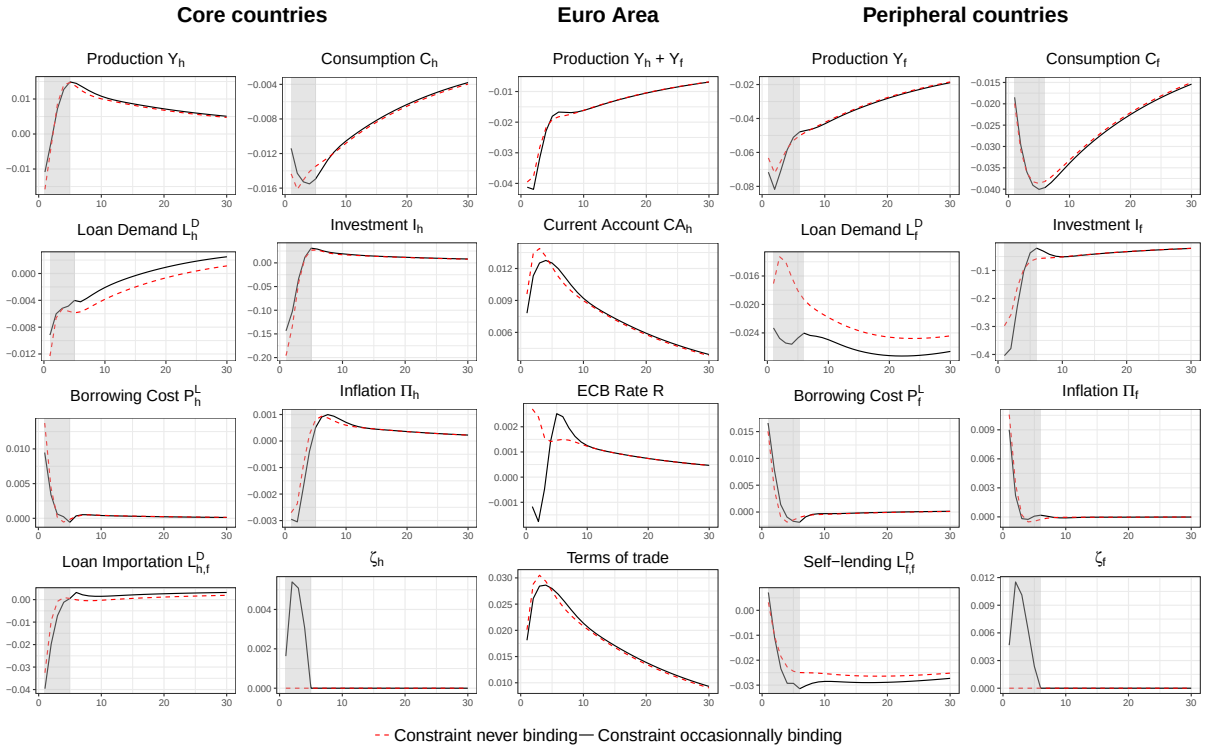

Figure 6: Shock on technology, without financial integration, response of the model with and without credit constraint

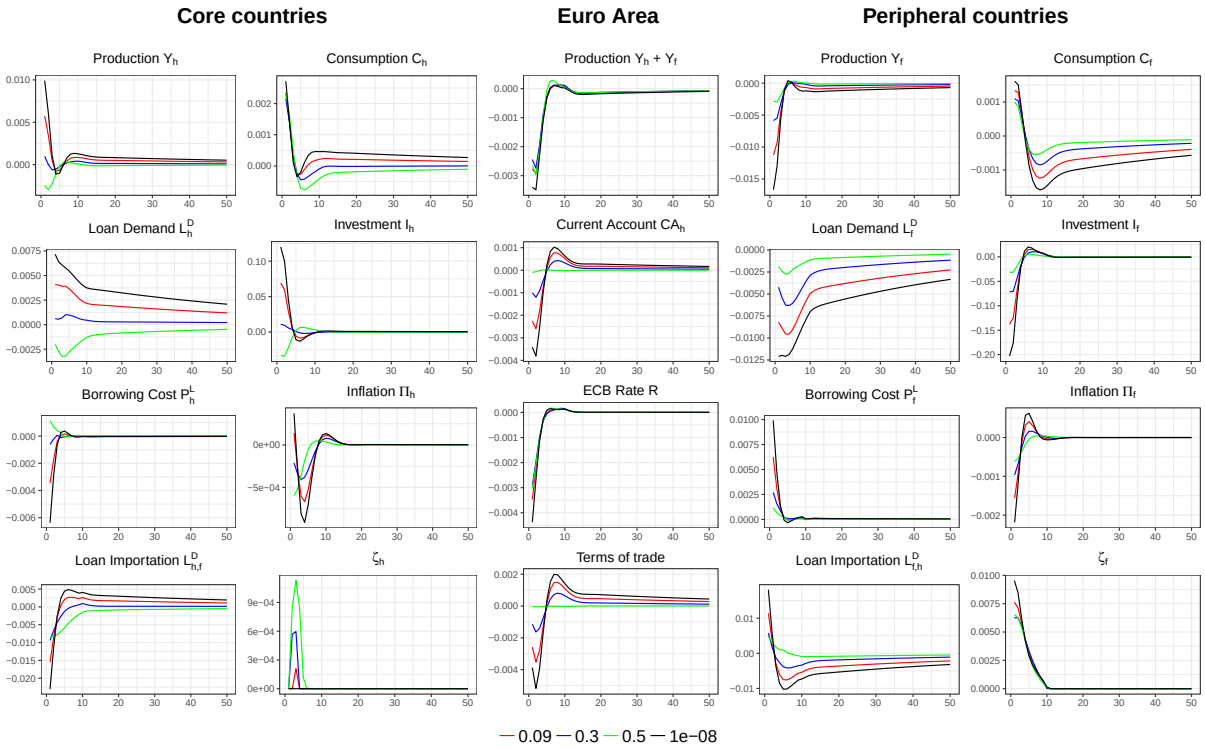

Figure 7: Shock on λ, different levels of financial integration

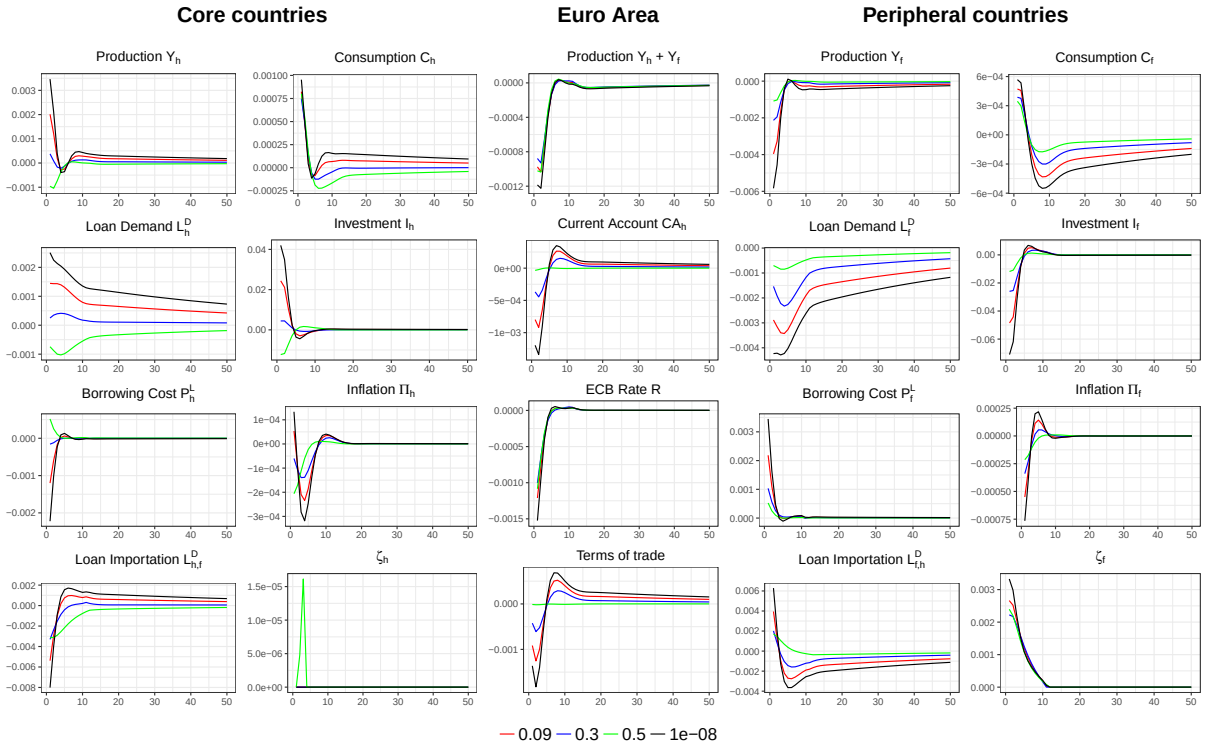

Figure 8: Shock on N^B, different levels of financial integration

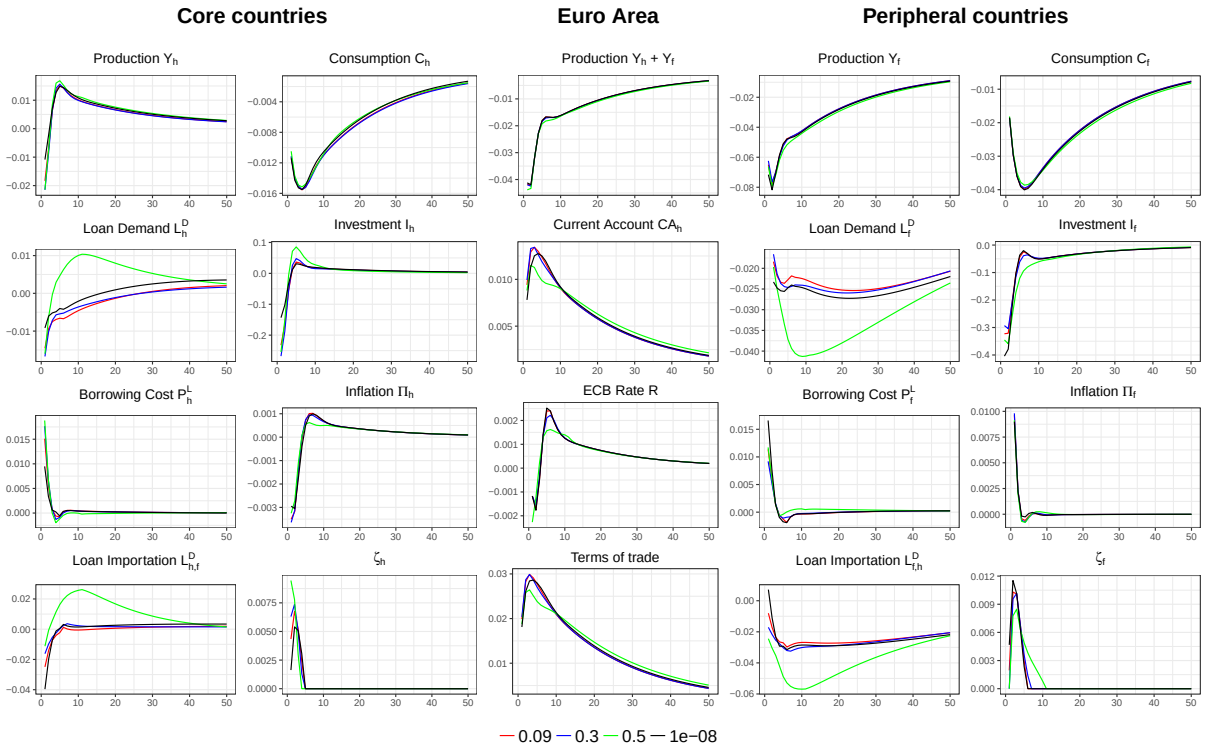

Figure 9: Shock on technology, different levels of financial integration

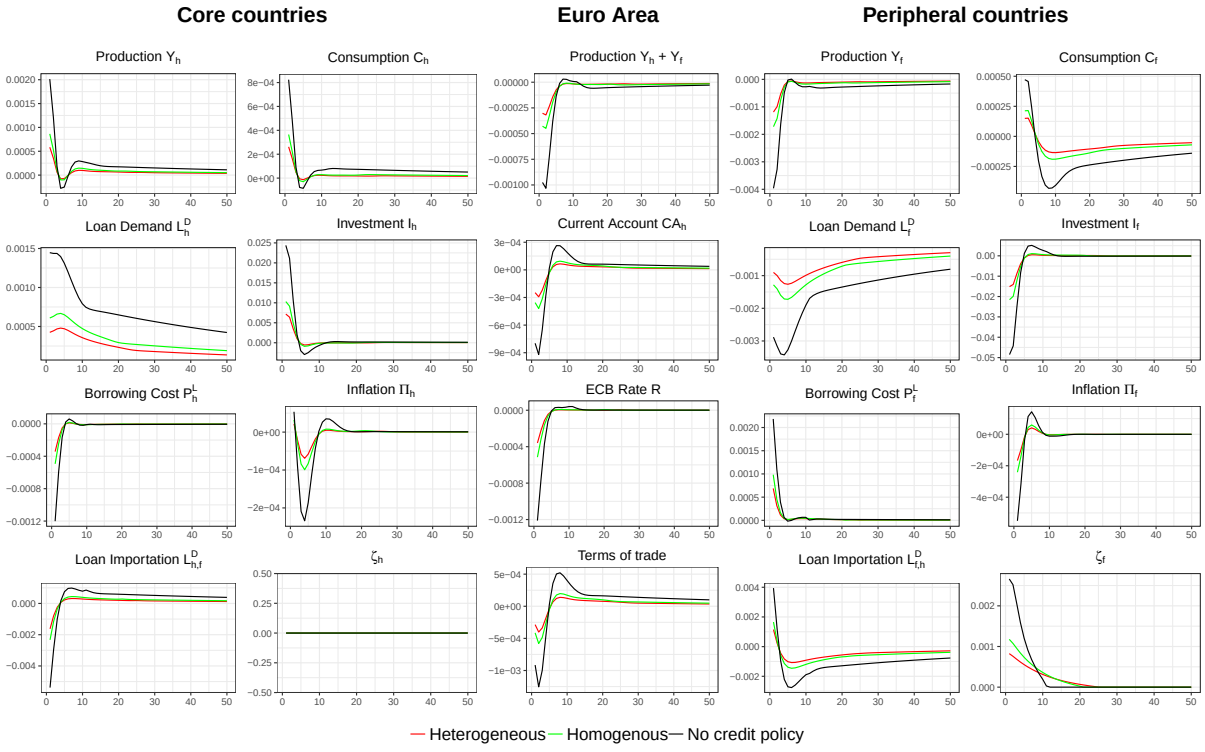

Figure 10: Shock on λ, different credit policies

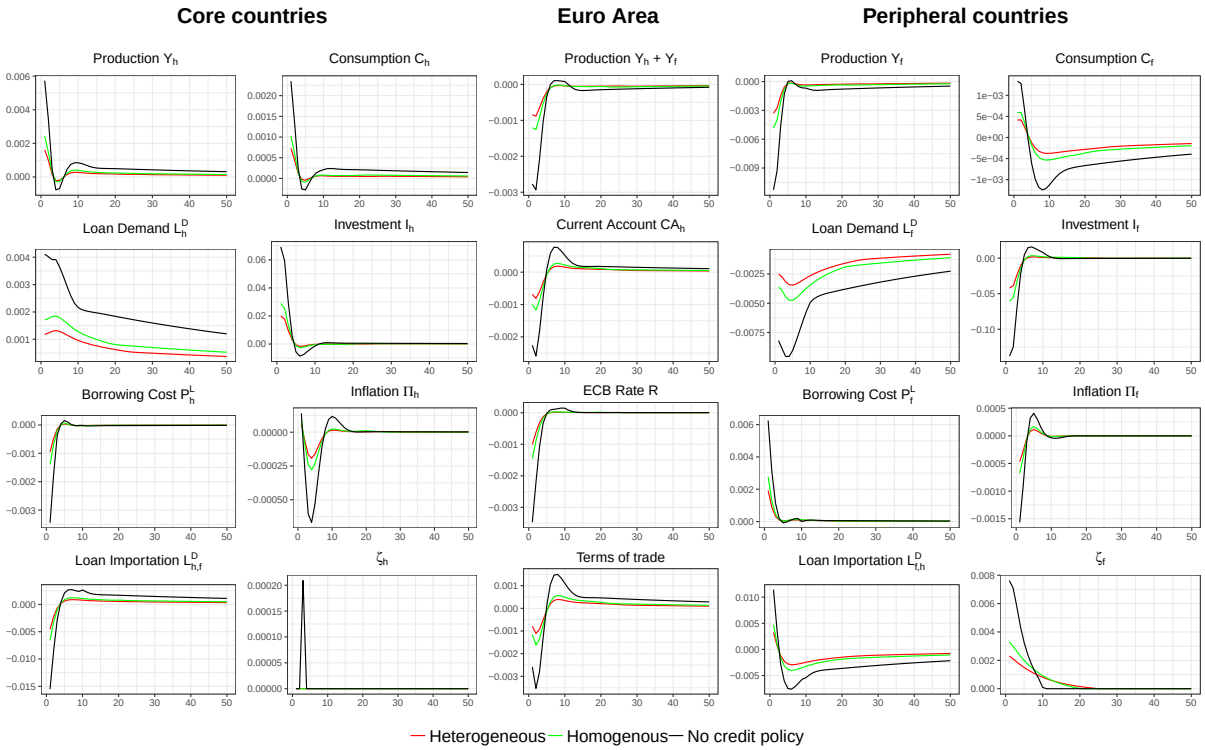

Figure 11: Shock on N^B, different credit policies

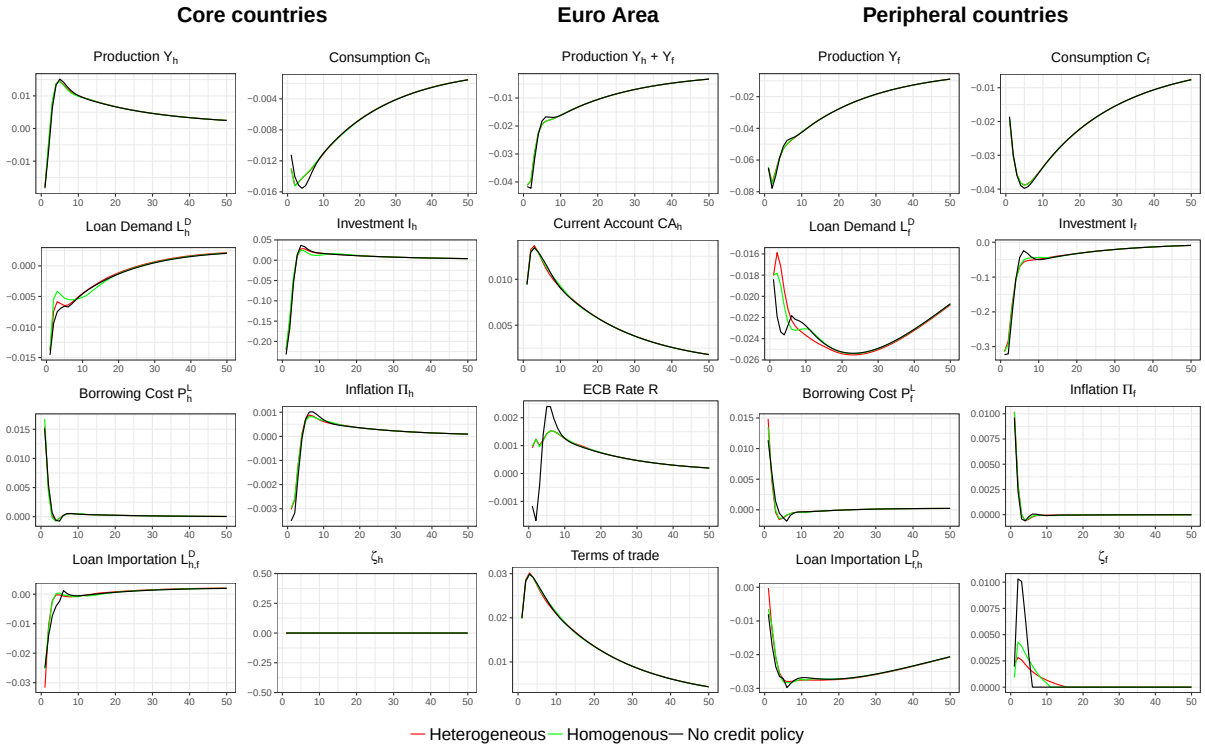

Figure 12: Shock on technology, different credit policies

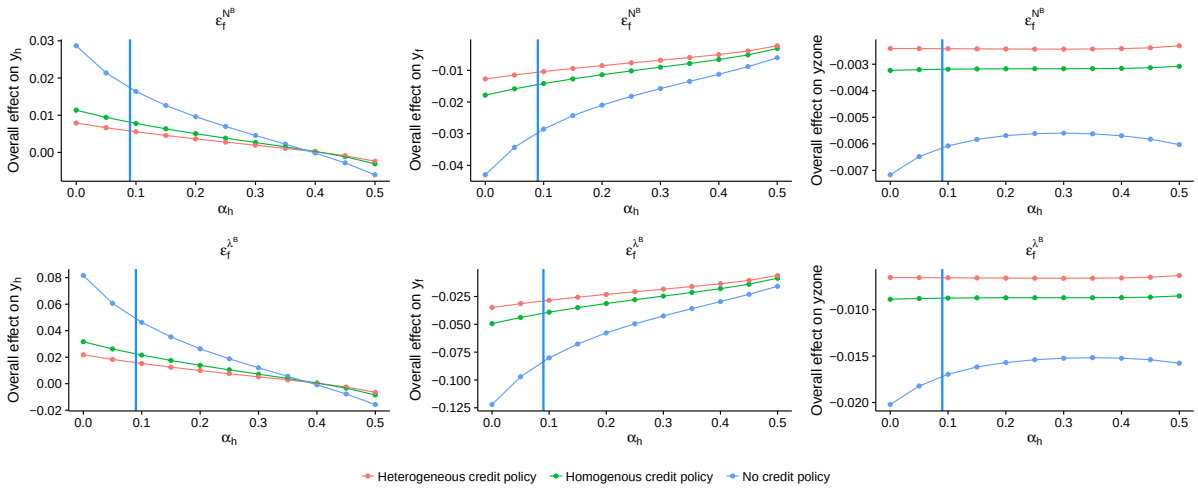

Figure 13: Cumulated effect of the financial shocks on the GDP of core countries, peripheral countries, and the whole eurozone, for different types of credit policies and different levels of financial integration

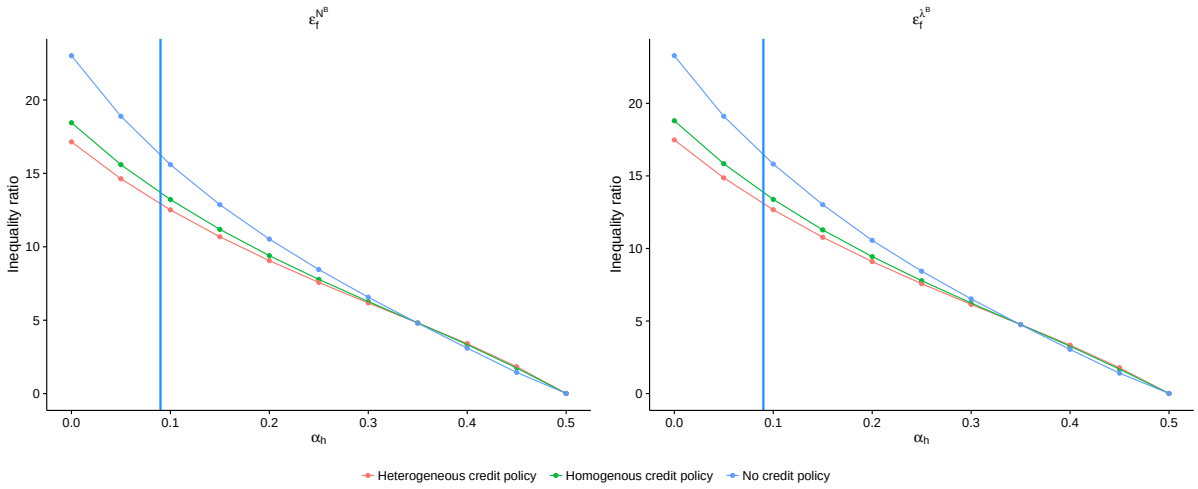

Figure 14: Inequality ratio following the realization of financial shocks, for different types of credit policies and different levels of financial integration