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Sovereign debt default and banking in a currency union

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Sovereign debt default and banking in a currency union[1]

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Abstract: This paper analyzes the role of banking in the transmission of sovereign debt default within a currency union. We build a 2-country (core and periphery) new-Keynesian model with an endogenous possibility of default on the periphery public debt. We introduce alternative banking representations, going from full integration to fragmentation. We calibrate the model on euro area data and show that the best fit to empirical data arises when we introduce some degree of fragmentation. However, we observe that a well integrated banking sector would reduce the negative consequences of default at the EA aggregated level and limit the welfare cost of stabilizing policies.

Keywords: Sovereign default, Banking, Currency union, New-Keynesian model.

Défaut souverain et secteur bancaire dans une union monétaire

Abstract : Ce papier étudie le rôle du secteur bancaire dans la transmission d'un défaut souverain, dans le cadre d'une union monétaire. Nous construisons un modèle néo-keynésien à 2 pays, avec possibilité de défaut souverain endogène dans un pays. Nous introduisons un secteur bancaire qui peut être complètement intégré, complètement fragmenté ou bien dans toute situation intermédiaire. Nous calibrons ce modèle sur données de la zone euro et montrons que les moments simulés sont les plus proches des données quand nous introduisons un certain degré de fragmentation. Nous montrons cependant qu'un secteur bancaire complètement intégré aurait permis, au niveau agrégé, de réduire les retombées négatives d'un défaut souverain et de limiter la perte de bien-être due aux politiques de stabilisation.

Mots-clefs : défaut souverain, secteur bancaire, union monétaire, modèle néo-keynésien.

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1 Introduction

The global financial crisis starting in 2007 prompted a reassessment of asset prices and growth prospect in the euro area (EA hereafter). As a result, in late 2009, countries like Ireland and Spain began to report – much – larger than expected fiscal deficits, rising spreads on sovereign debt. Some downgrades later, most periphery countries – also called GIIPS for Greece, Ireland, Italy, Portugal and Spain – were in deep troubles, with surges in sovereign bond yields and fears of default. At the same time, countries perceived as safe – we call them core countries – saw their sovereign yields reducing to a historical low.[1] The left-hand-side of Figure 1 displays this story. The sovereign crisis also led to credit restrictions to the private sector in the whole euro area. The right-hand-side of Figure 1 shows that between 2010 and 2012, interest rates on loans to non-financial corporations (NFC) increased by more than 100 basis points in the periphery and by approximately 60 basis points in the core.[2] We therefore observe spillovers from default risk on periphery sovereign debt (or default realization in the case of Greece) to the private credit and to the core countries. There is now a wide consensus on the role the banking system played in the transmission. De Bruyckere et al. (2012) among the others suggests two main channels of transmission: the capital channel as a sovereign default weakens the asset side of the bank's balance sheet and the collateral channel as sovereign bonds are often used as collateral on the interbank market in order to obtain funds needed to provide credit to the private sector. Moreover Brutti and Sauré (2012) using a VAR model show that strong interdependence between banks and cross-border exposures to sovereign debt explain up to 2/3 of the transmission of the Euro debt crisis. To look more precisely at the structure of the EA banking system, we use data from various sources.[3] We observe that until 2008, the EA banking sector became highly integrated. Public and private debt obligations of the troubled countries of the euro zone were largely held by creditors in other parts of the euro zone and, moreover, banks were also closely connected through cross-border interbank market. From 2009 onwards, banking data however show a gradual fragmentation as well as a 'flight-to-quality'. Many recent papers also underline this time-varying integration. For instance, the ECB (2012) or Abascal et al. (2013) explain the important role of the single currency in the process of financial integration but also show that this integration receded between 2008 and 2011.

In this paper we develop a new, comprehensive, model for a two-country economy that is able to study the role of the structure of the banking sector and to account for the previous stylized facts. We show that the best fit to empirical data arises when we introduce some degree of banking fragmentation. However, we observe that a well integrated banking sector would reduce the negative consequences of default at the EA aggregated level and limit the welfare cost of stabilizing policies.

Our contribution to the literature is twofold.

First we enlarge the literature on sovereign default by studying default in a currency union. There exist several models with explicit default modeling. In partial equilibrium setups, Eaton and Gersovitz (1981) and Arellano (2008) model default as an optimal choice of the government. Instead, in Bi and Leeper (2010) and Juessen et al. (2011), default results from a binding fiscal limit

[1] This is admittedly a very short and rough report of the historical developments. The interested reader may for instance refer to Lane (2012) for a detailed account.

[2] In the core, the average increase in the loan rate from 2010Q1 to 2011Q4 was of 0.6 percent with a minimum increase of 0.46 for France and a maximum of 0.76 for Finland. The region is therefore rather homogenous. In the periphery the average was of 1.32 percent but hiding a high degree of heterogeneity. Countries like Greece and Portugal faced an increase respectively of 1.94 and 2.16 percent whereas countries like Spain and Ireland of approximately 0.8 percent and Italy of 0.91.

[3] Appendix A reproduces these banking data and provides a short description.

impeding the government to raise enough funds to repay the debt. Another strand of the literature on sovereign default, to which our work contributes, focuses on the interaction between sovereign risk and the financial sector. In a partial equilibrium setup Gennaioli et al. (2010) and Bolton and Jeanne (2011) study the interaction between the sovereign default risk and the banking system. Both studies explore the role of bank's balance sheet and show that the greater is the default, the weaker are the bank's balance sheets determining international contagion and reduction in investment. Using a closed-economy DSGE model, Mallucci (2013) also shows how the cyclicality of bank's balance sheets magnifies the impact of sovereign debt crisis on the real economy. Corsetti et al. (2013) analyze the impact of strained government finances on macroeconomic stability and the transmission of fiscal policy. The key idea is that sovereign risk raises the funding costs of the private sector because of the increase in the costs of financial intermediation. van der Kwaak and van Wijnbergen (2013) analyze the interaction between bank rescues, financial fragility and sovereign debt risk in a closed economy. However all the previous mentioned studies focus at the closed economy level while data suggests that in a currency union the default of one country can have consequences also for the other economies. We consider for instance a *DSGE model* for a currency union to understand sovereign default and sovereign risk propagation. Guerrieri et al. (2012) build an international real business cycle model with country-specific banks and study the propagation of sovereign debt default realization. However they do not consider the effect of expectations nor the monetary policy dimension. Therefore their model is not equipped to explain both a sovereign default and a sovereign risk of default being the latter the most relevant shock in the EA sovereign debt crisis (only Greece effectively defaulted).

Second we contribute to the literature of financial frictions and banking in a currency union.

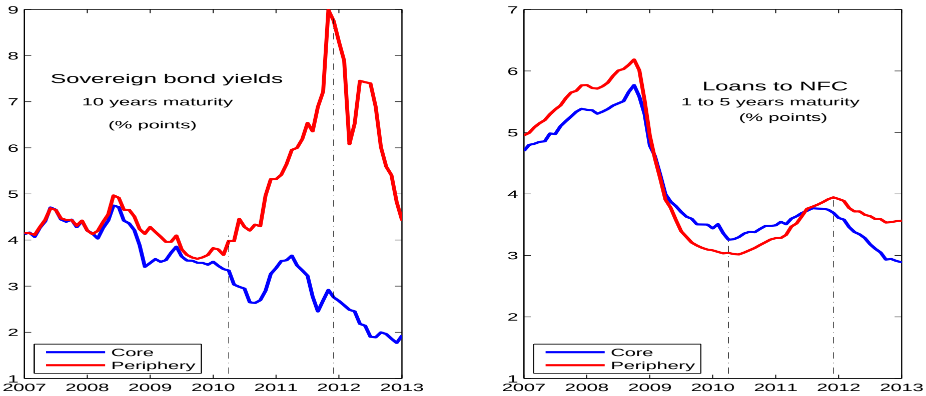
Monetary integration in a currency union is obvious and the key role of banks has been highlighted above, nevertheless very few papers have studied banking in a currency union. Current models either develop trade and banking without monetary policy (Enders et al., 2011; Guerrieri et al., 2012) or banking in a closed-economy new-Keynesian model (Gerali et al., 2010). This paper is a first attempt to combine the two dimensions. Bignon et al. (2013) also develop a currency union model with a banking sector. However they are interested in attesting the desirability of a currency union depending on different degrees of credit market integration.

More precisely, we build a 2-country DSGE model of a currency union, that is with a common monetary policy. Trade between countries follows Gali and Monacelli (2008). Regarding the banking sector representation, we follow Enders et al. (2011) and Kollmann (2013) by introducing a perfectly competitive banking sector playing at the EA wide level with a cost on capital shortage (bank capital channel). Moreover, given the expected importance of the banking sector, we do not focus on one single representation but look at different alternatives, from full integration to fragmentation. Fragmentation is a case of limited credit market integration that may come from technological as well as regulatory impediment when banks want to grant credit to non-residents. We capture this dimension via the bank collateral channel as in the case of fragmentation banks are more in favour of domestic credit and collateral. Default arises endogenously as in Corsetti et al. (2013), when actual debt-to-GDP becomes too close to a feasible – or sustainable – maximum level. The bank transmits this default to the real economy mainly through the bank capital channel and the collateral channel. It is worth noting we make the distinction between a default *risk* and a default *realization*. We calibrate the model on EA data.

We find that, first, using an integrated bank approach, realization has a deeper impact on output than risk, mainly through the bank capital and the bank collateral channels (lower excess capital and lower eligible collateral with realization). Moreover, both with risk and realization, the integrated bank assumption allows to share almost perfectly between regions the periphery sovereign troubles. Second, moving from an integrated bank representation to fragmentation prevents the full sharing of the periphery turmoil. As a result, the situation in the periphery deteriorates further which benefits to the core region because of a too loose – for the core – monetary policy. The aggregate situation at the EA wide level is worse with fragmentation. Third, our model reproduces the best empirical data when we introduce only some degree of fragmentation. Fourth, from a policy point of view, we see that counter-cyclical capital requirements targeting output growth reduces seriously the volatility of output without implying a too high welfare cost. Extending the Taylor rule to include sovereign spreads does not really allow to reduce output volatility. In general, whatever the policy, the welfare costs of stabilizing the economy are much lower under a well integrated banking sector. This result is in line with the findings of Bignon et al. (2013) showing that a in a currency union is optimal to have banking union.

Section 2 details the model. Section 3 explains the calibration. Section 4 presents the dynamic simulations. Section 5 concludes.

Figure 1: Evolutions of selected interest rates



Notes. Evolution of 10 years sovereign bond yields and of 1 to 5 years maturity loans to non financial corporations (NFC) for core and periphery countries. Core countries include: Austria, Belgium, Germany, France, Finland whereas periphery countries are: Greece, Ireland, Italy, Portugal and Spain. The aggregated series has been created by weighting each country by their GDP. The vertical dotted lines signal the beginning of the sovereign debt crisis (2010Q1) and its acknowledged end (2011Q4).

Data sources: respectively Datastream and the ECB Statistical Data Warehouse.

2 Model

We develop a two-country model for the euro area. We call the first country/region as *core* and we denote it by c hereafter. We call the second country/region as *periphery* and we denote it by p hereafter. We introduce nominal rigidities, monetary policy and an endogenous probability of default on the government debt. We first characterize a fully integrated banking sector via the use of a single iternational bank. We then introduce fragmentation. We assume symmetric countries in the sense that parameters are country invariant. The only departure from symmetry is that the core country has a lower debt level than the periphery country.[4]

2.1 Households

In each country $j \in \{c, p\}$, the representative household may consume C_t^j final goods, invest D_t^j in one-period (international) bank deposits or b_t^j in one-period sovereign debt. The – predetermined – gross nominal return on deposits is $R_{t-1}^{d,j}$ and $\epsilon_t^j \geq 0$ captures the share of outstanding sovereign debt lost by households because of – partial – sovereign default.[5] The household also supplies h_t^j hours to firms and receives wages w_t^j. It moreover owns the firms located in j and therefore receives their profits Υ_t^j, as well as a lump-sum income $H_t^{h,j}$ from the government. Finally, the household must pay taxes T_t^j and quadratic portfolio adjustment costs on deposits and sovereign debt, represented respectively by the parameters $\phi_d > 0$ and $\phi_b > 0$ in equation (1). These costs make the household's portfolio choices less sensitive to interest rate differentials.[6] It is worth noting that we segment both the sovereign debt market and the labour market at the household's level, i.e. the household in j may only hold debt from government j and work in country j. The household's budget constraint is:

$$C_t^j + D_t^j + b_t^j + T_t^j + \frac{\phi_d}{2}(D_t^j - D_{t-1}^j)^2 + \frac{\phi_b}{2}(b_t^j - \bar{b}^j)^2 = w_t^j h_t^j + \frac{R_{t-1}^{d,j}}{\Pi_t^j} D_{t-1}^j + \frac{R_{t-1}^{b,j} - \epsilon_t^j}{\Pi_t^j} b_{t-1}^j + \Upsilon_t^j + H_t^{h,j} , \tag{1}$$

where Π_t^j is final goods inflation and, throughout the paper, $\bar{z}$ represents the steady state of any variable z_t. The household's expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \left(\ln C_t^j + \psi_d \ln D_t^j - \frac{\psi_n}{2} \left(h_t^j \right)^2 \right) . \tag{2}$$

As in Enders et al. (2011), we assume that deposits provide utility to the household and we take a logarithmic utility. We also take a logarithmic instantaneous utility of consumption and a quadratic disutility of hours. $0 < \beta < 1$ is the subjective discount factor and ψ_d, $\psi_n > 0$ are parameters. The household maximizes (2) with respect to (1). It gives three first order conditions:

$$(C_t^j)^{-1} \left(1 + \phi_d (D_t^j - D_{t-1}^j) \right) = \frac{\psi_d}{D_t^j} + E_t \, \beta \, (C_{t+1}^j)^{-1} \left(\frac{R_t^{d,j}}{\Pi_{t+1}^j} + \phi_d (D_{t+1}^j - D_t^j) \right) , \tag{3}$$

$$(C_t^j)^{-1} \left(1 + \phi_b (b_t^j - \bar{b}^j) \right) = E_t \, \beta \, (C_{t+1}^j)^{-1} \, \frac{R_t^{b,j} - \epsilon_{t+1}^j}{\Pi_{t+1}^j} , \tag{4}$$

$$\frac{w_t^j}{C_t^j} = \psi_n h_t^j . \tag{5}$$

[4] As a result, public consumption at the steady state is lower in the periphery country because the cost of debt is higher. We could have alternatively assumed that taxes at the steady state are higher in the periphery country.

[5] Equations in the model express default *realization*. However, we will also consider default *risk* and we explain later how to modify the equations accordingly.

[6] See for instance Guerrieri et al. (2012) for similar costs. We could instead use alternative approaches as *e.g.* habit in consumption.

Euler equations (3) and (4) state that at equilibrium, marginal costs are equal to expected marginal income from respectively deposits and sovereign bonds. Equation (5) shows that the wage is equal to the marginal disutility of hours.

2.2 Entrepreneurs

In each country $j \in \{c, p\}$, entrepreneurs borrow from the (international) bank in the form of one-period loans L_t^j. They may consume $C_t^{e,j}$ or invest I_t^j in firms. In turn, investment increases firms' capital stock K_t^j according to:

$$K_t^j = (1-\delta)K_{t-1}^j + I_t^j, \tag{6}$$

where $0 < \delta < 1$ is the capital depreciation rate. Capital provides a net real return r_t^j and entrepreneurs pay a gross nominal interest rate $R_{t-1}^{l,j}$ on loans, as well as an adjustment cost on investment, as in Enders et al. (2011), represented by the parameter $\phi_i > 0$. The entrepreneurs' budget constraint is:

$$C_t^{e,j} + I_t^j + \frac{R_{t-1}^{l,j}}{\Pi_t^j} L_{t-1}^j + \frac{\phi_i}{2}(I_t^j - \bar{I}^j)^2 = L_t^j + r_t^j K_{t-1}^j \,. \tag{7}$$

The entrepreneurs expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \frac{\left(C_t^{e,j}\right)^{1-\sigma_e} - 1}{1-\sigma_e}, \tag{8}$$

where $\sigma_e > 0$ reflects the curvature of the instantaneous utility of consumption. By simplicity, we take a discount factor similar to the one of the household. We also assume segmented capital markets. The entrepreneurs maximize (8) with respect to (6) and (7). It gives two first order conditions:

$$(C_t^{e,j})^{-\sigma_e} = E_t\, \beta\, (C_{t+1}^{e,j})^{-\sigma_e} \frac{R_t^{l,j}}{\Pi_{t+1}^j}, \tag{9}$$

$$(C_t^{e,j})^{-\sigma_e}(1 + \phi_i(I_t^j - \bar{I}^j)) = E_t\, \beta\, (C_{t+1}^{e,j})^{-\sigma_e} \left(r_{t+1}^j + (1-\delta)(1 + \phi_i(I_{t+1}^j - \bar{I}^j))\right). \tag{10}$$

Equation (9) says that at equilibrium, the marginal income from loans is equal to the expected marginal cost, whereas equation (10) states that the marginal cost of investment is equal to its expected marginal income.

2.3 Firms

In each country $j \in \{c, p\}$, we have a uniform distribution between $[0, 1]$ of intermediate monopolistic firms, indexed by n_j. We also define $-j \in \{c, p\}$ as the complement of j. By simplicity, we ignore time subscripts whenever we have static equations. Let $d_j^j(n_j)$ be the intermediate goods produced in country j by the intermediate firm n_j and sold in country j. Similarly, let $d_j^{-j}(n_j)$ be the intermediate goods produced in country j by the intermediate firm n_j and sold in country $-j$.

Final firms' demand

In each country $j \in \{c, p\}$, there is a final firm combining intermediate goods from the j and $-j$ countries in order to produce a final good A^j according to a CES technology:

$$A^j = \left(\frac{A^j_j}{1-\alpha}\right)^{(1-\alpha)} \left(\frac{A^j_{-j}}{\alpha}\right)^{\alpha}, \tag{11}$$

where

$$A^j_j = \left(\int_0^1 \left[d^j_j(n_j)\right]^{\frac{1}{1+\theta}} dn_j\right)^{1+\theta}, \tag{12}$$

$$A^j_{-j} = \left(\int_0^1 \left[d^j_{-j}(n_{-j})\right]^{\frac{1}{1+\theta}} dn_{-j}\right)^{1+\theta}. \tag{13}$$

$0 < 1-\alpha < 1$ is the domestic bias, or equivalently α is an index of openness. $(1+\theta)/\theta > 1$ represents the elasticity of substitution between intermediate goods produced within any given country. The final firm's profit is:

$$P^j A^j - \int_0^1 p^j(n_j)\, d^j_j(n_j)\, dn_j - \int_0^1 p^{-j}(n_{-j})\, d^j_{-j}(n_{-j})\, dn_{-j}\,, \tag{14}$$

where P^j is the final goods price index in country j and $p^j(n_j)$ is the intermediate goods n_j price index in country j. It is worth noting that equation (14) takes into account that the two countries are part of a monetary union (nominal exchange rate equal one) and includes the law of one price, that is a given intermediate goods must have the same price in the two countries. For each country, let us define the ratio between the intermediate goods price index and the final goods price index $\phi^j(n_j) = p^j(n_j)/P^j$. We also define the real exchange rate of country j *vis à vis* country $-j$ as $Q^{-j}_j = P^{-j}/P^j$. Obviously, $Q^j_{-j} = 1/Q^{-j}_j$ and $Q^j_j = 1$. The final firm maximizes (14) with respect to (11). Using the above-mentioned definitions, it gives the two first order conditions:

$$\frac{d^j_j(n_j)}{A^j} = \left(\frac{\phi^j(n_j)}{(1-\alpha)}\right)^{-\frac{1+\theta}{\theta}} \left(\frac{A^j_j}{A^j}\right)^{-\frac{1}{\theta}}, \tag{15}$$

$$\frac{d^j_{-j}(n_{-j})}{A^j} = \left(\frac{\phi^{-j}(n_{-j})\, Q^{-j}_j}{\alpha}\right)^{-\frac{1+\theta}{\theta}} \left(\frac{A^j_{-j}}{A^j}\right)^{-\frac{1}{\theta}}. \tag{16}$$

Intermediate firms

An intermediate firm located in country j and indexed by n_j uses capital $K^j_{t-1}(n_j)$ and hours $h^j_t(n_j)$ to produce an intermediate good according to the Cobb-Douglas production function. Final firms in the two countries consume this intermediate production:

$$Y^j(n_j) \equiv d^j_j(n_j) + d^{-j}_j(n_j) = \left(K^j_t(n_j)\right)^{\mu} \left(h^j_t(n_j)\right)^{1-\mu}, \tag{17}$$

where $0 < \mu < 1$ is the elasticity of output to capital. The intermediate firm receives a – real – intermediate price $\phi^j_t(n_j)$ but has to pay an interest rate r^j_t on capital and a hourly wage w^j_t.

Moreover, since intermediate firms are monopolistic, they set the price but with an adjustment cost *à la* Rotemberg (1982) represented by the parameter $\kappa > 0$. The current profit of an intermediate firm n_j is:

$$\begin{aligned}\Upsilon_t^j(n_j) &= \phi_t^j(n_j)\left(d_{j,t}^j(n_j) + d_{j,t}^{-j}(n_j)\right) - r_t^j K_{t-1}^j(n_j) - w_t^j h_t^j(n_j) \\ &- \frac{\kappa}{2}\left(\frac{\phi_t^j(n_j)\Pi_t^j}{\phi_{t-1}^j(n_j)} - \bar{\Pi}^j\right)^2 \left(A_{j,t}^j + A_{j,t}^{-j}\right),\end{aligned} \tag{18}$$

where $\Pi_t^j = P_t^j / P_{t-1}^j$. The households hold the intermediate firms and they therefore maximize:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \left(\frac{C_{t+1}^j}{C_t^j}\right)^{-\sigma} \Upsilon_t^j(n_j). \tag{19}$$

with respect to the production equation (17) and the two demand equations (15) and (16). It gives three first order conditions:

$$\frac{h_t^j(n_j)}{K_{t-1}^j(n_j)} = \frac{(1-\mu)\, r_t^j}{\mu\, w_t^j}, \tag{20}$$

$$\mathrm{mc}_t^j(n_j) = \left(\frac{r_t^j}{\mu}\right)^{\mu} \left(\frac{w_t^j}{1-\mu}\right)^{1-\mu}, \tag{21}$$

$$\begin{aligned}\phi_t^j(n_j) + \theta\kappa \frac{\lambda_t^j(n_j)}{d_{j,t}^j(n_j) + d_{j,t}^{-j}(n_j)} &= (1+\theta)\, \mathrm{mc}_t^j(n_j) \\ &+ E_t \beta \left(\frac{C_{t+1}^j}{C_t^j}\right)^{-\sigma} \theta\kappa \frac{\lambda_{t+1}^j(n_j)}{d_{j,t}^j(n_j) + d_{j,t}^{-j}(n_j)},\end{aligned} \tag{22}$$

where $\lambda_t^j(n_j) = \left(\frac{\phi_t^j(n_j)\Pi_t^j}{\phi_{t-1}^j(n_j)} - \bar{\Pi}^j\right) \frac{\phi_t^j(n_j)\Pi_t^j}{\phi_{t-1}^j(n_j)} \left(A_{j,t}^j + A_{j,t}^{-j}\right)$.

Equation (20) shows that the labour-capital ratio is proportional to the capital-labour cost ratio. Equation (21) defines the marginal cost. Moreover, these two equations imply that the labour-capital ratio and the marginal cost are identical across all intermediates firms located in a given country. Equation (22) is the new-Keynesian Phillips curve and states that intermediate goods price is a markup over the marginal cost. If prices are perfectly flexible ($\kappa = 0$), the markup is $1+\theta$ and constant over time. With price rigidities ($\kappa > 0$) the markup becomes variable over time.

Aggregation

In equilibrium, all intermediate firms within a country $j \in \{c, p\}$ are identical and we may drop the index n_j in all above equations. We also have $d_{j,t}^j = A_{j,t}^j$ and $d_{j,t}^{-j} = A_{j,t}^{-j}$. The aggregation of equations (18), (20), (21) and (22) is straightforward. Moreover, equations (15), (16) and (17) respectively become:

$$\begin{aligned} \phi_t^j \; A_{j,t}^j &= (1-\alpha) \; A_t^j \, , \qquad (23) \\ Q_{j,t}^{-j} \; \phi_t^{-j} \; A_{-j,t}^j &= \alpha \; A_t^j \, , \qquad (24) \\ Y_t^j &= A_{j,t}^j + A_{j,t}^{-j} \;=\; \left(K_t^j\right)^{\mu} \left(h_t^j\right)^{1-\mu} \, . \qquad (25) \end{aligned}$$

Using equation (11), we can simplify further these equations into:

$$\begin{aligned} 1 &= \phi_t^j \; \phi_t^{-j} \, , \qquad (26) \\ Q_{j,t}^{-j} &= \left(\phi_t^j\right)^{\frac{2\alpha-1}{\alpha}} \, , \qquad (27) \\ \phi_t^j \; Y_t^j &= (1-\alpha) \; A_t^j + \alpha \; Q_{j,t}^{-j} A_t^{-j} \;=\; \phi_t^j \; \left(K_t^j\right)^{\mu} \left(h_t^j\right)^{1-\mu} \, . \qquad (28) \end{aligned}$$

Finally, taking the ratio of the real exchange rate at times t and $t-1$ gives:

$$\frac{Q_{j,t}^{-j}}{Q_{j,t-1}^{-j}} = \frac{\Pi_t^{-j}}{\Pi_t^j} \, . \qquad (29)$$

Summing equation (28) on j gives $\sum_j \phi_t^j \; Q_{c,t}^j \; Y_t^j = \sum_j Q_{c,t}^j \; A_t^j$, meaning that production is equal to demand in the whole currency area. Equation (29) shows that a higher inflation in the periphery country than in the core country leads to an increase in the real exchange rate of the core country, equivalent to a depreciation of the core "currency". In other words, a higher real exchange rate means an improved competitiveness.

2.4 Banking sector

We specify the banking sector as a bank *à la* Enders et al. (2011), *i.e.* a perfectly competitive bank playing at the EA wide level. The bank is physically located in country c but trades with all countries $j \in \{c, p\}$. More precisely, it receives deposits D_t^j from households, lends L_t^j to firms and buys s_t^j one-period bonds from the government. The bank may also buy B_t^{cb} one-period bonds from the central bank. The bank consumes profits in the two countries, that is it buys $C_t^{b,j}$ goods in each country. Since the central bank is common to the currency union and the bank is located in country c, we first need to express relative price indexes. The global production in the currency union is $Y_t = \sum_j Y_t^j$ and we define $\eta_t = Y_t^c / Y_t$ as the share of the c country. Then:

$$\begin{aligned} P_t &= \left(P_t^c\right)^{\eta_t} \left(P_t^p\right)^{1-\eta_t} \, , \qquad (30) \\ \Pi_t &= \frac{P_t}{P_{t-1}} \;=\; \left(\Pi_t^c\right)^{\eta_t} \left(\Pi_t^p\right)^{1-\eta_t} \, , \qquad (31) \\ \frac{P_t}{P_t^c} &= \left(Q_{c,t}^p\right)^{1-\eta_t} \, , \qquad (32) \\ \frac{P_{t-1}}{P_t^c} &= \frac{\left(Q_{c,t}^p\right)^{1-\eta_t}}{\Pi_t} \, . \qquad (33) \end{aligned}$$

The bank faces a capital requirement *à la* Enders et al. (2011) implying that it must keep a constant fraction $0 < \gamma < 1$ of loans as own capital. The bank may not meet this legal requirement, that is may have a negative x_t, but that is costly. The bank's balance sheet constraint is:

$$(1-\gamma)\sum_j Q^j_{c,t}L^j_t + \sum_j Q^j_{c,t}s^j_t + \left(Q^p_{c,t}\right)^{1-\eta_t} B^{cb}_t = \sum_j Q^j_{c,t}D^j_t + x_t\,. \tag{34}$$

Government bonds do not enter the requirement constraint because they were considered as risk-free, in line with standard features of capital regulation (see Guerrieri et al. (2012) for a similar representation). We nevertheless consider the possible inclusion of bonds in the constraint in section 4. The bank's budget constraint is:

$$\begin{aligned} & \sum_j Q^j_{c,t}C^{b,j}_t + \sum_j Q^j_{c,t}\frac{R^{d,j}_{t-1}}{\Pi^j_t}D^j_{t-1} + \sum_j Q^j_{c,t}L^j_t + \sum_j Q^j_{c,t}s^j_t + \left(Q^p_{c,t}\right)^{1-\eta_t} B^{cb}_t + \Omega(x_t) \\ + \quad & \Psi\left(\frac{\sum_j Q^j_{c,t}(1-\epsilon^j_t)^{\nu}s^j_t}{\sum_j Q^j_{c,t}L^j_t} - \frac{\sum_j \bar{Q}^j_c\ \bar{s}^j}{\sum_j \bar{Q}^j_c\ \bar{L}^j}\right) + \frac{\Gamma_l}{2}\sum_j\left(L^j_t - \bar{L}^j\right)^2 + \Gamma_d\sum_j\left(D^j_t - \bar{D}^j\right) \\ = \quad & \sum_j Q^j_{c,t}D^j_t + \sum_j Q^j_{c,t}\frac{R^{l,j}_{t-1}}{\Pi^j_t}\ L^j_{t-1} + \sum_j Q^j_{c,t}\frac{R^{b,j}_{t-1}-\epsilon^j_t}{\Pi^j_t}\ s^j_{t-1} + \left(Q^p_{c,t}\right)^{1-\eta_t}\frac{R_{t-1}}{\Pi_t}B^{cb}_{t-1} + H^{b,j}_t. \end{aligned} \tag{35}$$

The bank pays a gross nominal interest rate $R^{d,j}_{t-1}$ on deposits and receives gross nominal interest rates $R^{l,j}_{t-1}$, $R^{b,j}_{t-1}$ and R_{t-1} on respectively loans to firms, government bonds and central bank bonds. It is worth noting that the return on government bonds is risky, that is government in country j may default with a probability ϵ^j_t. Moreover, the bank faces four different costs. First, there is an operating cost, proportional to the size of the bank balance sheet (we approximate the size of the balance sheet through deposits), represented by the parameter $\Gamma_d > 0$. We find similar costs in Enders et al. (2011). Second, as in Guerrieri et al. (2012), we have quadratic adjustment costs on loans, represented by the parameter $\Gamma_l > 0$. Third, as explained above, there is a cost when capital is below requirements. The cost function must satisfy $\Omega(0) = 0$, $\Omega^{'}(0) \leq 0$ and $\Omega^{''}(.) > 0$ as in Enders et al. (2011). The bank therefore bears a positive cost when $x_t < 0$ and the cost is 0 when the bank exactly meets the requirements. We call the transmission of shocks through this cost the *bank capital channel.* Fourth, banks typically use government bonds as collateral in the secured interbank market. A reduction in their volume or quality decreases the ability of banks to collect funds from other banks and hence to sustain private credit supply. In our model, there is no interbank market and therefore no such collateral role for sovereign bonds. In order to nevertheless reproduce this channel, we introduce a collateral cost whenever the ratio between sovereign bonds and private loans is lower than the steady state. It is worth noting that the numerator of the ratio not only includes the volume of bonds but also a measure of riskiness, through the parameter $\nu \geq 0$, which represents the haircut applied to them. This cost function must therefore satisfy the same requirements as the capital cost, *i.e.* $\Psi(0) = 0$, $\Psi^{'}(0) \leq 0$ and $\Psi^{''}(.) > 0$. We call the transmission of shocks through this cost the *bank collateral channel.* We discuss in more details the role of the capital cost $\Omega(.)$ and the collateral cost $\Psi(.)$ further in this section. The bank's expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty}\beta^{t-s}\ \left(C^{b,c}_t\right)^{\vartheta}\left(C^{b,p}_t\right)^{1-\vartheta}\ . \tag{36}$$

The bank derives instantaneous utility from a Cobb-Douglas combination of consumption goods from countries c and p, where ϑ (resp. $1-\vartheta$) is the elasticity of the utility with respect to $C_t^{b,c}$ (resp. $C_t^{b,p}$). By simplicity, we take a discount factor similar to the one of the household. The bank maximizes (36) with respect to (34) and (35). It gives one definition (equation 37) and five first order conditions:

$$\lambda_t^b = \frac{\vartheta \left(C_t^{b,c}\right)^{\vartheta} \left(C_t^{b,p}\right)^{1-\vartheta}}{C_t^{b,c}} , \tag{37}$$

$$Q_{c,t}^p = \frac{1-\vartheta}{\vartheta} \frac{C_t^{b,c}}{C_t^{b,p}} , \tag{38}$$

$$\lambda_t^b(Q_{c,t}^j - \Gamma_d + Q_{c,t}^j\, \Omega^{'}(x_t)) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j \frac{R_t^{d,j}}{\Pi_{t+1}^j} , \tag{39}$$

$$\lambda_t^b \left(Q_{c,t}^p\right)^{1-\eta_t} (1 + \Omega^{'}(x_t)) = \beta E_t \lambda_{t+1}^b \left(Q_{c,t+1}^p\right)^{1-\eta_{t+1}} \frac{R_t}{\Pi_{t+1}} , \tag{40}$$

$$\begin{aligned} & \lambda_t^b \Bigg(Q_{c,t}^j - Q_{c,t}^j \Psi^{'} \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \, \bar{s}^j}{\sum_j \bar{Q}_c^j \, \bar{L}^j} \right) \frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\left(\sum_j Q_{c,t}^j L_t^j\right)^2} \\ + & \Gamma_l (L_t^j - \bar{L}^j) + (1-\gamma) Q_{c,t}^j\, \Omega^{'}(x_t) \Bigg) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j \frac{R_t^{l,j}}{\Pi_{t+1}^j} , \end{aligned} \tag{41}$$

$$\begin{aligned} & \lambda_t^b \Bigg(Q_{c,t}^j + Q_{c,t}^j \Psi^{'} \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \, \bar{s}^j}{\sum_j \bar{Q}_c^j \, \bar{L}^j} \right) \frac{(1-\epsilon_t^j)^{\nu}}{\sum_j Q_{c,t}^j L_t^j} + Q_{c,t}^j\, \Omega^{'}(x_t) \Bigg) \\ = & \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j \frac{R_t^{b,j} - \epsilon_{t+1}^j}{\Pi_{t+1}^j} . \end{aligned} \tag{42}$$

Equation (38) says that the ratio core consumption-periphery consumption depends on the relative prices, i.e. the higher is the price of p goods, the higher is the consumption of c goods. Equations (39), (40), (41) and (42) are Euler equations for – respectively – deposits, central bank bonds, private loans and sovereign bonds.

Discussion

We first focus on the *bank capital cost* $\Omega(.)$. By simplicity, let us assume only one region, no inflation and $\Psi(.) = 0$. Subtracting equation (39) from equation (41) and taking a first order Taylor expansion around the steady state gives:

$$\underbrace{(\Gamma_d - \gamma\Omega^{'}(0))}_{>0} \hat{\lambda}_t + \Gamma_l \bar{L} \hat{L}_t - \underbrace{\gamma\Omega^{''}(0)}_{>0} \hat{x}_t = \beta(\bar{R}^l - \bar{R}^d)\hat{\lambda}_{t+1} + \beta(\hat{R}_t^l - \hat{R}_t^d) ,$$

where a variable with a hat denotes the absolute ($\hat{R}_t^l$, $\hat{R}_t^d$ and $\hat{x}_t$) or relative ($\hat{\lambda}_t$ and $\hat{L}_t$) deviation from the steady state and a variable with a bar denotes the steady state. On the one hand, we see that the convexity of the cost is the crucial assumption. It makes increasing (resp. decreasing) the spread – between the lending rate and the deposit rate – when x_t is below (resp. above) the requirements. We also observe that the higher is the convexity, the higher is the transmission of the capital position to the spread. On the other hand, the assumption $\Omega^{'}(0) \leq 0$ is less important since the parameter in front of $\hat{\lambda}_t$ will always be positive. In the calibration and hence the subsequent analysis, we assume $\Omega^{'}(0) = 0$ and $\Omega^{''}(0) = \Gamma_x > 0$. By looking at equation (42), we could also point out that a fall in bank excess capital increases the spread $\hat{R}^l_t - \hat{R}^b_t$ exactly in the same way as the spread $\hat{R}^l_t - \hat{R}^d_t$. In section 4.2, we conduct a sensitivity analysis on Γ_x.

We then consider the *bank collateral cost* $\Psi(.)$. Once again, we simplify with one single region, no inflation and $\Omega(.) = 0$. To simplify the notation, we also define $(1-\epsilon_t)^\nu s_t/L_t \equiv \mathtt{cr}_t$. Subtracting equation (39) from equation (41) and taking a first order Taylor expansion around the steady state gives:

$$\Gamma_d \hat{\lambda}_t + \Gamma_l \bar{L}\hat{L}_t - \frac{\bar{\mathtt{cr}}\Psi^{'}(0)}{\bar{L}}(\hat{\lambda}_t - \hat{L}_t) - \underbrace{\left(\frac{\bar{\mathtt{cr}}\Psi^{''}(0)}{\bar{L}} + \frac{\Psi^{'}(0)}{\bar{L}}\right)}_{\equiv \eta} \hat{\mathtt{cr}}_t = \beta(\bar{R}^l - \bar{R}^d)\hat{\lambda}_{t+1} + \beta(\hat{R}^l_t - \hat{R}^d_t)\,,$$

where a variable with a hat denotes the absolute ($\hat{R}^l_t$, $\hat{R}^d_t$, $\hat{\epsilon}_t$ and $\hat{\mathtt{cr}}_t$) or relative ($\hat{\lambda}_t$ and $\hat{L}_t$) deviation from the steady state and a variable with a bar denotes the steady state. We observe that the elasticity of $\hat{R}^l_t - \hat{R}^d_t$ to $\hat{\mathtt{cr}}_t$ is $-\eta/\beta$, which has an ambiguous sign. Because we want an increase (resp. decrease) in the collateral ratio to reduce (resp. raise) the spread – between the lending rate and the deposit rate –, we therefore need $\eta > 0$ that is $\bar{\mathtt{cr}}\Psi^{''}(0) > -\Psi^{'}(0)$. In the subsequent analysis, we assume $\Psi^{'}(0) = 0$ and $\Omega^{''}(0) = \Gamma_p > 0$, which meets this requirement. Again by looking at equation (42), we could easily see that the collateral ratio $\hat{\mathtt{cr}}_t$ affects the spread $\hat{R}^l_t - \hat{R}^b_t$ with an elasticity $-\eta(1 + 1/\bar{\mathtt{cr}})/\beta < 0$. In section 4.2, we conduct a sensitivity analysis on Γ_p and also on the haircut ν.[7]

2.5 Government

In each country $j \in \{c, p\}$, the government consumes G^j_t and transfers lump-sum amounts $H^{h,j}_t$ to the household and $H^{b,j}_t$ to the bank. The government finances it through lump-sum taxes T^j_t from the household or public debt B^j_t according to:

$$H^{h,j}_t + H^{b,j}_t + G^j_t + \frac{R^{b,j}_{t-1} - \epsilon^j_t}{\Pi^j_t} B^j_{t-1} = T^j_t + B^j_t\,, \tag{43}$$

$$T^j_t = \bar{T} + \tau\left(B^j_{t-1} - \bar{B}^j\right)\,, \tag{44}$$

$$B^j_t = b^j_t + s^j_t\,, \tag{45}$$

$$G^j_t = \left(\bar{G}^j\right)^{1-\gamma_g}\left(G^j_{t-1}\right)^{\gamma_g}\exp(u^g_t)\,. \tag{46}$$

[7]The calibration therefore implies quadratic cost functions $\Omega(.)$ and $\Psi(.)$, under which the bank also incurs costs when the capital or the collateral ratio is above the steady state. The key point is that quadratic functions satisfy the assumptions stated above and, up to a linear approximation, yield the same predictions than more general cost functions. These quadratic cost functions are often used in the literature as for instance Gerali et al. (2010), Andrès et al. (2004) or Harrison (2011).

Equation (44) with $0 < \tau < 1$ implies that debt and taxes are positively correlated. In other words, the government does not only rely on debt to finance any budget deficit but also raises taxes, as estimated in Bohn (1998), rather than decreasing public consumption. This tax rule is similar to the one used in Corsetti et al. (2013).[8] Equation (45) states that both households and the bank own the sovereign debt. Finally, we define public consumption as a stochastic autoregressive process with $0 < \gamma_g < 1$ and u_t^g i.i.d.

Default

To determine the default rate ϵ_t^j we tightly refer to the methodology used by van der Kwaak and van Wijnbergen (2013). We assume a stochastic maximum level of *sustainable* debt-to-output BY_t^{max}:

$$BY_t^{max} = \bar{BY}^{max} + \gamma_b(BY_{t-1}^{max} - \bar{BY}^{max}) + u_t^b\,, \tag{47}$$

where $0 < \gamma_b < 1$ is the autoregressive component and u_t^b is a i.i.d. shock.[9] If no default occurs, the level of debt $\tilde{B}_t^j$ is:

$$G_t^j + \frac{R_{t-1}^{b,j}}{\Pi_t^j}\, B_{t-1}^j = T_t^j + \tilde{B}_t^j\,. \tag{48}$$

If the amount of debt to output $\tilde{B}_t^j/(4Y_t^j)$ is lower (resp. higher) than BY_t^{max}, the government does not (resp. does) default. We approximate this default process with a normal cdf:

$$\epsilon_t^j = F\left(\frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}\ ;\ 0\ ,\ \sigma^2\right) = \Phi\left(\frac{\frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}}{\sigma}\right). \tag{49}$$

where $\sigma > 0$ represents the variance and $\Phi(.)$ is the standard normal cdf. Let us define $X_{j,t}^b = \frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}$ with $\bar{X}_j^b$ its steady state, then the elasticity of – yearly – default wrt. debt to output is:

$$\texttt{elasticity}^j = \frac{4\Delta\epsilon_t^j}{\Delta X_{j,t}^b} = \frac{4}{\sigma}\,\phi\left(\frac{\bar{X}_j^b}{\sigma}\right), \tag{50}$$

where $\phi(.)$ is the standard normal pdf. In the subsequent analysis, we assume that only the periphery country may default, that is $\epsilon_t^c = 0$ and equation (49) only determines ϵ_t^p.

Realization versus risk

We investigate the effects of both default realization and default risk. With *default realization*, we simply assume $H_t^{h,j} = 0$ and $H_t^{b,j} = 0$. In this case, a – negative – stochastic shock in equation (47) reduces the maximum sustainable debt, which in turn increases default according to equation (49). This immediately decreases the government debt (equation 43) and therefore the assets of the bank

[8]The focus of this paper is not on taxation and we therefore use a lump-sum and non distortionary tax instead of a more sophisticated and distortionary tax scheme.

[9]In reality, the maximum sustainable government debt is not exogenous but depends on expected growth rates, on expected growth volatility or on the expected government ability to raise taxes (see for instance Collard et al., 2014). But this beyond the scope of this paper.

(equations 34 and 35) and of the households (equation 1). However, default also increases the sovereign interest rates and debt starts rising progressively in the subsequent periods.

With *default risk*, we follow Corsetti et al. (2013) and assume that the government does really default as explained above but transfers at the same time a lump-sum amount equivalent to the defaulted amount to the concerned agents (households and the bank):

$$\begin{aligned} H_t^{h,j} &= \frac{\epsilon_t^j}{\Pi_t^j}\, b_{t-1}^j \\ H_t^{b,j} &= \frac{\epsilon_t^j}{\Pi_t^j}\, s_{t-1}^j \end{aligned}$$

In other words, $H_t^{h,j}$ and $H_t^{b,j}$ are lump-sum transfers that (i) exactly compensates bond holders (households and the bank) for losses associated with the default realization and at the same time (ii) leaves the current level of debt unchanged. Default risk is therefore a default realization but with unobservable – lump-sum – compensation. As a result, the default risk is transmitted to the bank and the rest of the economy only through prices (higher risk premium) whereas the default realization is transmitted both through prices and quantities (partial loss for the holders of sovereign debt).

2.6 Monetary authority

The central bank sets the policy interest rate R_t according to a standard Taylor rule:

$$R_t = (R_{t-1})^{\gamma_m} \left(\bar{R}^d \left(\frac{Y_t}{\bar{Y}}\right)^{0.5} \left(\frac{\Pi_{t-1}}{\bar{\Pi}}\right)^{1.5} \right)^{1-\gamma_m}, \tag{51}$$

where $0 < \gamma_m < 1$ is the autoregressive parameter. The coefficients on output gap and inflation gap are standard as found for instance in Smets and Wouters (2003).

2.7 Closing the model

We close the model with the definitions of domestic demand in country $j \in \{c, p\}$:

$$A_t^j = C_t^j + C_t^{e,j} + C_t^{b,j} + I_t^j + G_t^j + \texttt{costs}_t^j\,, \tag{52}$$

where $\texttt{costs}_t^j$ collects all adjustment and operative costs related to households, entrepreneurs and firms in country j. Moreover, $\texttt{costs}_t^c$ also includes the costs related to the bank. These two definitions imply that we have a zero net-supply of central bank bonds, *i.e.* $B_t^{cb} = 0$.

3 Calibration

As already explained, we assume that the core economy and the periphery economy have the same structure, meaning that the parameters are similar in each country. The only difference between the two countries is the steady state level of debt and hence the steady state level of government consumption. The calibration refers to euro area stylized facts in 2010, that is at the onset of

Table 1: Parameter values

Parameter	Value	Description
Households		
β	0.99	Discount factor
ϕ_d	0.5	Deposit adjustment cost
ϕ_b	0.1	Bond adjustment cost
ψ_n	18.44	Weight of labour in (dis-)utility
ψ_d	0.01	Weight of deposits in utility
Global bank		
ϑ	0.5	Elasticity of substitution between home and foreign consumption goods
γ	0.05	Bank capital ratio requirement
Γ_d	0.005	Deposit operating cost
Γ_l	0.01	Loan adjustment cost
Γ_p	0.25	Collateral requirement cost
Γ_x	1.50	Capital requirement cost
ν	8	Elasticity of haircut to default applied to government bonds
Production		
δ	0.025	Capital depreciation rate
σ_e	0.01	Inverse of intertemporal elasticity of substitution in consumption (entrepreneur)
ϕ_i	0.2	Investment adjustment cost
α	0.3	Index of openess
θ	0.37	Markup in price setting
μ	0.3	Elasticity of production w.r.t. capital
κ	263	Price rigidities
Authorities		
τ	0.13	Elasticity of taxes w.r.t. debt
$\bar{T}/\bar{Y}^j$	0.12	Tax-output ratio objective
$\bar{B}^c/(4\bar{Y}^c)$	0.60	Debt-output ratio objective in the *core* country
$\bar{B}^p/(4\bar{Y}^p)$	0.85	Debt-output ratio objective in the *periphery* country
$\bar{BY}^{max}$	0.92	Maximum sustainable debt-output ratio
σ	0.015	Standard deviation of default pdf
$\bar{\Pi}$	1.00	Gross inflation objective
Shocks		
γ_m	0.85	Autoregressive parameter for Taylor rule
γ_g	0.85	Autoregressive parameter for governement spending shock
γ_b	0.8	Autoregressive parameter for sustainable debt-output ratio shock

the sovereign crisis. Time is discrete and one period represents one quarter. Table 1 presents an overview of the parameters while the calibration methodology is explained below.

Steady state restrictions

The similar structure of the two economies implies that the steady state inflation is also identical and we assume it to be zero, that is $\bar{\Pi} = \bar{\Pi}^j = 1$ (see later). The similar structure also implies the same marginal costs for the production of intermediate goods and therefore $\bar{\phi}^c = \bar{\phi}^d$ through equation (22). In turn, equations (23) and (24) imply $\bar{\phi}^j = 1$ and $\bar{Q}_j^{-j} = 1$. Regarding the bank, we follow Enders et al. (2011) and consider no excess capital at the steady state ($\bar{x} = 0$). Moreover, we also assume no default ($\bar{\epsilon}^j = 0$). Regarding the steady-state portion of sovereign bond held by households and the bank we follow Guerrieri et al. (2012) and assume that only one third of debt is held by households both in the core and the periphery.

Parameters governing the steady state

Taking the different Euler equations (3), (4), (9), (10), (39), (40), (41) and (42) at the steady state gives:

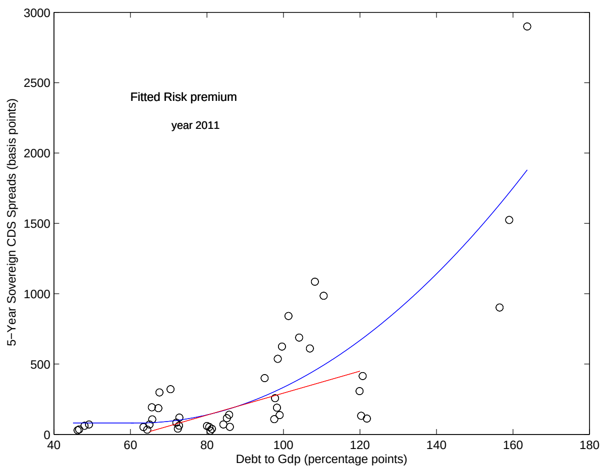
$$\begin{aligned}\bar{R}^{d,j} &= \frac{1 - \mathtt{a}\,\psi_d}{\beta} = \frac{1-\Gamma_d}{\beta}\,,\\ \bar{R} &= \bar{R}^{l,j} = \bar{R}^{b,j} = \frac{1}{\beta}\,,\\ \bar{r}^j &= \frac{1}{\beta} - 1 + \delta\,.\end{aligned}$$

We observe that the deposit rate $\bar{R}^{d,j}$ is negatively related to the deposit operating cost Γ_d, that is the bank compensates the cost of operating deposits through lower interest rates payments. We set the psychological discount factor $\beta = 0.99$ to have annualized interest rates on loans and bonds, as well as the monetary policy rate, equal to 4% at the steady state. We fix the deposit operating cost $\Gamma_d = 0.005$ to have annualized interest rates on deposits equal to 2%. We compute the weight of deposits in utility $\psi_d = \Gamma_d/\mathtt{a}$, where $\mathtt{a}$ is a parameter aggregating other parameters and steady states. Following the RBC literature we assume that hours $\bar{h}^j = 0.2$ meaning that agents work 20% of their time. This allows to determine the labour disutility parameter ψ_n. The production function is a Cobb-Douglas with the capital share $\mu = 0.3$ and setting the depreciation rate at $\delta = 0.025$ implies $\bar{K}^j/\bar{Y}^j = 6.24$ and $\bar{I}^j/\bar{Y}^j = 0.156$, in line with the RBC literature and empirical observations. We calibrate the price markup $\theta = 0.37$ as in Smets and Wouters (2003). Finally, we assume a bias for domestic goods and we calibrate $\alpha = 0.3 < 0.5$. This kind of bias is standard in the NOEM literature, as for instance in Gali and Monacelli (2008). The value we select is in the range used in recent quantitative macro-finance models. For a detailed description, we may for instance refer to Coeurdacier et al. (2007). This bias also determines the *gross* trade (the lower the bias, the higher the gross trade) but not the *net* trade. Since the two countries are symmetric, the net trade is zero at the steady state, whatever the value of α. Moreover, to keep again symmetry between regions, we impose that the bank has an identical preference between consuming core or periphery goods, *i.e.* $\vartheta = 1 - \vartheta = 0.5$.

Parameters related to policies

Following Enders et al. (2011), we set the required bank capital ratio at $\gamma = 0.05$. Empirically, the capital ratio for the major banks in the euro area has been found to be between 3% and 5%. Regarding monetary policy and as already explained above, we set the inflation objective of the central bank at 0%, implying $\bar{\Pi} = 1$. Increasing the inflation objective to a more realistic value of 2% would not modify our results. On the fiscal side, we specify our two country model for the euro area distinguishing between the core and periphery in terms of debt-to-GDP ratio. The periphery refers to the GIIPS (Greece, Ireland, Italy, Portugal and Spain) for which we assume a debt to GDP ratio $\bar{B}^p/(4\bar{Y}^p) = 85\%$ at steady state while for the core, the rest of the euro zone, we assume a ratio $\bar{B}^c/(4\bar{Y}^c) = 60\%$. These values are the same as Guerrieri et al. (2012) and they aggregate them from the IMF economic outlook for 2010. Taxes-to-output $\bar{T}/\bar{Y}^j$ are set at steady state to 12% of GDP in both regions, which is the level of indirect taxes in the euro area (source: OECD), implying a government consumption of 9.5% of GDP in the core and of 8.5% in the periphery. This asymmetry is due to the different steady state values of debt to GDP in the two regions. The periphery bears a higher interest rate burden on debt and must therefore reduce its steady state public consumption. We set the two parameters governing the default process – *i.e.* the maximum sustainable debt-to-output ratio $\bar{B}Y^{max}$ and the standard deviation σ of default pdf – in order to have an elasticity of default risk (or of sovereign risk premium) to debt of 0.1 around the steady state, in the periphery country, as shown in Figure 2.[10] The same calibration methodology is used by Corsetti et al. (2013) where we refer the reader for an exhaustive list of empirical works on the relationship between fiscal variables and yields on government bonds. As explained in section 2, we consider that only the periphery may default.

Figure 2: Sovereign risk premia *vs.* debt-to-GDP in EA countries



Notes. The figure plots the 5-year CDS spread for the year 2011 (quarterly observations) against the debt-to-Gdp level at quarterly frequency (black dots). The countries shown are: Austria, Belgium, Germany, France, Finland, Greece, Ireland, Italy, Portugal and Spain. The blue line is a quadratic interpolation whereas the red line is the tangent at the debt-to-GDP steady state. *Data sources*: Datastream.

[10]We choose the year 2011 because it corresponds to the period of troubles on the sovereign debt market. We see an increasing and strictly convex relationship between debt and spread. Removing Greek data would imply a more linear relationship.

Other steady state implications

First, our calibration implies that the size of the bank balance sheet (total assets or total liabilities) represents 140% of yearly total output ($4 \times (\bar{Y}^c + \bar{Y}^c)$). This number seems realistic. EA data compiled by the ECB show that total assets of euro area credit institutions over euro area GDP was 339% in 2010. However, focusing on loans to EA residents (save for monetary and financial institutions) and holdings of securities issued by EA residents (save for monetary and financial institutions), this ratio reduces to 166% which is therefore close to what we have.[11] Second, we have three private consumptions in each region, from the household, the bank and the entrepreneurs. With respectively 69% of GDP, 2% of GDP and 3% of GDP, we observe that most of the private consumption is at the household's level. Third, all the costs in the model are dynamics, that is they exist only outside the steady state.

Parameters governing the dynamics

This set of parameters does not affect the steady state of the model variables. They instead are set to obtain plausible dynamics. Regarding consumption and as often in the literature, we use a log-utility for households and a linear utility for banks. We assume that the entrepreneurs have a high intertemporal elasticity of substitution in consumption, that is they have a only slightly concave utility function. We set $\sigma_e = 0.01$. Adjustment costs on deposits, bonds, loans and investment (respectively represented by the parameters ϕ_d, ϕ_b, Γ_l and ϕ_i) are standard in DSGE models and their role is to smooth quantity reactions after a stochastic shock. We directly borrow the capital adjustment cost from Enders et al. (2011) and we set $\Gamma_x = 1.5$ to obtain a sufficiently persistent reaction of excess capital x_t, and therefore a strong enough bank capital channel. The collateral adjustment cost is crucial in our model. It gives an additional collateral role to sovereign bonds, both with respect to its volume (important in case of default realization) and quality (important in case of default risk). We set $\Gamma_p = 0.25$ and $\nu = 8$. We discuss further the role of these parameters in section 4.2. In the model we assume price rigidities through a menu cost κ *à la* Rotemberg. We calibrate this parameters of the new-Keynesian Phillips curve such as to reproduce the one estimated by Smets and Wouters (2003) with euro area data. There is not much empirical observations regarding the elasticity τ of taxes to debt. For instance, Corsetti et al. (2013) assume that taxes react to debt "sufficiently strongly" to ensure that debt remains bounded throughout their simulations. To objectify this calibration, we first calibrate the autocorrelation of the public expenditure shock (46) as $\gamma_g = 0.85$ to match the one we observe in EA aggregated data. Then we use this public expenditure shock – in the absence of default risk – to generate fluctuations in public consumption and debt. We set $\tau = 0.13$ to match the relative volatility of public consumption and debt with what we observe in EA data. We fix the remaining autoregressive parameters – γ_m and γ_b – to standard values between 0.8 and 0.85.

4 Dynamic simulations

To produce dynamic simulations, we take a first order approximation of the model equations. We study the consequences of a shock to the maximum sustainable debt-output ratio, represented by

[11] Source: ECB, Statistical Data Warehouse, Monetary statistics, Credit institutions and money market funds balance sheets, Aggregated balance sheet of euro area credit institutions.

equation (47). We calibrate the size of the shock in order to have an initial increase in default of 1%. The default in turn affects the whole economy, including the realized debt-output ratio and again default, through general equilibrium effects. As already mentioned, our calibration implies an elasticity of sovereign interest rates w.r.t. debt-output ratio around 0.1 in the periphery country. In other words, an increase in debt-to-GDP by 1 ppt raises the interest rate on sovereign debt by 0.1 ppt. In the subsequent simulations, we first investigate how default risk *vs.* default realization spread to the whole economy using the integrated bank, *i.e.* a single bank playing at the EA wide level as presented in section 2.4. Second, we conduct sensitivity analysis on the parameters related to the bank capital channel and the bank collateral channel, to better understand the role of these two frictions. Third, we move from a fully integrated banking system to a more fragmented one and check how it changes the transmission mechanisms. We also compare simulation results with alternative banking to what we know from empirical observations. Fourth and finally, we conduct a couple of policy analysis.

4.1 Defaults: from risk to realization

Figure 3 shows the impulse response functions under the risk assumption and the realization assumption regarding default, as explained in section 2. We assume a full integrated bank as presented in section 2.4.

Default risk

Figure 3 (blue line with dots) shows the model transmission of default risk to the banking sector and the real economy in the two regions. As explained in section 2.5, we remind that default risk is in fact a default realization immediately followed by a lump-sum compensation *à la* Corsetti et al. (2013). We obviously observe an increase in the sovereign rate in the defaulted country and a "flight-to-quality" to the core country. The increase in the periphery sovereign rate raises periphery public debt – through higher interest rate burden – whereas the decrease in the core sovereign rate reduces core public debt. Then the transmission from the banking sector to the real economy mainly goes through the bank capital channel and the bank collateral channel. As explained in section 2.4, the fall in excess capital raises the spread between the lending and the deposit rates. Moreover, the sovereign bond risk increases the haircut applied to the collateral. The eligible collateral ratio falls and this raises further the spread.[12] As a result, the volume of loans to the real economy shrinks, especially towards the periphery region. Inflation follows a similar pattern. Since inflation is smaller in the periphery country, the real exchange rate appreciates and net exports from the core region fall. In the end, although the sovereign crisis is located in the periphery region, we observe that the – initial – fall in output is quite similar in the two regions. The integrated bank therefore allows for an almost perfect transmission of the crisis.[13]

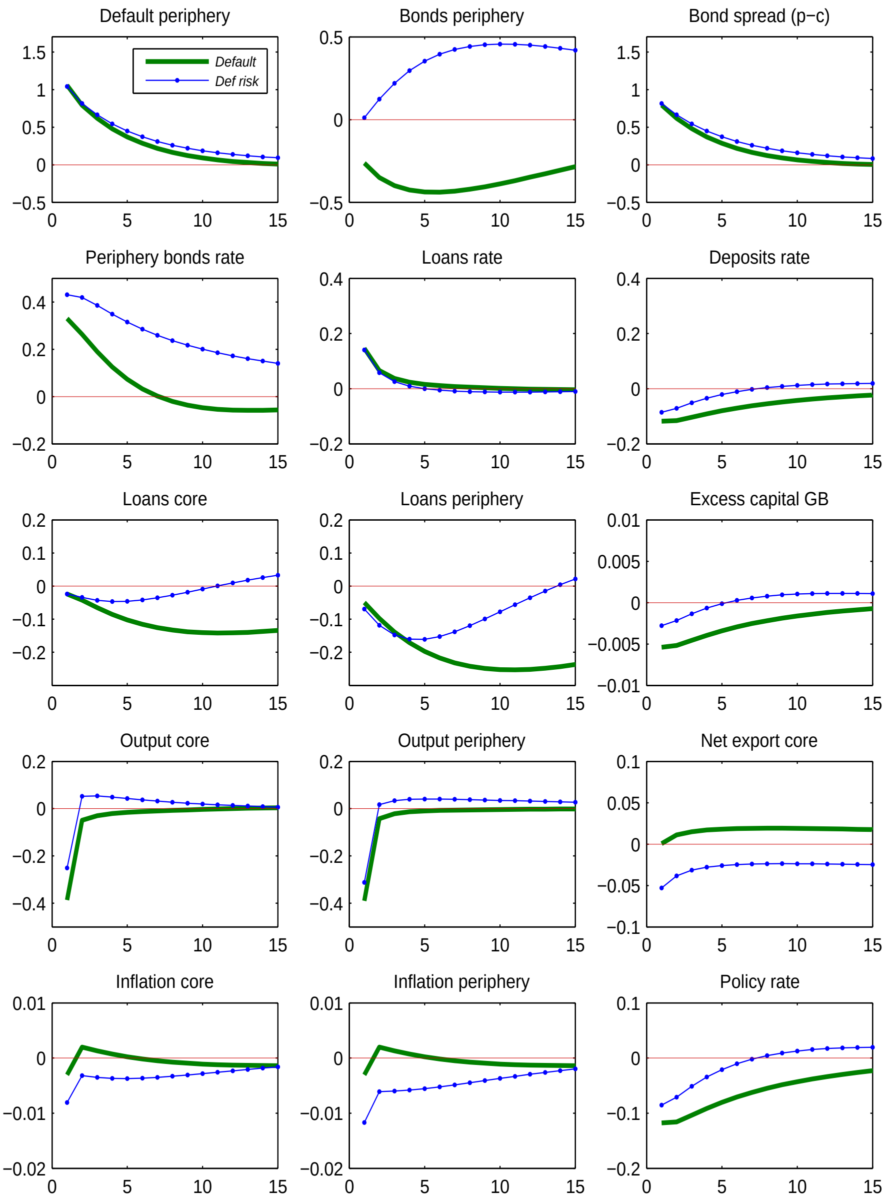
Default realization

Figure 3 (green line) shows the model transmission of default realization to the banking sector and

[12]The spread increase is similar in the two regions and therefore, figure 3 does not make the distinction between the core and periphery loan and deposit rate variables.

[13]We observe that after the initial fall, output immediately jumps above the steady state. This jump is due to a similar jump of labour and wages. One solution to smooth the labour and output reactions would be for instance to introduce a monopolistic labour supply with rigid wages, instead of the perfectly competitive labour market we currently have.

Figure 3: IRFs after a negative maximum sustainable debt-output ratio shock (deviations from the steady state)



Notes. 'Bank excess capital' is normalized with respect to the steady state size of the bank balance sheet. Deviations are expressed respectively in percentage points for ratios and rates and in percentage for volumes. The green line 'Default' represents the scenario with default realization. The evolutions of loan and deposit rates are similar in the two regions.

the real economy in the two regions. We see that the transmission is different from risk in many respects. First, default realization reduces the debt level in the periphery which limits the surge in the periphery bond rate. Second, the transmission from the banking sector to the real economy is stronger than with the risk scenario. The deeper falls in excess capital and in the eligible collateral ratio increase the bank capital cost and the bank collateral cost. This raises further the spread between the loan rate and the deposit rate, and *in fine* intensifies the fall in loans and in output. As with the risk scenario, we observe that the output follows a quite similar pattern in the two regions, due to the central position of the integrated bank and its 'crisis sharing'. Third, although output is lower with realization than with risk, inflation is higher. The lower deposit rate with realization makes the household more willing to consume. The implied lower marginal utility of consumption increases wage claims which in turn raises the marginal cost and hence inflation.[14]

In conclusion, we see that realization has a deeper impact on output than risk, mainly through the bank capital and the bank collateral channels (lower excess capital and lower eligible collateral with realization). Moreover, both with risk and realization, the integrated bank assumption allows to share almost perfectly between regions the periphery sovereign troubles.

4.2 Sensitivity analysis

We see above that default may transmit from the bank to the real economy through the bank capital and the bank collateral channels. Indeed, a sovereign shock weakens the bank capital position and the bank collateral position. The bank faces higher costs and as a consequence increases the lending-deposit interest rate spread. This reduces private loans. We show theoretically in section 2.4 that the higher the convexity of the capital and collateral costs, the higher is the transmission. In this section, we conduct a sensitivity analysis on the parameters governing the convexity, namely Γ_x for the capital cost and Γ_p for the collateral cost. Moreover, the collateral cost depends on the *eligible* collateral, that is the potential collateral less a haircut. The size of the haircut reflects the riskiness associated to the collateral. We conduct a sensitivity analysis the parameter ν representing the elasticity of the haircut to the riskiness.

The role of convexity in the bank capital channel

The parameter Γ_x represents the convexity of the bank capital cost $\Omega(.)$. Section 2.4 shows theoretically that when $\Gamma_x = 0$, a fall in excess capital x_t has no direct effect on the loan-deposit interest rate spread.[15] The higher Γ_x, the more a fall in excess capital increases the spread. Figure 4 provides a numerical illustration of the effects of a negative sovereign shock, for different values for the convexity. We give the average effect over the first 15 periods.[16] First, we observe that a change in Γ_x does not really change the transmission with a default risk (blue line with dots). Indeed, risk does not directly affect bank assets and therefore the capital position. The picture is different with a default realization which reduces assets and hence the capital position (green line). When $\Gamma_x = 0$, bank may let excess capital fall without cost consequences. When Γ_x is higher, the bank must restore its capital position to avoid costs. To do so, the bank increases its spread which slowdowns

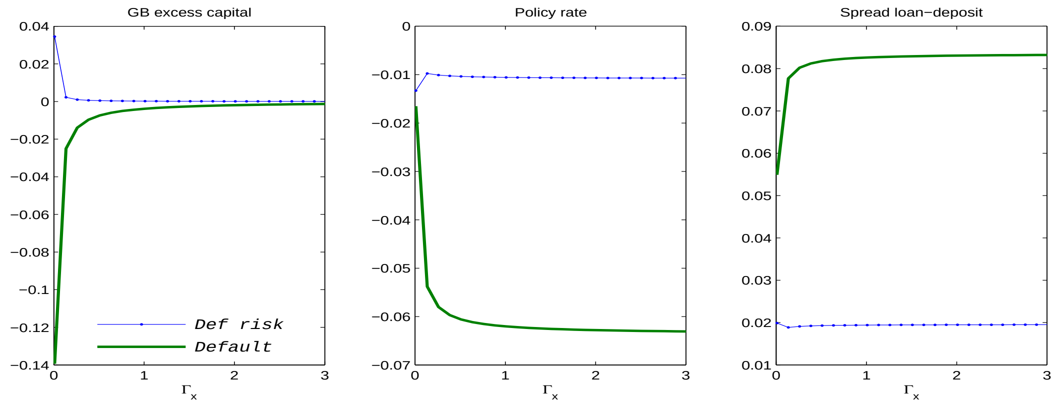
[14] Again, this is also due to the perfectly competitive labour market assumption. A monopolistic labour market with wage rigidities, as already mentioned in footnote 13, would change inflation behaviour.

[15] Although it may obviously have indirect effects through general equilibrium linkages.

[16] Reactions may become highly volatile with extreme values for the convexity. The average over 15 periods allows to give a more stable and accurate picture of what happens.

the economy as revealed by the policy rate. We see that a sufficiently high convexity may increase the transmission to the economy and hence to the policy rate by about 50% (the policy rate falls – on average over the first 15 periods – from 0.04 ppt when $\Gamma_x = 0$ to 0.06 ppt when Γ_x is above 1).

Figure 4: Effects of a negative maximum sustainable debt-output ratio shock, for different values of Γ_x (deviations from the steady state)



Notes. Average effects over 15 periods. Deviations are expressed respectively in percentage for volumes and in percentage points for rates. The green line 'Default' represents the scenario with default realization. The evolutions of the spread loan-deposit interest rate are similar in the two regions.

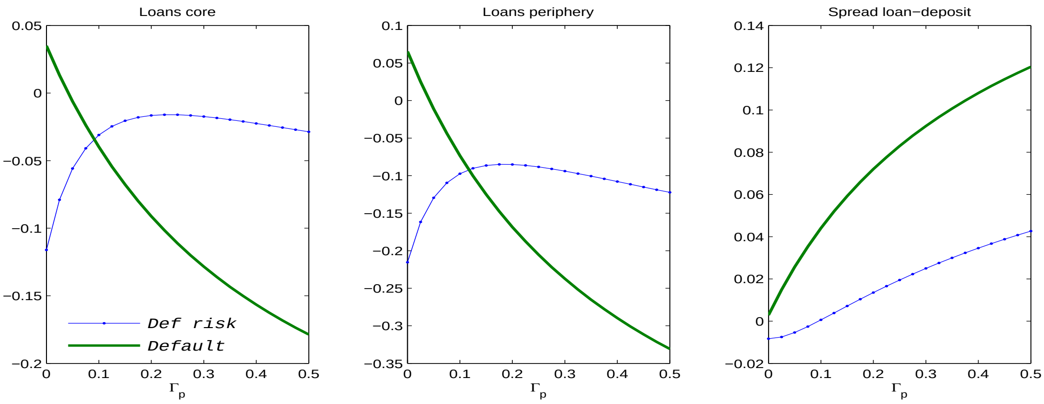
The role of convexity in the bank collateral channel

The parameter Γ_p represents the convexity of the bank collateral cost $\Psi(.)$. Section 2.4 shows theoretically that when $\Gamma_p = 0$, a fall in the collateral ratio $\mathtt{cr}_t$ has no direct effect on the loan-deposit interest rate spread. The higher Γ_p, the more a fall in collateral increases the spread. Figure 5 provides a numerical illustration of the effects of a negative sovereign shock, for different values for the convexity. To isolate the convexity effect from the haircut effect, we assume $\nu = 0$, *i.e.* there is no haircut whatever the riskiness of sovereign bonds. Focusing on default realization (green line), we observe that with a small Γ_p, there is almost no transmission of the shock to the economy. However, the transmission strongly increases along with the convexity. Indeed, default realization reduces the collateral and banks must reduce private loans to avoid high costs. The picture is more ambiguous with a default risk because risk does not reduce available collateral (remember we do not apply any haircut).

The role of haircut in the bank collateral channel

We see from equation (35) that the bank values sovereign bonds as collateral taking into account their riskiness, because the riskiness determines the size of the haircut applied. The parameter ν controls the elasticity between the riskiness and the haircut applied to the collateral. Figure 6 shows that the higher is the elasticity, the higher is the shock transmission to the economy, both with the risk scenario and the realization scenario. Indeed, higher values of the haircut reduce eligible collateral which makes bank borrowing more costly. As a consequence, the bank shrinks its balance sheet with lower credit to the private sector. We also observe that the quantitative effect of haircut

Figure 5: Effects of a negative maximum sustainable debt-output ratio shock, for different values of Γ_p (deviations from the steady state)



Notes. Average effects over 15 periods. Deviations are expressed respectively in percentage for volumes and in percentage points for rates. The green line 'Default' represents the scenario with default realization. The evolutions of the spread loan-deposit interest rate are similar in the two regions.

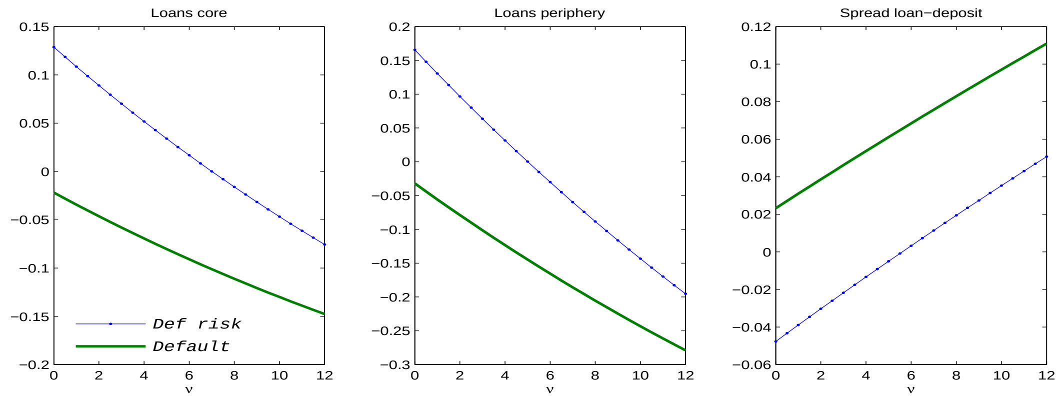
is sizable. For instance, without any haircut, a 1% default realization shock reduces private loans to the periphery by 0.05% on average over 15 periods whereas the same shock with $\nu = 10$, that is with an haircut of 10%, reduces loans by 0.25% on average.

In conclusion, convexity of the capital and collateral costs increase the transmission of the default realization shock. However, this convexity does not generate enough transmission with default risk. In this latter case, the role of the elasticity of haircut is crucial.

4.3 From integration to fragmentation in the banking sector

So far we assume a fully integrated banking system. However, although we have several banks playing at a global level inside the euro area, there are also some banks more exposed to their domestic market. Moreover, banking fragmentation probably increased during the financial crisis of 2007-2008 and the sovereign crisis of 2010-2011 (see section 1 for a discussion). In theory, assuming a full integration might induce a too strong transmission from periphery to core and as a result a too weak impact of default in the periphery. There are different ways to introduce fragmentation in the banking sector. For instance, we could assume one bank in each region with only local liabilities and assets, apart from sovereign bond holdings as in Guerrieri et al. (2012). Alternatively, we could keep one single bank but with two different bank capital constraints, one related to the core assets/liabilities and one related to the periphery ones. This would therefore imply two different bank capital costs. The only link between regions would be the maximization of a 'global profit'. Another possibility would be to have two different bank collateral costs, meaning that the bank having more sovereign bonds/collateral from one region has an incentive to increase private lending to the same region, and *vice versa*. This is a shortcut to banks with geographical asset specialization that is consistent with the view that banks might be more in favor of providing domestic credit and holding domestic collateral. A reason could be that it is indeed easier to attest the reliability

Figure 6: Effects of a negative maximum sustainable debt-output ratio shock, for different values of ν (deviations from the steady state)



Notes. Average effects over 15 periods. 'Bank excess capital' is normalized with respect to the steady state size of the bank balance sheet. Deviations are expressed in percentage points. The green line 'Default' represents the scenario with default realization. The evolutions of the spread loan-deposit interest rate are similar in the two regions.

of both domestic creditors and sovereigns. Another that with an insufficient harmonization of bankruptcy procedure whithin the EA, banks are more exposed to foreign defaults creating a bias towards domestic-banking.[17] In the subsequent analysis, we focus on the third approach because its implementation requires almost no modification of the initial model.[18]

Fragmentation

As shown in equation (35), the fully integrated bank does not make any distinction between the geographical origin of assets and the bank collateral cost is:

$$\Psi\left(\frac{\sum_j Q^j_{c,t}(1-\epsilon^j_t)^\nu s^j_t}{\sum_j Q^j_{c,t} L^j_t} - \frac{\sum_j \bar{Q}^j_c\, \bar{s}^j}{\sum_j \bar{Q}^j_c\, \bar{L}^j}\right), \tag{53}$$

with $\Psi(0) = 0$, $\Psi^{'}(0) \leq 0$, $\Psi^{''}(.) > 0$ and $\nu \geq 0$. With fragmentation, we assume that bonds from region j only help lending – through its collateral role on the secured interbank market – to the same region. In other words, we introduce a double cost making the distinction between core and foreign assets:

$$\mathtt{d} \sum_j \Psi\left(\frac{(1-\epsilon^j_t)^\nu s^j_t}{L^j_t} - \frac{\bar{s}^j}{\bar{L}^j}\right). \tag{54}$$

In this case, the j collateral is only useful for the j private lending. This modifies first order conditions (41) and (42) accordingly. We calibrate equation (54) as equation (53), with $\Psi^{'}(0) = 0$

[17] Bignon et al. (2013) provide an exaustive discussion on the limited credit market integration of the EA and on the advantages of a banking union.

[18] In appendix B, we also present the second alternative (two different capital constraints) and show that we obtain the same kind of results.

and $\Psi^{''}(.) = \Gamma_p > 0$ (see table 1 for the numerical values). $\mathtt{d} = 1/2$ is a new parameter calibrated such that the size of the cost after the shock is similar with the two types of formulation.

Comparison to existing empirical evidence

Before comparing simulation results with an integrated bank and with fragmentation, we first look at the FAVAR estimates from Neri and Ropele (2013) on the macroeconomic effects of the sovereign debt crisis for a subset of core and periphery countries of the euro area. Table 2 (row 'Data estimates') shows that, according to Neri and Ropele (2013), a 1 ppt increase in default risk in the periphery raises sovereign periphery bond interest rates by 1 ppt (full pass-through) and has no effect on sovereign core bond interest rates (no pass-through). However, the interest rates on private loans increase both in the periphery and the core region, although the increase is more pronounced in the periphery (respectively +0.3 ppt in p and +0.1 ppt in c). These results are in line with what we already observed from figure 1 in section 1. The fall in loans is important, with -1% in the core and -2% in the periphery. As a result the central bank reduces the policy rate by 0.3 ppt. Our simulation results with the integrated bank (row 'Model GB') are qualitatively in line with the FAVAR estimates. Quantitatively, we however observe that an integrated bank shares too much the periphery troubles with the core region. The increase in the periphery bond rate is limited to 0.4 ppt and the core bond rate falls by 0.4 ppt because of a flight-to-quality. The spread surge – between the periphery and the core bond rates – is therefore close to the data estimates but not its distribution among regions. Similarly, the model with an integrated bank provides equivalent rises in private lending rates although data show a more pronounced rise in the periphery. Finally, the model cannot reproduce the deep fall in loans – and output – and therefore the strong central bank reaction. Moving from a bank integration representation to fragmentation (row 'Model frag.') prevents the full sharing of the periphery turmoil. As a result, the situation in the periphery deteriorates and is now more in line to what we observe from data estimates. However, the situation in the core becomes too good. We observe that the lending rate to core firms decreases (-0.1 ppt) and therefore the volume of loans increases (+0.1%). We see from the simulations that these two polar banking representations (integrated bank *vs.* fragmentation) also produce polar results with contagion on the one hand and no contagion on the other hand. With fragmentation, the monetary policy is therefore too loose for the core region and too restrictive for the periphery region. Looking at EA aggregated variables, we see that the – negative – effect of the shock is about twice stronger with banking fragmentation than with banking integration (columns R, $L^c + L^p$ and $Y^c + Y^p$ in table 2).

According to data estimates, there is contagion but the periphery remained more severely hit. The last line of table 2 (row 'Model interm.') proposes a model with a banking sector between integration and fragmentation. To do so, we assume a collateral cost as:

$$\begin{aligned} & \mathtt{d}\,\Psi\left(\frac{\lambda s_t^c + (1-\lambda)Q_{c,t}^p(1-\epsilon_t^p)^\nu s_t^p}{\lambda L_t^c + (1-\lambda)Q_{c,t}^p L_t^p} - \frac{\lambda \bar{s}^c + (1-\lambda)\bar{Q}_c^p \bar{s}^p}{\lambda \bar{L}^c + (1-\lambda)\bar{Q}_c^p \bar{L}^p}\right) \\ + \quad & \mathtt{d}\,\Psi\left(\frac{(1-\lambda)s_t^c + \lambda Q_{c,t}^p(1-\epsilon_t^p)^\nu s_t^p}{(1-\lambda)L_t^c + \lambda Q_{c,t}^p L_t^p} - \frac{(1-\lambda)\bar{s}^c + \lambda \bar{Q}_c^p \bar{s}^p}{(1-\lambda)\bar{L}^c + \lambda \bar{Q}_c^p \bar{L}^p}\right), \end{aligned} \tag{55}$$

with $0 \leq \lambda \leq 1/2$. When $\lambda = 1/2$ and $\mathtt{d} = 1/2$, equation (55) is equivalent to equation (53) and we are back to the integrated bank formulation. When $\lambda = 0$, equation (55) is equivalent to equation (54) and we are back to the fragmentation case. Any other $0 < \lambda < 1/2$ gives an intermediate degree of fragmentation, the closer to 0 is λ, the stronger is the fragmentation. In the simulation, we assume $\lambda = 1/3$ and set $\mathtt{d} = 2$ such that the size of the cost after the shock is similar with the two other simulations. We see that this intermediate representation reproduces quite well the empirical evidence, at the exception of the deep fall in loans and output estimated in Neri and Ropele (2013). However, none of the three different models/banks is able to reproduce the fall.[19]

Table 2: Maximum pass-through of a 1 ppt increase in default risk in the periphery country to selected market interest rates, spreads and volumes

Rates	$R^{b,c}$	$R^{b,p}$	$R^{b,p} - R^{b,c}$	$R^{l,c}$	$R^{l,p}$	$R^{l,c} - R^{b,c}$	$R^{l,p} - R^{b,p}$	R
`Data estimates`	+0.0	+1.0	+1.0	+0.1	+0.3	+0.1	-0.7	-0.3
`Model GB`	-0.4	+0.4	+0.8	+0.2	+0.2	+0.5	-0.3	-0.1
`Model frag.`	-0.1	+0.3	+0.3	-0.1	+0.7	-0.1	+0.5	-0.2
`Model interm.`	-0.2	+0.4	+0.6	+0.1	+0.3	+0.3	-0.1	-0.1
Volumes	L^c	L^p	Y^c	Y^p			$L^c + L^p$	$Y^c + Y^p$
`Data estimates`	-1.0	-2.0	-2.0	-2.0			–	–
`Model GB`	-0.1	-0.2	-0.3	-0.3			-0.1	-0.2
`Model frag.`	+0.1	-0.4	-0.2	-0.7			-0.2	-0.5
`Model interm.`	-0.1	-0.2	-0.2	-0.4			–	–

Notes. Pass-through are expressed in percentage points for rates and in percentage for volumes. 'Data estimates' are from the FAVAR study of Neri and Ropele (2013). We aggregate individual countries belonging to their sample to produce aggregated core and periphery data. They do not show results for output but we proxy them with their data on industrial production. We normalize their results to a 1 ppt increase in risk by assuming a constant reaction elasticity. 'Model GB' provides simulation results using the integrated bank approach from section 2.4 and equation (53). 'Model frag.' provides simulation results using the fragmentation approach explained in equation (54). 'Model interm.' provides simulation results using the intermediate – between integration and fragmentation – approach explained in equation (55).

4.4 Policies

We see above that default has negative consequences for the currency area as a whole. In this section, we want to check how macro-prudential and monetary policies could – or could not – attenuate the effects of default. We assume that macro-prudential and monetary policies are *ex ante* policies, that is policies to prevent the realization of default. Therefore, we focus on default risk shocks – rather than default realization shocks – through a shock to the maximum sustainable debt-output ratio, represented by equation (47). For each policy, we consider an integrated banking sector *vs.* a fragmented one.

[19] On the one hand, the fall in loans and output in Neri and Ropele (2013) seems extremely strong, compared to the relatively limited increase in periphery bond rates. On the other hand, we might miss some links – and therefore underestimate the output effects –as for instance the possibility of default also for firms or the non-linear effects.

Counter-cyclical capital requirements

In the benchmark model, the capital requirement γ is constant. Basel III instead advocates for a counter-cyclical regulation, that is promoting financial soundness during good times in order to attenuate business cycle fluctuations. More precisely, Basel III foresees a regulatory framework under which a counter-cyclical capital surcharge - within a range of 0 to 2.5% of common equity - in addition to a capital buffer should help insuring a sufficient degree of protection against losses during the downturn of the economic cycle. In our simulation, we assume that γ may react respectively to output growth as in Angelini et al. (2012), private credit growth as in Quint and Rabanal (2013) or default expectations as in DeWalque et al. (2010). We assume a counter-cyclical regulation in the sense that γ is positively correlated to output and credit and negatively correlated to default. The general rule is as follows:

$$\gamma_t = 0.1\ \gamma + 0.9\ \gamma_{t-1} + \rho\ (X_t - \bar{X})\ .$$

When the requirements react to output growth, $X_t = \sum_j Y_t^j / \sum_j Y_{t-1}^j$ and we calibrate $\rho = 0.2 > 0$ according to Angelini et al. (2012). We also use their autoregressive parameter of 0.9. When the requirements react to private credit growth, $X_t = \sum_j L_t^j / \sum_j L_{t-1}^j$ and we calibrate $\rho > 0$ to obtain a similar volatility in γ_t as with the first policy and the integrated bank case ($\rho = 0.15$). Finally, when the requirements react to default, $X_t = E_t \epsilon_{t+1}^p$ and we calibrate $\rho < 0$ again to obtain a similar volatility in γ_t as with the first policy and the integrated bank case ($\rho = -0.021$).[20] So far in the model, regulated assets are only private loans ($\sum_j L^j$) as we may see from equation (34). We here also allow for the inclusion of sovereign bonds in the regulated assets ($\sum_j (L^j + s^j)$). This slightly modifies equation (34) as well as the first order condition (42).[21] Table 3 displays how the volatility of the economy changes depending on the regulation rule, for both an integrated and a fragmented banking system, and with or without the inclusion of sovereign bonds in the regulation. We do not only look at the change in volatility but we also look at the difference in welfare, both for the core and the periphery households, between the counter-cyclical policy equilibrium and the constant capital requirement equilibrium. To do so we compute a second order approximation of the expected utility equation (2) and compute the welfare cost – of moving from the acyclical to the counter-cyclical policy rule – as the fraction of consumption an agent would agree to give up each period in return for staying under the acyclical rule.[22]

We see from table 3 that with the benchmark/acyclical policy, the standard deviation of core and periphery outputs are around 0.25% with an integrated bank. With fragmentation, the volatility of the p region increases dramatically. We assume that the policy aim is to reduce the volatility in outputs and that only private loans are considered as regulated assets (lines 'L' in table 3). We see that the most powerful counter-cyclical policy is the one reacting to output growth, both under integrated banking and under fragmented banking representation. This policy requires a volatility of the capital ratio requirement parameter γ between 0.78 (integrated bank) and 1.21 (fragmentation), meaning that the parameter fluctuates roughly between 4% and 6%. However,

[20] Since we consider a single bank – with or without fragmentation – we assume a EA wide macro-prudential policy.

[21] So far we consider that regulated assets are only private loans (lines 'L' in table 3) or that all assets (private and public loans) are regulated without any distinction between assets (lines '$L + s$' in table 3). We could consider any intermediate situation with a weight 1 on private loans and a weight strictly between 0 and 1 on public loans. This would obviously also give intermediate results.

[22] This consumption equivalent welfare measure was originally introduced in Lucas (1987). It also obviously depends on the size of the shock.

Table 3: Effects of alternative counter-cyclical capital requirement rules

Capital requirements		Output volatility		Inflation volatility		γ volatility	Welfare costs	
		Core	Periph	Core	Periph	Global Bank	Core	Periph
Banking integration								
Acyclical	L	0.238	0.291	0.047	0.068	-	-	-
Output growth	L	-26.6%	-18.6%	0.84%	1.74%	0.784	+0.026%	-0.023%
	L+s	-55.0%	-48.9%	-39.8%	-37.8%	0.484	+3.47%	-7.82%
Credit growth	L	-3.06%	-2.53%	0.84%	0.58%	0.777	+0.017%	-0.016%
	L+s	-31.4%	-32.5%	-39.8%	-38.4%	0.478	+3.51%	-7.85%
Default	L	-0.88%	-0.85%	-2.54%	-1.16%	0.782	-0.029%	-0.032%
	L+s	-29.7%	-31.2%	-44.1%	-40.7%	0.479	+3.42%	-7.83%
Banking fragmentation								
Acyclical	L	0.209	0.625	0.044	0.061	-	-	-
Output growth	L	-53.4%	-13.0%	0.90%	1.97%	1.207	+0.22%	+0.26%
	L+s	-75.4%	-40.7%	-34.5%	-31.6%	0.783	+3.67%	-7.55%
Credit growth	L	-7.72%	-3.80%	0.00%	0.00%	0.884	-0.003%	+0.005%
	L+s	-32.0%	-31.1%	-35.4%	-32.9%	0.586	+14.09%	-6.95%
Default	L	-0.66%	-0.80%	-2.72%	-1.31%	0.727	-0.051%	-0.011%
	L+s	-24.3%	-27.7%	-38.2%	-34.9%	0.479	+3.18%	-6.97%

Notes. The 'Acyclical' line corresponds to the benchmark – acyclical – capital requirement rule (constant γ) and gives the relative standard deviations of output and inflation. We multiply the line by 100 for the easiness of reading. The lines 'Output growth', 'Credit growth' and 'Default' correspond to counter-cyclical rules reacting to these variables. For each counter-cyclical rule, we may regulate only private loans (line 'L') or all loans (line '$L + s$'). Results are expressed as percentage deviation from the benchmark except the banking integration column expressed in percentage point deviation.

this policy increases inflation volatility, but only marginally, and implies a welfare cost for the c region and also the p region in case of fragmentation. We observe that the total welfare cost (sum for the 2 regions) is negligible with an integrated bank but is more important with fragmentation. In the former case, the total cost is 0.026% − 0.023% = 0.003%, which represents approximately € 0.12 per person per quarter. In the later case, the total cost represents approximately € 19 per person per quarter. In other words, the welfare cost of stabilizing output is much lower under a well integrated banking sector.

We also see that including sovereign bonds as regulated assets improves results, whatever the rule (lines '$L+s$' in table 3). It reduces further the volatility of output while also decreasing the volatility of inflation. Moreover, changes in the policy parameter γ are lower. However, we have a strong dichotomy regarding welfare, with huge costs for the core and high gains for the periphery. These huge costs for the core – although there is a gain at the EA level – makes the policy more difficult to implement from a political point of view.

Extended Taylor rule

Equation (51) gives the Taylor rule we use in all the above simulations, with output gap and inflation gap as inputs. However, a sovereign crisis may harm the banking system and therefore hamper the transmission of monetary policy. As a result, a central bank might want to also include an index of sovereign distress as extra input for the conduct of its monetary policy. To analyze this, we follow Trabandt and Smets (2012) and augment the Taylor rule with the spread between the periphery and core sovereign interest rates:

$$R_t = (R_{t-1})^{\gamma_m} \left(\bar{R}^d \left(\frac{Y_t}{\bar{Y}}\right)^{\rho_y} \left(\frac{\Pi_{t-1}}{\bar{\Pi}}\right)^{\rho_\pi} \left(\frac{R_t^{b,p}}{R_t^{b,c}}\right)^{\rho_r} \right)^{1-\gamma_m} .$$

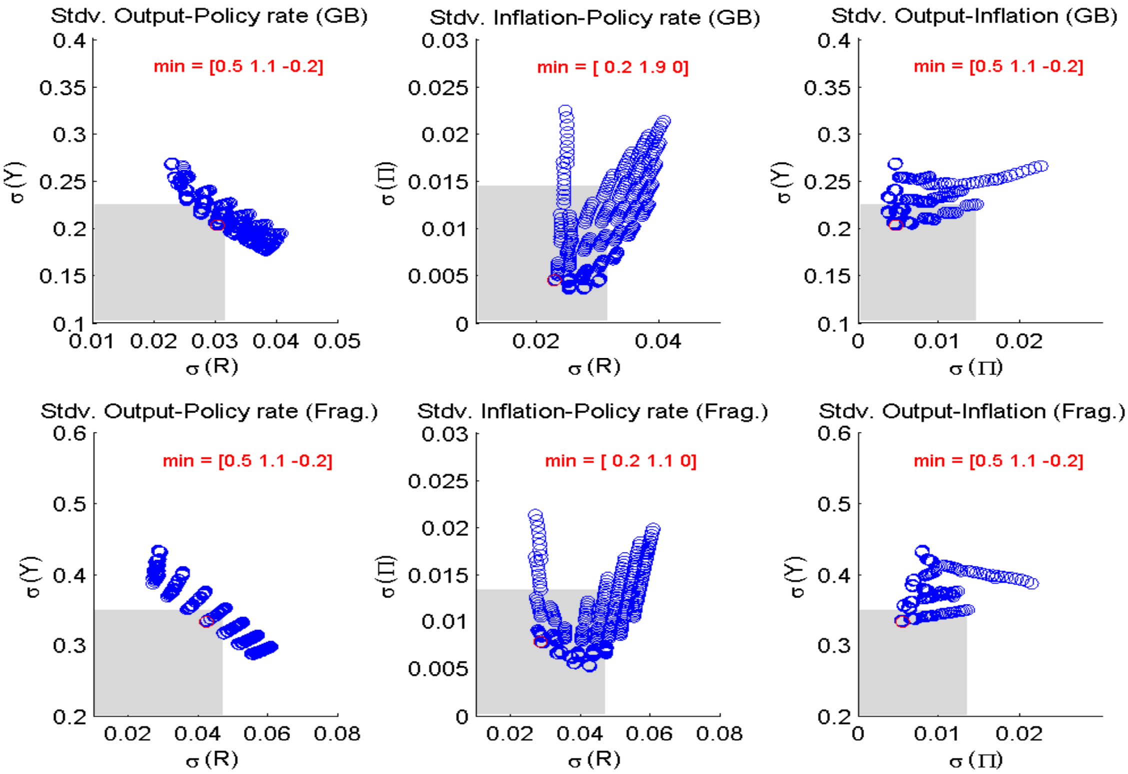
For any combination $[\rho_y \; \rho_\pi \; \rho_r]$, we compute the standard deviation of aggregate (EA wide) output, aggregate inflation and the policy rate. The only restrictions on these parameters we impose *a priori* are $0.2 \leq \rho_y \leq 0.8$, $1.1 \leq \rho_\pi \leq 1.9$ and $-0.2 \leq \rho_r \leq 0.0$. We center these restrictions on the benchmark calibration regarding ρ_y and ρ_π and we impose a countercyclical reaction of the policy rate to the spread, that is a negative ρ_r. Figure 7 shows the results, with each dot representing a specific combination of parameters.[23]

In the benchmark simulations, we impose $\rho_y = 0.5$, $\rho_\pi = 1.5$ and $\rho_r = 0$ and we look for combinations of parameters that could reduce the volatility of inflation and output with respect to this benchmark, without increasing the volatility of the policy rate. In figure 7, any better combination must be located in the gray area. On the one hand, we see from the first column of Figure 7 that it difficult to reduce substantially the volatility of output without increasing the volatility of the policy instrument. On the other hand, we see from the second column that we can decrease seriously the volatility of inflation by only playing with ρ_y and ρ_π, and keeping $\rho_r = 0$. Finally, the last column shows how we may reduce the volatility of output and inflation, keeping the volatility of the policy rate lower than in the benchmark. We see that the best combination is $\rho_y = 0.5$, $\rho_\pi = 1.1$ and $\rho_r = -0.2$, both with banking integration and with banking fragmentation. A reaction to the sovereign rate spread therefore always improves the situation, even though the main improvement

[23] We also look at the standard deviation of the disaggregated variables (distinction between c and p). Results with disaggregated variables are close to the aggregated ones. We therefore do not show them in Figure 7.

concerns inflation. Computing a welfare analysis as above shows that, with an integrated bank representation, moving from the benchmark rule with coefficients [0.5 1.5 0] to the extended optimal rule with coefficients [0.5 1.1 -0.2] produces a welfare gain in the EA as a whole representing approximately € 20 per person per quarter. However, the aggregate gain hides regional disparities since there is a loss in the core region. In case of banking fragmentation, there is a global cost of € 0.24.

Figure 7: Standard deviations depending on the Taylor rule specification



Notes. In each subplot, each blue dot represents a parameter combination for the Taylor rule. The red dot represents the parameter combination shown in the min=[p_1 p_2 p_3]. p_1 represents the weight on output gap, p_2 represents the weight on inflation and p_3 represents the weight on the spread. The gray area is delimited by the standard deviations in the benchmark case [0.5 1.5 0]. In the right-hand-side subplots, we only represent combinations when the standard deviation of the policy rate is lower than the one from the benchmark. All variables are EA aggregated.

Policy conclusions

From the above policy analysis, we see that counter-cyclical capital requirements targeting output growth reduces seriously the volatility of output without implying a too high welfare cost. Extending the Taylor rule does not really allow to reduce output volatility. In general, whatever the policy, the welfare costs of stabilizing the economy are much lower under a well integrated banking sector. This conclusion is in line with the main findings of Bignon et al. (2013) that the optimality of a currency union is restored only when credit limitations are reduced and banking union is achieved.

5 Conclusions

This paper studies the international transmission of sovereign debt default. More precisely, we build a 2-country model of the EA and look at the spillover from the periphery to the core. We show that a well integrated banking sector reduces the negative consequences at the EA wide level and limits the welfare cost of stabilizing policies.

From a modeling point of view, we here impose *ex ante* the type of banking representation (integration *vs.* fragmentation *vs.* intermediate). Obviously, this banking representation is not exogenous but endogenous and evolves according to the economic and/or financial situation. Moving from an exogenous to an endogenous banking structure would be an interesting extension. From a policy point of view, we focus on macro-prudential and monetary policies to attenuate the risk of default. An interesting avenue for future research would be to look at more structural policies, that is to look at policies to keep public debt at fair level in order to avoid the risk – and therefore the realization – of default. For instance, the new Fiscal Compact Treaty, the introduction of common area-wide eurobonds or a deeper level of fiscal union.

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A Integration vs. fragmentation of the financial sector in the euro area

Table 4: Sovereign debt holding

		Holders (% of total stock)			
Sovereign debt from	Year	Domestic banks	Other residents	Non-residents	Public institutions
France	2007	13	32	55	0
	2011	14	29	57	0
Germany	2007	30	21	49	0
	2011	23	14	63	0
Greece	2007	11	3	74	13
	2011	19	6	38	36
Ireland	2007	3	4	93	0
	2011	17	2	64	17
Italy	2007	12	34	49	5
	2011	17	29	43	11
Netherlands	2007	9	21	69	0
	2011	11	21	67	1
Portugal	2007	9	15	76	0
	2011	22	14	52	12
Spain	2007	21	21	48	10
	2011	27	20	34	19
Core	2007	23	24	53	0
	2011	19	19	61	0
Periphery	2007	13	27	54	6
	2011	20	24	42	15

Notes. 'Domestic banks' excludes the domestic central bank. 'Other residents' represents the domestic private sector less domestic banks. 'Non-residents' is the non-domestic private sector (bank and non-bank). 'Public institutions' is both domestic and non-domestic public institutions (including the ESCB). Source: Table 1 from Merler and Pisany-Ferry (2012), based on various national sources.

Table 4 gives a breakdown of sovereign debt by holding sectors. We directly borrow this table from Merler and Pisany-Ferry (2012). Data relate to the year 2007, that is before the start of the financial crisis, and the year 2011, that is at the height of the sovereign debt troubles. We see that in 2007, about 55% of the sovereign debt, both from the core countries and the periphery countries, were held by non-residents. Data cannot distinguish between banks and non-banks in the non-resident sector, as well as between other euro area residents and non-euro area residents. We also notice that domestic banks in the periphery hold relatively few domestic debt (13%). We observe significant changes between 2007 and 2011. First, non-residents reduce their – relative – holdings of periphery debt and increase theirs of core debt. Second, domestic banks in the periphery increase their – relative – holdings of domestic debt. In conclusion, we have a rather globalized sovereign debt market in 2007 whereas we see a flight-to-quality as well as a specialization of periphery banks between 2007 and 2011.

The first columns of Table 5 use BIS data and focus on the foreign claims of banks located in selected countries vis-à-vis the core region, the periphery region and the non-euro area countries. The foreign claims include claims on public debt but also all other – private – foreign claims. A limitation of the consolidated BIS data is that they do not include information on domestic claims. Data refer to 2009 and 2013, that is before and after the period of sovereign debt troubles. We see that in 2009, banks located in the core region have the same amount of foreign claims vis-à-vis the other core countries as vis-à-vis the periphery countries. Banks located in the periphery countries are more exposed to the core countries than to the other periphery countries. We also notice that all banks have a large exposure outside the euro area. Between 2009 and 2013, we observe a flight-to-quality. Core banks reduce their exposure to periphery and increase their exposure to the other core countries, whereas periphery banks reduce their exposure to other periphery countries to increase – relative – claims outside the euro area. Once again, we conclude that banks' *direct foreign exposures* are diversified in 2009 whereas we see a flight-to-quality between 2009 and 2013.

To better understand the integration of the euro area banking sector, we also look at the wholesale banking market using Monetary Financial Institutions (MFI) statistics compiled by the ECB. The last columns of Table 5 show that, on average, between 25% and 30% of MFI to MFI lending is cross-border. We however observe huge dispersions between countries depending on their size, with smaller countries having much higher cross-border positions than large countries. From 2009 and 2013, we see a geographical specialization but of limited size. This underlines that banks do not only have direct foreign exposures but also *indirect foreign exposures* through an integrated interbank market.

B Fragmentation of the financial sector: an alternative approach

In the main text, we introduce fragmentation through the bank collateral channel. We here look at an alternative fragmentation through the bank capital channel. To do so, we keep one single bank but with two different capital constraints, one related to the core balance sheet items and another related to the periphery ones. More precisely, we split equation (34) into one equation for each region $j \in \{c, p\}$:

$$(1-\gamma)Q^j_{c,t}L^j_t + Q^j_{c,t}s^j_t + Y^j_t/Y_t\,Q^j_{c,t}B^{cb}_t = Q^j_{c,t}D^j_t + x^j_t\,. \tag{56}$$

We therefore obtain two different excess capital variables x^j_t and therefore two different bank capital costs $\mathtt{d}\,\Omega(x^j_t)$. We calibrate the parameter $\mathtt{d}$ such that the size of the costs after the shock is the same between simulations. This modifies the first order conditions (39) to (42). Table 6 compares the maximum pass-trough of a 1 ppt increase in the periphery default risk under alternative banking specifications. We see that compared with integration, fragmentation worsens the situation in the periphery and improves the situation in the core. It also worsens the situation in the aggregated EA. These results hold whatever we introduce fragmentation through the bank collateral cost $\Psi(.)$ as in the main text or through the bank capital cost $\Omega(.)$ as in equation (56). Quantitatively, we however

Table 5: Selected banking statistics

		Direct Exposure Foreign claims vis-à-vis (%)			Indirect exposure Loans to MFIs (%)	
Banks from	Year	Core	Periphery	Other	Domestic	Euro Area
Austria	2009	19	9	72	74	26
	2013	16	5	79	81	19
Belgium	2009	32	21	46	20	80
	2013	30	17	53	30	70
Finland	2009	n.a.	n.a.	n.a.	88	12
	2013	n.a.	n.a.	n.a.	95	5
France	2009	19	24	58	82	18
	2013	25	18	57	85	15
Germany	2009	20	21	59	74	26
	2013	23	14	64	79	21
Greece	2009	6	1	92	21	79
	2013	22	1	78	55	45
Ireland	2009	15	14	71	76	24
	2013	9	3	88	57	43
Italy	2009	52	7	41	86	14
	2013	50	4	46	84	16
Luxembourg	2009	n.a.	n.a.	n.a.	38	62
	2013	n.a.	n.a.	n.a.	19	81
Netherlands	2009	27	16	57	42	58
	2013	35	8	57	59	41
Portugal	2009	19	38	43	49	51
	2013	21	30	49	67	33
Spain	2009	12	12	77	68	32
	2013	9	7	84	78	22
Core	2009	22	21	58	71	29
	2013	25	14	61	76	24
Periphery	2009	25	12	63	75	25
	2013	23	6	71	77	23

Notes. The Direct Exposure column shows the percentage of outstanding amount of consolidated foreign claims of reporting banks per country with respect to the core and periphery countries of the Euro Area, as well as with respect to all other countries. Source: BIS Quarterly Review March 2010 and 2014, table 9B and author's calculations. The Indirect Exposure column presents the percentage of outstanding amounts of loans of reporting banks per country to other financial institutions belonging to the same country and to the rest of the Euro Area (excl. the ESCB). Source: ECB, Statistical Data Warehouse and author's calculations. Data are reported for September 2009 and 2013.

observe that the collateral fragmentation produces stronger effects than the capital fragmentation. We could obviously combine the two fragmentation and this would increase further the asymmetry between the core and the periphery regions.

Table 6: Maximum pass-through of a 1 ppt increase in default risk in the periphery country to selected market interest rates and volumes

Rates		$R^{b,c}$	$R^{b,p}$	$R^{l,c}$	$R^{l,p}$	R	
`Model GB`		-0.4	+0.4	+0.2	+0.2	-0.1	
`Model frag.`	$\Psi(.)$	-0.1	+0.3	-0.1	+0.7	-0.2	
`Model frag.`	$\Omega(.)$	-0.0	+0.4	+0.2	+0.2	-0.1	
Volumes		L^c	L^p	Y^c	Y^p	$L^c + L^p$	$Y^c + Y^p$
`Model GB`		-0.1	-0.2	-0.3	-0.3	-0.1	-0.2
`Model frag.`	$\Psi(.)$	+0.1	-0.4	-0.2	-0.7	-0.2	-0.5
`Model frag.`	$\Omega(.)$	-0.0	-0.4	-0.2	-0.3	-0.2	-0.3

Notes. Pass-through are expressed in percentage points for rates and in percentage for volumes. 'Model GB' provides simulation results with banking integration, explained in section 2.4 and equation (53). 'Model frag. $\Psi(.)$' provides simulation results with fragmentation through the bank collateral channel, explained in equation (54). 'Model frag. $\Omega(.)$' provides simulation results with fragmentation through the bank capital channel, explained in equation (56).