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Stock and sovereign bond dynamics in the euro area

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Abstract: This paper proposes an original general equilibrium framework to study the evolution of the correlation on equity and sovereign bond markets in the euro area. More specifically we explore the role of credit constraints for this correlation by introducing financial intermediaries in a standard open economy financial macroeconomic model. We find that credit constraints change the response of macroeconomic variables to shocks and are therefore key for the behaviour of asset markets. Indeed our model with credit frictions is able to explain the stylized facts on correlation's behaviour between stock and sovereign bond markets in the euro-zone during the period 2000-2012. Before the sovereign debt crisis, a productivity shock can explain the negative relation between stock and bonds whereas a financial bubble shock the positive one. After 2010, a sovereign risk shock to the periphery can explain the heterogeneous behaviour of the stock-bond markets in the core and the periphery.

Keywords: Currency union, international financial markets, financial intermediaries, general equilibrium.

Corrélation entre marchés d'actions et titres publics en zone euro

Abstract : Ce papier étudie à partir d'un modèle d'équilibre général original l'évolution de la corrélation entre marchés d'actions et titres publics en zone euro. Plus spécifiquement, on explore le rôle des contraintes de crédit dans cette corrélation en introduisant des intermédiaires financiers dans un modèle standard en économie ouverte. On montre que les contraintes de crédit changent la dynamique des variables macroéconomiques à la suite de chocs et sont déterminantes dans le comportement des marchés financiers. En effet, le modèle proposé avec contraintes de crédit permet d'expliquer certains faits stylisés concernant la corrélation entre les marchés d'actions et de titres publics en zone euro entre 2000 et 2012. Avant la crise des dettes souveraines, un choc de productivité peut expliquer la relation négative entre action et titres publics tandis qu'un choc de bulle financière explique la relation positive. Après 2010, un choc de risque souverain dans les pays périphériques peut expliquer le comportement hétérogène des deux marchés au coeur et à la périphérie de la zone euro.

Mots-clefs : union monétaire, marchés financiers internationaux, intermédiaires financiers, équilibre général.

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1 Introduction

The understanding of the relation between stock and sovereign bond correlations is of primary importance for investors as well as for policy makers. From a finance point of view this correlation suggests a measurement of risk and diversification of investors' portfolio. From an economic point of view asset prices are the mechanism by which consumption and investment are allocated across time and states of nature. These decisions change according to the business cycle and the different sources of shocks that impact the economy. In this paper we study the determinants of asset market's comovements in the euro area from a macroeconomic perspective. In particular we show that credit constraints play a crucial role for the behaviour of asset markets.

Figure 1.1 and Table 1 show some stylized facts on the behaviour of sovereign bond and stock returns in the euro zone.[1] Since the beginning of the common currency union and up to 2009, we observe that the dynamics of sovereign bond yields in the core and in the periphery of the euro zone moved hand-in-hand. Both region's yields seem to be decreasing and converging towards the same value. This behaviour was interpreted as an indicator that the two area's sovereign bonds were perceived to be more and more safe and alike. After 2009, and more pronouncedly in 2010, the two region's yields started to diverge. In the core returns continued to decrease whereas in the periphery they rocketed. This evidence is what we refer to as flight-to-quality in the sovereign bond market. It shows that, since the beginning of the sovereign debt crisis, periphery sovereign bonds were perceived to be more risky and, for this reason, they were sold against the core, safer, ones. For what concerns the stock market, we observe that, during the whole euro area period, returns have been moving pretty much in line in the core and in the periphery. Notwithstanding the different crisis (financial first and sovereign then) the stock markets of the two regions were highly correlated: decreasing in the early 2000 after the dot-com crisis, increasing afterwards until the recent financial crisis with the consequent fall in the late 2007. Looking at the stock-bond correlation we can see a time-varying pattern. We identify four sub-periods. In Figure 1.1 the grey areas highlight the change in the sign of the correlation. In the period between 2000-2004 and 2007-2010 it is positive while in the period 2004-2007 is negative. After 2010, following the disruption in the bond market, the stock-bond correlations do not behave similarly in the two regions any more. In the core the stock-bond correlation is positive whereas in the periphery it becomes negative.

The understanding of which mechanisms have contributed to determine the behaviour of these asset markets is the focus of this paper.

Many empirical works have explained the determinants of the stock-bond comovements for the euro zone in terms of macroeconomic variables. Among the others Kim et al. (2006) and Andersson et al. (2008) explain the role of variables such as inflation, GDP growth, market uncertainty as main drivers of the correlations. Perego and Vermeulen (2016), in the light of the recent sovereign debt crisis, highlight the role of relative imbalances between the core and the periphery of the euro zone and of variables such as balance of payments among the euro area asset markets movements' determinants. The work of Adrian et al. (2010) showed the crucial role of financial intermediaries' balance sheet in the pricing of both the cross-section as well as the time series of asset prices. In the euro area, as the balance sheets of banks are highly exposed to sovereign bonds that are used as a source of collateral, troubles on the banking sector translate into lower credit for the private sector and, in this way, they might impact the equity market performance.

General equilibrium models in the macro-finance literature have focused on the one hand on the term structure of bond interest rates and on the asset pricing of stock and bonds in a closed economy. A good review of the stock-bond asset pricing literature is provided by Campbell et al. (2014) and Swanson (2016). The first explains the change in the stock-bond correlation in relation to monetary policy and

[1] Appendix A explains more in detail the data.

macroeconomic variables; the second provides a coprehensive framework to answer to different asset pricing puzzles in the macro-finance literature. However, the international dimension of asset markets is neglected. On the other hand, the new literature on open economy financial macroeconomics focuses on the international dimension of asset markets. Coeurdacier and Rey (2013) provide an exhaustive review of the literature on the home bias in international capital markets. Closer to our approach, the branch of this literature dealing with the hedging properties of bond and equities finds that bonds are better suited to hedge real exchange rate risk whereas equities non-tradable income risk. However, this set of models does not consider the role of financial intermediaries and the risk of default on sovereign bonds. Both dimensions proved to be crucial in the euro zone case.

This paper contributes to i) the asset pricing literature by building a general equilibrium model able to explain how different shocks and macroeconomic dynamics impact on the euro area stock-bond correlation; and to ii) the open economy financial macroeconomics literature by introducing financial intermediaries and theoretically studying their relation with asset markets.

We build a two-country real DSGE model with a banking sector and asset markets as this framework is the best equipped to study the transmission of shocks and the multiple linkages between the core and the periphery of the euro zone. For the banking sector representation we follow Enders et al. (2011) adding a collateral channel -based on sovereign bonds- to their perfectly competitive banking sector with a cost on capital storage (bank capital channel). There is an endogenous risk of default on sovereign bonds as in Corsetti et al. (2013). Equity markets are introduced as in Coeurdacier et al. (2007). This new framework allows for a comprehensive study of asset markets' dynamics looking at the impact of shocks originating in the equity market, the sovereign bond market as well as the real economy.

We find that the interaction between credit constraints in the banking sector and macroeconomic variables is a key driver of the time-varying stock-bond correlation. Constraints on bank's capital and collaterals determine a strong tightening of credit to firms and a pro-cyclical amplification of shocks. Moreover, the existence of credit constraints at the international bank level prompts more synchronization in asset markets' responses as there is a more homogeneous sharing of the effects of shocks between countries. We show that, in the presence of credit constraints, a sovereign risk shock reproduces the 2010-2012 facts on the euro area correlations. For the previous sample a productivity shock matches the negative stock-bond correlation during the years 2004-2006 while a financial expectation shock reproduces the positive correlation registered both during the dot-com and the subprime crisis period.

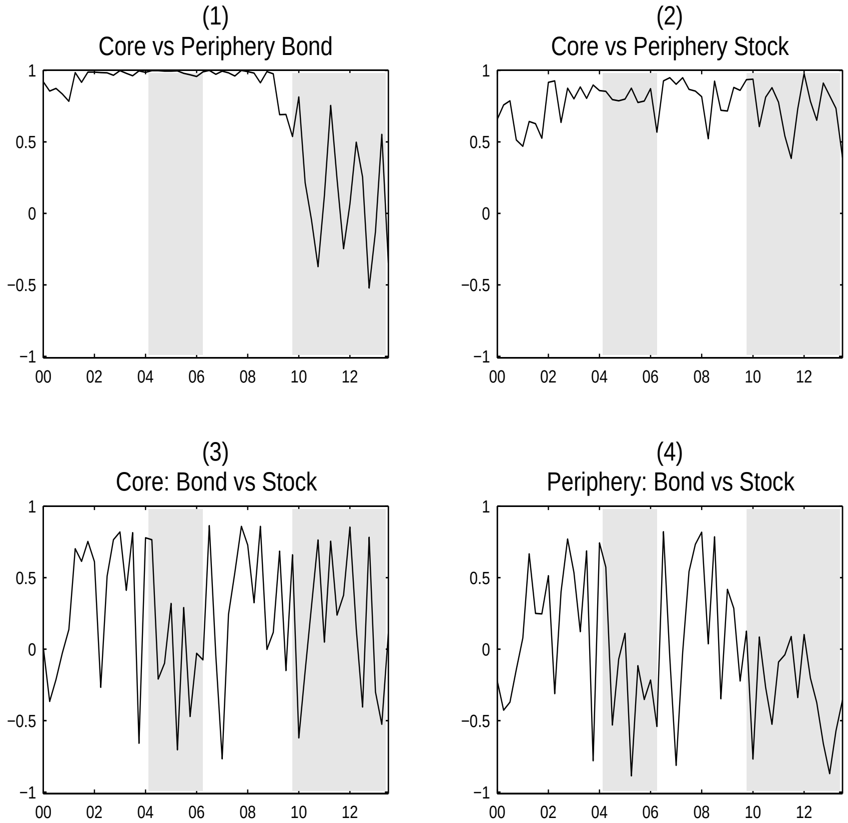
The remainder of the paper is structured as follows. Section 2 details the model, Section 3 explains the calibration and Section 4 shows the dynamic simulations. Section 5 concludes.

Table 1: Correlation data

	2000-2004	2004-2007	2007-2010	2010-2012	2000-2012
corr($R^{b,p}$,$R^{b,c}$)	0.94	0.98	0.88	0.17	0.71
corr($R^{S,p}$,$R^{S,c}$)	0.74	0.82	0.82	0.73	0.77
corr($R^{b,c}$,$R^{S,c}$)	0.34	-0.08	0.44	0.28	0.22
corr($R^{b,p}$,$R^{S,p}$)	0.18	-0.24	0.28	-0.19	-0.02

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$, $R^{S,j}$ the gross return on equity.

Figure 1.1: Realized correlations in the euro zone stock-bond markets



Notes. Stock market series are total return indexes on non-financial firms; bond series are DS benchmark 10 years index of yields to redemption. Countries belonging to the core are: Austria, Belgium, Finland, France and Germany. Whereas countries belonging to the periphery are: Greece, Ireland, Italy, Portugal and Spain. The series are aggregated at the core and periphery level by weighted average based on market capitalization for stock and government liabilities for bonds at the baseline values of 2002. The realized correlations are computed on quarterly windows and show the dynamic relations between the returns on stock and the yields on sovereign bond within the euro zone over the period 2000 to October 2013. The shaded areas highlight the change in the sign of the stock-bond correlations.

2 Model

We develop an international business cycle model for the euro area. It consists of two regions, 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. The model features an international banking sector, an equity market and an endogenous probability of default on sovereign debt. We assume that the two regions are perfectly symmetric except for a higher level of debt to output in the periphery country.

2.1 Households

In each country $j \in \{c, p\}$, the representative household may consume C_t^j, invest D_t^j in one-period bank deposits or b_t^j in one-period sovereign debt. Moreover households can invest in financial markets both in domestic and foreign equity $S_{i,t}^j$ issued by the respective firms-capital producers $i \in \{c, p\}$. By investing in deposits the households obtain $R_{t-1}^{d,j}$, the predetermined gross return on deposits. The expected gross return on sovereign bond is $R_{t-1}^{b,j}$ while the actual net return is $R_{t-1}^{b,j} - \epsilon_t^j$, where $\epsilon_t^j \geq 0$ captures the share of outstanding sovereign debt lost by households because of – partial – sovereign default.

The expected return on equity holdings is given by the price at which households can sell the share $\rho_{s,t}^j$

bought in the previous period and the dividend payout div_t^j coming from the capital producers. $Q_{j,t}^i$ is the real exchange rate of country i when country j is taken as the numeraire. The household also supplies h_t^j hours to the firms and receives wages w_t^j. Moreover, it owns the firms located in j and receives their profits Υ_t^j. Finally, the household receives a lump-sum transfer $H_t^{h,j}$ from the government and must pay taxes T_t^j as well as a quadratic portfolio adjustment cost on sovereign debt represented by the parameter $\phi_b > 0$ in equation (2.1). This cost makes the households' portfolio choices less sensitive to interest rate differentials. Additionally, the households pay a cost related to their equity holdings represented by the parameter $\phi_s > 0$. The households, in order to minimize the sum of the squared costs associated to equity holdings, optimally choose to hold the same amount of c and p shares. For this reason we can interpret this cost as a way to mimic preferences for a diversified portfolio. If the shares' holdings deviate from the optimal reference value, the households bear an additional cost. The household's budget constraint is:

$$\begin{aligned} C_t^j + D_t^j + b_t^j + \sum_i Q_{j,t}^i \rho_{i,t}^s S_{i,t}^j + \frac{\phi_s}{2} \sum_i Q_{j,t}^i \rho_{i,t}^s \left(S_{i,t}^j\right)^2 + \frac{\phi_b}{2}(b_t^j - \bar{b}^j)^2 \\ = w_t^j h_t^j + R_{t-1}^{d,j} D_{t-1}^j + (R_{t-1}^{b,j} - \epsilon_t^j) b_{t-1}^j + \sum_i Q_{j,t}^i (\rho_{i,t}^s + div_{i,t}) S_{i,t-1}^j \\ + \Upsilon_t^j + H_t^{h,j} - T_t^j. \end{aligned} \quad (2.1)$$

Throughout the paper, $\bar{z}$ represents the steady state of any variable z_t. The household's expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \left(\ln \left(C_t^j - \psi_n \frac{(h_t^j)^{\eta+1}}{\eta+1} \right) + \psi_d \ln D_t^j \right) \quad (2.2)$$

$0 < \beta < 1$ is the subjective discount factor, η is the inverse of the intertemporal elasticity of labour supply and $\psi_n, \psi_d > 0$ are parameters.[2] The household maximizes (2.2) subject to (2.1). It gives the following first order conditions (FOCs):

$$\psi_n (h_t^j)^\eta = w_t^j \ , \quad (2.3)$$

$$\lambda_t^j = \frac{\psi_d}{D_t^j} + E_t \beta \lambda_{t+1}^j R_t^{d,j} \ , \quad (2.4)$$

$$\lambda_t^j \left(1 + \phi_b (b_t^j - \bar{b^j})\right) = E_t \beta \lambda_{t+1}^j (R_t^{b,j} - \epsilon_{t+1}^j) \ , \quad (2.5)$$

$$Q_{j,t}^i \lambda_t^j (1 + \phi_s S_{i,t}^j) = E_t \beta \lambda_{t+1}^j (R_{i,t+1}^S) Q_{j,t+1}^i \ , \quad (2.6)$$

$$\lambda_t^j = \left(C_t^j - \psi_n \frac{(h_t^j)^{\eta+1}}{\eta+1} \right)^{-1} . \quad (2.7)$$

Equation (2.3) shows that the wage is equal to the marginal disutility of hours worked. Equations (2.4), (2.5) and (2.6) state that, at equilibrium, marginal costs are equal to expected marginal income from, respectively, deposits, sovereign bonds and equity. Equation (2.6) represents the FOCs for equity

[2]The choice of a GHH utility function is motivated by the international framework. The absence of wealth effect on the labour supply helps to match a series of empirical regularities as explained by Garcia-Cicco et al. (2010), Raffo (2008) and Schmitt-Grohe and Uribe (2012). Moreover, the results of the paper are not changed by using a different utility formulation (KPR for instance).

We introduce deposits in the utility function as in Enders et al. (2011) for steady state reasons. Nevertheless with this formulation deposits play the role of real value for cash. An increase in deposits increases the means of payments of the households and (ceteris paribus) increases their consumption.

holding for country j households with respect to country $i \in \{c,p\}$, $i \neq j$ issuer. The expected real return on equity is:

$$E_t[R^S_{i,t+1}] = \frac{E_t[\rho^s_{i,t+1}] + E_t[div_{i,t+1}] + u^s_t}{\rho^s_{i,t}}. \tag{2.8}$$

These returns are defined as the change in price plus the dividend payout. u^s_t is an i.i.d. shock to the expected returns. An increase (decrease) of u^s_t mimics overly optimistic (pessimistic) expectations on equity returns. It can be interpreted as a noise component, a subjective belief, that makes expectations on future returns detach from their fundamental values.[3]

Comparing equations (2.5) and (2.6) we can analyse the relation between the sovereign bond and equity rates in the households' portfolio. Let us define $R^{nb,j}_t$ as the net return on sovereign bonds. As we assume that only the periphery country can default, net returns are respectively given by

$$R^{nb,p}_t = R^{b,p}_t - E_t[\epsilon^p_{t+1}] , \tag{2.9}$$
$$R^{nb,c}_t = R^{b,c}_t. \tag{2.10}$$

Abstaining from adjustment costs and price dynamics, the relation between the sovereign bond and equity rates is the following:

$$E_t[R^S_{i,t+1}] = R^{nb,j}_t + \lambda^j_t \phi_s S^j_{i,t}. \tag{2.11}$$

Equation (2.11) shows that the two assets are not perfect substitute. There are two sources of differentiation: sovereign debt default and the cost associated to equity holdings. Changes in the amount of shares bought reduces the correlation between equity and sovereign returns. The more the shares held, the higher the return demanded by the households in order to hold such an asset. Analogously, periphery default on sovereign debt determines a wedge between the return on equity and periphery sovereign bonds.

2.2 Capital producers

The capital producers in country $j \in \{c,p\}$ have the choice of financing either via one-period loans from the bank or through asset markets in the form of equity. They may payout dividends, div^j_t, to the households or invest I^j_t in domestic firms. In turn, investment increases firms' capital stock K^j_t according to the following law of motion:

$$K^j_t = (1-\delta)K^j_{t-1} + I^j_t, \tag{2.12}$$

where $0 < \delta < 1$ is the capital depreciation rate. Capital provides a net real return r^j_t and capital producers pay a gross nominal interest rate $R^{l,j}_{t-1}$ on loans, as well as an adjustment cost on investment represented by the parameter $\phi_i > 0$.[4] If the capital producers decide to pay out dividends they face an adjustment cost represented by the parameter κ_d. As in Jermann and Quadrini (2012) the equity payout cost can be interpreted as a pecuniary cost as well as a way to model the speed of fund's adjustment when financial conditions change. In this model's specification of the cost, when κ_d is infinitely large capital producers have access to only one source of funds: bank loans. For smaller values, the capital producers can be financed both via (negative) dividend payouts and bank's loans. High values of κ_d oblige the capital producers to pay a high cost when they want to adjust the dividend payouts from

[3] For a detailed description of the financial expectation shock see Section 4.

[4] A convex adjustment cost on investment is common in the literature as it helps to match empirical behaviour of aggregate investment and prevents the investment demand curve to be perfectly elastic. For the early literature that assumes this cost see Gould (1968) and Lucas (1967) among others.

their steady state value. Lower values allow more flexibility in the payout policy. The capital producers' budget constraint is:

$$div_t^j + I_t^j + \frac{\phi_i}{2}(I_t^j - \bar{I}^j)^2 + \frac{\kappa_d}{2}(div_t^j - \bar{div}^j)^2 + R_{t-1}^{l,j}L_{t-1}^j = L_t^j + r_t^j K_{t-1}^j. \tag{2.13}$$

As equity shares are held internationally, the capital producers are owned by the households of both the core and the periphery country. They maximize:

$$\max E_s \sum_{t=s}^{\infty} (\beta^{e,j})^{t-s} \; div_t^j$$

subject to (2.12) and (2.13). With β^e being the time varying weighted average of the discount factors of the core and periphery households, expressed in terms of the capital producers' domestic price index:

$$\begin{aligned} \beta^{e,c} &= \beta \left(S_{c,t}^c \left(\frac{\lambda_{t+1}^c}{\lambda_t^c} \right) + S_{c,t}^p \left(\frac{Q_{c,t+1}^p}{Q_{c,t}^p} \frac{\lambda_{t+1}^p}{\lambda_t^p} \right) \right) , \\ \beta^{e,p} &= \beta \left(S_{p,t}^p \left(\frac{\lambda_{t+1}^p}{\lambda_t^p} \right) + S_{p,t}^c \left(\frac{Q_{c,t}^p}{Q_{c,t+1}^p} \frac{\lambda_{t+1}^c}{\lambda_t^c} \right) \right) . \end{aligned}$$

As equity shares are held internationally the discount factor of capital producers accounts for the relative importance of each owner's marginal utility. The weights are set according to the time-varying amount of shares each household holds of one country's capital producers. The first order conditions for this problem read:

$$\lambda_t^{e,j} = E_t \beta^{e,j} \lambda_{t+1}^{e,j} R_t^{l,j} , \tag{2.14}$$

$$\lambda_t^{e,j} q_t^j = E_t \beta^{e,j} \lambda_{t+1}^{e,j} \left(r_{t+1}^j + (1-\delta) q_{t+1}^j \right) , \tag{2.15}$$

$$I_t^j = \bar{I}^j + \frac{1}{\phi_I}(q_t^j - 1) , \tag{2.16}$$

$$\lambda_t^{e,j} = \frac{1}{1 + \kappa_d (div_t^j - \bar{div}^j)} , \tag{2.17}$$

where $\lambda_t^{e,j}$ is the Lagrangian multiplier associated to the capital producers' budget constraint.

Equation (2.14) says that, at equilibrium, the marginal income from loans is equal to the expected marginal cost weighted by the households discount factor. Equation (2.15) defines the shadow value of capital, q_t^j, as the expected discounted value of the marginal profits of having one additional unit of capital. If $q_t^j < 1$, meaning that the shadow value of capital is smaller than the price of capital, equation (2.16) states that investments should decline, if $q_t^j > 1$ that investments should increase.[5] Furthermore, from equation (2.15), we see that the shadow value of capital increases when the expected future dividend payouts are lower than the actual ones.

2.3 Nonfinancial firms

In each country $j \in \{c, p\}$ firms are perfectly competitive. The intermediate j firm produces a good that is sold in the domestic country as well as in the foreign one. A final firm in each country combines the intermediate goods from the j and $-j$ countries into a final one.

[5] This formulation of the investment equation follows Tobin's Q theory of investment (Tobin, 1969).

Final firms

In each region the demand for goods is a composite of the home and foreign intermediate goods. The aggregate demand for country j is:

$$A^j = \left(\frac{A^j_j}{1-\alpha}\right)^{(1-\alpha)} \left(\frac{A^j_{-j}}{\alpha}\right)^{\alpha} , \tag{2.18}$$

where A^j_j and A^j_{-j} are respectively the demands of the final firm j for goods j and $-j$. $0 < 1-\alpha < 1$ is the degree of home bias or, alternatively, it can be interpreted as the index of country openness. We set this parameter to be $0 < \alpha < 0.5$ implying a certain degree of home bias. The composite final good can be used for consumption and investment by all the agents in the economy.[6] The optimal demand for each variety of the final good is given by the following first order conditions:[7]

$$A^c_{c,t} = (1-\alpha)\frac{1}{\phi^c_t}A^c_t \ , \qquad A^p_{p,t} = (1-\alpha)\frac{1}{\phi^p_t}A^p_t \ ,$$
$$A^c_{p,t} = \alpha\frac{1}{Q^p_{c,t}\phi^p_t}A^c_t \ , \qquad A^p_{c,t} = \alpha\frac{Q^p_{c,t}}{\phi^c_t}A^p_t \ .$$

The welfare based price index (for both regions) corresponding to these preferences is:

$$P^j_t = (p^j_{j,t})^{(1-\alpha)}(p^j_{-j,t})^{\alpha}. \tag{2.19}$$

Dividing by P^j, and by the law of one price, the price index can be simplified as:

$$\begin{aligned} 1 &= \phi^j_t\phi^{-j}_t \ , \\ Q^{-j}_{j,t} &= (\phi^j_t)^{\frac{2\alpha-1}{\alpha}} \ , \end{aligned}$$

with $\phi^j_t = \frac{p^j_{j,t}}{P^j_t}$ being the share of domestic produced goods' prices in the domestic price index and $Q^p_{c,t} = \frac{e_t P^p_t}{P^c_t}$ being the real exchange rate for the core country. The nominal exchange rate e_t is set to 1 as the two economies belong to the same currency union.

Intermediate firms

There is a competitive non financial sector in the economy which produces a tradable good under a Cobb-Douglass production function. The inputs are capital and labour rented respectively from capital producers and households. The maximization problem of the firms reads:

$$\max \ \Upsilon^j_t$$

$$\text{s.t. } \Upsilon^j_t = \phi^j_t Y^j_t - w^j_t h^j_t - r^j_t K^j_{t-1} \ , \tag{2.20}$$
$$Y^j_t = Z^j_t \left(K^j_t\right)^{\mu} \left(h^j_t\right)^{1-\mu} , \tag{2.21}$$

where Z^j_t represents total factor productivity and $0 < \mu < 1$ is the elasticity of output to capital. The first order conditions for this maximization problem equate the marginal productivity of factors with

[6] We assume that the same Cobb-Douglas CES aggregator applies to the consumption bundles of all the agents as well as for investment. As a consequence the price index for consumption and investment is the same. For the choice of the CES function we follow Gali and Monacelli (2008).

[7] Optimal demands are the solution of the final firm maximization problem: $\{A^j_{j,t}, A^j_{-j,t}\}^{\infty}_{t=0}$ to maximize $P^j_t A^j_t - p^j_{j,t}A^j_{j,t} - p^j_{-j,t}A^j_{-j,t}$.

their marginal cost:

$$r_t^j = \mu \frac{\phi_t^j Y_t^j}{K_{t-1}^j} , \tag{2.22}$$

$$w_t^j = (1-\mu) \frac{\phi_t^j Y_t^j}{h_t^j} . \tag{2.23}$$

One source of aggregate risk in this model comes from the total factor productivity Z_t^j:

$$Z_t^j = \left(Z_{t-1}^j\right)^{\gamma_z} exp(u_t^z) , \tag{2.24}$$

that is represented as a stochastic autoregressive process with $0 < \gamma_z < 1$, and u_t^z i.i.d.

2.4 Banking sector

The banking sector is represented by an international and perfectly competitive bank *à la* Enders et al. (2011). The bank is located in the core but trades with all countries $j \in \{c, p\}$. It collects deposits D_t^j from households and can invest in sovereign bonds s_t^j as well as provide loans L_t^j to the firms in both regions. The bank maximizes its consumption, its profits, over the two regions. The bank faces a capital requirement having to set aside a fraction $0 < \gamma < 1$ of loans as own capital. The bank can deviate from legal requirements ($x_t = 0$) but this is costly. The bank's balance sheet constraint is:

$$(1-\gamma) \sum_j Q_{c,t}^j L_t^j + \sum_j Q_{c,t}^j s_t^j = \sum_j Q_{c,t}^j D_t^j + x_t . \tag{2.25}$$

The bank budget constraint is:

$$\begin{aligned} &\sum_j Q_{c,t}^j C_t^{b,j} + \sum_j Q_{c,t}^j R_{t-1}^{d,j} D_{t-1}^j + \sum_j Q_{c,t}^j L_t^j + \sum_j Q_{c,t}^j s_t^j + \Gamma_d \sum_j (D_t^j - \bar{D}^j) \\ &+ \frac{\Gamma_l}{2} \sum_j (L_t^j - \bar{L}^j)^2 + \frac{\Gamma_x}{2}(x)^2 + \frac{\Gamma_p}{2} \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^\nu s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \bar{s}^j}{\sum_j \bar{Q}_c^j \bar{L}^j} \right)^2 \\ &= \sum_j Q_{c,t}^j D_t^j + \sum_j Q_{c,t}^j R_{t-1}^{l,j} L_{t-1}^j + \sum_j Q_{c,t}^j (R_{t-1}^{b,j} - \epsilon_t^j) s_{t-1}^j + \sum_j Q_{c,t}^j H_t^{b,j} . \end{aligned} \tag{2.26}$$

The bank pays a real return $R_{t-1}^{d,j}$ on deposits, it receives $R_{t-1}^{l,j}$ on loans and $R_{t-1}^{b,j}$ on sovereign bonds. Sovereign bonds are risky assets as government can default on them with a probability ϵ_t^j. The bank might receive a lump-sum transfer $H_t^{b,j}$ from the government. Moreover, the bank faces different types of costs: operational costs on deposits as in Enders et al. (2011), captured by Γ_d; adjustments costs on loans, Γ_l, as in Guerrieri et al. (2012); and the cost of deviating from the legal requirement that, following Enders et al. (2011), we capture by $\Gamma_x > 0$. Additionally, the bank is subject to a collateral requirement cost $\Gamma_p(.)^2$ that we call the collateral constraint. Banks normally use sovereign bonds as collaterals in the secured interbank market in order to collect funds. A reduction in the volume or the quality of the collateral reduces the ability of banks to raise funds and therefore to sustain private credit supply. In this model, as there is no interbank market, we capture this channel by linking the overall supply of loans directly to the quantity, as well as the quality, of the collateral sovereign bonds. The parameter ν measures the riskiness of bonds and represents the haircut applied to them. In the case of a sovereign risk shock this cost introduces a demand for riskless bonds and determines the well known flight-to-quality in sovereign bond markets (more than obviously reducing the supply of credit to capital producers).[8]

[8]For a similar modelling of the banking sector, in a model that focuses on the sovereign debt transmission and the implications for monetary policy, see Perego and Pierrard (2016).

The bank utility is:

$$\max\, E_s \sum_{t\,=s}^{\infty} \beta^{t-s} (C_t^{b,c})^{\vartheta} (C_t^{b,p})^{1-\vartheta} \tag{2.27}$$

where ϑ is the share of consumption goods from country c in the utility that we set to 0.5 such that the bank consumes its profits equally in the two regions. The bank maximizes (2.27) with respect to (2.25) and (2.26). The first order conditions are:

$$\lambda_t^b = \vartheta \frac{(C_t^{b,c})^{\vartheta}(C_t^{b,p})^{1-\vartheta}}{C_t^{b,c}} \ , \tag{2.28}$$

$$Q_{c,t}^p = \frac{1-\vartheta}{\vartheta} \frac{C_t^{b,c}}{C_t^{b,p}} \ , \tag{2.29}$$

$$\lambda_t^b (Q_{c,t}^j - \Gamma_d + Q_{c,t}^j \Gamma_x x_t) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j R_t^{d,j} \ , \tag{2.30}$$

$$\begin{aligned} &\lambda_t^b \Bigg(Q_{c,t}^j - \Gamma_p Q_{c,t}^j \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \bar{s}^j}{\sum_j \bar{Q}_c^j \bar{L}^j} \right) \frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{(\sum_j Q_{c,t}^j L_t^j)^2} \\ &+ \Gamma_l (L_t^j - \bar{L}^j) + (1-\gamma) Q_{c,t}^j \Gamma_x x_t \Bigg) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j R_t^{l,j} \ , \end{aligned} \tag{2.31}$$

$$\begin{aligned} &\lambda_t^b Q_{c,t}^j \left(1 + \Gamma_p \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \bar{s}^j}{\sum_j \bar{Q}_c^j \bar{L}^j} \right) \frac{(1-\epsilon_t^j)^{\nu}}{\sum_j Q_{c,t}^j L_t^j} + \Gamma_x x_t \right) \\ &= \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j (R_t^{b,j} - \epsilon_{t+1}^j) \ . \end{aligned} \tag{2.32}$$

Equation (2.29) shows that the ratio of consumption of the bank for the two regions depends on the ratio of relative price indexes. Equations (2.30), (2.31), (2.32) represent respectively the Euler equation for deposits, loans and sovereign bonds.

2.5 Government

The government consumption in each region $j \in \{c, p\}$, G^j, is financed via lump-sum taxes, T_t^j, from the households, as well as via public debt, B_t^j, according to:

$$G^j + H_t^{h,j} + H_t^{b,j} + (R_{t-1}^{b,j} - \epsilon_t^j) B_{t-1}^j = B_t^j + T_t^j \ , \tag{2.33}$$

$$T_t^j = \bar{T} + \tau (B_t^j - \bar{B}) \ . \tag{2.34}$$

Moreover, the government may transfer $H_t^{h,j}$ to the households and $H_t^{b,j}$ to the bank. Both for the tax rule and the transfer specification we follow Corsetti et al. (2013). As estimated by Bohn (1998), taxes react positively to the increase in debt such as to stabilize it. This implies that the government cannot finance public expenditure only via debt.[9] Equation (2.33) also shows that sovereign default may happen through the term $0 \le \epsilon_t^j \le 1$. Everything else equal, a strictly positive ϵ_t^j reduces the stock of sovereign debt in the next period. Finally we define public expenditures as a fixed fraction, G^j, of debt at any period.

[9] As the focus of the paper is not on the fiscal dimension we use debt-smoothing lump-sum taxes rather than more complicated distortionary tax schemes.

Default

To determine the default rate ϵ_t^j we tightly refer to the methodology used by van der Kwaak and van Wijnbergen (2014) by introducing an exogenous fiscal limit for the economy. Behind this limit there is the intuition that there exists a maximum level of taxes that can be raised before the economy becomes politically unstable. This translates, through equation (2.34), into a maximum level of sovereign debt-to-output ratio BY_t^{max} that the government is able to service. We moreover assume that this maximum *sustainable* level is stochastic and follows:

$$BY_t^{max} = \bar{BY}^{max} + \gamma_b(BY_{t-1}^{max} - \bar{BY}^{max}) + u_t^b \,, \tag{2.35}$$

where $0 < \gamma_b < 1$ is the autoregressive component, and u_t^b is a i.i.d. shock. This stochastic behaviour aims at capturing the uncertainty around political instability in the context of sovereign debt and taxation.[10]

Let us define $\tilde{B}_t^j$ as the level of debt in the economy when no default occurs:

$$G_t^j + R_{t-1}^{b,j}\, B_{t-1}^j = T_t^j + \tilde{B}_t^j \,. \tag{2.36}$$

If this level of debt-to-output $\tilde{B}_t^j/(4Y_t^j)$ is lower (resp. higher) than the maximum sustainable level BY_t^{max}, the government does not (resp. does) default. In other words, we define the default decision Δ_t as:

$$\Delta_t = \begin{cases} 0 & \text{if } \frac{\tilde{B}_t^j}{4Y_t^j} < BY_t^{max} \\ 1 & \text{otherwise} \end{cases} \tag{2.37}$$

This default process Δ_t is a step function that we approximate with the continuous normal cdf:

$$\begin{aligned} \epsilon_t^j &= F\left(\frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max} \;;\; 0 \;,\; \sigma^2\right) \\ &= \Phi\left(\frac{\frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}}{\sigma}\right) \,, \end{aligned} \tag{2.38}$$

where $\sigma > 0$ represents the variance and $\Phi(.)$ is the standard normal cdf. We see that when $\sigma \to 0$, then $\epsilon_t^j \to \Delta_t$. A reduction (resp. increase) in the maximum sustainable level of debt-to-output, through the stochastic shock u_t^b in equation (2.35), increases (reduces) the default rate in the economy. Similarly, a higher (resp. lower) debt-to-output ratio $\tilde{B}_t^j/(4Y_t^j)$ increases (resp. reduces) the default rate in the economy. Agents in the economy observe the current economic conditions and, as a consequence, they form expectations on default according to equation (2.38). If we assume that only the periphery country can default, the difference between the core and the periphery sovereign interest rate -abstracting from other general equilibrium dynamics- is given by a wedge that reflects the default expectations:

$$R_t^{b,p} = R_t^{b,c} + E_t[\epsilon_{t+1}^p] \,. \tag{2.39}$$

The spread between the core and the periphery interest rate on sovereign bonds is driven by default expectations reflecting low economic growth and high levels of debt (with respect to the fiscal limit) in the periphery country.

[10] In reality, the maximum sustainable government debt level 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. (2015)). But this is beyond the scope of this paper.

Default risk A stochastic shock (negative for instance) to the maximum sustainable level of debt increases default implying a change in the interest rate on bonds as well as a direct loss on the households and bank's portfolio. This shock impacts for instance both on prices (interest rates changes) as on quantities (partial default on the amount of sovereign debt held by agents). To deal with the risk dimension of the shock we want to isolate the price effect from the quantity effect. In order to do so we assume that the government makes transfers to the households and the bank in order to compensate the loss:

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

In this way we capture the effect of a change in the interest rate on bonds and abstract from the consequences of the direct wealth loss. The same specification has been used by Corsetti et al. (2013). This procedure is helpful to reproduce the sovereign debt crisis' dynamics in the euro area where only Greece effectively, partially, defaulted.

2.6 Closing the model

Asset market clearing conditions

The sovereign bond market clearing condition for country $j \in \{c, p\}$ is:

$$B_t^j = b_t^j + s_t^j \tag{2.40}$$

where b_t^j and s_t^j is the amount of bonds held respectively by the households and the bank.

The equity market clearing condition for country $i \in \{c, p\}$ issuing and country $j \in \{c, p\}$ holding is:

$$1 = S_{i,t}^j + S_{i,t}^{-j} \tag{2.41}$$

implying that there is a fixed amount of shares traded in the economy normalized to 1.

Good market clearing condition

Let's define the domestic demand for country j as:

$$A_t^j = C_t^j + C_t^{b,j} + I_t^j + G_t^j + \texttt{costs}_t^j \tag{2.42}$$

where $\texttt{costs}_t^j$ collects all adjustment and operative costs beared by households, capital producers and firms in country j. Moreover, $\texttt{costs}_t^c$ also includes the costs related to the bank.

The good market clearing condition for each region j reads:

$$Y_t^j = A_{j,t}^j + A_{j,t}^{-j} \tag{2.43}$$

By summing them up we obtain the resource constraint for the two-country economy:

$$\sum_j \phi_t^j Q_{c,t}^j Y_t^j = \sum_j Q_{c,t}^j A_t^j \tag{2.44}$$

stating that the total production has to be equal to the demand in the whole currency area.

3 Calibration

Table 2 presents an overview of the parameters of the model. Most of the values are widely used in the DSGE and sovereign default literature. The calibration refers to euro area stylized facts. Time is discrete and one period represents one quarter. We specify the two country model for the euro area distinguishing between the core and the periphery in terms of debt-to-output ratios. The periphery refers to the GIIPS (Greece, Ireland, Italy, Portugal and Spain) for which we assume a higher debt to GDP ratio with respect to that of the core. We assume the same size for the core and periphery area in order to focus on the main asymmetry brought by differentials in debt levels.[11] Unless otherwise specified we opt for the same parameter choice in the two country blocs.

3.1 Parameters governing the steady state

At steady state all the agents in the economy discount the future via the same discount factor β as $\bar{\beta}^e = \beta$. We assume no default at steady state, $\bar{\epsilon}^j = 0$, both for the periphery and the core and that $\bar{x} = 0$ implying no excess bank capital at steady state. We set $\Gamma_D = 0.005$ and $\beta = 0.99$ in order to have the annualized returns on loans and bonds of 4% and on deposits of 2%.[12] Additionally we set ϕ_s equal to 0.01 in order to obtain an annualized return on equity of 6%[13] given a steady state holdings of domestic as well as foreign shares of $\bar{S}_i^j = 1 - \bar{S}_i^{-j} = 0.5$. This value is consistent with the studies of ECB (2012) and Jochem and Volz (2011) on the intra-EA home bias in equity holdings assessing a degree of cross-border holdings around 40-60%. For what concerns the sovereign bond holdings in the euro zone, we follow Guerrieri et al. (2012) and we assume that 33% of sovereign debt is held by domestic household and the rest by the bank.[14]

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 is between 3% and 5%. Finally the size of the bank balance sheet is of 111% of yearly total output ($\bar{Y}^c + \bar{Y}^p$). This number is in line with the euro area data on bank balance sheet for loans to and holdings of securities issued by euro area residents.

The loans to physical capital ratio is set at around 1/3 and it pins down the households weight on deposits Ψ_d. Ψ_n, the disutility of the labour parameter, is pined down by setting $\bar{h^j} = 0.2$ following the RBC literature implying that households work 20% of their time. We calibrate η, the parameter governing the shape of the labour disutility, in order to have a Frisch elasticity of 0.2 as it is in line with micro-based measures.[15] The production function is Cobb-Douglass with the capital share at 0.3; setting the depreciation rate at $\delta = 0.025$ implies $\bar{K}^j/\bar{Y}^j = 8.54$ and $\bar{I}/\bar{Y} = 0.21$ which is in line with the RBC literature and empirical observations. The consumption of households in total output is of 55% while the one of the bank of 2.3%. The consumption of the bank falls equally in the two regions as we impose $\vartheta = 0.5$. Finally, following the NOEM literature as in Gali and Monacelli (2008), we assume a bias for domestic goods and we calibrate $\alpha = 0.3 < 0.5$.[16]

On the fiscal side we distinguish between the core and the periphery in terms of debt-to-output ratios:

[11] Data on the euro area period suggest that the core output accounts for about 63-67% of EA output and the periphery for the remaining 33-37%. Calibrating the model accounting for different sizes for the core and the periphery would change the steady state of the model but not the dynamics.

[12] These steady state values are set to match the empirical evidence for the 10 years bond's returns and the 5 years maturity loans' rate. This choice is made in order to have comparable maturities on the two assets, given the data availability.

[13] This value is in line with the annualized returns from the non-financial corporation equity index for EA countries.

[14] We do not have data on non-resident holdings of sovereign debt so we assume that it is mainly held by banks rather than foreign households. A different assumption would not change the implications of the model as long as the majority of the debt held by household is domestic.

[15] MaCurdy (1981) and Altonji (1986) estimate the Frisch elasticity - determined from hours and wage fluctuations on an individual basis - to be in the range of 0 to 0.54.

[16] The value selected is in the range of those used in recent macro-finance model. For a detailed description see for instance Coeurdacier et al. (2007).

Table 2: Parameter values

Parameter	Value	Description
Households		
β	0.99	Discount factor
ϕ_b	0.001	Bond adjustment cost
ϕ_s	0.01	Stock adjustment cost
ψ_n	110	Weight of labour in (dis-)utility
ψ_d	0.05	Weight of deposits in utility
η	5	Inverse of the intertemporal elasticity of labour supply
Global bank		
ϑ	0.5	Elasticity of substitution between c and p consumption goods
γ	0.05	Bank capital ratio requirement
Γ_d	0.005	Deposit operating cost
Γ_l	0.05	Loan adjustment cost
Γ_p	0.5	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
ϕ_i	0.05	Investment adjustment cost
κ_d	11	Dividend adjustment cost
α	0.3	Index of openess
μ	0.3	Elasticity of production w.r.t. capital
Authorities		
τ	0.13	Elasticity of taxes w.r.t. debt
$\bar{G}^j/\bar{Y}^j$	0.20	Public consumption-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
Shocks		
γ_z	0.89	Autoregressive parameter for technological shock
γ_b	0.79	Autoregressive parameter for sustainable debt-output shock

we set the one of the periphery at 85%, at steady state, while the one of the core at 60%.[17] Public expenditures are set to 20% of GDP as in line with EA data.[18] We set the maximum level of debt $\bar{BY}^{max}$ and the standard deviation of default, σ, in order to obtain an elasticity of default risk to debt of 0.1 around the steady state for the periphery country.[19] Finally we assume that only the periphery can default on its debt.

3.2 Parameters governing the dynamics

This set of parameters does not affect the steady state but rather the dynamics of the model.[20] Regarding consumption, we assume a logarithmic utility function for households and a linear one for the bank in order to account for the different degrees of risk aversion (higher for the households and null for the bank).[21] Adjustment costs on bonds, loans, and investments (ϕ_b, ϕ_d and ϕ_i) are standard in the literature of DSGE and their values are reported in Table 2.

In the bank specification we borrow the capital constraint from Enders et al. (2011) and set $\Gamma_x = 1.5$. For what concerns the collateral cost we set $\Gamma_p = 0.5$ and $\nu = 8$.

On the capital producers' side, the adjustment cost on dividend payout is associated to the parameter κ_d that, in the benchmark calibration, is set such as to match the volatility of dividend payout for the EA over the period 1991-2013.[22]

For the elasticity of the fiscal rule we follow Corsetti et al. (2013) and set the value of $\tau = 0.13$ that is a sufficiently high value to ensure that the debt remains bounded during the simulations.

We calibrate the technology shock on EA data in order to match the volatility of output in the core and in the periphery for the period 1995Q1-2013Q4. The autocorrelation in the shock process, γ_z, is set to 0.89 in both countries, the volatility of the technology shock, σ_z, to 0.004 and the correlation between the shocks in the two regions is set to 0.5.[23]

In order to calibrate the maximum sustainable level of debt shock we identify the part of the riskiness indicator for the periphery debt that is not explained by debt-to-output. As a riskiness measure we compute the sovereign bond yield spread between periphery countries and Germany.[24] We calibrate consequently γ_b in equation (2.35) to 0.79 [25] and σ_b to 0.1 consistent with the standard deviation of the maximum sustainable level of debt with respect to output.

Finally the financial expectation shock is calibrated such as to match the EA volatility of the price-to-dividend ratio. We set $\sigma_s = 0.001$ accordingly.

[17] These values are in line with the IMF economic outlook for 2010.

[18] This implies that taxes-to-output are 22% of GDP for the core and 23% for the periphery where the difference is due to the different debt burden in the two regions that forces a higher taxation in the periphery.

[19] The elasticity of – yearly – default wrt. debt to output implied by the model is:

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

where $\phi(.)$ is the standard normal pdf and $X_{j,t}^b = \frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}$ with $\bar{X}_j^b$ its steady state. The methodology used to calibrate the default process follows the one of Corsetti et al. (2013) and the value of the elasticity of 0.1 is consistent with the empirical stylized facts for the EA for the year 2011.

[20] In each country the sum of all the dynamic costs accounts for 1% of domestic output.

[21] As a sensitivity analysis we substitute the utility function used in the baseline model with a KPR formulation as of King et al. (1988). Correlation results are unchanged to the new utility specification. Moreover the results are also qualitatively consistent to changes in the value of the intertemporal substitution of consumption. However, the baseline formulation helps to better match empirical regularities, given the absence of wealth effect on the labour supply, and to have correlation results closer to the data estimates.

[22] A similar cost is used by Jermann and Quadrini (2012). When κ_d is infinitely large capital producers have access to only one source of funds: bank's loans. For smaller values the capital producers can be financed both via dividend payouts and bank's loans.

[23] The autocorrelation of the technology process is estimated to be 0.88 in the core and 0.89 in the periphery and the volatility of output, respectively of 0.013 and 0.011, in the core and in the periphery.

[24] Appendix B explains the methodology used.

[25] This value is close to the one used by van der Kwaak and van Wijnbergen (2014), 0.8, for the same shock.

4 Dynamic simulation

To simulate the model we take a first order approximation of the model's equations.[26] Model correlations are computed from 50 simulations of the economy, each of 60 periods. The number 60 corresponds to the length, in terms of quarters, of the euro zone period data which we compare the model to. We look at the implications of a financial expectation shock, a technological shock and a sovereign risk shock for the international asset (equity and sovereign bond) markets. We will show that banking credit constraint (we will refer to them generally as credit constraint) play an important role for the behaviour of asset markets. In order to do so we simulate the benchmark model, as explained in Section 2, with a version without credit constraint. We do so by shutting down the collateral constraint and the cost on excess capital ($\Gamma_x = \Gamma_p = 0$). Moreover, we study the importance of capital producers' financing decisions for the correlations on asset markets. We compare for instance the previous models with a version characterized by low adjustment costs on dividend payouts ($\kappa_d = 1$ vs. the benchmark $\kappa_d = 11$).

Finally, we provide a supportive evidence on the shocks that can quantitatively reproduce the asset markets' correlations during the euro period and in particular during the sovereign debt crisis. Additionally, in Appendix C, we compare the model to standard business cycle stylized facts to attest its consistent performance with respect to reference macroeconomic variables' behaviours.

4.1 Financial expectation shock

Under the efficient market hypothesis (EMH), any fluctuation in stock prices is fully efficient as it reflects investors' expectations about future firm's profits. Recently however, part of the academic world started to doubt about the prevailing view that stock prices fluctuations are fully efficient. Behavioural economists started to attribute the imperfections in financial markets to a combination of cognitive biases[27] and various other predictable human errors in reasoning and information processing challenging the EMH theory by putting forward the idea that financial market are characterized by 'irrational exuberance' in the form of successive cycles of excesses of optimism and pessimism.[28] In our model we do not aim at reproducing the dynamics leading to higher returns' expectations and the consequent increase in prices. We rather take this process as given and we introduce a positive shock on the returns' expectations such as to mimic these subjective irrational believes.[29] We assume this shock to be common to the core and the periphery of the EA as suggested by the similar behaviour of stock returns, Figure A.2, and of price dividend ratios, Figure 4.1.

Figure D.1 in Appendix D presents the impulse response functions (IRFs hereafter) for the model with and without credit constraints. We will further investigate the role of more or less flexible dividend payout policy of the capital producers. Finally, we compare the model's results with the correlations over the period 2000-2004 and 2007-2010.

[26] The model is solved using Dynare 4.4.3. For more information refer to Adjemian et al. (2011).

[27] Examples of cognitive biases as overconfidence, overreaction, information bias, etc...

[28] Shiller (2005) defines 'irrational exuberance' as a psychological contagion that spreads from person to person after news of a price increase occurs, bringing more investors to buy and effectively start the bubble. As a consequence, according to him, a large part of price movements during a bubble is caused by speculative purchases. Analogously, Adam et al. (2014) suggest that are self-reinforcing belief dynamics, triggered by fundamentals, that explain the most of US stock prices fluctuations. In their model if agents become optimistic, this causes an increase in actual stock prices, confirming agents' expectations and feeding a stock price bubble.

[29] Although assuming an irrational shock in a framework characterized by rational agents might look contradictory, it is consistent with a theoretical framework á la Adam and Marcet (2011). In their model agents are 'internally rational' as they make fully optimal decisions by maximizing discounted expected utility under uncertainty, but at the same time they may not be 'externally rational' as they may not know the true stochastic process for the payoff of relevant variables that are beyond their control as prices.

Model without credit constraints

Without credit constraints, a financial expectation shock has a very limited impact on rates and variables. On the equity side the shock drives up the stock price and, temporarily, the equity returns. This entails an increase in the capital producers' demand for loans driving up the interest rate. The bank, by arbitrage, demands a higher return on sovereign bonds in order to hold them and it accumulates excess capital. The increase in the interest rate on sovereign bonds determines an increase in the stock of debt and hence of taxation. As households foresee future taxation, they decrease consumption and savings both in sovereign bonds and in deposits. Output falls in both regions after a couple of periods as also investments slightly, but persistently, decrease. Table 3 shows the correlations. As the shock is assumed to hit the two regions in the same way it entails a one-to-one correlation between equity markets and a very high correlation in the sovereign bond one. In the absence of credit constraints, column (1) and (2), we notice that the cross asset correlation is almost null. This is due to the negligible change of sovereign bonds' interest rates as opposed to the change in equity returns. As we can notice, more flexible dividend payout do not change the results. This is not surprising as the shock affects directly the equity market ruling out the effectiveness of a different dividend payout policy.

Model with credit constraints

When we introduce credit constraints the impact of the shock amplifies. The capital constraint impedes the bank to be too leveraged (positive excess capital) and forces the bank to cut on part of the asset side. As a consequence of the capital constraint, the bank decreases loans and sovereign bonds in order to reduce the excess capital and the related cost. This drives up both loan and sovereign bond rates even more. On the production side it determines a stronger decrease in investments, capital and output. The fall in investment is driven by the fact that while households are overly optimistic, capital producers are not. As returns on equity increase, households are willing to buy more of this asset and reduce the other sources of investment (deposits and sovereign bonds). On the capital producers' side the higher lending rates and the expectations of future lower growth reduce loans' demand and investments (despite the fact that capital producers resort to internal financing via lower dividends).

At the same time, via collateral channel, a decreased loans' demand brings to a reduction in the demand of collaterals for the bank. As a consequence sovereign bond returns increase. On impact both the returns on equity and the interest rate on sovereign bonds raise determining a positive correlation that drives the difference between column (1)-(2) and (3)-(4) in Table 3. As soon as the effect of the shock ends, both rates decrease as households suddenly revise downwards their return expectations. As for the case without credit constraints, a different dividend payout policy does not change the results.

Financial expectation shock in the data

The period between 2007-2010 is what we refer to as the financial crisis that started with a real estate bubble; the period 2000-2004 instead, on the one hand was characterized by the end of the dot-com bubble and, on the other hand, it was the converging period after the introduction of the common currency.[30] In order to attest the presence in the data of such a period of high expected returns we look at the price-dividend ratio (PD henceforth) for an aggregate of EA core and periphery countries. [31] As we can notice, this ratio was high around the years 2000 and again in 2006-2008. However, the shock we identify as the financial expectation shock not only includes the rising part of the bubble but also its decline. In

[30]For the concurrence of the two effects in this period we should be cautious in explaining it via a financial expectation shock. However, looking at the performance of the stock market in Figure A.2, and at the realized correlations, we notice a strong similarity with the behaviour of the asset markets in the period 2007-2010.

[31]PD ratios are usually used as measures of expected returns in the stock market. In the US stock market, for which this data is available, PD ratios comove almost perfectly with expected returns based on investors' surveys.

Table 3: Correlation data vs financial expectation shock

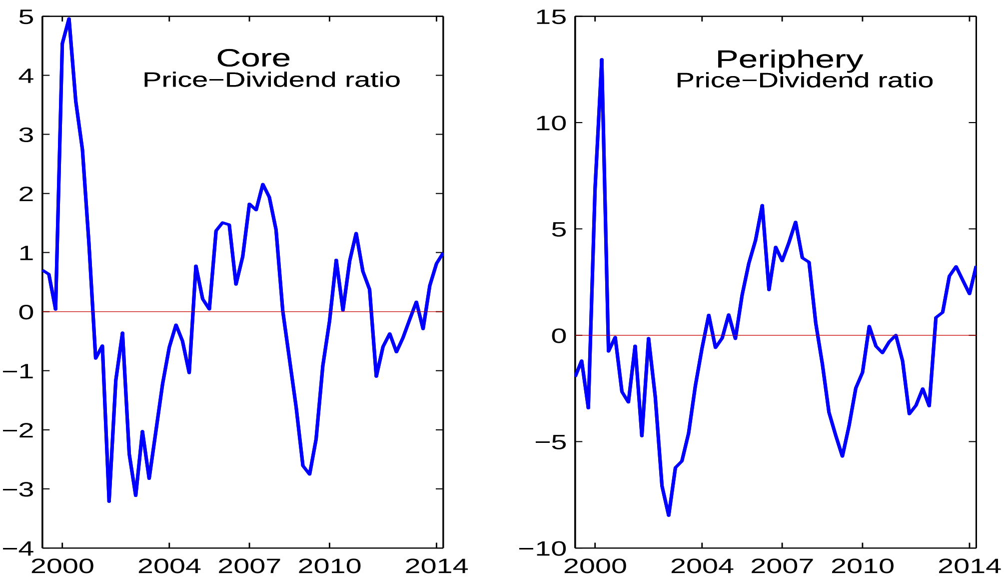
	Model				Data	
	No credit constr.		Credit constr.		2000	2007
	Bench. (1)	Flex. *div* (2)	Bench. (3)	Flex. *div* (4)	2004	2010
corr($R^{b,p}$,$R^{b,c}$)	0.94	0.95	0.99	0.99	0.94	0.88
corr($R^{S,p}$,$R^{S,c}$)	1	1	1	1	0.74	0.82
corr($R^{b,c}$,$R^{S,c}$)	0.002	0.004	0.54	0.52	0.34	0.44
corr($R^{b,p}$,$R^{S,p}$)	-0.002	-0.002	0.51	0.50	0.18	0.28

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity. 'Bench.' is the benchmark model calibrated as explained in section 3; 'Flex. *div*' is the model with a lower adjustment cost on dividend payout. The different model specifications are simulated after a positive shock to core and periphery equity returns' expectations.

this perspective we look at the PD ratio increase and identify two periods: between the end of the '90 until 2003 and the 2005-2009 horizon. The behaviour of the stock markets, in both periods, have been regarded by scholars and media to be due to speculative bubbles.

When we compare the model with and without credit constraints to the correlations in these periods, Table 3, we see that only the model with credit constraint can reproduce closely the data.

Figure 4.1: Price-Dividend ratio for core and periphery stocks



Notes. The figure plots the price-dividend ratio for the stock index in the core and the periphery against their HP-trends. Prices and dividends are expressed in real terms after being deflated by the domestic price consumption index. Core and Periphery series are geometric averages for the set of countries belonging to each region. Countries belonging to the core are: Belgium, Finland, France and Germany. Whereas countries belonging to the periphery are: Ireland, Italy, Portugal and Spain. *Data sources*: Datastream and author's calculations.

4.2 Technology shock

Figure D.2 in Appendix D shows the effect of a positive technology shock to the core country. In the following we compare the model with and without credit constraints in the case of more or less flexible dividend payout policy of the capital producers. As a supportive evidence we compare the model's results with the correlations over the period 2004-2007.

Model without credit constraints

In the absence of credit constraints, that is when the bank's capital and collateral channels are not working, our model delivers the same dynamics as the international real business cycle model as of Backus et al. (1992). A positive productivity shock brings the marginal productivity of the factors of production to increase in the core country. Households work more, consume more and save more in the form of deposits. The bank provides more loans to the core capital producers driving down the loan interest rate. The shadow value of capital increases determining an increase in investments. Output increases and the real exchange rate, for the core, depreciates. In the periphery the relative change in prices determines an increase in output, labour and consumption as now core goods are cheaper. Moreover, households substitute consumption for savings decreasing the supply of deposits and driving up the interest rate. Investment in the periphery slightly increases as a consequence of the wealth effect brought about by the relative change in prices. The bank supplies less loans increasing the interest rate on periphery loans.

As of the equity market, in the core region capital producers payout, pro-cyclically, more dividends and households buy more of domestic and foreign issued equity. The price of core shares increases and this drives the increase in the equity return. In the periphery, instead, capital producers payout negative dividends in an attempt to use internal resources to finance the higher investments as external resources (loans) are now more expensive. A negative dividend payout coupled with a fall in stock prices, as the periphery is not affected by the technology shock, determines a fall in equity returns. Finally, regarding sovereign bonds, as households in the core country enjoy more the effects of the productivity shock, they also increase the demand of domestic sovereigns driving down the interest rate. In the periphery, instead, the demand decreases determining a higher interest rate. Table 4, column (1), shows these dynamics in terms of correlations. If we allow capital producers to be more flexible in their dividend payout policy, column (2), we see that only the correlation on the equity market changes.[32] In the core, capital producers increase dividend payouts such as to further sustain the rise in the stock price and in the return on equity. In the periphery, capital producers payout even less dividends than in the previous case. This behaviour allows the capital producers to further self-finance their operations, increase investment and push up the stock price. In turn, this entails a lower decrease (and eventually a slight increase) in the periphery equity returns.

Model with credit constraints

In the scenario without constraints the bank accumulates negative excess capital. After the positive technology shock the bank collects resources from the households (deposits) but does not provide enough loans to the firms. The unused resources translate into bank's consumption.

The capital constraint instead forces the bank to avoid to be too indebted with no counterpart on the asset side of the balance sheet. Once we introduce the capital constraint, the bank keeps less unused resources for lending activities and provides more loans to the economy. In doing so the interest rate on loans decreases for the two regions providing an incentive for the capital's producers to be financed through the bank. As a consequence, in the periphery, dividend payout fall less and the demand of loans

[32] In the model, a more flexible dividend payout policy is achieved by reducing the adjustment cost on dividends' parameter, κ_d, from 11 to 1.

increases determining a more pronounced increase in investments. The stock price increases following the behaviour of investment and driving up the return on equity. Moreover, the augmented investments further sustain the output increase in both countries. Consumption, in both countries, increases as well. Via the collateral constraint, the bank demands also more sovereign bonds in order to support the private credit supply. Both core and periphery sovereign interest rates fall. On the equity market, the increase in investment drives a stronger increase in equity prices that is reflected in higher equity returns in both regions. Table 4, column (3), shows these dynamics in terms of correlations.

With credit constraint, on the one hand a positive technological shock in the core triggers a positive increase in equity returns both in the core and in the periphery; on the other hand, it determines an equal increase in the demand of sovereign bonds, as collaterals, that drives the interest rate on these assets down. As a consequence, the bond-stock correlation is negative both in the core and in the periphery implying a certain degree of diversification for investor's portfolio. These results are not affected by increasing the flexibility of dividend payouts as shown in column (4). Capital producers in the periphery payout less dividends whereas those in the core payout more. These decisions determine a further (slight) increase in stock prices and equity returns. However, in the presence of credit constraint, allowing capital producers to decide their payout policy does not affect asset market's correlations.

Table 4: Correlation data vs Technology shock

	Model				Data
	No credit constr.		Credit constr.		2004-2007
	Bench. (1)	Flex. *div* (2)	Bench. (3)	Flex. *div* (4)	
corr($R^{b,p}$,$R^{b,c}$)	-0.75	-0.75	0.79	0.82	0.98
corr($R^{S,p}$,$R^{S,c}$)	-0.07	0.35	0.87	0.88	0.82
corr($R^{b,c}$,$R^{S,c}$)	-0.19	-0.18	-0.11	-0.13	-0.08
corr($R^{b,p}$,$R^{S,p}$)	-0.29	-0.32	-0.06	-0.09	-0.24

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity. 'Bench.' is the benchmark model calibrated as explained in section 3; 'Flex. *div*' is the model with a lower adjustment cost on dividend payout. The different model specifications are simulated after a correlated (positive) technology shock between the core and the periphery.

Technology shock in the data

The 2004-2007 period came between the burst of the dot-com bubble and the beginning of the real estate bubble whose burst turned into the recent financial crisis. The 2004-2007 period was characterized by a growing path for the euro zone GDP reflected in a good performance of the stock market.[33] By looking at the correlation on the stock-bond market in this period, Figure 1.1, we observe a change in its time-varying behaviour with respect to the preceding and the following period. We read this change as an indication that something happened in this interval of time that drove, or became the main determinant of, the negative comovement.

In Figure 4.2 we show the behaviour of GDP per person employed, GDP per hour and multi-factor productivity for Italy and Germany.[34]

[33]See for instance Figure A.2 in Appendix A.

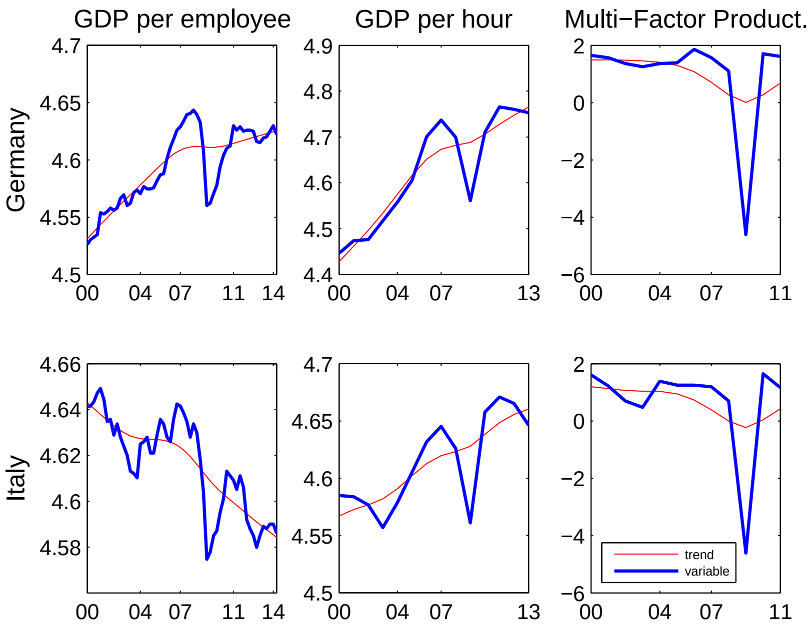
[34]GDP per hour worked is a more reliable measure than GDP per employee and in particular captures labour productivity. Multi-factor productivity (MFP) additionally relates a change in output to several types of inputs and it is measured residually as the change in output that cannot be accounted for by changes in the combined inputs.

We consider Germany as the representative for the core countries whereas Italy for the periphery. Given the scarce availability of data for consistent samples over the different EA countries, we decided to show the behaviour of two representatives.

As we can see, in the period 2006-2007, all the GDP indicators show a higher than average productivity in both countries. As GDP measures do not adjust instantaneously to shocks we could infer that in the years preceding 2006, and up to 2007, there could have been a positive shock to productivity.[35] By looking at the MFP data we can see that between 2004 and 2007 productivity was above the trend providing additional evidence of a positive TFP shock in the period under consideration.

In Table 4 we show that by introducing a positive technology shock in the model we manage to reproduce the correlation of this period. Additionally, as for the previous shock, only the model with credit constraints is able to match the data for all the correlations analysed.

Figure 4.2: Indicators of a technology shock



Notes. The figure plots a selection of macroeconomic indicators for Germany and Italy. 'GDP per employee' refers to the GDP per person employed in the total economy; 'GDP per hour' refers to the manufacturing sector only and 'Multi-Factor Product.' shows the growth rate of multi-factor productivity for the whole economy. The series are plotted against their trends computed via Hodrick-Prescott filtering. Data on GDP per person is at quarterly frequency whereas the other two measures are at the annual one. *Data sources*: OECD statistics.

4.3 Sovereign risk shock

A sovereign risk shock in the periphery is mimicked by a shock to the maximum level of sustainable debt that determines an increase in the expected default rate on the periphery sovereign bonds.

Figure D.3 in Appendix D shows the IRFs after a sovereign risk shock for the model with and without credit constraints. We will further investigate the role of more or less flexible dividend payout policy of the capital producers. Finally, we compare the model's results with the correlations over the period 2010-2012.

[35] The abrupt fall in all the indicators in 2009 should not be considered as a negative technology shock but rather as the consequence of the burst of the real estate bubble and the beginning of the financial crisis with its consequent reduction in credit and fall in production activities.

Model without credit constraints

Without credit constraints an increase in the maximum sustainable level of debt brings to a wealth loss for the periphery households via taxation. They decrease consumption of both domestic as well as foreign goods. Given the home biased composition of their consumption basket, the decrease in consumption in the periphery leads to a reallocation of relative prices with the appreciation of the core currency. The marginal productivity of factors of production falls, determining a decrease in labour and output. Furthermore, as the shadow value of capital falls, investments decrease which reduces capital. In the core, the change in relative prices brings employment, capital and output to increase. Also core consumption increases as foreign goods are relatively cheaper.

For what concerns the bank's related dynamics, loans' demand falls in both regions decreasing the interest rate. In the periphery, households decrease the supply of deposits and increase the holdings of sovereign bonds. In the core, households increase both deposits and the sovereign bond holdings. As the net return on sovereign bonds decreases, the bank decides to hold less of these assets on impact. However, as after impact the net return on sovereign bond increases, the bank decides to invest more in the periphery bonds driving an increase in its excess capital.

On the equity side, households in the periphery buy more of both domestic as well as foreign issued equity. At the same time capital producers payout more dividends both in the core and in the periphery. Such a behaviour in the periphery determines a faster disinvestment; in the core an attempt to keep a high price and return on equity. However, the price of equity falls in both regions as the expected discounted value of future dividends decreases. This, in turn, leads to a decrease in the return on equity in both regions, though more pronounced in the periphery country. Table 5, column (1), shows these dynamics in terms of correlations. In column (2) we see that allowing capital producers to be more flexible on their payout policy changes the correlation on the equity market. Both in the core and in the periphery they payout more dividends as explained above. As a consequence the periphery stock price further falls whereas the core stock price increases. In turn, the positive increase in the core stock price drives a different dynamics of equity returns in the two regions: an increase in the core and a decrease in the periphery. All the reported effects are, however, quite small.

Model with credit constraints

When credit constraints are introduced, the impact of the shock magnifies. The capital constraint impedes the bank to be too leveraged (positive excess capital) and forces the financial intermediary to cut on part of the asset side. As a consequence, the bank decreases the supply of loans. This in turn hampers the fall in investment in the periphery and leads core capital producers also to decrease investments. The consequent fall in capital in the two regions brings a fall in output, wages and labour supply in the periphery, and a short lasting increase in core output and employment. Real exchange rate dynamics drive the different behaviour. Nevertheless, as also core investments fall, output in the core is forced to decrease after the initial boost. Consumption falls more than before and this time also in the core country.

At the same time, the collateral constraint forces the bank to hold sovereign bonds as a collateral for the provision of credit to the private sector. The collateral requested not only accounts for the quantity of sovereign bonds held by the bank but also for their quality. For instance, a sovereign shock that decreases the quality of periphery collaterals, by increasing the default rate on sovereign bonds, forces the bank to hold more of these assets in order to make up for the loss in quality. This determines a flight to quality between the risky sovereigns (periphery bonds) and the riskless ones (core bonds).[36] Additionally, this

[36] We refer to flight-to-quality in bond markets by comparing the level of the correlation before 2010, that was very high, to the one during the sovereign debt crisis that fell to approximately 0.2. The flight-to-quality in the sovereign bond market

Table 5: Correlation data vs Sovereign risk

	Model				Data
	No credit constr.		Credit constr.		2010-2012
	Bench. (1)	Flex. *div* (2)	Bench. (3)	Flex. *div* (4)	
corr($R^{b,p}$,$R^{b,c}$)	0.16	0.15	0.28	0.25	0.17
corr($R^{S,p}$,$R^{S,c}$)	0.99	-0.85	0.99	0.99	0.73
corr($R^{b,c}$,$R^{S,c}$)	0.22	0.22	0.67	0.49	0.28
corr($R^{b,p}$,$R^{S,p}$)	-0.60	-0.60	-0.14	-0.16	-0.19

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity. 'Bench.' is the benchmark model calibrated as explained in section 3; 'Flex. *div*' is the model with a lower adjustment cost on dividend payout. The different model specifications are simulated after a negative shock to the maximum sustainable level of debt in the periphery.

behaviour drives a wedge in the return from deposits and sovereign bonds that induces the households to invest more in deposits than in sovereign bonds.

For what concerns equity, the owners of the firms demand more equity payouts in order to sustain their consumption. Regardless of the increase in dividend payouts, equity prices fall reflecting the decrease in investments. As a consequence, the equity returns in the two regions decrease of almost the same amount.

The disruption of the sovereign bond market and the high correlation on the stock one ultimately impact in a different way on the core and periphery stock-bond correlations. In the core the correlation is positive. After a sovereign risk shock, on the one hand the interest rate on bonds is lowered by the flight-to-quality towards this asset; on the other hand, the equity returns decrease as firms are affected by a credit crunch that impacts negatively on investment and output. In the periphery the correlation turns instead to be negative as the sovereign returns spike whereas the stock returns decrease. As for the previous shocks, in the case of credit constraints, the capital producers' payout policy does not affect the correlations as we can see from column (3) and (4).

Sovereign risk shock in the data

The period 2010-2012 was characterised by the sovereign debt crisis of the euro zone. Periphery countries experienced increasing troubles on their sovereign debt reflected in high interest rates.[37] Prior to this crisis[38], the level of debt-to-output has been the main determinant of the interest rate demanded on sovereign bonds. However, during the sovereign debt crisis a big part of the riskiness was not explained by the level of debt-to-output. In order to identify this shock we regress the level of debt-to-output onto the sovereign bond yields' spreads vis-à-vis Germany as explained in Appendix B. The residuals are plotted in Figure 4.3.

As we can see, until 2010 the yields (or riskiness vis-à-vis Germany) were well explained by the previous level of risk as well as debt (residuals centred around zero). From 2010 the model does not fit the data as well as before meaning that something else was the driver of the risk. This is the shock we identify and that has its major impact between 2010 and 2012.[39]

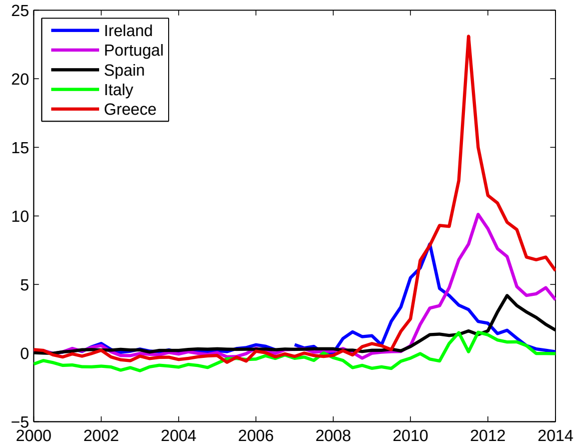
has been widely documented by media and scholars in the recent years. Among the others see for instance Barrios et al. (2009) for an analysis of core-periphery sovereign bond spreads.

[37]See for instance Figure A.2 in Appendix A.

[38]The main issues shaping the crisis were weak actual and potential growth, low competitiveness and large (and growing) debt-to-output ratios. See for instance Petrakis et al. (2013).

[39]If we run the panel regression by splitting the sample before and after 2010 and compare the R^2, we see that it is much lower in the second sample. This provides additional evidence of a change in the explanatory power of debt-to-output.

Figure 4.3: Sovereign risk shock for EA periphery countries



Notes. The figure plots the residuals from the panel estimation on sovereign yields spreads that identifies the sovereign risk shock. The countries shown are: Greece, Ireland, Italy, Portugal and Spain. *Data sources*: Author's calculations.

5 Conclusion

This paper proposes an original general equilibrium framework to study the evolution of the correlation on equity and sovereign bond markets in the euro area. More specifically we explore the role of credit constraints for this correlation by introducing financial intermediaries in a standard open economy financial macroeconomic model. We show that credit constraints (i) amplify shocks and (ii) change the response of variables to shocks being key for the behaviour of asset markets. Without credit constraints, asymmetric shocks in the union imply asymmetric impacts on the core and periphery asset markets. The existence of credit constraints at the international bank level prompts more synchronization in asset markets' responses and a more homogeneous sharing of the effects of shocks between countries. Capital producers' dividend payout policy can affect the behaviour of the stock market only in the case of unconstrained credit. This is not surprising as constraints on bank's capital and collaterals determine a strong tightening of credit to firms and a pro-cyclical amplification of shocks that leaves a small margin of manoeuvre to firms.

Finally, we show that the model with credit constraints is able to explain the stylized facts on correlations' behaviours in the EA stock and sovereign bond markets during the period 2000-2012. We find that a productivity shock can explain the negative relation between stock and bonds before the sovereign debt crisis whereas that a financial expectation shock can account for the positive one. After 2010, the heterogeneous behaviour of the core and periphery stock-bond markets can be reproduced by a sovereign risk shock to the periphery.

This paper is a first attempt to introduce financial intermediaries in an otherwise standard open economy macroeconomic framework. Future research should focus more on the bank representation of leverage as well as on its regulation. Moreover, a closer look at the central bank's dimension and monetary policy would be worthy. Finally, it could be of interest to add to the dimension of asset markets by including bank and corporate debt in the model. On the firm side, introducing corporate debt and allowing for new issuing of equity would refine the capital choice of firms and add new insights to the corporate finance literature.

References

Adam, K., Beuteland, J., and Marcet, A. (2014). Stock price booms and expected capital gains. *Working Papers 14-12, University of Mannheim, Department of Economics.*

Adam, K. and Marcet, A. (2011). Internal rationality, imperfect market knowledge and asset prices. *Journal of Economic Theory*, 146:1224–1252.

Adjemian, S., Bastani, H., Juillard, M., Karamé, F., Mihoubi, F., Perendia, G., Pfeifer, J., Ratto, M., and Villemot, S. (2011). Dynare: Reference manual, version 4. *Dynare Working Papers, 1, CEPREMAP.*

Adrian, T., Moench, E., and Shin, H. S. (2010). Financial intermediation, asset prices, and macroeconomic dynamics. *Staff Reports 422, Federal Reserve Bank of New York.*

Agresti, A. M. and Mojon, B. (2001). Some stylized facts on the euro area business cycle. *ECB working paper*, 95.

Altonji, J. G. (1986). Intertemporal substitution in labor supply: Evidence from micro data. *The Journal of Political Economy*, 94 (3):S176–S215.

Andersson, M., Krylova, E., and Vähämaa, S. (2008). Why does the correlation between stock and bond returns vary over time? *Applied Financial Economics*, 18:139–151.

Backus, D. K., Kehoe, P. J., and Kydland, F. E. (1992). International real business cycles. *The Journal of Political Economy*, 100(4):745–775.

Barrios, S., Iversen, P., Lewandowska, M., and Setzer, R. (2009). Determinants of intra-euro area government bond spreads during the financial crisis. *Economic Papers 388, European Commission Directorate-General for Economic and Financial Affairs.* European Commission Directorate-General for Economic and Financial Affairs.

Bec, F., Cahuc, P., Collard, F., Drugeon, J.-P., Fairise, X., Fève, P., Glachant, J., Hairault, J.-O., Henin, P.-Y., Kempf, H., Langot, F., Lebon, I., Portier, F., Schubert, K., Tallon, J.-M., Wigniolle, B., and Zylberberg, A. (2000). *Analyse macro économique 2.*

Bohn, H. (1998). The behavior of u.s. public debt and deficits. *Quarterly Journal of Economics*, 113:949–963.

Campbell, J. Y., Pflueger, C., and Viceira, L. M. (2014). Monetary policy drivers of bond and equity risks. *NBER Working Paper 20070.*

Coeurdacier, N., Kollmann, N., and Martin, R. (2007). International portfolios with supply, demand and redistributive shocks. *NBER international Seminar on Macroeconomics 2007*, pages 231–263.

Coeurdacier, N. and Rey, H. (2013). Home bias in open economy financial macroeconomic. *Journal of Economic Literature*, 51(1):63–115.

Collard, F., Habib, M., and Rochet, J.-C. (2015). Sovereign debt sustainability in advanced economies. *Journal of the European Economic Association*, 13(3):381–420.

Corsetti, G., Kuester, K., Meier, A., and Mueller, G. J. (2013). Sovereign risk, fiscal policy, and macroeconomic stability. *Economic Journal*, 123.

ECB (2012). Financial integration in europe. *European Central Bank Report.*

Enders, Z., Kollmann, R., and Muller, G. (2011). Global banking and international business cycles. *European Economic Review*, 55:407–426.

Gali, J. and Monacelli, T. (2008). Optimal monetary and fiscal policy in a currency union. *Journal of International Economics*, 76:116–132.

Garcia-Cicco, J., Pancrazi, R., and Uribe, M. (2010). real business cycles in emerging countries? *American Economic Review*, 100(5):2510–31.

Gould, J. (1968). Adjustment costs in the theory of investment of the firm. *The Review of Economic Studies*, 35:47–55.

Guerrieri, L., Iacoviello, M., and Minetti, R. (2012). Banks, sovereign debt and the international transmission of business cycles. *NBER International Seminar on Macroeconomics.*

Jermann, U. and Quadrini, V. (2012). Macroeconomic effects of financial shocks. *American Economic Review*, 102:238–271.

Jochem, A. and Volz, U. (2011). Portfolio holdings in the euro area - home bias and the role of international, domestic and sector-specific factors. *Deutsche Bundesbank discussion paper. Series 1: Economic Studies*, No 07.

Kim, S. J., Moshirian, F., and Wu, E. (2006). Evolution of international stock and bond market integration: Influence of the European Monetary Union. *Journal of Banking and Finance*, 30(5):1507–1534.

King, R. G., Plosser, C. I., and Rebelo, S. T. (1988). Production, growth and business cycles i. the basic neoclassical model. *Journal of Monetary Economics*, 21:195–232.

Lucas, R. E. (1967). Adjustment cost and the theory of supply. *Journal of Political Economy*, 75:321.

MaCurdy, T. E. (1981). An empirical model of labor supply in a life-cycle setting. *The Journal of Political Economy*, 89 (6):1059–1085.

Ohanian, L. E. and Raffo, A. (2012). Aggregate hours worked in oecd countries: new measurement and implications for business cycles. *Journal of Monetary Economics*, 59(1):40–56.

Perego, E. and Pierrard, O. (2016). Sovereign debt default and global banking in a currency union. *CEPREMAP working paper 1612.*

Perego, E. and Vermeulen, W. (2016). Macro-economic determinants of european stock and government bond correlations: A tale of two regions. *Journal of Empirical Finance*, 37:214–232.

Petrakis, P., Kostis, P., and Valsamis, D. (2013). *European Economics and Politics in the Midst of the Crisis; From the Outbreak of the Crisis to the Fragmented European Federation.* New York and Heidelberg: Springer.

Raffo, A. (2008). Net exports, consumption volatility and international business cycle models. *Journal of International Economics*, 75:14–29.

Schmitt-Grohe, S. and Uribe, M. (2012). What's news in business cycle. *Econometrica*, 80(6):2733–2764.

Shiller, R. J. (2005). *Irrational Exuberance.* Princeton University Press, Second edition.

Swanson, E. T. (2016). A macroeconomic model of equities and real, nominal, and defaultable debt. *Mimeo.*

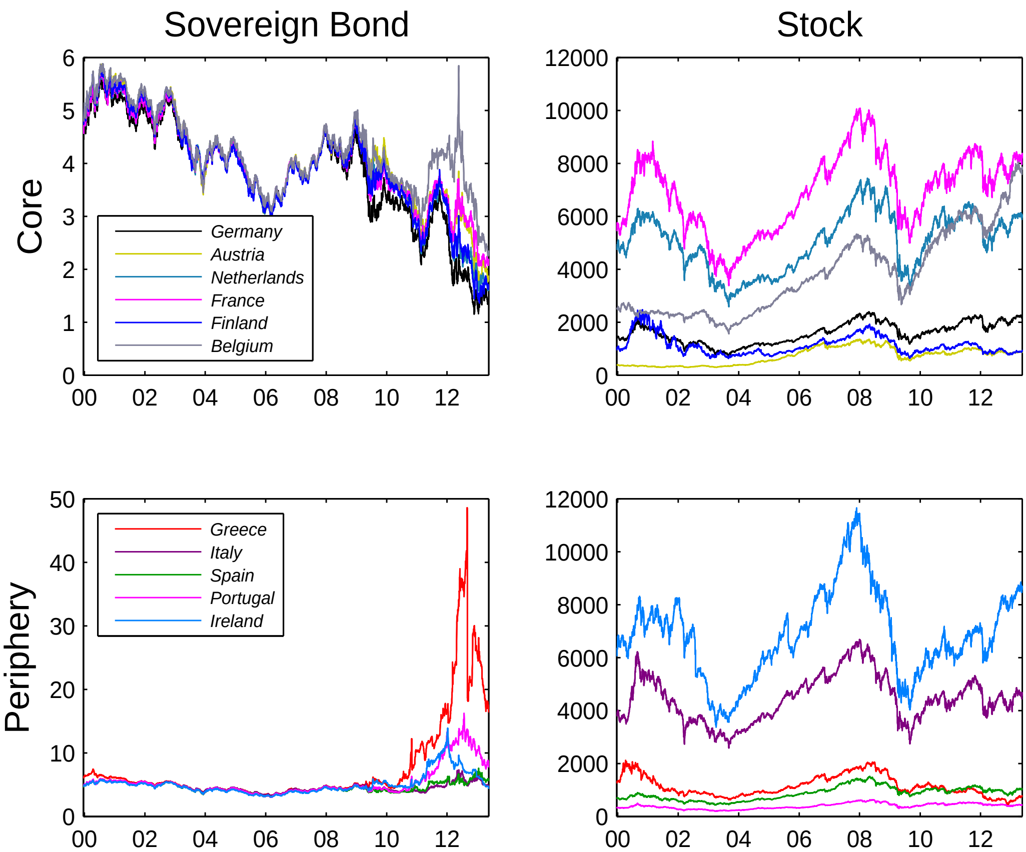
Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking*, 1:15–29.

van der Kwaak, C. and van Wijnbergen, S. (2014). Financial fragility, sovereign default risk and the limits to commercial bank bail-outs. *Journal of Economic Dynamics and Control*, 43:218–240.

A Individual return series

In this appendix we present the disaggregated behaviour of sovereign bond and stock markets in the euro zone. The figure presents data from the year 2000 to October 2013. Legends for the individual countries refer to the rows.

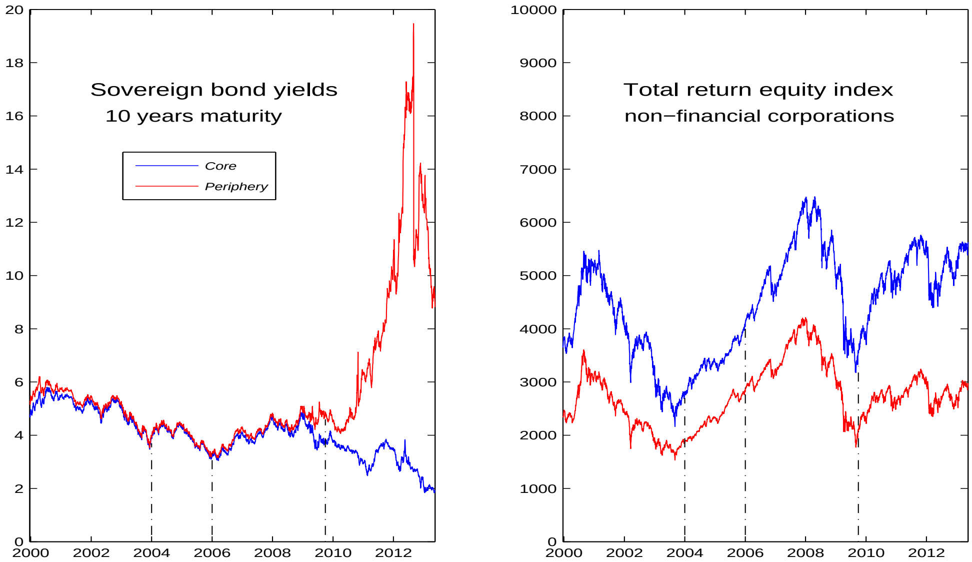
Figure A.1: Behaviour of core and periphery bond and stock returns



Notes. Stock market series are total return indexes on non-financial firms; bond series are DS benchmark 10 years index of yields to redemption.

Data Source: Datastream.

Figure A.2: Returns in the euro zone stock-bond markets



Notes. Stock market series are total return indexes on non-financial firms; bond series are DS benchmark 10 years index of yields to redemption. Countries belonging to the core are: Austria, Belgium, Finland, France and Germany. Whereas countries belonging to the periphery are: Greece, Ireland, Italy, Portugal and Spain. The series are aggregated at the core and periphery level by weighted average based on market capitalization for stock and government liabilities for bonds at the baseline values of 2002.

Data source: Datastream.

B Sovereign risk shock

In this appendix we present a detailed explanation of the methodology used to estimate the sovereign risk shock and we compare it with different panel specifications. Data for the yield series are taken from Datastream for the 10 years central government bonds. The $Yield$ series used in the estimations are computed as the difference of periphery country yields from the one of Germany. *Debt* data are expressed as percentage of output and are taken from the quarterly national account statistics from Eurostat. The periphery countries we consider are the GIIPS: Greece, Ireland, Italy, Portugal and Spain over the period 2000Q2-2013Q4.

B.1 Derivation of the panel formulation

From equation (2.39) we can see that the difference between the periphery and core returns on sovereign bonds depends on expectations of default. These expectations are themselves dependent on the changes in the level of debt-to-output and the stochastic maximum sustainable level of debt, equation (2.38). In the data we capture this relation by regressing the debt-to-output ratio of periphery countries to the yield spread between those countries and Germany, taken as the benchmark for the core.[40] The residuals of this regression are the maximum sustainable level of debt (MSD). In other words, the stochastic MSD is the part of risk of sovereign bonds' yields unexplained by changes in levels of debt-to-output as expressed by the following relation:

$$Yield_{i,t} = \beta_b \, Debt_{i,t} + u_{i,t} \, ,$$

where

$$u_{i,t} = BY_t^{max} - \bar{BY}^{max}$$

from equation (2.35). We additionally assume that the MSD series follow the autoregressive process:

$$u_{i,t} = \gamma_b \, u_{i,t-1} + u_{i,t}^b$$

where $0 < \gamma_b < 1$ is the autoregressive component, and u_t^b is a i.i.d. shock. By substituting the $u_{i,t}$ definition into the Yield expression we obtain:

$$\begin{aligned} Yield_{i,t} &= \beta_b \, Debt_{i,t} + u_{i,t} \\ &= \beta_b \, Debt_{i,t} + \gamma_b \, u_{i,t-1} + u_{i,t}^b \\ &= \beta_b \, Debt_{i,t} + \gamma_b \, (Yield_{i,t-1} - \beta_b \, Debt_{i,t-1}) + u_{i,t}^b \, . \end{aligned}$$

By further re-expressing in differences, we estimate a panel using as dependent variable the first difference of yield spread, $\Delta \, Yield$ and as independent variable the level of yield spread, $Yield$, the level of debt-to-output, *Debt* as well as its first difference $\Delta \, Debt$. We additionally control for country fixed effects α_i. The shock we identify is the residual of the following panel regression[41]:

$$\begin{aligned} &\Delta \, Yield_{i,t} = \beta_b \, \Delta \, Debt_{i,t} - \gamma \, (Yield_{i,t-1} - \beta_b \, Debt_{i,t-1}) + \alpha_i + u_t^b \, , \\ &\qquad \text{for } i = \text{Greece, Ireland, Italy, Portugal, Spain;} \\ &\qquad t = 2000q2, \ldots, 2013q3. \end{aligned} \tag{B.1}$$

[40]An alternative measure is the CDS on the underlying sovereign bonds. Unfortunately the data availability for this variable is limited to the period 2007-2012 that is when the sovereign debt shock is expected to be observed. For this reason we use yields in deviation from the benchmark risk-free asset (Germany's bonds) on the sample period 2000Q2-2013Q4 as a proxy for the CDS informations.

[41]For details on the estimations and the choice of the panel model see Appendix B.

where α_i are country fixed effects. Notice that $(1 - \gamma_b) = \gamma$ in equation (B.1). So by estimating $\hat{\gamma}$ we know $\hat{\gamma_b}$ that we interpret as the persistence parameter of the MSD shock. Finally, in order to calibrate the volatility of $u^b_{i,t}$, σ^b_t, we could reconstruct the series of the MSD as $u_{i,t} = Yield_{i,t} - \beta_b\, Debt_{i,t}$.

B.2 Alternative panel estimations

Table B.1 presents the estimation results for equation (B.1) when controlling for different set of fixed effects.[42]

The specification in column (1) does not include fixed effects in order to get a preliminary idea of the sign of the coefficients, which indeed have the expected sign. In column (2) and (3) we include respectively, first only year and then also quarter fixed effects to control for time specific shocks common to all countries. The sign of the coefficients of interest remains unchanged. Then, in column (4) we include year and country fixed effects to control for any country specific factor affecting the change in the riskiness. Although this might appear the best specification in terms of explained variance, our final purpose is to use the error component as a proxy for exogenous riskiness shock. By including year (or even quarter) fixed effects, any time specific exogenous shock is absorbed by fixed effects, and thus removed from the error component. In contrast, we want the error term to capture also exogenous shock common to all countries, thus we remove year fixed effects from specification (4). Finally, in column (5) we show our preferred estimation including only country fixed effects. The sign and the magnitude of coefficient do not change a lot, but the error component now (potentially) contains exogenous shock common to all countries.

Table B.1: Alternative panel estimations

Variables	(1) Δ Yield	(2) Δ Yield	(3) Δ Yield	(4) Δ Yield	(5) Δ Yield
Δ Debt	0.0587**	0.0346**	0.0243**	0.0192*	0.0531**
	(0.0177)	(0.00986)	(0.00724)	(0.00864)	(0.0140)
Lag Yields	-0.145*	-0.173*	-0.168*	-0.227**	-0.211*
	(0.0581)	(0.0644)	(0.0651)	(0.0590)	(0.0792)
Lag Debt	0.00273	0.00177	0.00174	0.00954	0.0109
	(0.00291)	(0.00280)	(0.00279)	(0.00940)	(0.00946)
Country FE	no	no	no	yes	yes
Year FE	no	yes	yes	yes	no
Quarter FE	no	no	yes	no	no
Observations	260	260	260	260	260
R-squared	0.110	0.275	0.295	0.331	0.147
Number of i	5	5	5	5	5

Errors are cluster at country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

[42] The data sample has been cleaned from outliers by removing the top and bottom 1 percentile.

C Business cycle statistics

In this appendix we compare the model's second moments with the cyclical properties of EA data. We simulate the model with a correlated technology shock between the core and the periphery and calibrated as explained in section 3. Table C reports the standard deviations of sample moments that, as in section 4, are computed from 50 simulations of the economy, each of 60 periods. As with the data, the statistics in our simulations refer to Hodrick-Prescott filtered variables.

We compare the model with EA data on business cycle second moments.[43] In the specific, we refer to the ECB study of Agresti and Mojon (2001) where they present data for individual euro area countries for the period '70-'80 until 2000 for investment, output and consumption. In Data (1) of table C we present their statistics by taking the average between countries belonging to the core and the periphery of the EA (except Ireland). Data on hours worked, 'N', are taken from Ohanian and Raffo (2012) on the period 1960-2010. As they only present an aggregate for euro area countries[44] we cannot disentangle the core and periphery statistics and we use one estimate for the two regions. In Data (2) we additionally provide statistics based on the author's calculations. Variables are logged and HP-filtered, except for Q that is only HP-filtered, with a 1600 smoothing weight. Data comes from the OECD economic outlook and covers the period 1995Q1-2013Q4. 'N' is hours worked and 'W' is compensation per employee divided by number of hours worked. 'Q' is the real exchange rate of the core with respect to the periphery. This variable has been created as the ratio between the consumption price index in the core and in the periphery.[45] [46]

As of model's simulations, we present moments for the benchmark model (with credit constraints) 'Bench.'; for a model without constraints, 'No credit constr.' and for the benchmark model with low adjustment cost on dividends 'Flex. *div*'. Among the different model's specifications, 'Bench.' is the one that reproduces the closer the business cycle stylized facts in the two regions. As we can notice, the model delivers statistics consistent with the data although 'C' and 'I' are too volatile. This can be explained by the fact that we have a reduced representation of all the linkages and shocks that exist and hit the EA economy as the model was not constructed with this purpose. However it shows to behave qualitatively in line with the performance of models in the RBC literature although, for some variables, not quantitatively. These results are consistent through out the different model's specifications.

[43] Both for the model and for the data, standard deviations are always presented relative to the one of output in the domestic country.

[44] In detail they consider an average for France, Germany and Italy.

[45] The countries considered for the core region are France and Germany whereas those belonging to the periphery are Italy, Spain and Portugal.

[46] In Data (2) we find that the volatility of wages is higher than the one of hours worked. This is contradictory with the empirical estimates of the US business cycle as well as with national studies for EA countries (see for instance Bec et al. (2000), paper 20, for a study on France). However, on the one hand these studies have been conducted on a different time period and on single countries rather than for an aggregate of the EA, on the other, the time period we consider could have strongly influenced the data given the recent financial crisis first and the sovereign debt crisis then.

Table C.1: Individual country statistics

	France	Germany	Italy	Spain	Portugal
	Absolute standard deviations				
Y	0.0107	0.0155	0.0128	0.0108	0.0116
C	0.0075	0.0063	0.0099	0.0132	0.0141
I	0.0310	0.0382	0.0255	0.0392	0.0385
N	0.0069	0.0075	0.0054	0.0059	0.0068
W	0.0110	0.0120	0.0139	0.0187	0.0148
	Standard deviations relative to output				
C	0.7033	0.4034	0.7691	1.2225	1.2184
I	2.9038	2.4572	1.9848	3.6278	3.3314
N	0.6481	0.4805	0.4178	0.5457	0.5859
W	1.0283	0.7753	1.0843	1.7324	1.2830

This table presents the disaggregated behaviour of selected business cycle statistics for France, Germany, Italy, Spain and Portugal. Variables are log and HP-filtered. Data comes from the OECD economic outlook and covers the period 1995Q1-2013Q4. 'N' is hours worked and 'W' is compensation per employee divided by number of hours worked.

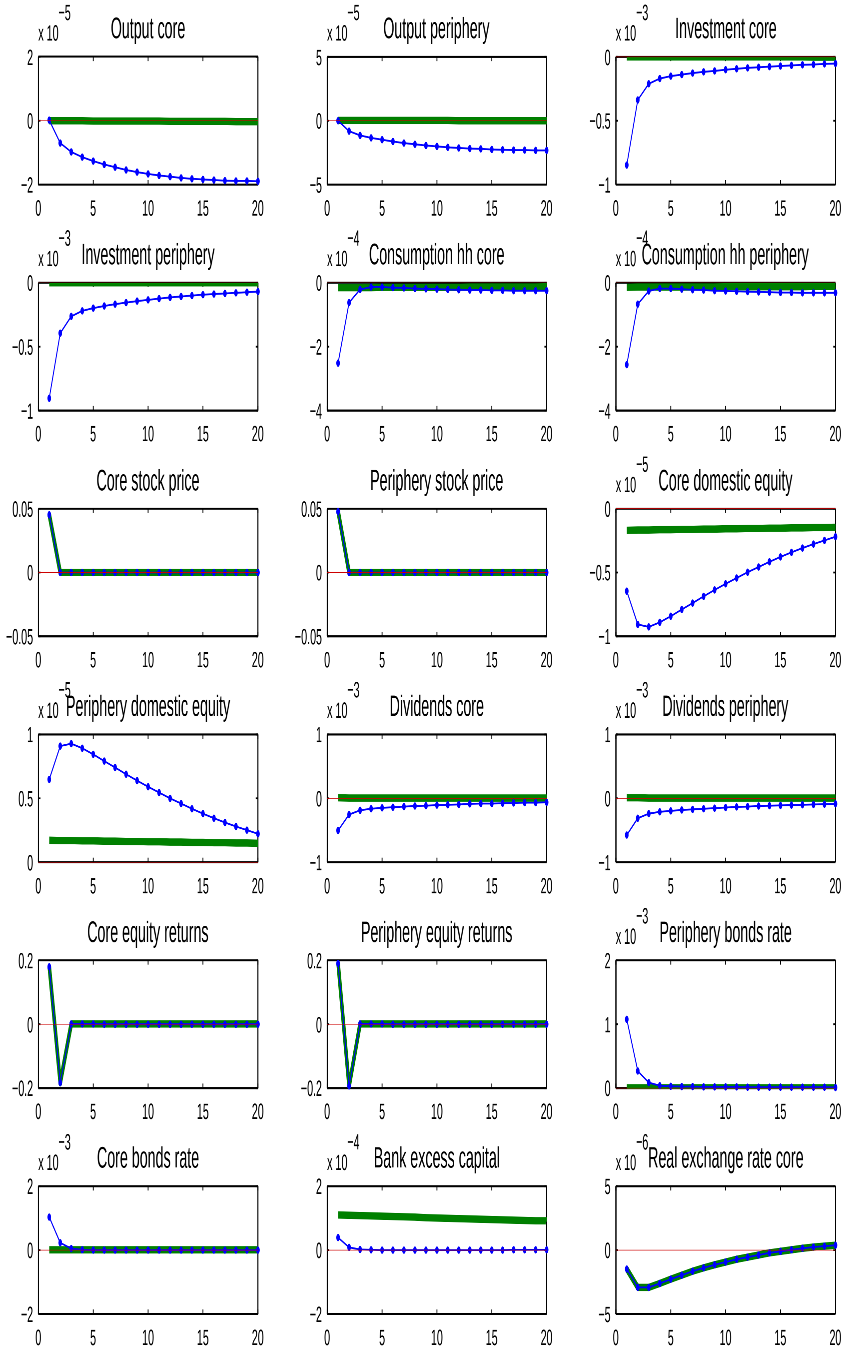
Table C.2: Business cycle statistics

	Data		Model		
	(1)	(2)	Bench.	No credit constr.	Flex. *div*
			Standard deviations relative to output		
Core					
Y^c	1.00	1.00	1.00	1.00	1.00
C^c	1.00	0.45	1.51	2.12	1.61
I^c	2.83	2.58	8.5	4.47	7.6
N^c	0.78	0.45	0.45	0.46	0.45
W^c	-	0.77	0.21	0.21	0.21
Q^c	-	0.36	0.19	0.19	0.20
Periphery					
Y^p	1.00	1.00	1.00	1.00	1.00
C^p	1.05	0.87	1.57	2.13	1.64
I^p	3.05	2.49	8.6	4.46	7.5
N^p	0.78	0.31	0.46	0.45	0.45
W^p	-	1.13	0.21	0.21	0.20
			Correlation with output		
Core					
C^c	0.68	0.64	0.94	0.88	0.95
I^c	0.72	0.92	0.95	0.97	0.89
N^c	-	0.36	0.96	0.95	0.96
W^c	-	0.27	0.96	0.95	0.96
Q^c	-	0.23	0.45	0.42	0.41
Periphery					
C^p	0.69	0.77	0.95	0.87	0.94
I^p	0.62	0.91	0.95	0.97	0.90
N^p	-	0.08	0.96	0.96	0.96
W^p	-	0.47	0.96	0.96	0.96

We present the results for a correlated productivity shock in the core and in the periphery of the EA. We present moments for the benchmark model with banking frictions 'Bench.', without 'No credit constr.' and with low adjustment cost on dividends 'Flex. *div*'. Standard deviations and correlations are always presented relative to output of the domestic country. Data (1) is taken from Agresti and Mojon (2001) on the sample period '70-'80-2000. N^j, hours worked in Data (1), are taken from Ohanian and Raffo (2011) on the period 1960-2010 while W^j is not available for an aggregate of EA countries. Data (2) on the EA business cycle is taken from the OECD economic outlook at quarterly frequency for the period 1995Q1:2013Q4 and are based on author's calculations.

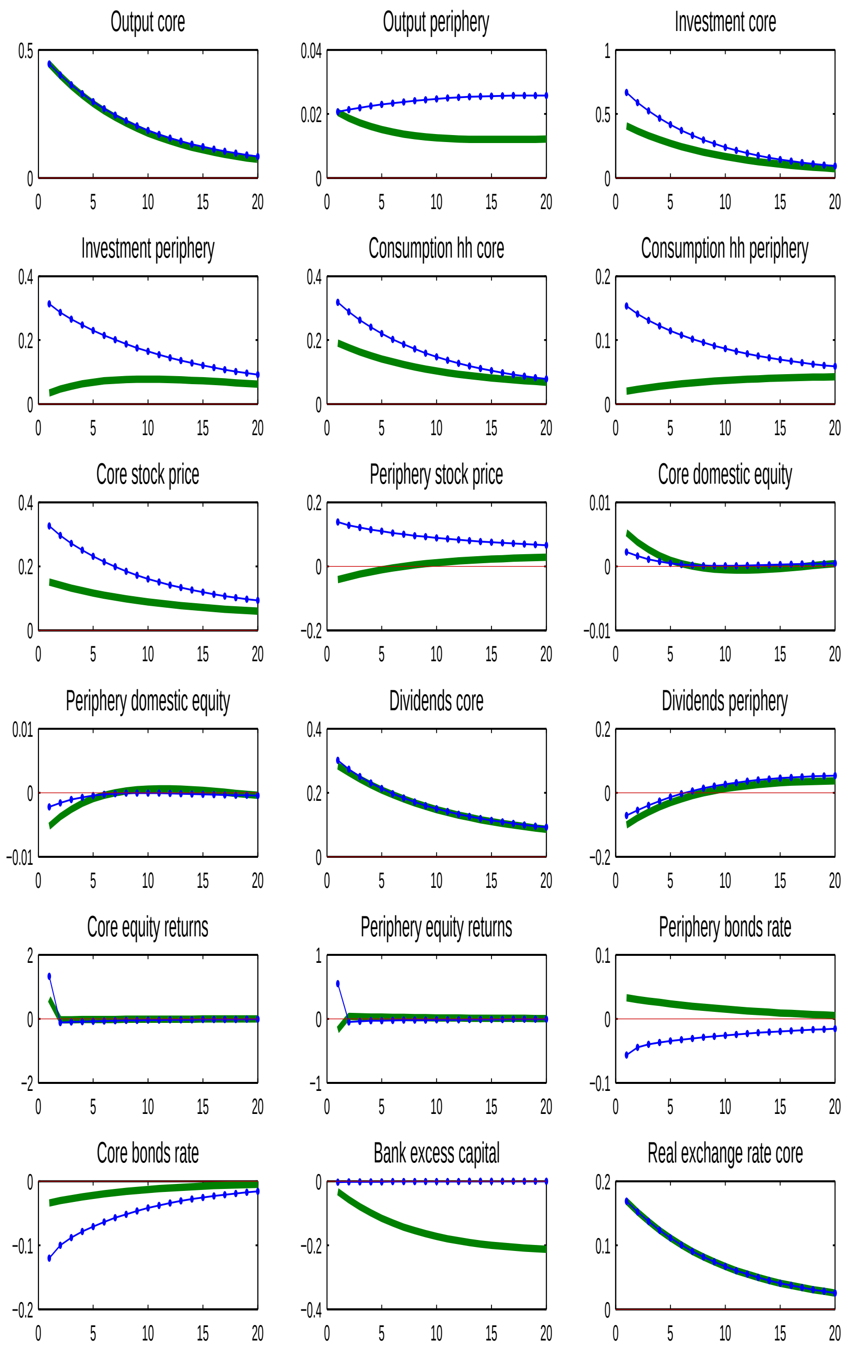
D Dynamic simulations

Figure D.1: IRFs after a positive financial expectation shock.



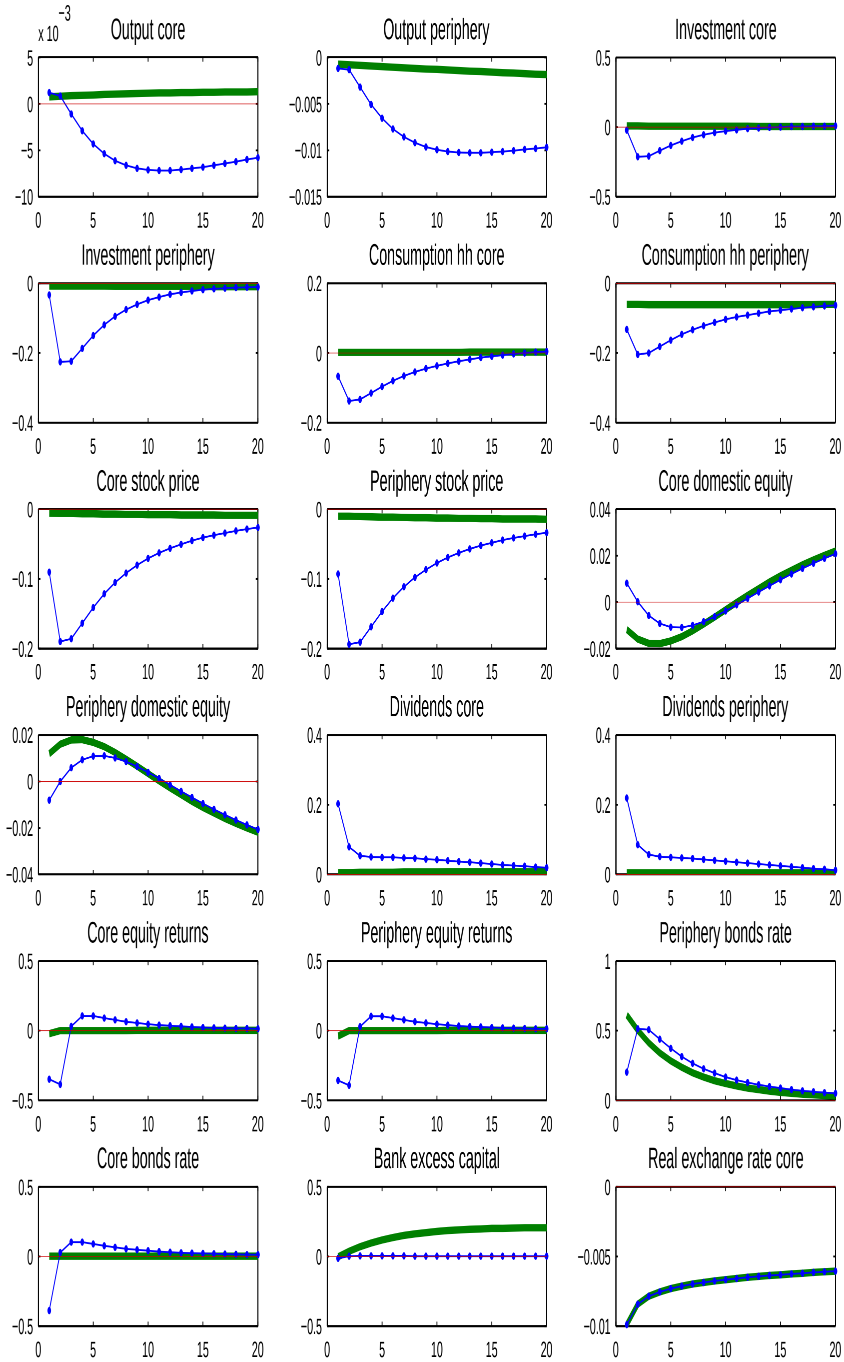
Notes. The shock is to the (union) equity market returns. IRFs show the benchmark model (dotted line) vs model without credit constraints (solid line). Results, in deviation from the steady state, are expressed respectively in percentage points for rates and in percent for the remaining variables.

Figure D.2: IRFs after a positive technology shock in the core.



Notes. IRFs show the benchmark model (dotted line) vs model without credit constraints (solid line). Results, in deviation from the steady state, are expressed respectively in percentage points for rates and in percent for the remaining variables. 'Core domestic equity' stands for the equity of the core country held by core households. Analogously, 'Periphery domestic equity' stands for the equity of the periphery country held by periphery households.

Figure D.3: IRFs after a negative maximum sustainable debt-output ratio shock in the periphery.



Notes. IRFs show the benchmark model (dotted line) vs model without credit constraints (solid line). Results, in deviation from the steady state, are expressed respectively in percentage points for rates and in percent for the remaining variables. 'Core domestic equity' stands for the equity of the core country held by core households. Analogously, 'Periphery domestic equity' stands for the equity of the periphery country held by periphery households.