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Real Effects of Sovereign Bond Market Spillovers in the Euro Area☆

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Abstract

This paper develops a small open economy model to investigate the impact of rising sovereign bond market spreads on the real economy. One key element of the model is a "sovereign risk channel" through which tensions in the sovereign bond market tend to spill over into private credit markets. The model is estimated with Bayesian methods and data for "high-spread" countries in the euro area. It turns out that spread shocks during the Euro crisis had a negative effect on real GDP growth in these countries, up to 0.8 percentage points (PP) Portugal and Ireland, 0.3 PP in Italy and 0.2 PP in Spain.

Keywords: Small open economy, Business cycles, Sovereign risk premium, DSGE modeling (JEL: E32, E43, F41)

1. Introduction

Sovereign bond spreads have risen sharply during the sovereign debt crisis in the euro area, most notably in Greece, Portugal, Ireland, Spain and Italy. It is argued that because of the sovereign risk channel – meaning that tensions in the sovereign bond market tend to spillover into private credit markets (see Corsetti et al., 2013) – higher public funding costs dampened economic activity. However, to the best of my knowledge, (academic) literature quantifying the impact of higher sovereign bond spreads on the economic activity is still very scarce.[1] Using an estimated dynamic stochastic general equilibrium (DSGE) model, the present paper addresses this issue. The analysis suggests that the contribution of sovereign spread shocks on GDP growth during the euro crisis was negative, up to 0.8 percentage points (PP) in 2011 in Portugal and Ireland, respectively, 0.3 PP in 2012 in Italy and 0.2 PP in 2012 in Spain. In single quarters,

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[1]The European Commission (2012) has recently investigated the impact of falling sovereign risk premia on GDP, but neither for single countries nor within an estimated model.

the highest negative contribution to GDP growth amounted to 1.7 PP in Portugal, 1.2 PP in Ireland, 0.4 PP in Italy and 0.3 PP in Spain (all in annualized terms). Results are robust to different specifications of preferences.

From a theoretical perspective, the existence of a sovereign risk channel is backed by a concept called “sovereign ceiling”: In any country, no debtor can have a better rating (and thus lower funding costs) than the government because, in principle, the government could always tax the private sector (see Durbin and Ng, 2005). Yet, to the extent that firms have an international base, the concept may not apply as some authors argue, including Durbin and Ng (2005). Empirical evidence suggests, however, that the argument still holds, in particular in EMU countries. For example, the IMF (2011) reports that there are evident spillovers from the European sovereign debt crisis to the corporate sector, especially for the “high-spread” euro area countries Greece, Portugal, Ireland, Spain and Italy. Furthermore, the ECB (2010) finds strong evidence for spillover effects from sovereign bond markets in the euro area. Corsetti et al. (2012) report that sovereign and corporate CDS spreads in “high-spread” countries are significantly and highly correlated (with a coefficient of 0.71).

The model developed in this paper is an extension of the canonical small open economy real business cycle (RBC) model in line with, for example, Mendoza (1991). It has been widely used in the literature of international macroeconomics as it is tractable, but still able to explain the evolution of key macroeconomic variables. For the analysis to be pursued, the canonical model is extended along two important dimensions: First, a sovereign risk channel is implemented. Second, preferences are modified so as to include valuable government spending in line with to Coenen et al. (2013). The latter modeling choice introduces a wealth effect on labor supply and generates a comovement of government spending and output. The model is estimated with Bayesian methods. Important countries for the estimation are Spain, Portugal, Ireland and Italy.[2] By using the Kalman filter, it is possible to conduct an historical shock decomposition to back out the impact of spread shocks on, inter alia, GDP growth.

The current paper is related to a strand of literature that tries to quantify the effects of fiscal policy within DSGE models. Mostly, the focus of the literature is on the impact of fiscal policy measures in the context of the recent financial and euro crisis (see e.g. Coenen et al., 2012a, 2012b, 2013, Cwik and Wieland, 2011, Drautzburg and Uhlig, 2011, or Leeper et al., 2010). The focus of the present paper is slightly different because it assesses the impact of *sovereign risk* on output in the context of the recent euro crisis. The European Commission (2012) investigates the potential effects of falling sovereign risk premia for “high-spread” countries using the large-scale DSGE model QUEST III (see Ratto et al., 2009). The European Commission (2012), however, neither estimates the model that includes spread shocks nor does it consider single countries separately. Furthermore, this paper is partly related to a field of research trying to quantify the importance of country spreads in explaining business cycles in emerging economies

[2] Greece cannot be used due to a lack of reliable data.

(see, for example, Neumeyer and Perri, 2005, and Uribe and Yue, 2006). The model employed here is similar to the workhorse model of this literature, except that the latter has no role for a public sector.

2. The model

For the analysis to follow, I use an extension of the standard neoclassical small open economy model (see e.g. Mendoza, 1991). The model here departs from the canonical version of the neoclassical model in two dimensions: First, a sovereign risk channel is introduced meaning that the sovereign bond interest rate influences the interest rate relevant for households and firms, the private sector interest rate. Firms are affected by the private sector interest rate through a working capital constraint. I.e., firms have to finance (a fraction of) the wage bill before production takes place. Thereby, labor costs depend not only on wages, but also on the real interest rate. This feature creates a link from interest rates to the supply side of the economy. Furthermore, with the preferences introduced by Greenwood, J., Hercowitz, Z. and Huffman, G. W. (1988), in the following called GHH-prefences, the impact reaction of labor following a spread shock is negative, creating a contractionary effect of spread shocks on impact.[3] Second, preferences are modified such that household utility depends on government spending in a non-separable way. This modification enables the model to generate a positive reaction of output to government spending shocks without dropping GHH-preferences.

2.1. Households

The small open economy is populated by a large number of identical households whose preferences can be described by the following lifetime utility function

$$E_0 \sum_{t=0}^{\infty} \zeta_t \eta_t^c \frac{(\tilde{c}_t - \mu\, \bar{\tilde{c}}_{t-1} - \kappa\, h_t^{\omega})^{(1-\gamma)} - 1}{1-\gamma} \tag{1}$$

where h_t denotes hours worked, ω determines the Frisch elasticity of labor supply and γ measures the curvature of the period utility function. κ scales labor disutility. μ measures the degree of *external* habit formation ($\bar{\tilde{c}}_{t-1}$ is taken as given by the household) and η_t^c denotes a preference shock. $\zeta_{t+1} = \beta\ (1 + (c_t - c) - \kappa\ (h_t^{\omega} - h^{\omega})\ )^{-\psi}\, \zeta_t$ is the endogenous discount factor. Endogenizing the discount factor and setting $\psi > 0$ high enough assures stationary net foreign assets (see Schmitt-Grohe and Uribe (2003) for a discussion). $\tilde{c}_t$ is aggregate consumption and defined as a constant elasticity of substitution (CES) aggregate as in Coenen et al. (2013),

$$\tilde{c}_t = \left(\alpha_G^{\frac{1}{\nu_G}}\, c_t^{\frac{\nu_G - 1}{\nu_G}} + (1-\alpha_G)^{\frac{1}{\nu_G}}\, g_t^{\frac{\nu_G - 1}{\nu_G}} \right)^{\frac{\nu_G}{\nu_G - 1}} \tag{2}$$

[3] GHH-prefences are a standard choice in the literature of international real business cycles, see, among others Mendoza, 1991, Neumeyer and Perri, 2005, and Uribe and Yue, 2006.

where c_t denotes private consumption of the household and g_t government consumption. α_G is a share parameter and measures the importance of private consumption for aggregate consumption. $\nu_G > 0$ measures the elasticity of substitution between private and government consumption. $\nu_G \to 0$ implies perfect complements and $\nu_G \to \infty$ implies perfect substitutes. $\nu_G = 1$ leads to the Cobb-Douglas case. The household's period budget constraint is given by

$$\begin{aligned} c_t + i_t + R^p_{t-1}\, d_{t-1} + b_t + T_t + k_{t-1}\, \frac{\phi}{2}\, \left(\frac{k_t}{k_{t-1}} - 1\right)^2 \\ = h_t\, w_t + k_{t-1}\, u_t + d_t + b_{t-1}\, R^g_{t-1}(1-\vartheta_t) + T^p_t. \end{aligned} \tag{3}$$

The household can invest in three types of assets, physical capital k_t, government bonds b_t and foreign bonds d_t. Physical capital earns a return u_t and evolves according to the following law of motion

$$k_t = k_{t-1}\ (1-\delta) + i_t\, \eta^i_t \tag{4}$$

where δ denotes the depreciation rate, i_t denotes investment and η^i_t represents an investment-specific technology shock. Changes in the stock of capital are subject to convex capital adjustment costs $k_{t-1}\frac{\phi}{2}\ \left(\frac{k_t}{k_{t-1}} - 1\right)^2$. The parameter $\phi > 0$ determines the importance of adjustment costs. Investments in government bonds b_t have a promised gross return of R^g_t. However, in any period, the government may (partially) default and pay back only a fraction $(1-\vartheta_t)$ of its outstanding debt (with $\vartheta_t \in [0,1]$). This approach of introducing default is similar to Corsetti et al. (2013). Foreign bonds d_t indicate the net foreign *debt* position for which the household has to pay the private sector gross real interest rate R^p_t. Apart from income generated by assets, the household receives labor income $h_t\, w_t$, where w_t denotes the wage rate, and lump-sum transfers T^p_t. The household uses its resources to pay for further investments including adjustment costs $i_t + k_{t-1}\, \frac{\phi}{2}\ \left(\frac{k_t}{k_{t-1}} - 1\right)^2$, debt including interest $R^p_{t-1}\, d_{t-1}$, consumption c_t and lump-sum taxes T_t.

The household chooses contingent plans for $\{c_t, h_t, i_t, k_t, d_t, b_t\}_{t=0}^{\infty}$ so as to maximize lifetime utility given by equation (1) subject to the period budget constraint (3), the law of motion for capital (4) and transversality conditions for capital, foreign and government bonds. Further, the household takes as given the processes of $\left\{\bar{\tilde{c}}_{t-1}, R^p_t, R^g_t, u_t, w_t\right\}_{t=0}^{\infty}$. Substituting i_t by the law of motion for capital (4) and denoting λ_t as the Lagrange multiplier associated with the budget constraint 3, the resulting first order conditions with respect to c_t, h_t, k_t, d_t and b_t are (in this order)

$$\lambda_t = \eta_t^c \; (\tilde{c}_t - \mu\,\tilde{c}_{t-1} - \kappa\,h_t^{\omega})^{(-\gamma)} \; \left(\alpha_G^{\frac{1}{\nu_G}} \, c_t^{\frac{\nu_G-1}{\nu_G}} + (1-\alpha_G)^{\frac{1}{\nu_G}} \, g_t^{\frac{\nu_G-1}{\nu_G}}\right)^{\frac{1}{\nu_G-1}} \; \alpha_G^{\frac{1}{\nu_G}} \, c_t^{\frac{(-1)}{\nu_G}} \tag{5}$$

$$\lambda_t w_t = \eta_t^c \; (\tilde{c}_t - \mu\,\tilde{c}_{t-1} - \kappa\,h_t^{\omega})^{(-\gamma)} \; \kappa\,\omega\,h_t^{\omega-1} \tag{6}$$

$$\begin{aligned} &\lambda_t \left(\frac{1}{\eta_t^i} + \phi\left(\frac{k_t}{k_{t-1}} - 1\right)\right) \\ &= \beta_t\,E_t\lambda_{t+1} \left(\frac{1-\delta}{\eta_{t+1}^i} + u_{t+1} + \frac{k_{t+1}\,\phi\left(\frac{k_{t+1}}{k_t} - 1\right)}{k_t} - \frac{\phi}{2}\left(\frac{k_{t+1}}{k_t} - 1\right)^2\right) \end{aligned} \tag{7}$$

$$\lambda_t = \beta_t\,E_t\lambda_{t+1}\,R_t^p \tag{8}$$

$$\lambda_t = \beta_t\,E_t\lambda_{t+1}\,R_t^g\;(1-\vartheta_{t+1}) \tag{9}$$

The interpretation of the first order conditions is straightforward. Equation (5) states that in the optimum, marginal utility of wealth must equal marginal utility of consumption. Equation (6) introduces the consumption-leisure tradeoff. It determines the optimal amount of labor supply by equating the wage rate measured in terms of utility to the disutility of labor. Combining equations (5) and (6), and assuming $\alpha_G = 1$ for illustrative purposes, yields $w_t = \kappa\omega h_t^{\omega-1}$. As can be seen, labor supply depends only on the wage rate, i.e. there is no wealth effect. This is a well-known characteristic of GHH-preferences. Equation (7) is an Euler equation with respect to physical capital. In the optimum, the utility loss of an additional unit of capital (which is forgone consumption including marginal adjustment costs) must be equal to the expected discounted utility gain of an additional unit of capital (which is the expected rent on capital net of depreciation and adjustment costs). Equations (8) and (9) are Euler equations with respect to foreign and government bonds.

2.2. Firms

The firm produces output y_t with the following Cobb-Douglas production function

$$y_t = \eta_t^a\,k_{t-1}^{\alpha}\,h_t^{1-\alpha} \tag{10}$$

where η_t^a is a total factor productivity (TFP) shock. As it is standard in the RBC literature, firms hire labor and capital from perfectly competitive markets. Moreover, production is subject to a working-capital constraint (see, among others, Neumeyer and Perri, 2005). The underlying assumption is that firms have to pay a fraction φ of the wage bill at the beginning of the period whereas output is produced at the end of the period. This mismatch forces the firm to borrow $\varphi w_t h_t$ (working capital) at the gross rate R_t^p from the beginning of period t until the end of that same period. Hence, labor costs amount to $w_t h_t + \varphi w_t h_t (R_t^p - 1)$. Given factor prices w_t and u_t, the firm chooses the optimal amount of capital k_{t-1}[4] and labor h_t so as to maximize profits $y_t - \left[u_t k_{t-1} + w_t h_t + \varphi w_t h_t (R_t^p - 1)\right]$. The first order conditions associated with this static maximization problem are

$$u_t = \eta_t^a \, \alpha \, \left(\frac{k_{t-1}}{h_t}\right)^{\alpha-1} \tag{11}$$

$$w_t \, \left(1 + \varphi \, \left(R_t^p - 1\right)\right) = \eta_t^a \, (1-\alpha) \, \left(\frac{k_{t-1}}{h_t}\right)^{\alpha} \tag{12}$$

Equation (11) equates the marginal costs of capital with the marginal product of capital and equation (12) equates the marginal cost of labor with the marginal product of labor. Clearly, the marginal cost of labor rises with the private sector interest rate R_t^p as well as the fraction φ. The private sector interest rate is defined as the sum of the world interest rate, R_t, given exogenously for the small open economy, plus a private sector spread S_t^p,

$$R_t^p = \left(1 + S_t^p\right) \, R_t. \tag{13}$$

The private sector spread is exogenous for the firm. Following Garcia-Cicco et al. (2010), the world interest rate is assumed to be constant. Finally, note that equations (11) and (12) together with the fact that the production function is homogeneous of degree one imply that profits are zero for all t.

2.3. Government

The government has to obey the following budget constraint

$$b_{t-1} \, R_{t-1}^g (1 - \vartheta_t) + T_t^p + g_t = b_t + T_t \tag{14}$$

Public expenditures include government spending g_t, repayment of debt $b_{t-1} \, R_{t-1}^g (1 - \vartheta_t)$ and the transfer to households T_t^p. In the following, it is assumed that $T_t^p = b_{t-1} \, R_{t-1}^g \vartheta_t$ similar to Corsetti et al. (2013). This assumption assures that sovereign default is without any redistributional effect. What matters is the *risk* of sovereign default as captured by the sovereign spread.[5] Government spending is assumed to follow an AR(1) process

$$g_t - g = \rho^g \, (g_{t-1} - g) + \varepsilon_t^g \tag{15}$$

where g denotes steady state government spending and ε_t^g is a shock to government spending. The government finances its expenses either by issuing debt b_t or by collect-

[4] To be precise, the firm chooses demand for capital k_t^{demand} in period t. Market clearing ensures that k_t^{demand} equals capital supply k_{t-1}, chosen by households in period $t-1$.

[5] As Corsetti et al. (2013) point out, this implication is in line with empirical evidence provided by Yeyati and Panizza (2011). The latter find that output costs mainly occur before the default and less so at the time of the default.

ing lump-sum taxes T_t. The latter are assumed to follow the process

$$T_t - T = \rho^T \; (T_{t-1} - T) + \psi^T \; (b_{t-1} - b) \tag{16}$$

where T denotes steady state lump-sum taxes and $\psi^T > 0$ is a feedback coefficient for public debt assuring that public debt is stationary. The government bond yield R_t^g is equal to

$$R_t^g = \left(1 + S_t^g\right) \; R_t \tag{17}$$

where S_t^g denotes the sovereign spread. The spread is assumed to follow an AR(1) process as in Neumeyer and Perri (2006),

$$S_t^g - S^g = \rho^S \, (S_{t-1}^g - S^g) + \varepsilon_t^S \tag{18}$$

where S^g denotes the steady state sovereign spread and ε_t^S a sovereign spread shock. The sovereign spread shock can be interpreted as the effect of non-fundamental factors during the Euro crisis. Theoretically, sovereign spreads or risk premia are driven by default and liquidity risk. For the euro area, Favero and Missale (2012) and Barrios et al. (2009) provide strong evidence that liquidity risk is a small or even negligible driver of sovereign yield spreads. Moreover, they find no evidence for a *linear* effect of default risk – proxied by country-specific fundamentals – on sovereign spreads, giving support to the chosen specification in equation 18.[6]

To capture the idea of a sovereign risk channel, changes in the sovereign spread are assumed to affect the private sector credit spread, S_t^p. In general, changes in the sovereign spread do not translate one-to-one in changes of the private sector credit spread. Therefore, a "spillover coefficient" $\theta \in [0, 1]$ is introduced to control for the magnitude of the spillover leading to $\Delta S_t^p = \theta \Delta S_t^g$.

The model is closed by describing the law of motion of the remaining structural shocks, i.e. η_t^c, η_t^i and η_t^a. They follow an AR(1) process in logs,

$$log\left(\eta_t^x\right) = \rho^x \, log\left(\eta_{t-1}^x\right) + \varepsilon_t^x \tag{19}$$

where ε_t^x is an i.i.d. shock and $\rho^x \in [0, 1)$ the persistence parameter for $x \in \{c, i, a\}$. A complete summary of the set of equations can be found in the Appendix.

2.4. Inspecting the mechanisms

To shed light on the most important transmission mechanisms of the model, the effects of both the spread shock and the government spending shock are analyzed in more detail in this subsection.

[6] Note that Favero and Missale (2012) and Barrios et al. (2009) find a *non-linear* effect of fundamentals only through the interaction with risk perception or other global risk factors.

2.4.1. Spread shock

A rise in the sovereign spread increases the private sector real interest rate through the assumed sovereign risk channel. Given a rise in the private sector real interest rate, foreign debt becomes relatively more expensive. Thus, the household pays back foreign debt and invests less in the home country.[7] To generate a drop in output on impact following a spread shock labor has to drop as well. While the drop in investments is a standard channel in a small open RBC model, the drop in labor is not and depends on the strength of the wealth effect. The mechanism can be explained by looking at the labor supply and demand curves. They can be derived formally from the (linearized) first order conditions in equations (5), (6) and (12). Combining equations (5) and (6) and setting $\mu = 0$ for illustrative purposes yields the labor supply curve[8]

$$w_t - w = \frac{z_c}{z_w}(c_t - c) + \frac{z_g}{z_w}(g_t - g) + \frac{z_{1,h}}{z_w}(h_t - h) \tag{20}$$

with the constants $z_w > 0$, $z_c > 0$, $z_g < 0$ and $z_{1,h} > 0$ in general, i.e. for reasonable steady state and deep parameter values.[9] Assume for now $\alpha_G = 1$ implying "pure" GHH-preferences. Consumption as well as government spending drop out of equation (20) and there is no wealth effect on labor supply. Hence, an increase in the interest rate leaves the position of the labor supply curve unchanged. In contrast, the labor demand curve shifts down. To see why, look at the linearized and rearranged first order condition of the firm, equation (12)

$$w_t - w = z_R(R_t^p - R^p) + z_k(k_{t-1} - k) + z_{2,h}(h_t - h) \tag{21}$$

with $z_R < 0$, $z_k > 0$ and $z_{2,h} < 0$.[10] The resulting equilibrium on the labor market is associated with a lower wage rate and lower equilibrium labor (see Panel a in Figure 1). Note that ω, inversely related to the Frisch elasticity, determines the slope of the labor supply curve. Therefore, the Frisch elasticity is crucial for the strength of the reaction of labor in equilibrium and thus the effect of the spread shock on impact. With $\alpha_G < 1$,

[7] If the household is a net creditor initially, the return on (physical) capital at home is relatively smaller leading to a drop in investment at home, too.

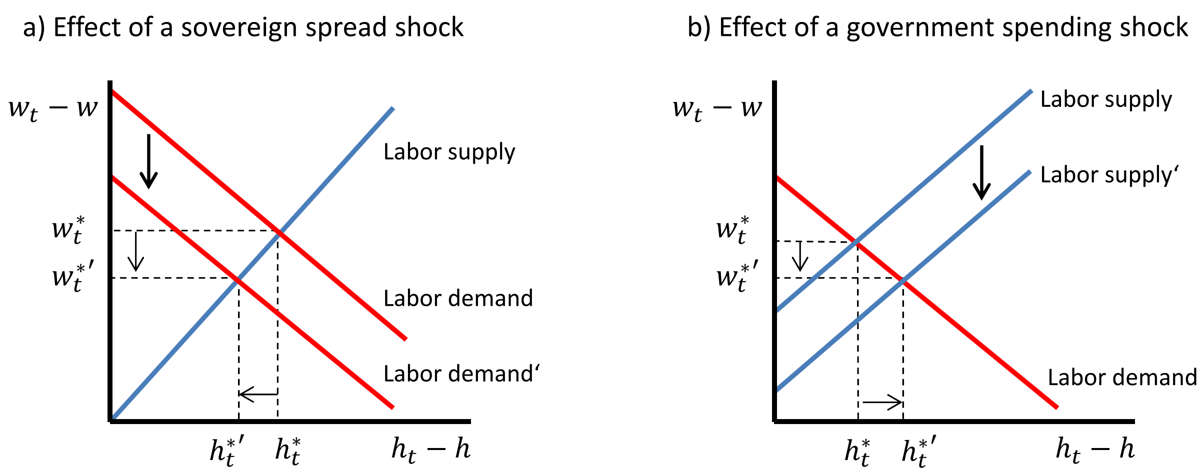
[8] In the following, variables without time index denote steady state values.

[9] The constants are $z_w = \left(\alpha_G^{\frac{1}{\nu_G}} c^{\frac{\nu_G-1}{\nu_G}} + (1-\alpha_G)^{\frac{1}{\nu_G}} g^{\frac{\nu_G-1}{\nu_G}}\right)^{\frac{1}{\nu_G-1}} \alpha_G^{\frac{1}{\nu_G}} c^{\frac{(-1)}{\nu_G}} > 0$,
$z_g = \left(\alpha_G^{\frac{1}{\nu_G}} c^{\frac{\nu_G-1}{\nu_G}} + (1-\alpha_G)^{\frac{1}{\nu_G}} g^{\frac{\nu_G-1}{\nu_G}}\right)^{\frac{1}{\nu_G-1}-1} w\alpha_G^{\frac{1}{\nu_G}} c^{\frac{(-1)}{\nu_G}} \frac{1}{\nu_G} (1-\alpha_G)^{\frac{1}{\nu_G}} c^{\frac{\nu_G-1}{\nu_G}} > 0$,
$z_c = -w\alpha_G^{\frac{1}{\nu_G}} c^{\frac{(-1)}{\nu_G}} \frac{1}{\nu_G} c^{-1} \left(\alpha_G^{\frac{1}{\nu_G}} c^{\frac{\nu_G-1}{\nu_G}} + (1-\alpha_G)^{\frac{1}{\nu_G}} g^{\frac{\nu_G-1}{\nu_G}}\right)^{\frac{1}{\nu_G-1}} \left(\frac{1}{1+\left(\frac{1-\alpha_G}{\alpha_G}\right)^{\frac{1}{\nu_G}} \left(\frac{g}{c}\right)^{\frac{\nu_G-1}{\nu_G}}} - 1\right)$ and
$z_{1,h} = \kappa\omega(\omega-1)h^{\omega-2} > 0$. Since $\left(\frac{1-\alpha_G}{\alpha_G}\right)^{\frac{1}{\nu_G}} \left(\frac{g}{c}\right)^{\frac{\nu_G-1}{\nu_G}} > 0$, it follows that $z_c > 0$.

[10] The constants are $z_R = -\frac{w\varphi}{1+(R^p-1)\varphi} < 0$, $z_k = (1-\alpha)\alpha\frac{k^{\alpha-1}}{h^\alpha} > 0$ and $z_{2,h} = (1-\alpha)(-\alpha)\frac{k^\alpha}{h^{\alpha+1}} < 0$.

there is a wealth effect on labor supply. I.e., following a spread shock which implies a negative wealth effect, the labor supply curve shifts down. It is ultimately an empirical question whether this effect is strong enough to reverse the drop in labor on impact.

Figure 1: Labor market equilibrium



2.4.2. Government spending shock

In the standard neoclassical model, the effects of government spending shocks operate through a negative wealth effect. Hence, in an otherwise standard RBC model with "pure" GHH-preferences, government spending shocks would be without effect on labor. This implies that, in equilibrium, neither output nor investment would react to increased government spending. In this case, private consumption decreases one to one with government spending. One way to overcome this obvious shortcoming is by introducing non-separable valuable government spending as in Coenen et al. (2013). In this case, government spending directly influences the consumption-leisure trade-off and generates an incentive for labor to rise. Formally, this becomes obvious when looking again at the linearized first order condition in equation (20). An increase in government spending shifts down the labor supply curve. In equilibrium, labor and thus output increase (see Panel b in Figure 1).

3. Estimation

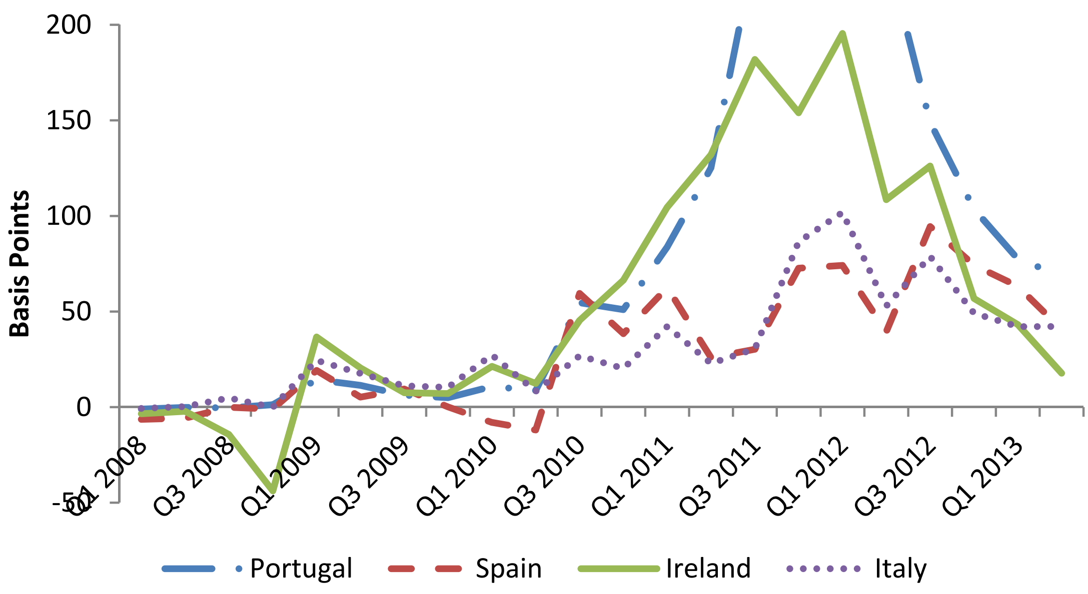
3.1. Data

The model is estimated employing Bayesian estimation methods using quarterly data of Spain, Portugal, Italy and Ireland over the sample period 2000Q1 to 2013Q2. These countries are chosen because they exhibited substantial increases in sovereign spreads and were perceived as "high-spread" countries during the euro crisis. The following seasonally adjusted nominal time series are taken from Eurostat: gross domestic product, final consumption of households, gross capital formation and final consumption of general government. Their real values are calculated by using the GDP deflator. The time series for the sovereign spread is calculated by subtracting one year euro repo rates from one year government bond yields of the respective country. The resulting time series are displayed in Figure 2. Both euro repo rates and government bond yields are taken from Datastream.[11] To allow for a matching of observables and model variables, the observed time series must be stationary. As it is common in the DSGE literature, they are first-differenced in logs and demeaned (see, among others, Smets and Wouters, 2007). The measurement equation then reads

$$X_t^{obs} = log(x_t) - log(x_{t-1}) \tag{22}$$

where X_t^{obs} denotes the transformed observable and $x \in \{y, c, i, g\}$ the corresponding model variable. The observed sovereign quarterly spread is simply matched with S_t^g.

Figure 2: Sovereign Spreads



Note: Sovereign spreads are on a quarterly basis and measured in basis points. The spread of Portugal peaks in 2011Q4 with 497 basis points. Spreads are calculated by subtracting the one year Euro repo from one year government bond yields of the respective country.

[11]The identification codes are Y70422 for one year euro repo rates and GVXX03(CM01) for one year sovereign bond yields, where XX denotes the country code.

3.2. Calibration

The complete derivation of the steady state can be found in the Appendix and a summary of the calibration can be found in Table 2. The following calibration choices are quite standard in the RBC literature (see, e.g., King et al., 1988, or Baxter and King, 1993): The steady state discount factor β is chosen to imply an annualized real interest rate of $2,5\%$. The parameter scaling labor disutility κ is calibrated to match a steady state value of hours worked h of $1/3$. The depreciation rate δ is set to an annualized depreciation rate of 10%. Finally, the output elasticity of capital, α, is set to 0.4. Concerning the government sector, the debt to GDP-ratio b/y is set to 2.4 implying a yearly debt ratio of 60%, consistent with the Maastricht criteria. In all countries, the government spending to GDP ratio is roughly 20% on average over the sample period, so it is set to 20% for all countries. Further, the steady state value of lump-sum taxes closes the government budget constraint and the debt feedback parameter is set to $\psi_T = 0.1$, assuring stationary government debt. Note that due to Ricardian equivalence, the feedback parameter does not affect the evolution of the real economy. The steady state spread S^g must be set to zero in the non-stochastic steady state. Finally, the net foreign debt position d, being the only country-specific calibration choice, matches its respective sample average.[12] There are a few parameters which are poorly identified and therefore calibrated. γ, the parameter governing risk aversion, is set to 2 as in Uribe and Yue (2006). φ is set to 1 as in Neumeyer and Perri (2005) implying that the wage bill must be financed fully in advance. Finally, the spillover coefficient θ is set to 0.5 in line with the European Commission (2012).

3.3. Prior selection

A summary of the priors can be found in Tables 3 to 6. Priors are the same across countries. The prior for external habit formation μ is set to 0.3 similar to Uribe and Yue (2006). The prior for investment adjustment costs ϕ is in line with Forni et al. (2009). The prior mean of ω is set to 3 implying a Frisch elasticity of $\frac{1}{\omega-1} = \frac{1}{2}$. The chosen value is in the middle of the range found in the literature: In a survey, Reichling and Whalen (2012) reports values from 0 to 0.8 for the Frisch elasticity at the intensive margin. Further, the prior mean of α_G, the parameter governing the importance of government consumption for aggregate consumption in the utility function, is set to 0.75 roughly in line with Coenen et al. (2013). The prior mean of the elasticity of substitution between private and government consumption ν_G is set to 0.5, implying mild complementarity. Finally, the parameter governing the speed of convergence of net foreign debt ψ is transformed into a parameter between 0 and 1, $\psi^{trans} = 1/(1+\psi)$ making it possible to impose a beta distribution as prior distribution. The prior mean is set to 0.9, implying approximately $\psi = 0.1$ and a smooth transition of net foreign debt to the steady state.

[12]Data are taken from the World Development Indicators database, see http://data.worldbank.org/data-catalog/world-development-indicators.

3.4. *Posterior distributions*

The main characteristics of the (marginal) posterior distributions are displayed in Tables 3 to 6. The posterior mode is found by maximizing the posterior kernel. Mean and confidence intervals are based on two Markov chains with 300,000 draws (60,000 draws are discarded in a burn-in phase). Prior and posterior plots as well as convergence diagnostics can be found in the Appendix.

The estimation results show a substantial homogeneity across countries in terms of parameter estimates. This result implies that different results across countries are rather driven by different shocks and not by different preferences. The parameter governing the Frisch elasticity, ω, is close to its prior mean indicating that the data are not very informative for this parameter. The estimate of α_G is well below one for all countries implying a meaningful role of government spending and the presence of non-negligible wealth effects on labor supply. Further, there is evidence for strong complementarities between private and public consumption since ν_G is significantly below one, more so in Portugal and Ireland. Also Coenen et al. (2013) find evidence for complementarities for the euro area as a whole. Finally, the persistence of spread shocks is estimated to be lower than the prior mean except for Ireland.

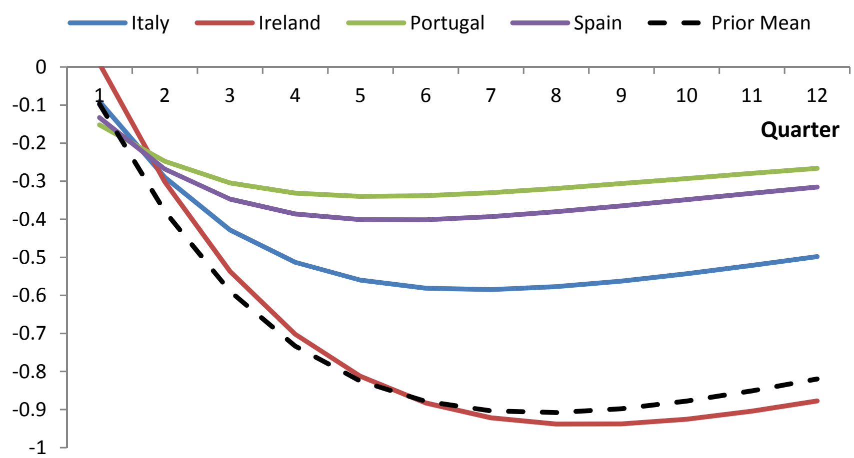
4. Results

4.1. *Baseline model*

Figure 3 plots the impusle responses to a temporary spread shock of 177 basis points on impact, which is the same size as used by the European Commission (2012). The dashed line represents the impulse response at the prior mean. Compared to the European Commission (2012), the impact is slightly lower. The latter, however, consider a permanent change in the spread shock. Increasing the persistence of the spread would also increase the contractionary (medium-run) effect. Figure 3 also plots the impulse responses at the prior modes of single countries. Except for Ireland, the estimated effects following a spread shock is much smaller. This result is, inter alia, driven by differing estimates of the persistence of spread shocks. In Ireland, the persistence of spread shocks is relatively higher, implying a larger negative wealth effect. Hence, the effect is stronger in the medium run, but weaker in the short run.

To further evaluate the effects of the spread shock, I carry out an historical shock decomposition of quarter on quarter GDP growth (see Figures 4 and 5). The focus is on the contribution of spread and government spending shocks. Spread shocks had a negative effect in all countries, most notably from 2010 to 2012 at the peak of the euro crisis. The size of the contribution of spread shocks was different across countries though. The biggest negative impact was 1.7 PP in Portugal in 2011Q4, 1.2 PP in Ireland in 2012Q2, 0.4 PP in Italy in 2012Q1 and 0.3 PP in Spain in 2012Q1 (all in annualized terms). Further, Table 1 gives an overview of the cumulative yearly impact of the spread shock in the years 2010 to 2012 (columns denoted by "baseline"). The strongest negative contribution for Portugal and Ireland was in 2011 (0.8 PP) and for Italy and Spain in 2012 (0.3 PP and 0.2 PP, respectively). Interestingly, the total cumulative contribution to GDP

Figure 3: Impulse responses of GDP to a spread shock



Note: Figure shows impulse response functions of GDP to a sovereign spread shock in different countries, based on the prior mean (dashed line) and posterior mode estimates. The size of the spread shock is 177 basis points on impact. All deviations are in percent to steady-state values.

growth between the years 2010 and 2012 was roughly 1.5 PP in Portugal and roughly 1.7 PP in Ireland although Portugal's increase in the spread was more than twice as high as Ireland's increase. However, this result is reflected by the impulse responses in Figure 3. To put the size of the spread shock into perspective, government spending shocks are also visible in Figures 4 and 5 and in Table 1. The negative contributions of government spending shocks seem to pick up in the years 2010 to 2012 and may reflect the fiscal austerity measures implemented in "high-spread" countries. Compared to government spending shocks, spread shocks turn out to be less important for the evolution of real GDP growth.

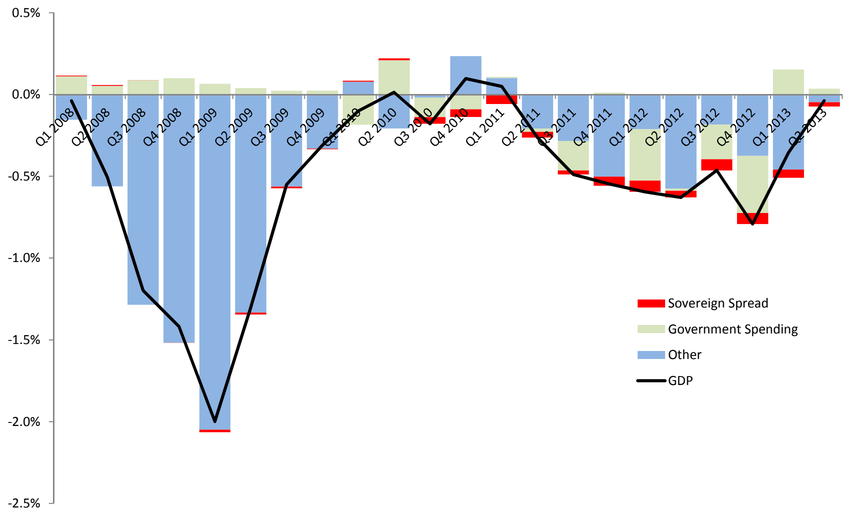
Table 1: Cumulative impacts

		Portugal		Ireland		Spain		Italy	
		Baseline	$\alpha_G = 0$	Baseline	$\alpha_G = 0$	Baseline	$\alpha_G = 0$	Baseline	$\alpha_G = 0$
2010	Sov. Spread	-0.10	-0.13	-0.15	-0.22	-0.07	-0.09	-0.08	-0.09
	Gov.Spending	0.06	0.00	-0.87	0.00	-0.19	0.00	-0.06	0.00
2011	Sov. Spread	-0.80	-1.06	-0.79	-0.92	-0.17	-0.19	-0.15	-0.20
	Gov.Spending	-1.23	0.00	-1.75	0.00	-0.18	0.00	-0.46	0.00
2012	Sov. Spread	-0.63	-0.48	-0.79	-0.70	-0.24	-0.26	-0.32	-0.33
	Gov.Spending	-0.75	0.00	-1.06	0.00	-0.89	0.00	-0.58	0.00

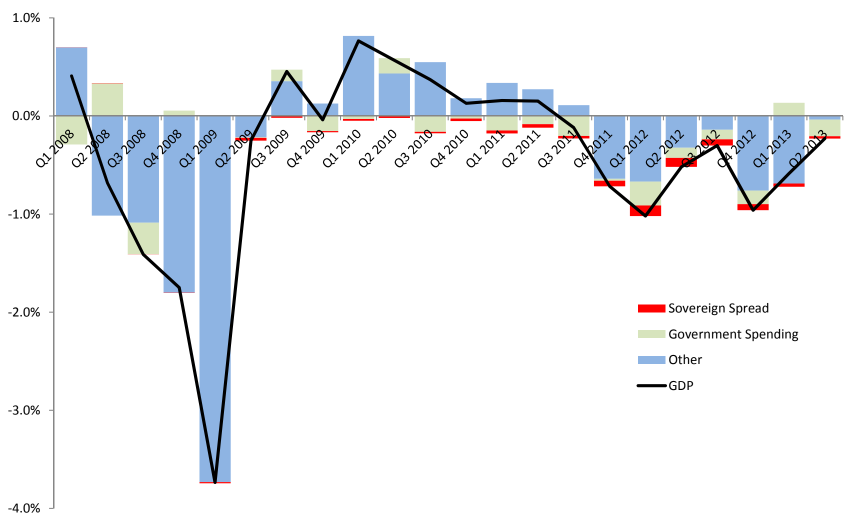
Note:: Table displays the cumulative impact on GDP growth of sovereign spread and government spending shocks (in percentage points). The cumulative impact is calculated by summing up the quarterly contributions. As a robustness check, the model is estimated under the restriction $\alpha_G = 0$.

Figure 4: Shock decomposition of GDP growth

(a) Spain



(b) Italy



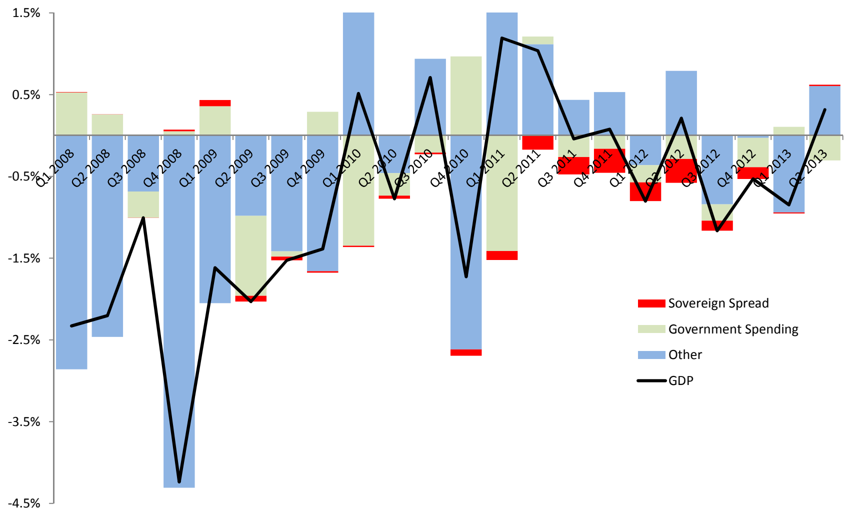
Note: Figure shows quarter-on-quarter GDP growth rates (demeaned) and the contribution of spread, government spending and other shocks. The contribution of other shocks is the sum of the contributions coming from TFP, preference and investment technology shocks as well initial conditions. To annualize, rates have to be multiplied by four.

4.2. Robustness analysis

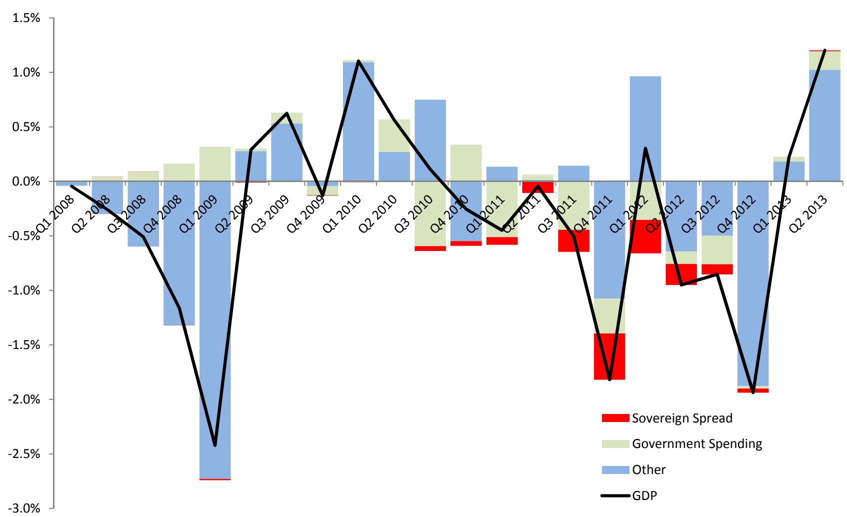
As a robustness check, the model is re-estimated under the restriction $\alpha_G = 0$, i.e. government spending is not utility-enhancing. As a result, there is no wealth effect on labor supply and one can expect stronger effects of the spread shock on impact. Figure 6 plots again the impulse responses at the prior mean and posterior modes. Impact

Figure 5: Shock decomposition of GDP growth

(a) Ireland



(b) Portugal

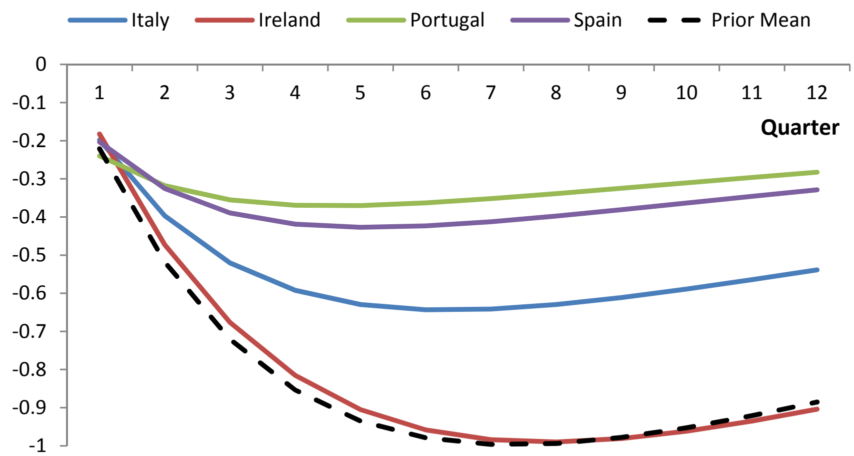


Note: Figure shows quarter-on-quarter GDP growth rates (demeaned) and the contribution of spread, government spending and other shocks. The contribution of other shocks is the sum of the contributions coming from TFP, preference and investment technology shocks as well initial conditions. To annualize, rates have to be multiplied by four.

reactions are now slightly stronger. Overall, however, the estimated impulse responses are roughly the same. Also the contribution of the spread shock during the Euro crisis does not change much as Table 1 reveals (columns denoted by "$\alpha_G = 0$"). Only for Portugal and Ireland, there is a slightly stronger effect in 2011 and a slightly weaker effect in 2012. This pattern, however, is consistent with the observation, that the impact reaction following a spread shock is higher for $\alpha_G = 0$. Finally note that without a wealth effect on labor supply, government spending shocks neither affect labor (supply) nor output. Hence, the contribution of government spending shocks to the development of GDP growth is zero.

]

Figure 6: Impulse responses of GDP to a spread shock - robustness analysis



Note: Figure shows impulse response functions of GDP to a sovereign spread shock in different countries, based on the prior mean and posterior mode estimates. The model is estimated under the restriction $\alpha_G = 0$. The size of the spread shock is 177 basis points on impact. All deviations are in percent to steady-state values.

5. Conclusion

The present paper assesses empirically the impact of rising sovereign spreads during the European sovereign debt crisis using a DSGE model. The model is an extension of the canonical small open economy RBC model. Extensions include a sovereign risk channel meaning that tensions in the sovereign bond market tend to spill over to the private credit market. The model is estimated with Bayesian methods and data for Portugal, Ireland, Italy and Spain. The results suggest that sovereign spread shocks had a negative effect on GDP growth during the euro crisis. The negative contribution amounted up to 0.8 PP in Portugal and Ireland, respectively, 0.3 PP in Italy and 0.2 PP in Spain (in annualized terms).

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Appendix

Complete set of equations

$$\beta_t = \beta\ (1 + c_t - c - \kappa\ (h_t^{\omega} - h^{\omega}))^{\frac{\left(-\left(1-\psi^{trans}\right)\right)}{\psi^{trans}}} \tag{23}$$

$$c_t + i_t + R_{t-1}^{p}\, d_{t-1} + b_t + T_t + k_{t-1}\, \frac{\phi}{2}\, \left(\frac{k_t}{k_{t-1}} - 1\right)^2 = h_t\, w_t + k_{t-1}\, u_t + d_t + b_{t-1}\, R_{t-1}^{g} \tag{24}$$

$$\tilde{c}_t = \left(\alpha_G^{\frac{1}{\nu_G}}\, c_t^{\frac{\nu_G - 1}{\nu_G}} + (1 - \alpha_G)^{\frac{1}{\nu_G}}\, g_t^{\frac{\nu_G - 1}{\nu_G}}\right)^{\frac{\nu_G}{\nu_G - 1}} \tag{25}$$

$$\lambda_t = \alpha_G^{\frac{1}{\nu_G}}\, \eta_t^{c}\, (\tilde{c}_t - \mu\, \tilde{c}_{t-1} - \kappa\, h_t^{\omega})^{(-\gamma)}\, \left(\alpha_G^{\frac{1}{\nu_G}}\, c_t^{\frac{\nu_G - 1}{\nu_G}} + (1 - \alpha_G)^{\frac{1}{\nu_G}}\, g_t^{\frac{\nu_G - 1}{\nu_G}}\right)^{\frac{1}{\nu_G - 1}}\, c_t^{\frac{(-1)}{\nu_G}} \tag{26}$$

$$c_t^{\frac{(-1)}{\nu_G}}\, \left(\alpha_G^{\frac{1}{\nu_G}}\, c_t^{\frac{\nu_G - 1}{\nu_G}} + (1 - \alpha_G)^{\frac{1}{\nu_G}}\, g_t^{\frac{\nu_G - 1}{\nu_G}}\right)^{\frac{1}{\nu_G - 1}}\, w_t\, \alpha_G^{\frac{1}{\nu_G}} = \kappa\, \omega\, h_t^{\omega - 1} \tag{27}$$

$$k_t = k_{t-1}\ (1 - \delta) + i_t\, \eta_t^{i} \tag{28}$$

$$\begin{aligned} &\lambda_t\, \left(\frac{1}{\eta_t^{i}} + \phi\, \left(\frac{k_t}{k_{t-1}} - 1\right)\right) \\ &= \beta_t\, E_t\, \lambda_{t+1}\, \left(\frac{1 - \delta}{\eta_{t+1}^{i}} + u_{t+1} + \frac{k_{t+1}\, \phi\, \left(\frac{k_{t+1}}{k_t} - 1\right)}{k_t} - \frac{\phi}{2}\, \left(\frac{k_{t+1}}{k_t} - 1\right)^2\right) \end{aligned} \tag{29}$$

$$\lambda_t = \beta_t\, \lambda_{t+1}\, E_t\, R_t^{p} \tag{30}$$

$$\lambda_t = \beta_t\, \lambda_{t+1}\, E_t\, R_t^{g}\, (1 - \vartheta_t) \tag{31}$$

$$R_t^{g} = \left(1 + S_t^{g}\right)\, R_t \tag{32}$$

$$R_t^{p} = R_t\, \left(1 + S_t^{g}\, \theta\right) \tag{33}$$

$$y_t = \eta_t^{a}\, k_{t-1}^{\alpha}\, h_t^{1-\alpha} \tag{34}$$

$$w_t\, \left(1 + \varphi\, \left(R_t^{p} - 1\right)\right) = \eta_t^{a}\, (1 - \alpha)\, \left(\frac{k_{t-1}}{h_t}\right)^{\alpha} \tag{35}$$

$$u_t = \eta_t^{a}\, \alpha\, \left(\frac{k_{t-1}}{h_t}\right)^{\alpha - 1} \tag{36}$$

$$log\, (\eta_t^{a}) = \rho^{a}\, log\, \left(\eta_{t-1}^{a}\right) + \varepsilon_t^{a} \tag{37}$$

$$log\, (\eta_t^{c}) = \rho^{c}\, log\, \left(\eta_{t-1}^{c}\right) + \varepsilon_t^{c} \tag{38}$$

$$log\left(\eta_t^i\right) = \rho^i \, log\left(\eta_{t-1}^i\right) + \varepsilon_t^i \tag{39}$$

$$R_t = R \tag{40}$$

$$b_{t-1} \, R_{t-1}^g + g_t = b_t + T_t + w_t \, h_t \, \tau_t^w \tag{41}$$

$$T_t - T = \rho^T \ (T_{t-1} - T) + \psi^T \ (b_t - b) \tag{42}$$

$$g_t - g = \rho^g \ (g_{t-1} - g) + \varepsilon_t^g \tag{43}$$

$$S_t = \rho^S \, S_{t-1} + \varepsilon_t^S \tag{44}$$

$$y_t^{obs} = log\,(y_t) - log\,(y_{t-1}) \tag{45}$$

$$i_t^{obs} = log\,(i_t) - log\,(i_{t-1}) \tag{46}$$

$$c_t^{obs} = log\,(c_t) - log\,(c_{t-1}) \tag{47}$$

$$g_t^{obs} = log\,(g_t) - log\,(g_{t-1}) \tag{48}$$

Steady state derivation

Steady state real interest rates are given by $R = R^g = \frac{1}{\beta}$ with the spread, S, and the fraction of default, ϑ, being zero in the deterministic steady state (see equations (30) to (33)). The return on capital is given by $u = \frac{1}{\beta} - 1 + \delta$ (see equation (29)). The capital to labor ratio is then given by $\frac{k}{h} = \frac{u}{\alpha}^{\frac{1}{\alpha-1}}$ (see equation (36)). Hence, the wage rate is $w = (1-\alpha)\frac{k}{h}^{\alpha} \frac{1}{1+\varphi(R^g-1)}$ (see equation (35)). With targeted steady state employment, steady state capital, k, can be derived using the capital labor ratio. Output, y, can be derived from the production function which is equation (34). Investments are then $i = \delta k$ (see equation (28)). Government debt, b, external debt, d, and government spending, g, follow as calibrated fractions of output. Lump sum taxes close the government budget constraint (41), $T = g + b(R^g - 1)$. Consumption closes the household budget constraint (24), $c = d(1-R) + b(R-1) + wh + uk - i + T$. $\tilde{c}$ follows by its definition (25). κ is set to support the choice of steady state employment, $\kappa = \frac{w\alpha_G^{\frac{1}{\nu_G}} (\alpha_G^{frac1\nu_G} c^{\frac{nu_G-1}{nu_G}} + (1-\alpha_G)^{\frac{1}{nu_G}} g^{\frac{nu_G-1}{u_G}})^{\frac{1}{\nu_G-1}} c^{\frac{-1}{\nu_G}}}{\omega h^{\omega-1}}$ using equation (27). Finally, λ follows from its first order condition (26).

Tables and Figures

Table 2: Benchmark calibration

	Parameter	Value	Description
Preferences	γ	2	Risk aversion
	β	0.9938	Implies an annual real interest rate of 2.5%
	κ	12.53	Implies hours worked of 1/3
Technology	α	0.4	Capital share
	δ	$\frac{0.1}{4}$	Depreciation rate
	φ	1	working capital constraint
Government	b/y	0.6 x 4	Debt-to-GDP ratio
	g/y	0.2	Government spending-to-GDP ratio
	ψ_T	0.1	Debt feedback coefficient
	$S^g = S^p$	0	Sovereign bond spread
	d/y	-	Net foreign debt position over GDP
	θ	0.5	Spillover coefficient

Note: The net foreign debt position over GDP, d/y, is country specific and set to the observed sample average (2000 to 2012). In detail $d/y = -0.01$ in Italy, $d/y = 0.03$ in Spain, $d/y = 0.69$ in Ireland and $d/y = 0.13$ in Portugal.

Table 3: Priors and posteriors for **Spain**

Parameter	Prior			Posterior			
	Distrib.	Mean	St.Dev.	Mode	Mean	5%	95%
A. Preferences							
ω	Gamma	3	0.5	3.24	3.29	2.50	4.10
μ	Beta	0.3	0.1	0.14	0.17	0.08	0.27
ν_G	Gamma	0.5	0.25	0.75	0.72	0.22	1.14
α_G	Beta	0.75	0.1	0.76	0.80	0.68	0.91
B. Elasticity of discount factor							
ψ_{trans}	Beta	0.9	0.05	0.98	0.98	0.96	0.99
C. Capital adjustment costs							
ϕ	Gamma	4	0.5	4.87	4.89	4.10	5.66
D. Shock processes							
ρ^a	Beta	0.75	0.1	0.97	0.96	0.94	0.98
ρ^i	Beta	0.75	0.1	0.95	0.94	0.91	0.97
ρ^c	Beta	0.75	0.1	0.87	0.85	0.74	0.96
ρ^g	Beta	0.75	0.1	0.94	0.93	0.90	0.98
ρ^S	Beta	0.75	0.1	0.61	0.61	0.52	0.70
ε^a	Inv. Gamma	0.001	2	0.0056	0.0057	0.0048	0.0067
ε^i	Inv. Gamma	0.001	2	0.0056	0.0058	0.0045	0.007
ε^c	Inv. Gamma	0.001	2	0.0237	0.0292	0.018	0.0399
ε^g	Inv. Gamma	0.001	2	0.0051	0.0052	0.0044	0.0061
ε^S	Inv. Gamma	0.001	2	0.0017	0.0018	0.0015	0.002

Note: The posterior distributions are based on two Markov chains, each with 300,000 draws, with 30% of the draws being discarded in a burn-in phase. The average acceptance rates were roughly 29.5% and 29.6%, respectively.

Table 4: Priors and posteriors for **Portugal**

Parameter	Prior			Posterior			
	Distrib.	Mean	St.Dev.	Mode	Mean	5%	95%
A. Preferences							
ω	Gamma	3	0.5	2.84	2.78	2.03	3.51
μ	Beta	0.3	0.1	0.16	0.18	0.09	0.27
ν_G	Gamma	0.5	0.25	0.23	0.30	0.12	0.47
α_G	Beta	0.75	0.1	0.77	0.79	0.73	0.86
B. Elasticity of discount factor							
ψ_{trans}	Beta	0.9	0.05	0.90	0.89	0.84	0.95
C. Capital adjustment costs							
ϕ	Gamma	4	0.5	5.49	5.55	4.73	6.39
D. Shock processes							
ρ^a	Beta	0.75	0.1	0.93	0.92	0.88	0.96
ρ^i	Beta	0.75	0.1	0.90	0.89	0.83	0.94
ρ^c	Beta	0.75	0.1	0.82	0.78	0.65	0.91
ρ^g	Beta	0.75	0.1	0.91	0.89	0.84	0.94
ρ^S	Beta	0.75	0.1	0.59	0.59	0.51	0.67
ε^a	Inv. Gamma	0.001	2	0.0079	0.0079	0.0065	0.0093
ε^i	Inv. Gamma	0.001	2	0.0086	0.0089	0.007	0.0108
ε^c	Inv. Gamma	0.001	2	0.0350	0.0421	0.0247	0.0601
ε^g	Inv. Gamma	0.001	2	0.0078	0.0081	0.0068	0.0094
ε^S	Inv. Gamma	0.001	2	0.0055	0.0056	0.0046	0.0066

Note: The posterior distributions are based on two Markov chains, each with 300,000 draws, with 30% of the draws being discarded in a burn-in phase. The average acceptance rates were roughly 28.9% and 28.4%, respectively.

Table 5: Priors and posteriors for **Ireland**

Parameter	Prior			Posterior			
	Distrib.	Mean	St.Dev.	Mode	Mean	5%	95%
A. Preferences							
ω	Gamma	3	0.5	3.33	3.33	2.55	4.12
μ	Beta	0.3	0.1	0.15	0.17	0.07	0.27
ν_G	Gamma	0.5	0.25	0.26	0.28	0.15	0.40
α_G	Beta	0.75	0.1	0.73	0.72	0.67	0.77
B. Elasticity of discount factor							
ψ_{trans}	Beta	0.9	0.05	0.98	0.97	0.95	0.99
C. Capital adjustment costs							
ϕ	Gamma	4	0.5	4.30	4.38	3.59	5.15
D. Shock processes							
ρ^a	Beta	0.75	0.1	0.92	0.91	0.88	0.95
ρ^i	Beta	0.75	0.1	0.89	0.88	0.82	0.94
ρ^c	Beta	0.75	0.1	0.71	0.71	0.57	0.85
ρ^g	Beta	0.75	0.1	0.92	0.91	0.86	0.97
ρ^S	Beta	0.75	0.1	0.77	0.77	0.70	0.83
ε^a	Inv. Gamma	0.001	2	0.0153	0.0158	0.0131	0.0184
ε^i	Inv. Gamma	0.001	2	0.0138	0.0146	0.0112	0.0179
ε^c	Inv. Gamma	0.001	2	0.0683	0.0759	0.0497	0.1024
ε^g	Inv. Gamma	0.001	2	0.0112	0.0115	0.0097	0.0133
ε^S	Inv. Gamma	0.001	2	0.0024	0.0025	0.0021	0.0029

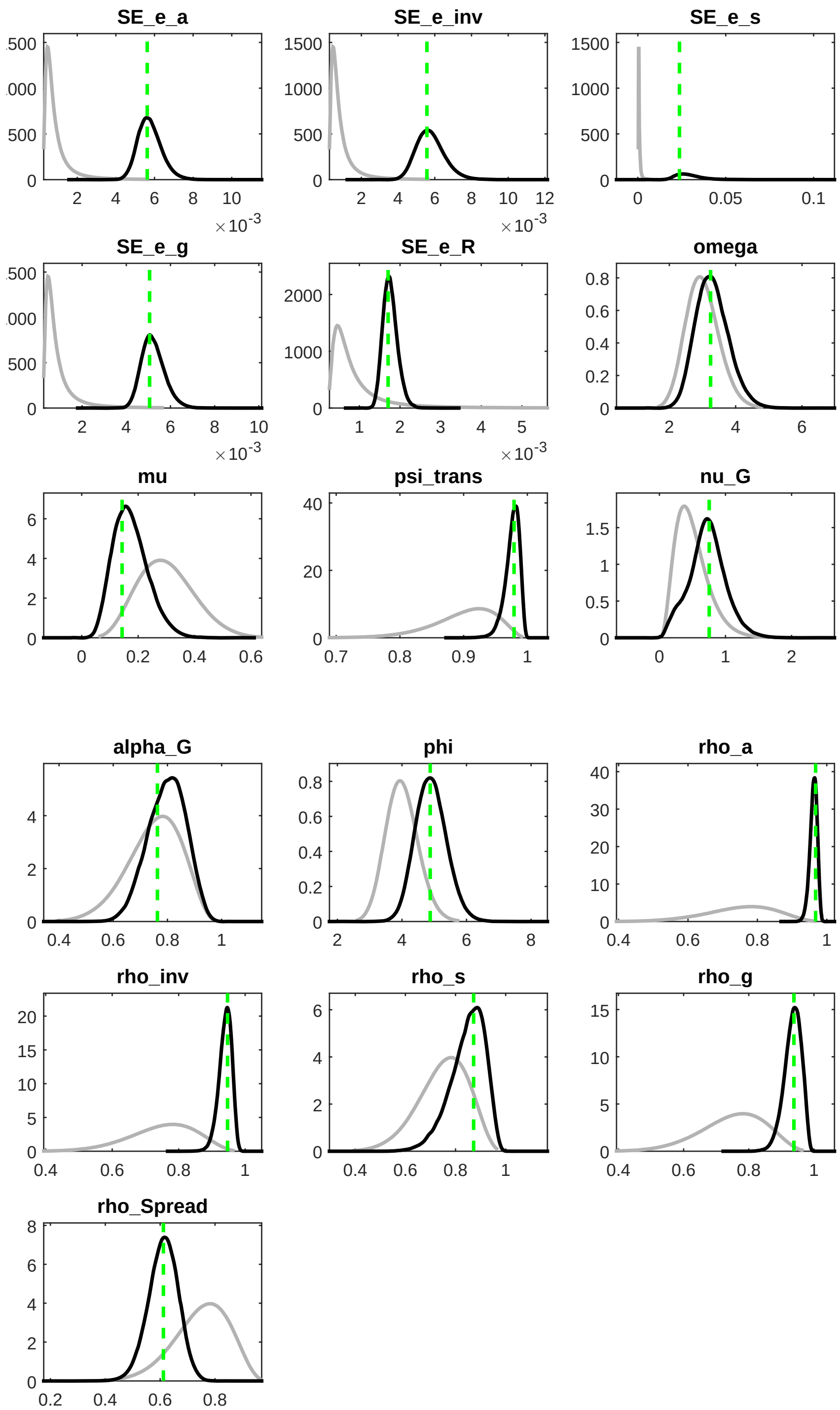
Note: The posterior distributions are based on two Markov chains, each with 300,000 draws, with 30% of the draws being discarded in a burn-in phase. The average acceptance rates were roughly 30.1% for both chains.

Table 6: Priors and posteriors for **Italy**

Parameter	Prior			Posterior			
	Distrib.	Mean	St.Dev.	Mode	Mean	5%	95%
A. Preferences							
ω	Gamma	3	0.5	3.18	3.19	2.39	3.95
μ	Beta	0.3	0.1	0.23	0.25	0.13	0.36
ν_G	Gamma	0.5	0.25	0.75	0.85	0.55	1.13
α_G	Beta	0.75	0.1	0.68	0.72	0.64	0.80
B. Elasticity of discount factor							
ψ_{trans}	Beta	0.9	0.05	0.97	0.96	0.94	0.99
C. Capital adjustment costs							
ϕ	Gamma	4	0.5	4.58	4.63	3.85	5.38
D. Shock processes							
ρ^a	Beta	0.75	0.1	0.94	0.93	0.90	0.96
ρ^i	Beta	0.75	0.1	0.90	0.88	0.83	0.94
ρ^c	Beta	0.75	0.1	0.84	0.82	0.72	0.92
ρ^g	Beta	0.75	0.1	0.88	0.87	0.80	0.94
ρ^S	Beta	0.75	0.1	0.69	0.69	0.61	0.76
ε^a	Inv. Gamma	0.001	2	0.0072	0.0073	0.006	0.0085
ε^i	Inv. Gamma	0.001	2	0.0048	0.0051	0.0039	0.0062
ε^c	Inv. Gamma	0.001	2	0.0170	0.0202	0.0132	0.0269
ε^g	Inv. Gamma	0.001	2	0.0067	0.0069	0.0058	0.008
ε^S	Inv. Gamma	0.001	2	0.0014	0.0014	0.0012	0.0017

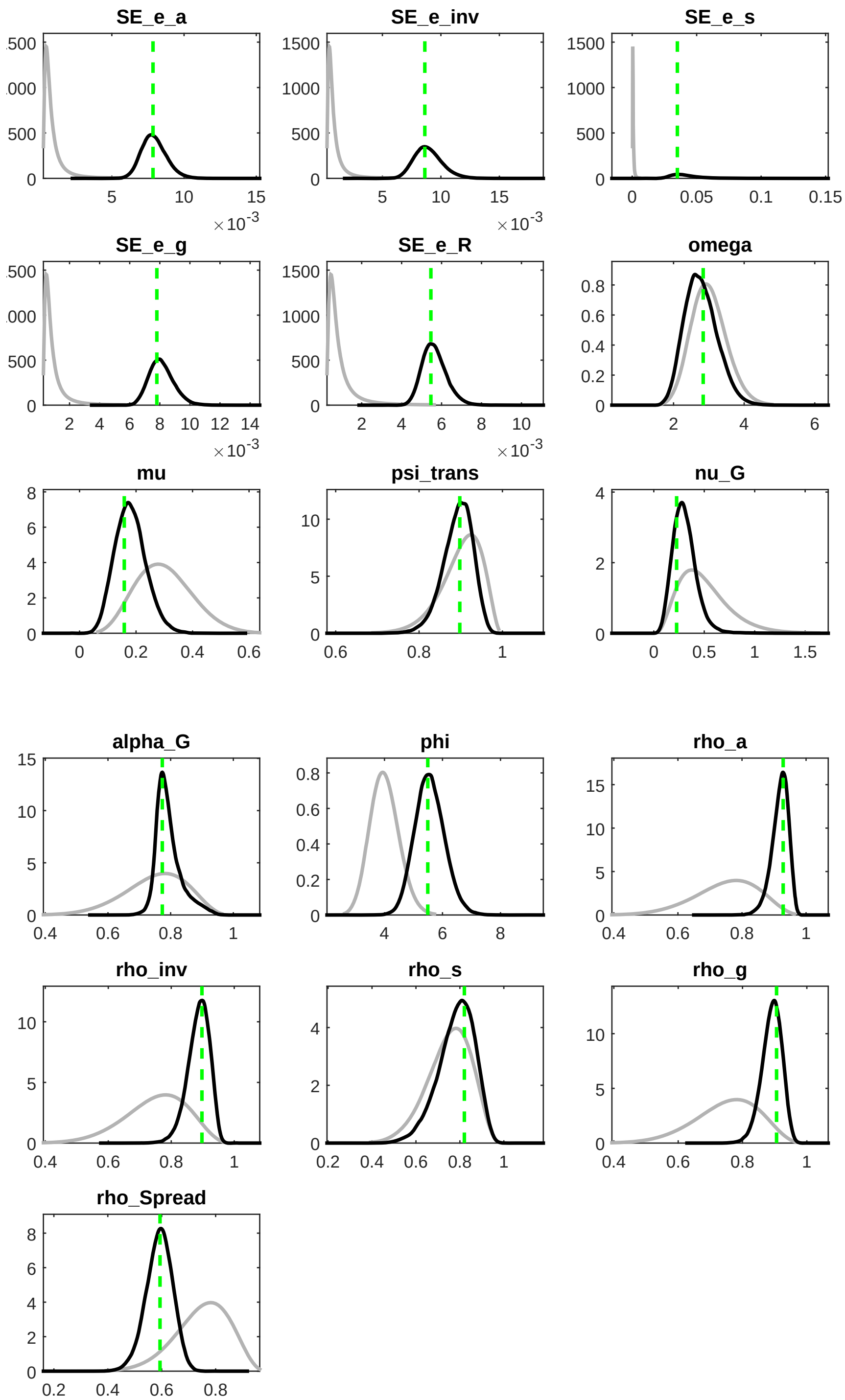
Note: The posterior distributions are based on two Markov chains, each with 300,000 draws, with 30% of the draws being discarded in a burn-in phase. The average acceptance rates were roughly 32.2% and 32.1%, respectively.

Figure 7: Priors and Posteriors - Spain



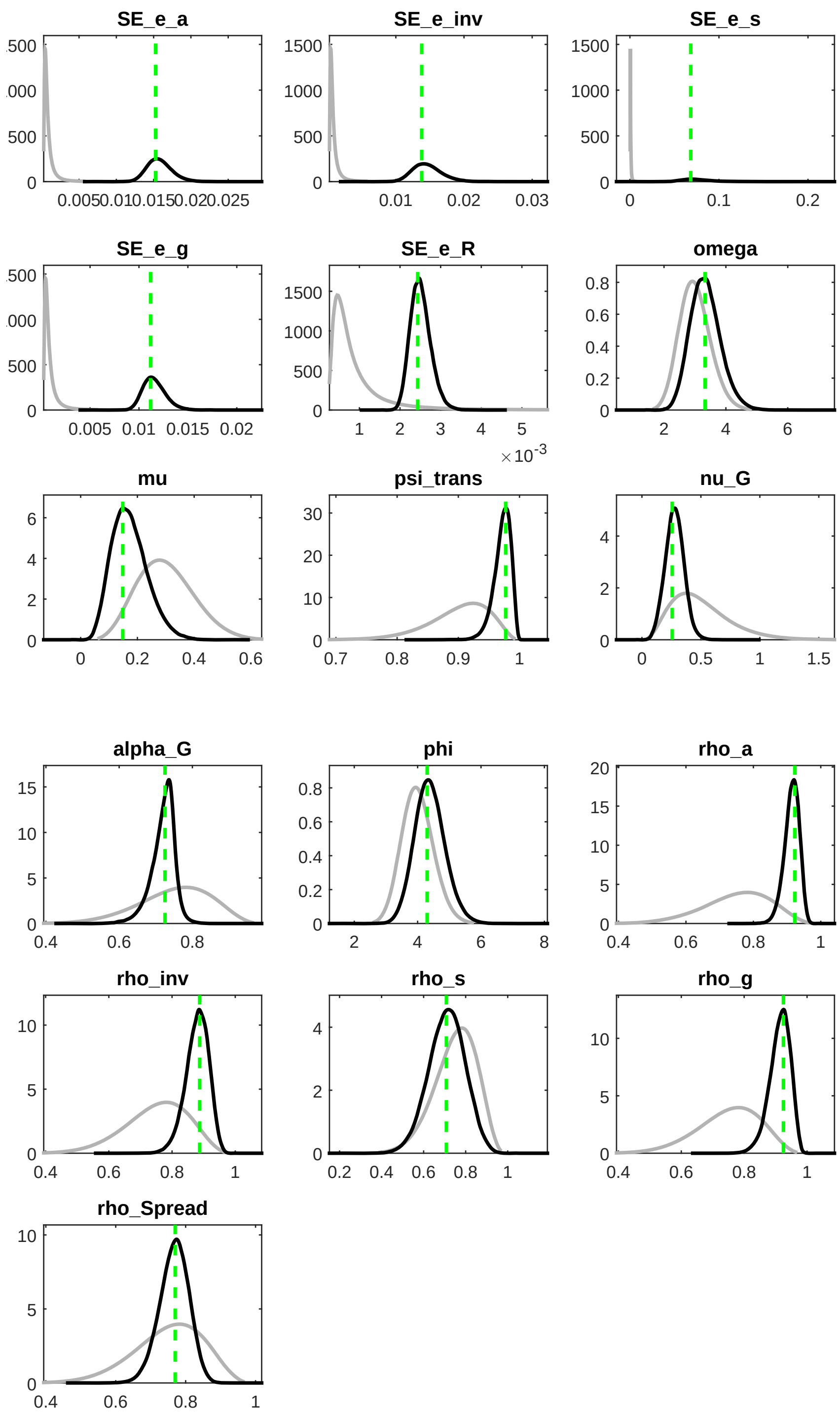
Note: Figure shows for all estimated parameters prior distribution (gray line), posterior distribution (black line) and posterior mode (green dashed line). *_a stands for productivity, *_inv for investment, *_s for preference, *_g for government spending and *_R or *_Spread for spread shock.

Figure 8: Priors and Posteriors - Portugal



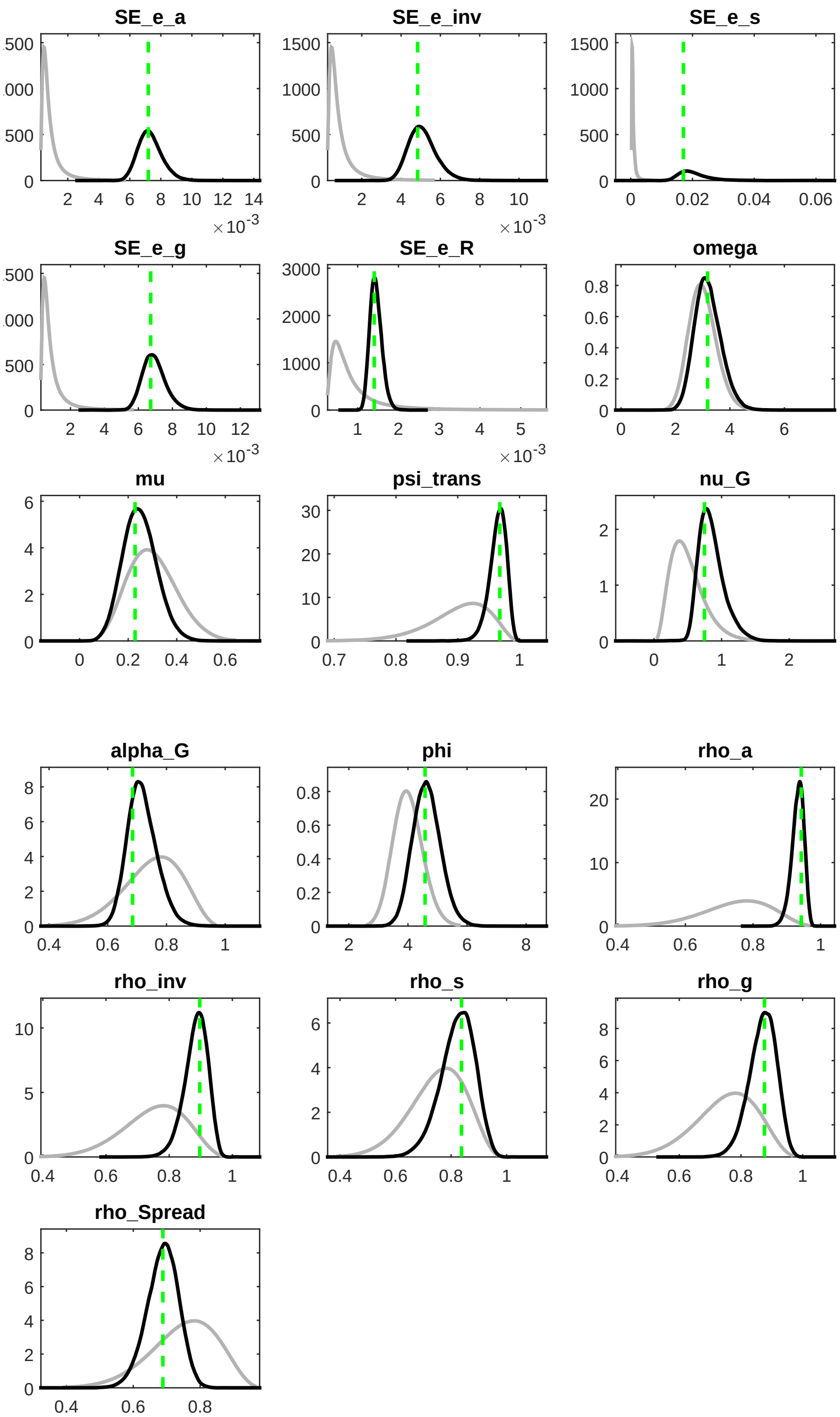
Note: Figure shows for all estimated parameters prior distribution (gray line), posterior distribution (black line) and posterior mode (green dashed line). *_a stands for productivity, *_inv for investment, *_s for preference, *_g for government spending and *_R or *_Spread for spread shock.

Figure 9: Priors and Posteriors - Ireland



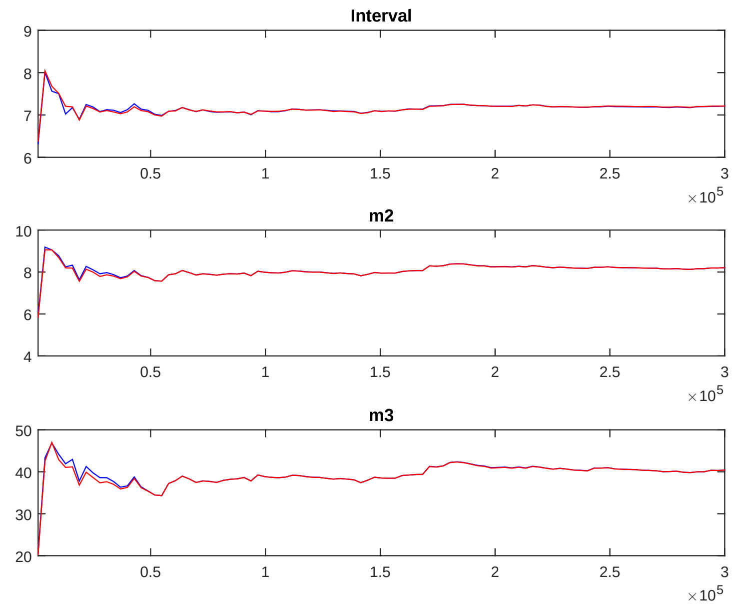
Note: Figure shows for all estimated parameters prior distribution (gray line), posterior distribution (black line) and posterior mode (green dashed line). *_a stands for productivity, *_inv for investment, *_s for preference, *_g for government spending and *_R or *_Spread for spread shock.

Figure 10: Priors and Posteriors - Italy



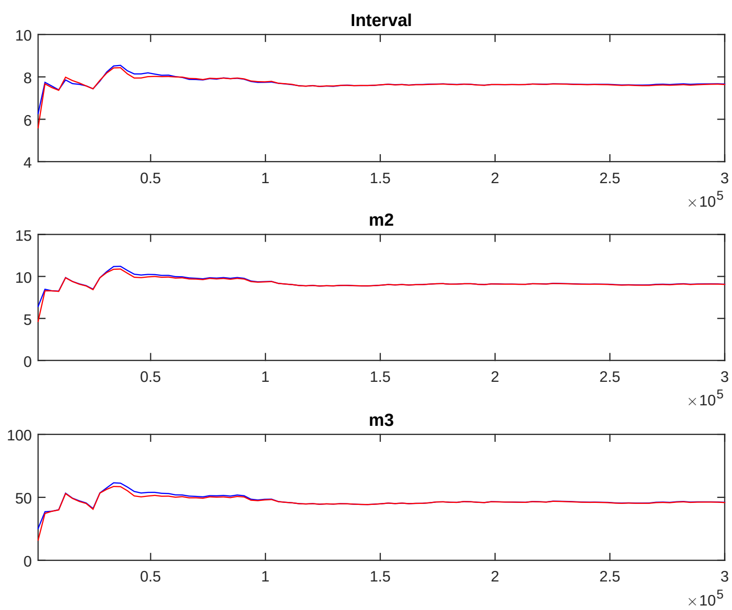
Note: Figure shows for all estimated parameters prior distribution (gray line), posterior distribution (black line) and posterior mode (green dashed line). *_a stands for productivity, *_inv for investment, *_s for preference, *_g for government spending and *_R or *_Spread for spread shock.

Figure 11: Convergence diagnostics - Spain



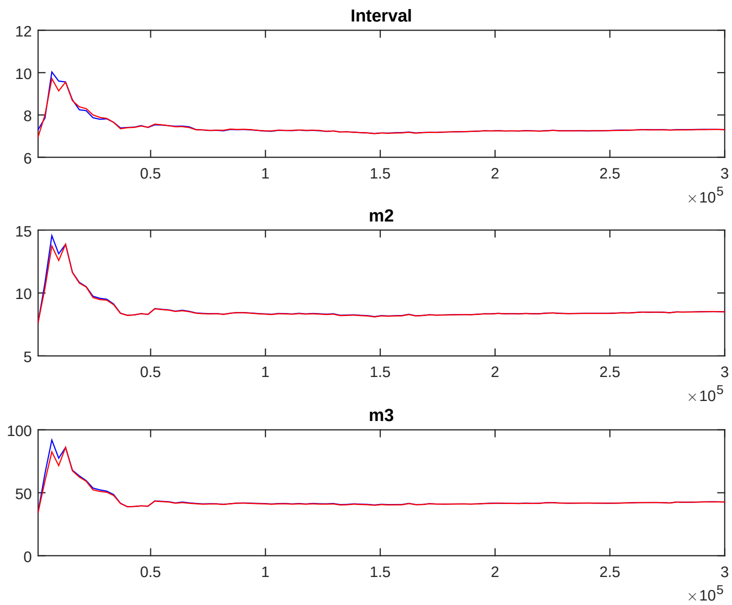
Note: Figure shows Monte Carlo Markov Chain (MCMC) multivariate diagnostics (see Brooks and Gelman, 1998, and Adjemian et al., 2011, for details).

Figure 12: Convergence diagnostics - Portugal



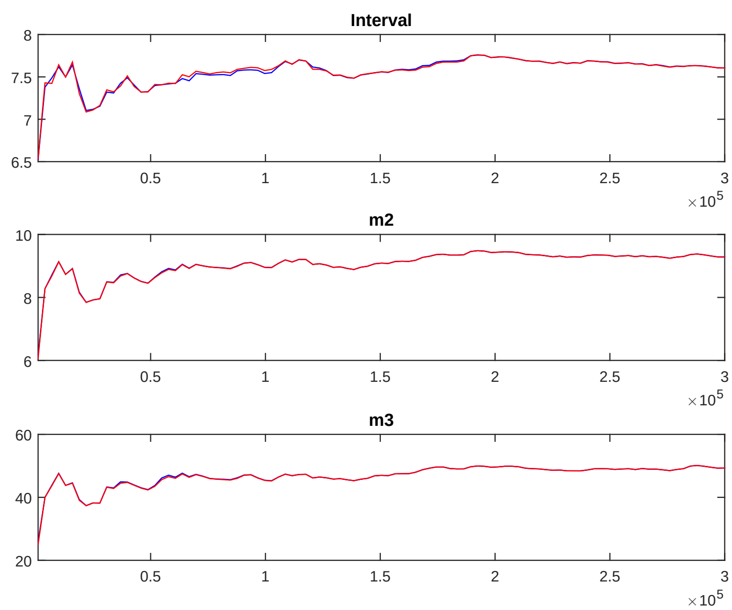
Note: Figure shows Monte Carlo Markov Chain (MCMC) multivariate diagnostics (see Brooks and Gelman, 1998, and Adjemian et al., 2011, for details).

Figure 13: Convergence diagnostics - Ireland



Note: Figure shows Monte Carlo Markov Chain (MCMC) multivariate diagnostics (see Brooks and Gelman, 1998, and Adjemian et al., 2011, for details).

Figure 14: Convergence diagnostics - Italy



Note: Figure shows Monte Carlo Markov Chain (MCMC) multivariate diagnostics (see Brooks and Gelman, 1998, and Adjemian et al., 2011, for details).