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GOVERNMENT INTERVENTION AND LABOR MARKET DYNAMICS

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ECONOMICS

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Resume. This thesis contributes to the general equilibrium modelling of monetary economies from both the theoretical and empirical perspectives. Research outcomes are summarized in three original research papers.

The first introduces a non zero sovereign and private default probability in a large scale monetary, open economy, search and matching model. The main research objective is testing whether the emergence of a financial wedge modelled in the form of a sovereign risk channel can reduce the size or even reverse the sign of the Keynesian fiscal multiplier, conditional to alternative fiscal consolidation measures. The subset of the model parameter space that satisfies the empirical identification requirements issubset of the model parameter space that satisfies the empirical identification requirements is estimated with Bayesian techniques using a large set of data of EZ peripheral countries (Greece, Ireland, Italy, Portugal and Spain). From stochastic simulation analyses conducted at the posterior mean estimates posterior simulations it is shown that the unconditional relation between sovereign risk and macroeconomic fundamentals is weak, and that fiscal contractions are self-defeating, such that the sovereign risk channel, contrary to the theoretical predictions of a recent literature, amplifies the Keynesian effects of the fiscal contraction. The consideration of a liquidity trap environment does not reverse, but reinforces, these results.

The second paper introduces a distinction between the wage negotiated by newly hired workers and incumbents in a monetary, open economy, search and matching model. The main research objective is to evaluate the efficacy of two labor market targeted fiscal policies, a hiring subsidy and a wage subsidy for new hires of labor, and to compare them with that implied by standard fiscal instruments. Even in this case, the subset of the model parameter space that satisfies the empirical identification requirements is estimated with Bayesian techniques using data for high unemployment countries of the EZ periphery (Greece, Ireland, Italy, Portugal and Spain). From posterior simulations it is shown that, except Greece, the labor market policies are not superior to standard fiscal expansions in stimulating economic activity, and their employment-enhanching effects are clearly dominant only in the long term and at the Greece and Ireland's model parameter estimates. The consideration of a liquidity trap environment reinforces these results, showing that expansionary policy actions triggering a deflation can be procyclical when the interest rate zero lower bound binds.

The third paper addresses the issue of the consideration of heteogeneous consumers in general equilibrium models. Heterogeneity in consumption behavior is generally recognized as a useful and powerful modelling assumption from both the theoretical and empirical perspectives. This paper shows that most of the analyses considering such an assumption are characterized by somehow strong assumptions which make the apparent heterogeneity illusory in many respects. By relaxing some of the contextual hypotheses in the labor market dimension that seem to be crucial in the previous literature, and considering type-specific workers at the very root of the microfoundations, the paper proves that substantial differences emerge in both the static solutions and in model dynamics. By means of a calibration experiment differences are shown to be relevant not only for the labor market variables but also for that of real and monetary variables.

Sovereign Debt, Default Risk and Fiscal Consolidation in the EZ Periphery

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Abstract

We consider non zero sovereign and private default probabilities in a monetary, open economy, search and matching model. We empirically evaluate whether the emergence of a financial wedge in the form of a sovereign risk channel can reduce the size or even reverse the sign of the Keynesian fiscal multiplier, conditional to alternative fiscal consolidation measures. The model is estimated with Bayesian techniques using data of EZ peripheral countries (Greece, Ireland, Italy, Portugal and Spain). From posterior simulations we show that *i)* the unconditional relation between sovereign risk and macroeconomic fundamentals is weak; *ii)* fiscal contractions are self-defeating, such that the sovereign risk channel amplifies the Keynesian effects of the fiscal contraction. The consideration of a liquidity trap environment does not reverse, but reinforces, these results.

JEL classification: E32, E52, E62, E63, C11

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Introduction

A number of advanced economies, following the global financial crisis, experienced increases in sovereign debt that were unprecedented during peacetime. Such an evolution, which is still ongoing, has been particularly worrying in the periphery of the euro-zone. Even if different factors are likely to have played a role, the early stages of the sovereign debt surge were characterized by strong uncertainty about sovereign debt sustainability in all the peripheral countries, leading to rising bond and credit rates that worsened the stressed public and private finances. Concerns about the risks of contagion (Guerrieri et al. 2012) led governments and European institutions to to set-up coordinated measures targeted to gain control over strained public budgets, i.e. to debt reduction and fiscal consolidation.

Despite the general acknowledgement of the fact that, historically, a number of alternative and not mutually exclusive factors played a role in successful debt reductions (Reinhart and Sbrancia 2011)[1], the recently signed Treaty on Stability, Coordination and Governance ("fiscal compact"), to be ratified in national parliaments by the end of 2013, establishes a set of policy measures that are - to a large extent - rooted in the automatic implementation of austerity plans in the case of structural deficits.

The effectiveness of these fiscal arrangements, backed by the hypothesis of expansionary fiscal contractions (Giavazzi and Pagano 1990, 1996, Alesina and Perotti 1997, Alesina and Ardagna 2010), is still highly debated and miss a widespread scientific consensus (Romer and Romer 2010, Guajardo et. al. 2011, Ramey 2011), and continue to receive large interest in macroeconomic research.

The hypothesis of a sovereign risk channel, suggested by the observation of a strong unconditional correlation between government bond and private sector spreads (Harjes 2011), has recently provided further support to the idea of expansionary austerity, aside from the concepts of Ricardian equivalence and crowding-out effects of private expenditure.

From the theoretical perspective, Corsetti et al. (2013) show that, by modelling the sovereign default risk as an increasing function of the debt *level* in a general equilibrium monetary model, and considering a spillover effect from government bond rates to the private sector's credit conditions, fiscal contractions lead to a reduction of the government expenditure fiscal multiplier. When the economy operates in a liquidity-trap environment, and for high levels of public debt, the sign of the Keynesian multiplier can even be reversed, giving rise to expansionary fiscal contractions. The economic intuition is that, irrespective of the monetary policy regime, a fiscal retrenchment, by reducing the level of debt, is expected to lead to a reduction in the sovereign default risk, which is translated into reduced bond and lending rates to the private sector. The improved credit conditions, i.e. reduced real interest rates, tend to dampen the size of fiscal multipliers and, in the limit condition of a constrained monetary policy regime, can even stimulate an economic expansion.

The consideration of a sovereign risk channel can thus overturn the key result of a recent stream of literature showing that, when the monetary authority is constrained by a binding zero-lower-bound (ZLB), fiscal contractions - because of their deflationary implications - induce a rise in the real interest rate of the same size of the deflation, leading to a strong economic contraction. The interaction between fiscal and monetary policy regimes is crucial for the efficacy of the fiscal stimulus, particularly in a liquidity-trap environment, in which the size of fiscal multipliers is maximized (Christiano et al. 2011a, Eggertsson 2011, Eggertsson and

[1] These range from sustained economic growth to financial repression with inflationary commitment, from default or restructuring of debt to the implementation of austerity plans.

Krugman 2012).

In this paper we develop a monetary model to evaluate the empirical validity of the sovereign risk channel hypothesis and of the related result of the possible emergence of expansionary fiscal contractions. We calculate and compare the country-specific dynamic multipliers of financially equivalent fiscal policies affecting government consumption, transfers and investments on the expenditure side, and direct and indirect consumption taxes on the revenue side. The monetary model is estimated with Bayesian techniques on a large set of data for five major EZ peripheral countries, i.e. Greece, Ireland, Italy, Portugal and Spain (the PIIGS). Policy simulations consider both a standard environment in which the domestic economies operate at their full potential and a non standard liquidity-trap environment, with a binding ZLB.

The model is characterized by the joint consideration, in an otherwise standard closed-economy monetary model with nominal and real imperfections (Christiano et al. 2005, Smets and Wouters 2007), of some theoretical extensions that are functional to the analysis.

In particular, the design of the monopolistically competitive financial sector (Gerali et al. 2010, Curdia and Woodford 2010), in which we assume non zero default probabilities on the side of both private and public borrowers, is key for the emergence of the sovereign risk channel. On this respect, we basically follow the strategy adopted by Corsetti et al. (2013) by formalizing a relation between sovereign default probability and interest rate spreads without providing an explicit model of the default event.

However, we also substantially depart from their formal setting by assuming a different shape of the cumulative distribution function for the sovereign default probability, partly different economic fundamentals, considering both the debt and the net foreign asset to GDP *ratios* as arguments of the default probability function, and by explicitly formalizing a private sector default probability.

The choice of considering the debt to GDP *ratio* in the place of the debt *level* has two major justifications: on the one hand, it ensures consistency with the empirical literature, addressing economic growth and the ability of the government to service its debt as fundamental triggers of the default risk (Yeyati and Panizza 2011, Mendoza and Yue 2012, De Grauwe and Ji 2013); on the other hand, it highlights the close link between the size of the fiscal multipliers and the sign of the sovereign risk channel effects. In fact, when the former are sufficiently high, the debt to GDP ratio can increase following a fiscal contraction, leading to further deflationary pressure through increased bond and lending rate spreads. In other terms, the sovereign risk channel can operate in the opposite direction than predicted.

The consideration of the net foreign assets position as an important trigger of sovereign default risk is common in the empirical literature (Edwards 1986, De Grauwe and Ji 2013). Default episodes are in fact often preceded by large imbalances in the net foreign asset position. A fiscal retrenchment, by improving the foreign position through reduced imports, is likely to mitigate the financial pressure of international lenders.

Results show that *i)* the default risk channel can be only marginally effective, since the estimated unconditional relation between fundamentals and spreads is very weak; *ii)* conditional to fiscal retrenchments, the default risk channel operates in the opposite direction than predicted, such that it tends to amplify the Keynesian effects of the fiscal contraction.

The reason for the latter result is that, irrespective of the fiscal instrument being considered, the fiscal contraction leads to a temporary but persistent increase in the debt to GDP ratio, triggering a rise in default probabilities and interest rate spreads, whilst the improvement in the NFA position to GDP ratio, stimulating a reduction in default probabilities and spreads, is not sufficient to reverse the former effect.

The analysis also shows that two key factors are responsible for such result: *first*, the low estimated elasticities of the default probability to the debt to GDP and NFA position ratios lead to very small variations in bond and lending rates; *second*, the relatively high size of the fiscal multipliers implies that a decrease in the debt to GDP ratio is never observed following a fiscal contraction, ruling out even negligible reductions in the interest rates.

These results remain valid even under a deep recession characterized by a binding ZLB, since the fiscal contraction continue to lead to a worsening of the debt to GDP ratio and thus to an increase of the sovereign default probability in all countries considered in the analysis. Consistent with the results of a recent literature addressing the relevance of the interaction between fiscal and monetary policy regimes (Christiano et al. 2011a, Eggertsson 2011, Eggertsson and Krugman 2012), the consideration of a constrained monetary policy regime tends to increase the efficacy of the contractionary fiscal measures directly affecting domestic demand, while reducing the effectiveness of the contractionary policies that can lead to increased marginal costs and inflation, as are those based on direct taxes increases (Eggertsson 2011) and on expenditure cuts negatively affecting the production potential. Interestingly, the differences in results obtained under the constrained and unconstrained monetary policy regime are not as high as predicted by the theoretical literature. This outcome is related to the degree of monetary policy activism implicit to the policy reaction rule, which is estimated to be particularly low in the PIIGS, such that the real interest rate variations to shocks in the unconstrained regime are not much distant from those that would hold in the policy-constrained regime.

The paper is organized as follows: Section one describes the model, focusing in particular on the theoretical extensions implemented in the design of the financial sector. Section two provides the details of the Bayesian estimation of the country-specific models. Here we describe the data and their transformations, we address issues of empirical identification, the calibration and the elicidation of priors for the structural model and the Bayesian SVAR parameters, and discuss the posterior estimates. Section three provides a discussion of simulation results, explaining the propagation mechanics in the constrained and unconstrained monetary policy environments. Section four concludes.

1 The model

We jointly consider a number of extensions to the now standard set-up of the new-Keynesian monetary model, characterized by the presence of nominal and real frictions in both goods and labor markets (Christiano et al. 2005, Smets and Wouters 2007). *First*, we introduce a monopolistically competitive financial sector (Gerali et al. 2010, Curdia and Woodford 2010) which is subject to costly Rotemberg pricing and non zero default probabilities on the side of both public and private borrowers, such that a sovereign default risk channel emerges (Corsetti et al. 2013). *Second*, in order to allow the evaluation of the effects of the policies on the net foreign position,.we consider a small open economy framework, developed along the lines of Adolfson et al. (2007) and Christiano et al. (2011b), in which the foreign sector is exogenous with respect the domestic economy and its evolution is described by a structural vector auto-regressive system (SVAR). *Third*, we develop a detailed representation of the non Walrasian labor market, basically following Diamond (1982), Mortensen and Pissarides (1994), and Pissarides (2000) for the introduction of hiring costs and matching frictions, and Gertler et al. (2008) and Gertler and Trigari (2009) for the representation of the staggered Nash-wage bargaining between unions and firms. The preferred specification of the labor market allows the evaluation of the unemployment implications of the alternative fiscal policies. *Fourth*, we adopt a reasonably detailed specification of the fiscal sector, whose relevance for macroeconomic dynamics is recuperated by considering that a fraction of households are liquidity constrained. The design of the fiscal sector marginally resembles that proposed in Drautzburg and Uhlig (2011). We consider unemployment benefits in addition to the standard fiscal instruments characterizing the expenditure and revenues sides of fiscal models, and an optimal definition of the public investment and capital decisions, ensuring that the production potential is optimized.

The major novelty in the design of the monopolistically competitive financial sector is the consideration of a non zero default probability for both private sector and public sector borrowers, obtained by formalizing a cumulative distribution function relating the sovereign default probability to the debt and the NFA position to GDP ratios, and the private sector default probability to the sovereign default probability. Default risks are traduced in bond and lending rate spreads through the consideration of a no arbitrage condition between deposits and domestic bond holdings, and an optimality condition for credit institutions including the Loss Given Default of the bank in the case of counterparty default, respectively.

1.1 Households

1.1.1 Optimizers

A continuum of liquidity unconstrained households indexed by $j \in [0,1]$ have access to a complete set of contingent claims[2]. The representative household is assumed to maximize the following lifetime utility function:

$$\max_{C_t^r, B_t^r, B_t^{*r}, K_t^{p,r}, I_t^r, u_t^k} E_0 \sum_{t=0}^{\infty} \beta^t \left[\xi_t^c \frac{(C_t^r - h\widetilde{C}_{t-1})^{1-\sigma_c}}{1-\sigma_c} - \chi_t n_t \right] \tag{1}$$

where C_t^r is a composite consumption index, $h\widetilde{C}_{t-1}$ denotes external habits σ_c is the consumption curvature parameter and $0 \leq n_t \leq 1$ denotes the fraction of household members who are employed. ξ_t^c and χ_t are two preference shocks which are assumed to follow the i.i.d. processes $\xi_t^c = e^{\varepsilon_{\xi^c,t}}$ and $\chi_t = \chi \mu^{(1-\sigma_c)t} \xi_t^n$, respectively, where $\xi_t^n = e^{\varepsilon_{\xi^n,t}}$[3].

Each household purchases consumption and investment goods by means of after tax labor and capital incomes, after tax unemployment benefits, dividends and government transfers. The budget constraint is thus given by:

$$\begin{aligned}
& (1+\tau_t^c)C_t^r + I_t^r + \frac{B_t^r}{P_t R_t^g} + \frac{e_t B_t^{*r}}{P_t R_t^{g*} \Phi(\frac{A_t}{Y_t}, \frac{e_t}{e_{t-1}}, R_t^{g*} - R_t^g, \widetilde{\phi}_t)} + \frac{D_t^r}{P_t} \\
= \; & Tr_t^r + \frac{R_{t-1} D_{t-1}^r}{P_t} + \left[\left(1 - p_t^{d,g}\right) + z^g p_t^{d,g} \right] \frac{B_{t-1}^r}{P_t} + \frac{e_t B_{t-1}^{*r}}{P_t} + \\
& (1-\tau_t^n) \left[\frac{W_t}{P_t} n_t + b_t^u (1-n_t) \right] + \left[(1-\tau_t^k) \left[\frac{R_t^k}{P_t} u_t^k - a(u_t^k) \right] + \delta \tau_t^k \right] k_{t-1}^{p,r} + \frac{\Pi_t^p \mu^t}{P_t}
\end{aligned} \tag{2}$$

[2] This standard hypothesis ensures that households are homogeneous with respect to consumption and asset holdings choices, such that the notation can be simplified by dropping the j-index.

[3] The peculiar specification of the stochastic scaling factor of labor disutility χ_t is chosen to ensure balanced growth.

where I_t^r is private investment, $A_t = \frac{e_t B_{t+1}^*}{P_t}$ is the aggregate net foreign asset position of the domestic economy, e_t is the nominal effective exchange rate and $\frac{D_t^r}{P_t}$ denotes household's deposits to financial intermediaries in real terms. B_t^r and B_t^* are domestic and foreign bond holdings, respectively, P_t is the consumption price index and $R_t^g = R_t q_{b,t}$, $R_t^{g*} = R_t^* q_{b,t}^*$ are the domestic and foreign interest rates on government bonds, where R_t, R_t^* denote the respective policy rates and $q_{b,t}$, $q_{b,t}^*$ are the home and foreign spreads on government bonds, respectively, the latter defined within the SVAR system for the foreign variables. The variable $p_t^{d,g}$ and the parameter z^g denote the sovereign debt default probability and the recovery rate on defaulted bonds. $\frac{R_t^k}{P_t}$ is the real return on capital $K_t^{p,r}$, u_t^k and $a\left(u_t^k\right)$ denote the utilization rate and its adjustment cost[4], respectively, and δ is the private capital depreciation rate. $\frac{W_t}{P_t}$ is the real wage and $\frac{\Pi_t^p \mu^t}{P_t}$ define real dividends, where μ denotes the long-run trend growth of labor-augmenting productivity. Government transfers TR_t^r, unemployment benefits $b_t^u = b\mu^t$[5] and the tax rates on consumption τ_t^c, on labor income τ_t^n and on capital τ_t^k complete the budget constraint of the Ricardian household. The term $\Phi_t = \Phi(\frac{A_t}{Y_t}, \frac{e_t}{e_{t-1}}, R_t^{g*} - R_t^g, \widetilde{\phi}_t)$ in (2) denotes the risk premium on foreign bond holdings in the modified uncovered interest parity (UIP) equation $E_t\left(\frac{e_{t+1}}{e_t}\right) = \frac{R_t^g}{\Phi_t R_t^{g*}}$, i.e.:

$$\Phi_t = \exp[-\widetilde{\phi}_a\left(\frac{A_t}{Y_t} - \frac{A}{Y}\right) - \widetilde{\phi}_r\left(R_t^{g*} - R_t^g\right) + \widetilde{\phi}_s\left(1 - \frac{e_t}{e_{t-1}}\right) + \widetilde{\phi}_t] \tag{3}$$

where $\widetilde{\phi}_t$ is a time varying shock to the risk premium, which is assumed to follow the AR(1) stochastic process $\widetilde{\phi}_t = \widetilde{\phi}_{t-1}^{\rho_{\widetilde{\phi}}} e^{\varepsilon_{\widetilde{\phi},t}}$ and $\widetilde{\phi}_a$, $\widetilde{\phi}_s$ and $\widetilde{\phi}_r$ are positive elasticities. Our specification ensures the satisfaction of the usual equilibrium requirements (Lundvik 1992, Schmitt-Grohé and Uribe 2001) and adds some flexibility to alternative modified UIP equations adopted in the literature (e.g. Adolfson et al. 2008 and Christiano et al. 2011b). The log-linear representation of the modified UIP is the following:

$$E_t\left(\Delta e_{t+1}\right) = \widetilde{\phi}_s \Delta e_t + \left(1 - \widetilde{\phi}_r\right)\left(R_t^g - R_t^{g*}\right) + \widetilde{\phi}_a\left(A_t - Y_t\right) - \widetilde{\phi}_t$$

were the parameter $\widetilde{\phi}_s$ defines the autoregressive behavior of the expected change in the nominal exchange rate and $\widetilde{\phi}_r \geq 0$ denotes the elasticity to the interest rate differential on bond holdings, allowing for the emergence of the "forward premium puzzle" (for $\widetilde{\phi}_r > 1$), i.e. the negative correlation between interest rate differentials and expected exchange rate variations often observed in empirical trials[6].

The law of motion of physical capital is described by the following equation:

$$K_t^{p,r} = (1-\delta)K_{t-1}^{p,r} + q_{i,t}\left[1 - S(\frac{I_t^r}{I_{t-1}^r})\right] I_t^r \tag{4}$$

where $S(\frac{I_t^r}{I_{t-1}^r})$ defines the private investment adjustment cost function, with curvature parameter ψ^i, and $q_{i,t}$ is an investment-specific shock, which is assumed to follow the i.i.d. stochastic process $q_{i,t} = e^{\varepsilon_{q_i,t}}$.

Aggregate demand for type X_t goods, $X_t = (C_t, I_t)$, is obtained as a CES index of domestically produced

[4] The function $a\left(u_t^k\right)$ is assumed to be strictly increasing and convex, with curvature parameter ψ^k. The utilization rate relates effective to physical capital in a standard fashion, i.e. $K_t^r(i) = K_{t-1}^{p,r}(i) u_t(i)$.

[5] In order to ensure long-run balanced growth, b_t^u is assumed to grow at the labor augmenting productivity growth rate μ.

[6] In the modified UIP adopted in Adolfson et al. (2008) the autoregressive component is not independent on the elasticity to the interest rate differential, and the chosen prior does not allow for a direct emergence of the forward premium puzzle. Compared to the specification adopted in Christiano et al. (2011b), our modified UIP adds the autoregressive component.

and imported goods, such that:

$$X_t = \left[(1-\nu)^{\frac{1}{\eta}} \left(X_t^d \right)^{\frac{\eta-1}{\eta}} + \nu^{\frac{1}{\eta}} \left(X_t^m \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{5}$$

where, from households' cost minimization, $X_t^d \,(1-\nu) \left(\frac{P_t^d}{P_t} \right)^{-\eta} X_t$ and $X_t^m = \nu \left(\frac{P_t^m}{P_t} \right)^{-\eta} X_t$ are, respectively, the aggregate available domestic and foreign produced goods, ν denotes the import share parameter and η is the elasticity of substitution between domestic and imported goods. P_t^d and P_t^m denote the price indexes of domestic and imported goods, respectively, such that:

$$P_t = \left[(1-\nu) \left(P_t^d \right)^{1-\eta} + \nu \left(P_t^m \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{6}$$

From the first order condition (F.O.C.) for consumption, the following consumption Euler equation is obtained:

$$C_t^r - hC_{t-1}^r = \left[\beta R_t \frac{P_t}{P_{t+1}} \frac{(1+\tau_t^c)}{(1+\tau_{t+1}^c)} \frac{\xi_{t+1}^c}{\xi_t^c} \right]^{-\frac{1}{\sigma_c}} \left(C_{t+1}^r - hC_t^r \right) \tag{7}$$

1.1.2 The rule-of-thumb household

Liquidity constrained and unconstrained households have the same number of workers:

$$n_t = n_t^r = n_t^{nr} \tag{8}$$

From the budget constraint of the liquidity constrained household the following consumption equation is obtained:

$$C_t^{nr} = \frac{1}{(1+\tau_t^c)} \left[Tr_t^{nr} + (1-\tau_t^n) \frac{W_t}{P_t} n_t + (1-\tau_t^n) b_t^u (1-n_t) \right] \tag{9}$$

where it is evident that rule-of-thumbers spend all their net income (from labor, government transfers and unemployment benefits) in consumption goods.

1.2 Firms

1.2.1 Intermediate sector

Each intermediate firm (i) operates in a perfectly competitive environment combining private capital public infrastructures and labor. The production technology is as follows:

$$Y_t^i(i) = \xi_t^a \left[\frac{K_{t-1}^g}{\int_0^1 Y_t^i(j)dj} \right]^{\frac{\xi}{1-\xi}} \left[K_t(i) \right]^{\alpha} \left[\mu^t n_t(i) \right]^{(1-\alpha)} \tag{10}$$

where K_t^g is public capital, α and ξ are the private and public capital shares in production, respectively, and $\xi_t^a = \xi_{t-1}^{a^{\rho_{\xi^a}}} e^{\varepsilon_{\xi^a,t}}$ is an AR(1) process defining the evolution of total factor productivity.

The optimizing firm chooses the optimal quantity of capital by solving the following maximization problem:

$$\max_{K_t(i)} P_t^i Y_t^i(i) - R_t^k K_t(i) \quad \text{s.t. (10)}$$

whose re-arranged F.O.C. yields:

$$R_t^k(i) = \alpha P_t^i(i) \frac{Y_t^i(i)}{K_t(i)} \tag{11}$$

where $P_t^i(i)$ is the intermediate sector price index.

Since a fraction ϑ^b of the wage bill $W_t n_t$ is anticipated by borrowing from financial intermediaries, the cost of one unit of labor is $R_t^t W_t$, where:

$$R_t^t(i) = \vartheta^b \left[1 - p_t^{dp}(i)\right] R_t^l(i) + \left(1 - \vartheta^b\right) + d_t^{cp}(i) \tag{12}$$

is the effective interest rate. $p_t^{dp}(i)$ denotes the firm's default probability and $d_t^{cp}(i) = \vartheta^b p_t^{dp}(i) R_t^l(i)$ is the cost of default per unit of borrowed cost of labor.

1.2.2 Final sector: wholesalers and retailers in the domestic, import and export sectors

For expositional convenience, a joint description of the structure of the final good sector, composed of domestic, import and export wholesalers and retailers, is provided.

Domestic wholesale firms buy the homogenous good Y_t^i from domestic intermediate good producers at the price P_t^i, and differentiate the homogeneous product into $Y_t^d(i)$ using a linear technology. Wholesalers sell their goods under monopolistic competition to domestic retailers, who use the differentiated goods $Y_t^d(i)$ to produce the composite final good Y_t^d.

Wholesale firms in the import sector buy the homogenous good Y_t^* from foreign retailers at the foreign price P_t^*, and obtain a differentiated good $Y_t^m(i)$. Wholesale importing firms sell their goods under monopolistic competition to import retailers who use the differentiated goods $Y_t^m(i)$ to produce the composite final good Y_t^m.

Finally, wholesale export firms buy the homogenous good Y_t^d from domestic retailers at the price P_t^d and produce a differentiated good $Y_t^x(i)$ using a linear technology. Wholesalers in the export sector sell their goods under monopolistic competition to export retailers, who use the differentiated goods $Y_t^x(i)$ to produce the composite final good Y_t^x.

We consider a variable demand elasticity in the three sectors, indexed by $k = (d, m, x)$, by assuming a flexible variety aggregator à la Kimball (1995):

$$\left[\int_0^1 G\left(\frac{Y_t^k(i)}{Y_t^k}; \lambda_{p,t}^k\right) di\right] = 1$$

such that the domestic retailers demand function for differentiated goods is:

$$Y_t^k(i) = Y_t^k G'^{-1}\left[\frac{P_t^k(i)}{P_t^k} \varkappa_{p,t}^k\right] \tag{13}$$

where:

$$\varkappa_{p,t}^{k} \equiv \int_{0}^{1} G'\left(\frac{Y_t^k(i)}{Y_t^k}; \lambda_{p,t}^{k}\right) \frac{Y_t^k(i)}{Y_t^k} di$$

The optimization problem of wholesalers firms that are allowed to re-optimize their prices reads:

$$\max_{\widetilde{P}_t^k(i)} E_t \sum_{j=0}^{\infty} \left(\beta \xi_p^k\right)^j \vartheta_{t+j} \left[\widetilde{P}_t^k\left(i\right) X_{t,t+j}^k - MC_{t+j}^k\right] Y_{t+j}^k\left(i\right)$$

$$\text{s.t. (13) and } X_{t,t+j}^k = \begin{cases} 1 & for\ j=0 \\ \Pi_{l=0}^{j}\left(\pi_{t+l-1}^k\right)^{\iota_p^k} \pi_*^{1-\iota_p^k} & for\ s=1,...,\infty \end{cases}$$

where $MC_t^d = P_t^i$, $MC_t^m = e_t P_t^*$ and $MC_t^x = P_t^d / e_t$ are the nominal marginal costs of the domestic, import sector and export sector wholesalers, respectively. The term $\left(\beta \xi_p^k\right)^j \vartheta_{t+j}$ denotes the stochastic discount factor of the firm, where ξ_p^k is the Calvo probability of price adjustment. $\lambda_{p,t}^k = e^{\varepsilon_{p,t}^k}$ are *i.i.d.* stochastic processes defining the time-varying markups[7] and $X_{t,t+j}^k$ denote price indexation functions.

The first order condition for the optimality problem above is given by:

$$E_t \sum_{j=0}^{\infty} \left(\xi_p^k \beta\right)^j \vartheta_{tt+j} Y_{t+j}^k\left(i\right) \left[\widetilde{P}_t^k(i) X_{t,t+j}^k + \left(\widetilde{P}_t^k(i) X_{t,t+j}^k - MC_{t+s}^k(i)\right) \frac{1}{G'^{-1}\left(\nu_t^k\right)} \frac{G'\left(\theta_{t+j}^k\right)}{G''\left(\theta_{t+j}^k\right)}\right] = 0 \qquad (14)$$

where $\theta_t^k = G'^{-1}\left(\nu_t^k\right)$, $\nu_t^k = \frac{P_t^k(i)}{P_t^k} \varkappa_{p,t}^k$, and the aggregate domestic price indexes read:

$$P_t^k = \left(1 - \xi_p^k\right) P_t^k(i) G'^{-1}\left[\frac{P_t^k(i)}{P_t^k} \varkappa_{p,t}^k\right] + \xi_p^k P_{t-1}^k \left(\pi_{t-1}^k\right)^{\iota_p^k} \pi_*^{1-\iota_p^k} G'^{-1}\left[\frac{P_{t-1}^k \left(\pi_{t-1}^k\right)^{\iota_p^k} \pi_*^{1-\iota_p^k}}{P_t^k} \varkappa_{p,t}^k\right] \qquad (15)$$

1.3 Financial sector and default risks

1.3.1 Financial intermediaries and private default risk

In each period t a continuum of monopolistically competitive banks receives deposits $D_t\left(i\right)$ from the households and supplies loans $L_t\left(i\right)$ to banks in the retail sector at the nominal interest rate $R_t^l\left(i\right)$. Retail banks purchase differentiated loans from the monopolistically competitive banks and aggregate them in the single composite loan $L_t = \left[\int_0^1 L_t\left(i\right)^{(\Lambda_t^l - 1)/\Lambda_t^l}\right]^{\Lambda_t^l/(\Lambda_t^l - 1)}$, purchased by the intermediate good producer firms at the interest rate R_t^l for anticipated wage payments $W_t n_t$.The term $\Lambda_{p,t+j}^l$ represents the stochastic loan demand elasticity in the credit sector, which is assumed to follow the AR(1) stochastic process $\Lambda_t^l = \Lambda^{l(1-\rho_\Lambda)} \Lambda_{t-1}^{l(\rho_\Lambda)} e^{\varepsilon_{\Lambda,t}}$.

Intertemporal cost minimization implies that the optimal loan demand is given by $L_t\left(i\right) = \left(R_t^l\left(i\right)/R_t^l\right)^{-\Lambda_t^l} L_t$. At the end of each period, the monopolistically competitive bank pays back the interest-augmented initial de-

[7] We assume i.i.d. mark-up shocks in order to enhance the identifiability of the price equations. For a more in dept explanation of this point, see the estimation section below and Giuli and Tancioni (2012).

posits $R_tD_t(i)$ and ownership profits to households. The representative monopolistically competitive bank maximizes its profit function facing Rotemberg-type costs for adjusting the interest rate on loans:

$$\max_{D_t(i),IB_t,R^l_t} E_t\sum_{s=0}^{\infty}\beta^s\frac{\Lambda_{t+s}P_t}{\Lambda_tP_{t+s}}\left[\left(1-p^{d,p}_t\right)R^l_{t+s}(i)\,L_{t+s}(i)-R_{t+s}D_{t+s}(i)-R_{t+s}IB_{t+s}(i)-\frac{\kappa_b}{2}\left(\frac{R^l_{t+s}(i)}{R^l_{t+s-1}(i)}-1\right)^2L_{t+s}(i)\right] \tag{16}$$

subject to the credit balance sheet constraint:

$$D_{t+s}(i)+IB_{t+s}(i)=L_{t+s}(i)+Q_{t+s}(i)$$

where $IB_t(i)$, $Q_t(i)=\phi^qD_t(i)$ and ϕ^q denote interbank borrowing, the bank amount and the bank ratio of reserves respectively, and κ_b in (16) denotes the Rotemberg adjustment cost parameter.

The observed strong co-movement between government bond and lending rates indicates that the market valuation of sovereign debt assets affects the private sector credit conditions[8]. In order to capture this relation, we assume a non zero default probability in the private sector, described by the following cumulative density function:

$$p^{d,p}_t=\frac{1-\exp\left[-\varphi^{s,p}\left(p^{d,g}_t\right)^{\phi^{s,p}}\right]}{1-\exp\left[-\left\{\varphi^{s,p}+\left(1-p^{d,g}_t\right)^{\phi^{s,p}}\right\}\right]} \tag{17}$$

where $\varphi^{s,p}$ and $\phi^{s,p}$ are the scale and the shape parameters of the private sector default c.d.f., respectively, such that:

$$p^{d,p}_t=\begin{cases}1 & if\quad p^{d,g}_t=1\\ 0 & if\quad p^{d,g}_t=0\end{cases}$$

Equation (17) expresses to which degree the probability of default of sovereign debt $p^{d,g}_t$ spills-over the private sector. Given values for the scale and the shape parameters in (17), our preferred formulation ensures a flexible and accurate representation of the actual relations between private sector credit and government bond spreads emerging in country-specific time series data.

Note that, compared to the formulation adopted in Corsetti et al. (2013), who assume a direct log-linear relation between government and credit rate spreads, we model the underlying relation between the sovereign debt and private sector default probabilities.

From the optimality condition of the monopolistically competitive bank, the following lending rate equation is obtained:

$$R^l_t(i)=\frac{1}{\left(1-p^{d,p}_t\left(1-z^p\digamma\nu_t\right)\right)}\frac{1}{\Lambda^l_t-1}\left[\Lambda^l_tR_t-\kappa_b\left[\left(\frac{R^l_t(i)}{R^l_{t-1}(i)}-1\right)\frac{R^l_t(i)}{R^l_{t-1}(i)}-\beta\frac{P_t\Lambda_{t+1}}{P_{t+1}\Lambda_t}\left(\frac{R^l_{t+1}(i)}{R^l_t(i)}-1\right)\frac{R^l_{t+1}(i)}{R^l_t(i)}\frac{L_{t+1}(i)}{L_t(i)}\right]\right] \tag{18}$$

where z^p is the share of the Gordon's firm value $\digamma\nu_t=\left[p^d_t(i)\,y_t(i)-r^k_tk_t(i)-w_tn_t(i)\right]/\left[r^k_t-(\mu-1)\right]$, determining the Loss Given Default (LGD) $1-z^p\digamma\nu_t$ of the bank in the case of counterparty default[9]. The

[8] Harjes 2011 provides evidence about these spill-over effects.

[9] Instead of considering the standard Gordon's firm value model, we consider the value of the entire production and supply

above expression highlights that, in our setting, the lending rate is determined by the risk free rate, the mark-up and the cost of adjusting the interest rate as in the standard literature considering imperfect credit markets (Gerali et al. 2010, Curdia and Woodford 2010), as well as by the survival rate of the private sector firms and the LGD.

1.3.2 The sovereign default risk

Along the lines of the analysis in Corsetti et al. (2013), we do not model the event of default as the result of a strategic decision (Eaton and Gersovitz 1981 Yue 2010, Arellano 2008, Mendoza and Yue 2012), but relate the sovereign default probability to two fundamental triggers addressed in the literature (Edwards 1986, Manasse and Roubini 2009, De Grauwe and Ji 2013): *i)* the government debt to GDP ratio B_t/Y_t and *ii)* the NFA position to GDP ratio A_t/Y_t. Our preferred specification for the sovereign default probability is defined by the cumulative distribution function:

$$p_t^{d,g} = \left\{1 - \exp\left[-\varphi^{s,g}\left(\lambda_b \frac{B_t}{Y_t} + \lambda_a \frac{A_t^-}{Y_t}\right)\right]\right\}^{\phi^{s,g}} \tag{19}$$

such that, $\frac{\partial p_t^{d,g}}{\partial B_t} > 0$, $\frac{\partial p_t^{d,g}}{\partial A_t} < 0$ and:

$$p_t^{d,g} = \begin{cases} 1 & if \quad \frac{B_t}{Y_t} = +\infty \cap \frac{A_t^-}{Y_t} = +\infty \\ 0 & if \quad \frac{B_t}{Y_t} = \frac{A_t}{Y_t} = 0 \end{cases}$$

where A_t^- is the net foreign indebtedness.

From the optimality condition for deposits and domestic bond holdings, and since $R_t^g = R_t q_t^b$, the following no arbitrage condition must hold:

$$R_t = R_t q_t^b \left[\left(1 - p_{t+1}^{d,g}\right) + z^g p_{t+1}^{d,g}\right] \tag{20}$$

where $z^g = \sigma_z \frac{\phi^i}{\phi^{i*}} \frac{Y}{Y^*}$ is the recovery rate on government bond in the case of sovereign debt default. The parameters ϕ^i and ϕ^{i*} denote the domestic and foreign contribution to a hypothetical international insurance institution (e.g. the IMF) and σ_z is the efficiency parameter defining the relation between contribution and insurance coverage (e.g. the quota of SDRs to the IMF).

Given the positions above and considering the no arbitrage condition (20), the interest rate spread on government bonds reads:

$$q_t^b = \frac{1}{\left[1 - (1 - z^g)\, p_t^{d,g}\right]} \tag{21}$$

where the government bond premium q_t^b emerges as a result of a non zero probability $p_t^{d,g}$ of sovereign debt default.

Note that, aside from the consideration of the net foreign assets position, our preferred specification of the sovereign default risk depart from the one adopted in Corsetti et al. (2013) in two main respects: first,

chain, that is, the value of the intermediate and final sector firm.

we do not consider a fiscal limit, i.e. an upper bound for the debt to GDP ratio, on the grounds that such a limit is neither theoretically nor empirically identifiable. Second, in line with the empirical literature, we consider the debt to GDP *ratio* in the place of the debt *level*, in order to take into account the crucial role of the GDP dynamics in the definition of the sovereign default risk addressed in the literature (Yeyati and Panizza 2011, Mendoza and Yue 2012), relate the analysis more closely to the available empirical literature, addressing the debt to GDP ratio as a fundamental measure of the capacity of the government to service its debt, and consider the evolution of the NFA position to GDP ratio as an additional trigger of sovereign the default probability (Edwards 1986, De Grauwe and Ji 2013). Note also that the consideration of the debt to GDP ratio implies that the size and the sign of the default risk channel crucially depends on the size of the fiscal multipliers. When fiscal multipliers are large, fiscal contractions can lead to transitory but persistent increases in the debt to GDP ratio, activating a default risk channel operating in an opposite - pro-cyclical - direction than predicted.

Figure 1 depicts, for different levels of the debt to GDP ratio and of the sensitivity parameter λ_b, the behavior of the default probability function and of the government bond spread, considering a parameterization which is consistent with the data of the five economies in the analysis. The shape parameter $\phi^{s,g}$ is fixed to a value of 20, whilst the scale parameter $\varphi^{s,g}$ is fixed such that, given an elasticity coefficient $\lambda_b = 0.5$, the observed intersections between the debt to GDP ratio and the government bond spread for each country belong to the default probability surface.

FIGURE 1 about here

It is interesting to note that the second surface denotes a country-specific upper limit in the sovereign debt interest rate spread. Such a limit is the result of the consideration of a ceiling in the service cost of debt, which we assume to be reached for bond interest rate levels (and thus spreads) for which the service cost equals the country-specific value of output. Note that the different ceilings depend exclusively on the different steady state debt to GDP ratios, fixed to the 2012 values, and on the different steady state policy rates[10].

1.4 The labor market

The matching process is described by a standard Cobb-Douglas matching technology:

$$m_t = \sigma_m \upsilon_t^{\sigma_n} u_t^{1-\sigma_n} \tag{22}$$

where σ_m is the matching efficiency parameter, υ_t is the number of vacancies and $u_t = 1 - n_{t-1}$ denotes the unemployment rate once the labor force stock has been normalized to one. The chosen timing in the unemployment relation shows that individuals entering the labor force stock activate their job search immediately, whilst workers that loss their job in t are not able to search for a new one in the same period of the separation event. Given the job filling rate $q_t = m_t/\upsilon_t$ and the job finding rate $s_t = m_t/u_t$, the labor market tightness can equivalently be defined as $\theta_t = \upsilon_t/u_t$ or $\theta_t = s_t/q_t$.

Under the assumption of exogenous separation, the employment law of motion is described by the following

[10] This implies that the variations in the spreads related to the variations in the debt to GDP ratios should be interpreted as temporary variations, consistent with stable steady state debt to GDP ratios.

dynamic equation

$$n_t = (1-\rho)\, n_{t-1} + m_t \tag{23}$$

where ρ is the separation rate.

1.4.1 Workers value functions

Let $W_t(w_t)$ be the worker value of being matched to a job evaluated at the wage w_t and U_t be the value of being unemployed at time t. The value of the employment/unemployment states are the following:

$$W_t(w_t) = (1-\tau_t^n)\frac{w_t}{P_t} - \frac{\chi_t}{\Lambda_t} + \beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left[(1-\rho)\left[\theta_w W_{t+1}(w_t) + (1-\theta_w)W_{t+1}(w_{t+1}^*)\right] + \rho U_{t+1}\right]\right] \tag{24}$$

$$U_t = (1-\tau_t^n)b_t^u + \beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left[s_{t+1}\left(\theta_w W_{t+1}(w_t) + (1-\theta_w)W_{t+1}(w_{t+1}^*)\right) + (1-s_{t+1})U_{t+1}\right]\right] \tag{25}$$

where θ_w is the Calvo parameter defining the probability of being unable to re-optimize the wage in $t+1$, Λ_t is the Lagrange multiplier and w_t^* is the re-optimized wage. From equations (24) and (25) the net value of being employed, i.e. the worker' surplus $W_t(w_t) - U_t$, is obtained.

1.4.2 Firms value functions

Let $J_t(w_t)$ be the asset value of a job evaluated at the wage w_t:

$$J_t(w_t) = (1-\tau_t^p)(\zeta_t - R_t^t\frac{w_t}{P_t^d}) + (1-\rho)\widetilde{\beta}\mu E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left(\theta_w J_{t+1}(w_t) + (1-\theta_w)J_{t+1}(w_{t+1})\right)\right] \tag{26}$$

where P_t^d is the domestic price index, τ_t^p denotes the business profits tax rate and $\zeta_t = (1-\alpha)P_t^i Y_t/n_t$ the marginal productivity of labor.

Given the value of a vacancy:

$$J_t^v = -\kappa + q_t\left[\theta_w J_t(w_{t-1}) + (1-\theta_w)J_t(w_t^*)\right] \tag{27}$$

and imposing the free entry condition, $J_t^v = 0$, the vacancy posting condition is obtained

$$\frac{\kappa}{q_t} = \theta_w J_t(w_{t-1}) + (1-\theta_w)J_t(w_t^*) \tag{28}$$

1.4.3 Nash wage bargaining

Given the the worker' surplus $W_t(w_t) - U_t$, the firm's asset value of a job $J_t(w_t^*)$ and the union's bargaining power ς, the Nash-bargaining solution is given by $\varsigma(1-\tau_t^n)J_t(w_t^*) = (1-\varsigma)\,(1-\tau_t^p)\,[W_t(w_t^*) - U_t]$. Plugging the value functions in the latter equation, the optimal real wage reads:

$$w_t^* = \Theta_t \left[\varsigma\zeta_t + (1-\varsigma)\left(b_t^u + \frac{\chi_t}{\Lambda_t} \right) \right] + \frac{1}{(1-\tau_t^p)} \Theta_t \varsigma (1-\rho) \widetilde{\beta} \mu E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \frac{\kappa}{q_{t+1}} \left(1 - \Xi_t \frac{\Upsilon_{t+1}^n}{\Upsilon_{t+1}^p} \right) \right]$$
$$+\Theta_t \sum_{j=1}^{\infty} \frac{\Lambda_{t+j}}{\Lambda_t} \left((1-\rho)\widetilde{\beta}\mu\gamma_w \right)^j \left\{ (1-\varsigma) E_t \left[\Upsilon_{t+1}^n \left((w_{t+1}^* - w_t^*) - \frac{s_{t+1}}{1-\rho}(w_{t+1}^* - w_t) \right) \right] \right.$$
$$\left. + \varsigma E_t \left[\Upsilon_{t+1}^p \left(R_{t+1}^t \frac{w_{t+1}^*}{p_{t+1}^d} - R_t^t \frac{w_t^*}{p_t^d} \right) - \left(\Upsilon_{t+1}^p - \Xi_t \Upsilon_{t+1}^n \right) \left(R_{t+1}^t \frac{w_{t+1}^*}{p_{t+1}^d} - R_t^t \frac{w_t}{p_t^d} \right) \right] \right\} \quad (29)$$

where we have used the transformations $\Upsilon_t^i = (1-\tau_t^i)/(1-\tau_{t-1}^i)$, for $i = (n, p)$, $\Xi_t = (1-\rho-s_t)/(1-\rho)$, $\Theta_t \equiv 1/\left[1 - \varsigma\left(1 - 1/p_t^d\right)\right]$, $p_t^d = P_t^d/P_t$, and w_t is the average real wage $w_t = [\theta_w w_{t-1} + (1-\theta_w)w_t^*]$. Note that, for $\tau_t^i = 0$ the real wage equation (29) resolves in a standard Nash wage equation (Gertler and Trigari 2009).

1.5 Government policies

1.5.1 The monetary authority

The Central Bank sets the nominal interest rate $R_t \equiv 1 + r_t$ according to a contemporaneous rule considering inflation, output and output growth deviations from the respective steady state values. The policy instrument is adjusted gradually, giving rise to interest rate smoothing:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}} \right)^{\rho^R} \left[\left(\frac{\pi_t}{\overline{\pi}} \right)^{\psi_1} \right]^{1-\rho^R} \left(\frac{Y_t}{Y_{t-1}} \right)^{\psi_2} + \epsilon_t^r \quad (30)$$

where ρ^R defines the degree of interest rate smoothing, ψ_1 and ψ_2 are the feedback coefficients to CPI inflation π_t[11], and output growth, respectively. The stochastic term ϵ_t^r denotes the monetary policy shock, which is assumed to be white noise $\epsilon_t^r = e^{\varepsilon_t^r}$. Similar to money-growth rules, implementation of this policy rule does not require knowledge about the natural rate of interest or of the level of potential output, both of which are unobserved[12].

The fact that the countries being considered in this study all joined a common currency and a centralized monetary policy since 1999 (2001 for Greece) implies that, at the estimation stage, a regime break has to be taken into account. To implement such a structural break, we will consider a permanent observed exogenous shock acting as a multiplicative regime-shift dummy variable on all the three monetary policy coefficients.

[11] CPI inflation is obtained as a weighted average considering domestic and imported price variations, i.e.: $\pi_t = \left[(1-\nu)\left(p_t^d \pi_t^d\right)^{1-\eta} + \nu\left(p_t^m \pi_t^m\right)^{1-\eta} \right]^{\frac{1}{1-\eta}}$.

[12] The hypothesis that the central bank targets trend output instead of the output that would have prevailed in the absence of nominal rigidities has been adopted in the empirical literature (e.g. Del Negro et al. 2007, Adolfson et al. 2007) and is consistent with the main objective of our analysis, which is basically empirical.

1.5.2 The fiscal authority

By expressing government consumption, government transfers, hiring subsidies and unemployment benefits in terms of domestic goods, the government budget constraint in real terms reads:

$$\begin{aligned}
&\frac{P_t^d}{P_t}\left[G_t + I_t^g + (1-\tau_t^n)\, b_t^u\,(1-n_t)\right] + \phi^i Y_t + TR_t + \left[\left(1-p_t^{d,g}\right) + z^g p_t^{d,g}\right]\frac{B_{t-1}}{P_t} + d_t^{c,g}\frac{B_{t-1}}{P_t} \\
= \; &\frac{B_t}{P_t R_t^g} + \tau_t^c C_t + \tau_t^n w_t n_t + \tau_t^k\left[r_t^k u_t^k - a(u_t^k) - \delta\right] K_{t-1}^{p,r} + \tau_t^p\,(\zeta_t - w_t)
\end{aligned}$$

where $d_t^{c,g} = (1-z^g)\, p_t^{d,g}$ is the unit cost of sovereign default, $G_t = G_{t-1}^{\rho_g} Y_t^{(1-\rho_g)\eta_{gy}} D_t^{\eta_{gd}} e^{\varepsilon_{g,t}}$ and $TR_t = TR_{t-1}^{\rho_{tr}} Y_t^{(1-\rho_{tr})\eta_{try}} D_t^{\eta_{trd}} e^{\varepsilon_{tr,t}}$ are the partial adjustment stochastic processes for government expenditures for consumption and transfers, respectively, with D_t denoting the government financial need, and $\varepsilon_{g,t}$, $\varepsilon_{tr,t}$ *i.i.d.* shocks.

The government financial need D_t is the following:

$$\begin{aligned}
D_t \equiv\; &\frac{P_t^d}{P_t}\left[G_t + I_t^g + (1-\tau_t^n)\, b_t^u\,(1-n_t)\right] + \phi^i Y_t + TR_t + \frac{B_{t-1}}{P_t} + \left[\left(1-p_t^{d,g}\right) + z^g p_t^{d,g}\right]\frac{B_{t-1}}{P_t} \\
&+ d_t^{c,g}\frac{B_{t-1}}{P_t} - \tau_t^c C_t - \tau_t^n w_t n_t - \tau_t^k\left[r_t^k u_t^k - a(u_t^k) - \delta\right] K_{t-1}^{p} - \tau_t^p\,(\zeta_t - w_t)
\end{aligned} \tag{31}$$

A fraction ψ_τ of D_t is financed with distortionary taxation on consumption, labor income, capital and on business profits, such that:

$$\psi_\tau\,(D_t - D) = (\tau_t^c - \tau^c)\, C_t + (\tau_t^n - \tau^n)\, w_t n_t + \left(\tau_t^k - \tau^k\right) K_{t-1}^p\left[r_t^k u_t^k - a\left(u_t^k\right) - \delta\right] + (\tau_t^p - \tau^p)\,(\zeta_t - w_t) \tag{32}$$

whilst the remaining fraction is financed by issuing government bonds:

$$\frac{B_t - B}{P_t R_t^g} = (1-\psi_\tau)\,(D_t - D) \tag{33}$$

We assume that the different tax rates are partially adjusted by choosing the vector of government tax instruments $\boldsymbol{\omega} = \left[\omega^c \omega^n \omega^k \omega^p\right]'$, where $\omega^c + \omega^n + \omega^k + \omega^p = 1$.

$$\omega^c \psi_\tau\,(D_t - D) = (\overline{\tau}_t^c - \tau^c)\, C_t \tag{34}$$

$$\omega^n \psi_\tau\,(D_t - D) = (\overline{\tau}_t^n - \tau^n)\, w_t n_t \tag{35}$$

$$\omega^k \psi_\tau\,(D_t - D) = \left(\overline{\tau}_t^k - \tau^k\right)\frac{k_{t-1}^p}{\mu}\left[r_t^k u_t^k - a\left(u_t^k\right) - \delta\right] \tag{36}$$

$$\omega^p \psi_\tau\,(D_t - D) = (\overline{\tau}_t^p - \tau^p)\,(\zeta_t - w_t) \tag{37}$$

where $\overline{\tau}_t^i$, $i = c, n, k, p$, denotes the systematic component on the revenue side, which relates to the stochastic tax rate considering a first order autoregressive stochastic wedge $\eta_t^{\tau^i}$ denoting the discretionary component, such that $\tau_t^i = \overline{\tau}_t^i \eta_t^{\tau^i}$, with $\eta_t^{\tau^i} = \eta_{t-1}^{\tau^i \rho_{\tau^i}} e^{\varepsilon_{\tau^n,t}}$.

An optimal rule is considered for government investment expenditures. The fiscal authority is assumed to choose the public capital stock K_t^g and public investment I_t^g by maximizing the distance between output Y_t and the financial need, i.e.:

$$\begin{aligned} &\max_{K_t^g, I_t^g} E_t \sum_{j=t}^{\infty} \beta^{t+j} \frac{\Lambda_{t+j}}{\Lambda_t} \left[Y_{t+j} - D_{t+j} \right] \\ \text{s.t. } Y_t &= (\xi_t^a)^{(1-\xi)} (K_{t-1}^g)^{\xi} (K_t)^{\alpha(1-\xi)} \left[\mu^t n_t \right]^{(1-\alpha)(1-\xi)} \\ K_t^g &= (1-\delta^g) K_{t-1}^g + q_t^{i^g} \left[1 - S^g(\frac{I_t^g}{I_{t-1}^g}) \right] I_t^g \end{aligned}$$

where δ^g is the public capital depreciation rate and $S^g(\frac{I_t^g}{I_{t-1}^g})$ denotes the government investment adjustment cost function, with curvature parameter ψ^{ig}. The first order conditions for government capital and investment are, respectively:

$$\beta E_t \left[(1-\delta^g) \Lambda_{t+1}^{k^g} q_t^{k^g} + \Lambda_{t+1} \xi (\xi_{t+1}^a)^{(1-\xi)} (K_t^g)^{\xi-1} (K_{t+1})^{\alpha(1-\xi)} \left(\mu^{t+1} n_{t+1} \right)^{(1-\alpha)(1-\xi)} \right] - \Lambda_t^{k^g} = 0$$

$$\beta E_t \left[q_{t+1}^{i^g} \Lambda_{t+1}^{k^g} S^{g\prime}(\frac{I_{t+1}^g}{I_t^g})(\frac{I_{t+1}^g}{I_t^g})^2 \right] + \Lambda_t^{k^g} q_t^{i,g} \left[1 - S^g(\frac{I_t^g}{I_{t-1}^g}) - S^{g\prime}(\frac{I_t^g}{I_{t-1}^g})(\frac{I_t^g}{I_{t-1}^g}) \right] - \frac{P_t^d}{P_t} \Lambda_t = 0$$

where $\Lambda_t^{k^g}$ is the shadow price of government capital and $q_t^{i^g} = q_{t-1}^{i^{g^{\rho_{ig}}}} e^{\varepsilon_{ig,t}}$ is a stochastic process for the government investment-specific shock.

1.6 Model closure

Given the presence of intertemporally optimizing households $j \in [0, 1-\phi^h]$ and of rule-of-thumb households $j \in (1-\phi^h, 1]$, aggregate consumption and government transfers are given by:

$$C_t = \left(1 - \phi^h \right) C_t^r + \phi^h C_t^{nr} \tag{38}$$

and

$$TR_t = \left(1 - \phi^h \right) TR_t^r + \phi^h TR_t^{nr} \tag{39}$$

where, given $d = TR_t^{nr}/TR_t^r$, the fraction of government transfers to Ricardian and non Ricardian households are, respectively: $TR_t^r(i) = \frac{TR_t}{1+\phi^h(d-1)}$ and $TR_t^{nr}(i) = \frac{dTR_t}{1+\phi^h(d-1)}$.

Since only Ricardian households hold bonds and accumulate capital, aggregate variables are related to the vector of Ricardian-specific variables as follows:

$$X_t = \left(1 - \phi^h \right) X_t^r$$

where $X_t = [I_t, K_t^p, K_t, B_t, B_t^*]'$.

Market clearing for the foreign bond market and the final goods market requires that at the equilibrium the following two equations for net foreign assets evolution and aggregate resources are satisfied:

$$\frac{e_t B_{t+1}^*}{\Phi_t R_t^* q_t^{b*}} = e_t P_t^x \left(C_t^x + I_t^x \right) - e_t P_t^* \left(C_t^m + I_t^m \right) + e_t B_t^* \tag{40}$$

and:

$$C_t^d + C_t^x + I_t^d + I_t^x + G_t + I_t^g + \frac{\kappa_b}{2}\left(\frac{R_{t+s}^l(i)}{R_{t+s-1}^l(i)} - 1\right)^2 L_{t+s}(i) \leq Y_t - a\left(u_t^k\right)K_{t-1}^p - \kappa_t \upsilon_t \quad (41)$$

where $C_t^x + I_t^x = \left[\frac{P_t^x}{P_t^*}\right]^{-\eta_*} Y_t^*$ are total exports, with η_* denoting the foreign demand elasticity parameter[13].

The stationary representation of the model is obtained by scaling the real variables with respect to the trending technology process. The scaled model is then log-linearized around the deterministic steady state, taking into account that the presence of a deterministic term in the productivity growth process affects the coefficients of the dynamic equations.

The resulting log-linearized model is composed of 55 structural equations and of 22 shock processes, of which eight are assumed to be first order autoregressive and the remaining 14 are assumed to be *i.i.d.*. The economic relations are described by 67 structural parameters (including the fiscal and monetary policy rules coefficients), whilst the stochastic component of the model is defined by 30 coefficients (22 for the standard deviations of shocks and eight for the autoregressive coefficients)[14].

1.7 The foreign economy

Foreign output (y_t^*), inflation (π_t^*), short and long-term interest rates $\left(r_{s,t}^* \text{ and } r_{b,t}^*, \text{ respectively}\right)$ are exogenous to the variables of the small domestic economy and their evolution is described by a fourth-order structural Bayesian B-VAR, where contemporaneous correlations are defined by the structure of the stochastic component matrix $\mathbf{B}$. Formally:

$$\mathbf{A}(L)\begin{bmatrix} \pi_t^* \\ \Delta y_t^* \\ r_{s,t}^* \\ r_{b,t}^* \end{bmatrix} = \mathbf{B}\begin{bmatrix} \varepsilon_t^{\pi^*} \\ \varepsilon_t^{y^*} \\ \varepsilon_t^{r_s^*} \\ \varepsilon_t^{r_b^*} \end{bmatrix}, \quad \mathbf{A}_0 = \mathbf{I}_4, \quad \boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \mathbf{I}_4) \quad (42)$$

$$\mathbf{B} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}, \quad \mathbf{B}\mathbf{B}' = \boldsymbol{\Omega}$$

The assumptions on the contemporaneous correlations matrix $\mathbf{B}$ are consistent with the hypothesis that output and inflation do not respond contemporaneously to the other shocks in the system (Adolfson et al. 2008)[15], and that the 10-years government bond rate is post-recursive with respect to the short-term interest rate.

[13] At the estimation stage we will also consider an additive stochastic process ϱ_t in the aggregate resources constraint, i.e. a first order autoregressive measurement error $\varrho_t = \varrho_{t-1}^{\rho_\varrho} e^{\varepsilon_{\varrho,t}}$. Such a shock is generally considered in the empirical literature in order to enhance the estimates when these include output and all its components appearing in the model.

[14] We denote as structural parameters those defining preferences, technology, elasticities, real and nominal rigidities in the good and labor markets, as well as the coefficients describing the monetary and fiscal policy reaction rules. The seven autoregressive coefficients are those describing the memory of the technology process around the deterministic trend, of the structural shock on government investments, on exports, the home bias, the uncovered interest parity, the long-term interest rate spread and the memory of a measurement error included in the aggregate constraint.

[15] Consistently with the results in Adolfson and Lindé (2011), the over-identifying restriction that output does not respond contemporaneously to the price shock is not rejected by the data at the standard 5% criterion.

The SVAR system adds four linear stochastic equations to the economic and stochastic relations of the domestic economy model, resulting in a total of 81 equations and 26 shocks.

2 Bayesian estimation

Even considering a particularly large data-set, the rich parameterization of the model precludes the estimation of the entire parameter space, since a subset of this space remains empirically unidentifiable (Canova and Sala 2009, Iskrev 2010a,b, Koop et al. 2011)[16]. For this reason, only the subset of the parameter space that satisfies the theoretical and empirical identification conditions is estimated using the Bayesian method, whilst for the remaining subset we adopt dogmatic priors specified according to the available country-specific evidence and to conventional calibration values.

A Bayesian approach is adopted also for the estimation of the foreign variables SVAR, in this case considering a partially modified Minnesota priors specification approach[17].

2.1 Data issues and measurement equations

To enhance the empirical identification of the widest fraction of the structural parameters space, we use a large set of domestic and foreign quarterly variables to estimate the country-specific models.

Considering the domestic economies, 22 observables are considered: (log differences of) of real per capita GDP[18] $\left(\Delta y_t^{obs}\right)$, consumption $\left(\Delta c_t^{obs}\right)$, investment $\left(\Delta i_t^{obs}\right)$, imports $\left(\Delta m_t^{obs}\right)$, exports$\left(\Delta x_t^{obs}\right)$, the real wage $\left(\Delta w_t^{obs}\right)$, real government expenditures for consumption $\left(\Delta g_t^{obs}\right)$, investment $\left(\Delta i_t^{g,obs}\right)$ and transfers $\left(\Delta tr_t^{obs}\right)$; the tax rate on labor income $\left(\tau_t^{n,obs}\right)$, on business profits $\left(\tau_t^{p,obs}\right)$, on capital $\left(\tau_t^{k,obs}\right)$ and on consumption $\left(\tau_t^{c,obs}\right)$; the unemployment rate $\left(u_t^{obs}\right)$, the (quarterly) rates of change of the price deflators for consumption $\left(\pi_t^{c,obs}\right)$, import $\left(\pi_t^{m,obs}\right)$, export $\left(\pi_t^{x,obs}\right)$ and for the domestic sector $\left(\pi_t^{y,obs}\right)$; the nominal effective exchange rate $\left(e_t^{obs}\right)$, the (quarterly) short-term interest rate, the 10-years government bond rate and the lending rate to non financial corporations $\left(r_{s,t}^{obs}, r_{b,t}^{obs} \text{ and } r_{l,t}^{obs} \text{ respectively}\right)$. All real variables are referred to the base-year 2005.

Considering the variables for the foreign sector, the log difference of real output $\left(y_t^{*,obs}\right)$ is obtained from the real world output index (base-year 2005) and short and long-term interest rates $\left(r_{s,t}^{*,obs} \text{ and } r_{b,t}^{*,obs}\text{, respectively}\right)$ are obtained as weighted averages of the corresponding figures for the US and the EMU area, with weights given by the relative importance of the two economic areas in domestic capital movements. The foreign price deflator $\left(\pi_t^{*,obs}\right)$ is obtained from the real effective exchange rate definition equation using observed data on domestic inflation, the nominal and the real effective exchange rates. A total of 26 variables is thus considered in the country-specific estimates[19].

[16] Even if log-linearized around the deterministic steady state, these structures are in fact characterized by relevant nonlinearities in parameter convolutions, such that the likelihood generated by the model can be uninformative, i.e. multimodal or flat with respect to some parameter values.

[17] The choice of using the Bayesian method for the estimation of the SVAR is based on recent results showing its good properties both within sample and in terms of minimization of the predictive variance of the resulting model (Banbura et al. 2010).

[18] Per capita variables are obtained considering the labor force as the normalizing variable.

[19] To the best of our knowledge, the use of such a high number of observables in the estimates is unprecedented in the literature on empirical DSGE models.

All data are taken from official sources and cover the period 1980:1-2012:4[20]. Real variables of the private domestic sector, their deflators and the nominal short and long-term interest rates are taken from the OECD-Economic Outlook database. Nominal and real effective exchange rate indexes, defined at the base-year 2005, the world real output index (2005 = 100) and the lending rates to nonfinancial corporations are taken from the IMF-International Financial Statistics database. Data for government expenditures and revenues are, for the quarterly frequency (1999 – 2012), from the IMF Government Financial Statistics database and, for the yearly frequency, from the OECD-Tax Statistics database and from the IMF Finance Statistics Yearbook [21].

Before linking the observed variables to the theoretical counterparts, some of the latter are transformed in order to get full consistency with the statistical definitions. In particular, the transformations take into account that, differently from the statistical aggregates, consumption and investment in the theoretical model are composites of domestic and imported goods and output also includes the hiring cost and that related to changes in the capital utilization rate.

Further transformations are needed in order to make the data consistent with the theoretical steady states and in particular with the model property of balanced growth (μ), a theoretical prediction which is not supported by the evidence in all the countries being considered, in particular for export and import shares. More specifically, the positive/negative excess trends in real variables are removed by considering sample deviations from the steady state output growth rate μ in the measurement equations of all the real variables in the system, such that the theory-consistent stationary great ratios are restored.

Formally, considering the vector of real per capita variables $\mathbf{x}'_t = (c_t,\, i_t,\, m_t,\, x_t,\, w_t,\, g_t,\, i^g_t,\, tr_t,\, y^*_t)$, of tax rates $\boldsymbol{\tau}'_t = \left(\tau^n_t,\, \tau^p_t,\, \tau^k_t,\, \tau^c_t\right)$, of inflation rates $\boldsymbol{\pi}'_t = (\pi^c_t,\, \pi^m_t,\, \pi^x_t,\, \pi^y_t,\, \pi^*_t)$, of short-term, bond and lending interest rates $\mathbf{r}'_{s,t} = \left(r_{s,t},\, r^*_{s,t}\right)$, $\mathbf{r}'_{b,t} = \left(r_{b,t},\, r^*_{b,t}\right)$ and $r_{l,t}$, the 26 measurement equations linking the linearized model variables to the respective observables read as follows:

$$\begin{bmatrix} \Delta y^{obs}_t \\ \Delta \mathbf{x}^{obs}_t \\ \boldsymbol{\tau}^{obs}_t \\ u^{obs}_t \\ \boldsymbol{\pi}^{obs}_t \\ \mathbf{r}^{obs}_{s,t} \\ \mathbf{r}^{obs}_{b,t} \\ r^{obs}_{l,t} \\ e^{obs}_t \end{bmatrix} = \begin{bmatrix} \widetilde{y}_t - \widetilde{y}_{t-1} + \log \mu \\ \widetilde{\mathbf{x}}_t - \widetilde{\mathbf{x}}_{t-1} + \log \mu + \log \boldsymbol{\mu}_{xy} \\ \widetilde{\boldsymbol{\tau}}_t + \boldsymbol{\tau} \\ \widetilde{u}_t + u \\ \widetilde{\boldsymbol{\pi}}_t + \log \boldsymbol{\pi} \\ \widetilde{\mathbf{r}}_{s,t} - \log \overline{\boldsymbol{\beta}}^{(.,*)} + \log \boldsymbol{\pi}^{(c,*)} \\ \widetilde{\mathbf{r}}_{b,t} - \log \overline{\boldsymbol{\beta}}^{(.,*)} + \log \boldsymbol{\pi}^{(c,*)} + \mathbf{q}^{b(.,*)} \\ \widetilde{r}_{l,t} - \log \overline{\beta}^{(.,*)} + \log \pi^c + p^{d,p} \\ \widetilde{e}_t + \log e \end{bmatrix} \tag{43}$$

where the coefficients μ_{xy} denote the excess trend (or excess growth rate) of each observed generic real per capita variable in $\mathbf{x}^{obs}_t$ from the real per capita GDP growth rate, μ. $\boldsymbol{\tau}$, $-\log \overline{\boldsymbol{\beta}}$, $\boldsymbol{\pi}$, $\mathbf{q}^b$, $q^{d,p}$ and s denote the (steady state) tax rates, the domestic and foreign real interest rates, the inflation rates, the domestic and

[20] Because of the lack of quarterly time series prior to 1990 for Ireland and to 2000 for Greece, quadratic interpolation methods are applied to yearly observations to obtain the quarterly figures 1980:1-1989:4 and 1980:1-1999:4 for Ireland and Greece, respectively.

[21] Even in this case, since quarterly data are available only after 1999:1, adjustments to changing definitions and quadratic interpolation methods are applied to yearly observations in order to obtain the quarterly frequency for the preceding time span. A detailed description of the data manipulation is provided in a technical appendix of the paper, available upon request from the authors

foreign government bond rate spreads, the lending rate default probability and the nominal effective exchange rate, respectively, and u denotes the steady state unemployment rate.

2.2 Calibrated parameters

Calibrated values are chosen taking into account both sample and extraneous evidence when informative for the theoretical parameters, and conventional values when such information is missing.

We impose 29 dogmatic priors on the 67-dimensional structural parameters space. Absent country-specific information, 17 structural parameters are fixed to common values across countries. These are the steady-state mark-up coefficients λ_p^d, λ_p^m and λ_p^x, fixed to the conventional value of 1.2, consistent with prior demand elasticities for domestic, import and export sector firms equal to 6; the Kimball endogenous demand elasticity parameters κ_ϵ^d, κ_ϵ^m and κ_ϵ^x, fixed to the conventional value of 10 (Eichenbaum and Fisher 2007, Smets and Wouters 2007); the parameter defining the fraction of government transfers to Ricardian and non Ricardian households d, fixed to 1, consistent with an hypothesis of equally distributed transfers; the three parameters defining the partial indexation mechanism for the domestic, import and export sectors , i.e. ι_p^d, ι_p^m and ι_p^x, respectively, all fixed to zero in order to allow for an interpretation of the (observed) frequency of price changes in terms of (theoretical) price re-optimization[22]; the exchange rate sensitivity to the net foreign assets to GDP ratio $\widetilde{\phi}_a$, fixed to the arbitrary small value of 1^{-3}([23]); the private and government capital depreciation rates, δ and δ^g, respectively, both fixed to the conventional value of 0.025; the steady-state mark-up coefficient for the credit sector Λ^l, fixed to the value of 1.025, consistent with a demand elasticity parameter equal to 40; the shape parameter for the government default probability function $\phi^{s,g}$ in (19), fixed to 20 in order to capture the recent observed nonlinear relation between fundamentals and government bond spreads; the scale parameter for the private sector default probability $\varphi^{s,p}$ in (17), fixed to 5 to initialize the estimation of the corresponding shape parameter $\phi^{s,p}$ in a neigborhood of a unit prior value, consistent with the relatively stable relation between the lending and the government bond rate spreads observed in the data; the world contribution to the IMF parameter ϕ^{i*}, fixed to 0.008 according to the observed total SDR (in USD) to world GDP ratio[24].

The remaining 12 dogmatic priors for structural parameters are fixed considering country-specific evidence. These are the trend growth parameter μ, fixed considering the sample growth rate of per capita GDP, the discount factor β, calibrated considering the country-specific trend growth and the average real interest rate, the home bias parameter $(1-\nu)$, fixed according to the country-specific sample evidence on import shares, the separation rate ρ, fixed to the country estimates provided by Hobijn and Sahin (2009), the parameter defining the frequency of wage re-optimization θ_w, fixed to the country estimates provided in Druant et al. (2012), and the parameter defining the unemployment benefit b^u, fixed according to the country-specific replacement rates provided in the OECD-LFS data base (Christoffel et al. 2009). The private capital share α, the matching efficiency parameter σ_m and the labor disutility scale parameter χ are calibrated such that the labor share, the unemployment rate and the job finding rate steady-state values evaluated at the prior parameterization

[22] Under the hypothesis of indexation, prices are changed period by period, ruling out any intepretation of the observed frequencies of price changes in terms of frequencies of price re-optimizations.

[23] Such a small value ensures the satisfaction of the stability conditions (Lundvik 1992, Schmitt-Grohé and Uribe 2001) while minimizing the exchange rate persistence induced by its "technical" relation with the NFA evolution.

[24] We assume full equivalence between the amount of resources devoted to the IMF and SDR quotas.

match the sample counterparts for each country[25]. Considering the country-specific dogmatic priors for the financial sector parameters, the contribution to the IMF parameter ϕ^i is set according to the country SDR quota (in Euro) to GDP ratios, whilst the international insurance efficiency parameters σ_z is fixed such that the debt repayment rate parameter z^g in (*20*) matches the country-specific sample SDR quota. The country-specific scale parameter of the government default probability function $\varphi^{s,g}$ is fixed in the following manner: given the country-specific z^g parameter and the sample government bond rate differential q^b (evaluated with respect to the short-term interest rate), the country-specific government default probability $p^{d,g}$ is obtained from equation (*21*). The latter univocally determines the country-specific scale parameter $\varphi^{s,g}$ from (*19*), given the common shape parameter $\phi^{s,g}$, the sample debt to GDP ratio and a prior value for the government default probability λ_b.

Finally, the coefficients in the system of measurement equations (43), i.e. those in the vector of deviations from GDP trend $\boldsymbol{\mu}_{xy}$, in the vectors of tax rates $\boldsymbol{\tau}$, of inflation rates $\boldsymbol{\pi}$, of domestic and foreign real interest rates and bond rate spreads, $-\log \overline{\boldsymbol{\beta}}$ and $\mathbf{q}_b$, respectively, and the long-run nominal effective exchange rate e, are fixed to the respective sample means.

The seven exclusion restrictions for the identification of the foreign variables' SVAR, i.e. the zero restriction for b_{12}, b_{13}, b_{14}, b_{21}, b_{23}, b_{24} and b_{34} add further seven dogmatic priors. Table 1 summarizes the common and country-specific dogmatic priors adopted in model estimation for the structural parameters.

TABLE 1 ABOUT HERE

2.3 Priors for estimated parameters

The subset of (38) structural model parameters who is not affected by evident identification problems, the 34 coefficients defining the stochastic component (30 for the domestic economy model and 4 for the foreign SVAR) and the 73 coefficients of the SVAR system (nine for the elements of the **B** matrix and 64 for the vector autoregressive component) are estimated with the Bayesian method[26].

Outside the Calvo price parameters, the prior distributions are common across countries and are specified following the standard practice: *i)* the shape of the probability density functions is the gamma and the inverted gamma for parameters theoretically defined over the $\mathbb{R}^+$ range, the beta for parameters defined in a $[0-1]$ range and the normal for priors on parameters theoretically defined over the $\mathbb{R}$ range; *ii)* prior means and standard deviations are defined on the basis of sample information (when available), or considering the results of previous analyses[27]. In order to enhance the estimation of parameters subject to weak empirical identifiability, informative priors are adopted such that a certain degree of curvature in the log-kernel is obtained.

The prior means for the Calvo parameters of the domestic, import and export sectors, (ξ_p^d, ξ_p^d ξ_p^d, respec-

[25] Sample data for the job finding rate are obtained by elaborating the information in the OECD Labor Force Survey data-base series "Unemployment by duration".

[26] Operationally, posterior modes are obtained by maximizing the log-posterior kernel (resulting from the prior distribution and the conditional distribution approximated by the Kalman filter) with respect to the model parameters, and posterior distributions are obtained from the Metropolis-Hastings Monte Carlo Markov chain (MCMC) numerical integration algorithm. Two chains of 500k iterations are considered.

[27] The standard practice of considering results from previous studies is not free of limitations, since the validity domain of prior evidence is not independent of the model being considered.

tively) are specified according to the country-specific micro-evidence provided in Druant et al. (2012)[28], i.e. 0.71 for Greece, 0.75 for Ireland, 0.69 for Portugal and 0.70 for Italy and Spain. Since the available information does not distinguish across sectors, we adopt a relatively high value for the prior standard deviation, equal to 0.1. A weak gamma-distributed prior with mean 1.5 and standard deviation 0.4 is adopted for the import and export Armington elasticities η and η^* (Adolfson et al. 2008, Christiano et al. 2011b).

Considering the modified UIP equation, the autoregressive coefficient $\widetilde{\phi}_s$ is assumed to be beta-distributed with prior mean 0.5 and prior s.d. 0.15, whilst for the country risk adjustment coefficient $\widetilde{\phi}_r$ we basically follow Christiano et al. (2011b), assuming a (more) diffuse gamma distribution with prior mean 1.25 and prior s.d. 0.5.

The private and public investment adjustment cost parameters ψ^i and ψ^{ig} are assumed to be normally distributed around a prior mean of 5 with a prior s.d. of 2.5, and the utilization rate curvature parameter ψ^k is assumed to be beta-distributed with prior mean 0.5 and prior s.d. 0.15 (Christiano et al. 2011b).

Concerning the preference parameters, the consumption curvature parameter σ_c is assumed to be normally-distributed with a prior mean of 2 and a prior s.d. of 0.1, whilst the external habits parameter is assumed to be beta-distributed and centered around 0.8 with a prior s.d. of 0.1. The prior for the fraction of liquidity constrained households is rather diffuse, with mean 0.25 and s.d. 0.10[29].

Considering the labor market-specific parameters, a relatively weak beta-distributed prior with mean 0.5 and s.d. 0.15 is assumed for the matching function share parameter σ_n and the union's relative bargaining power parameter ς. The prior for the hiring cost parameter κ is assumed to be gamma-distributed with mean 0.05 and s.d. 0.01, a prior mean value consistent with a hiring cost to GDP ratio $\frac{\kappa v}{Y}$ close to 1%.

Considering the financial sector parameters defining the government and private sector default probabilities and interest rate spreads, a gamma-distributed prior with mean 0.5 and s.d. 0.25 is adopted for the sensitivity coefficients λ_b and λ_a (to the debt and net foreign assets to GDP ratios, respectively), and the shape parameter for the private sector default probability function $\phi^{s,p}$ is assumed to be normally-distributed with a prior mean of 1 and a prior s.d. of 0.5. These mean values are set jointly with the dogmatic priors on the other financial sector parameters and ensure exact correspondence between the steady state government bond and lending rate spreads and their sample counterparts. The parameter defining the fraction of borrowed wage bill ϑ_b is assumed to be beta-distributed with prior mean 0.5 and s.d. 0.25, whilst the lending rate adjustment cost parameter κ_b is assumed to be gamma-distributed with prior mean 3 and s.d. 1.5 (Gerali et al. 2010). The very diffuse prior distributions adopted for these parameters reflect our imprecise prior opinions, and imply that their posterior estimates will be dominated by the conditional distribution.

Concerning the monetary policy parameters, the interest rate smoothness coefficient ρ^R is assumed to be beta-distributed with prior mean 0.75 and prior s.d. 0.2, the inflation response parameter ψ_1 is assumed to be normally distributed with prior mean 2 and s.d. 0.2, whilst the output growth sensitivity parameter ψ_2 is assumed to be beta-distributed with prior mean (s.d.) of 0.25 (0.1). The three shift parameters accounting for the monetary policy structural break in the smoothness coefficient and in the feedback coefficients are assumed to be normally distributed with zero prior mean and s.d. equal to 0.2.

[28] The Kimball curvature, Calvo and mark-up (or demand elasticity) parameters are not separately identifiable, as testified by the results of preliminary identification checks at the prior values (Iskrev 2010a,b). We adopt the standard practice of fixing the Kimball and mark-up parameters to ensure the empirical identification of the estimated Calvo parameters.

[29] The preference parameters, even if separately identifiable in our setting, are not fully variation-free. The choice of a relatively tight prior for the consumption curvature parameter enhances the identifiability of the other parameters.

Considering the fiscal policy parameters, a beta-distributed prior with mean 0.75 and s.d. 0.15 is adopted for the autoregressive components ρ_{τ^c}, ρ_{τ^n}, ρ_{τ^k} and ρ_{τ^k} in the tax rates partial adjustment equations, and ρ_g, ρ_{tr} in the government consumption and transfers equations, respectively. For the coefficients denoting the sensitivity of these expenditure components to output, η_{gy} and η_{try}, an informative and normally distributed prior with mean 1 and s.d. 0.1 is adopted, consistent with the hypothesis of long-run balanced growth of public expenditures. A weakly informative beta-distributed prior with mean 0.05 and s.d. 0.02 is chosen for the parameters η_{gd} and η_{trd}, defining the sensitivity of public consumption and transfers to the government financial need. The latter prior is equivalent to that chosen for the sensitivity of the tax rates to the financial need ψ_τ, basically following the calibration value adopted in Drautzburg and Uhlig (2011). Finally, a weakly informative beta-distributed prior with mean 0.25 and s.d. 0.10 is adopted for the tax instruments ω^c, ω^n and ω^k, whilst ω^p is restricted to be equal to $1-\left(\omega^c+\omega^n+\omega^k\right)$.

Considering the stochastic component of the models, the prior opinions for the autoregressive coefficients of the seven persistent shock processes (i.e., ρ_{ξ^a}, ρ_{i^g}, $\rho_{\tilde{\phi}}$, ρ_{q_b}, ρ_{ϱ}, ρ_ν and ρ_x) are commonly described by a weakly informative beta-distributed prior with mean 0.75 and s.d. 0.15[30]. For the standard errors of the 26 innovations, we assume a prior mean of 0.01 with two degrees of freedom for all shocks, except those multiplying convolutions of parameters whose values are outside the $\left[10^{-1},\ 10\right]$ range, that are scaled accordingly.

The prior opinions on the estimated structural parameters are summarized in the first column of the result Table 2 (panels a-f).

The elicidation of priors for the foreign variables' SVAR is based on the partially modified Minnesota priors approach (Doan et al. 1984, Litterman 1986, Sims and Zha 1998) suggested by Banbura et al. (2010). Accordingly, priors are specified under the hypothesis of independent AR(1) processes (random walks for variables close to non-stationarity), with prior variabilities decreasing in the power of the lag order of the SVAR i (net of an overall shrinkage parameter λ, calibrated according to the number of variables in the system) and scaled considering the variables' error variance ratios σ_m^2/σ_n^2, the latter approximated by the estimated residuals of univariate autoregressive representations. Formally, the prior moments for the 73 coefficients of the fourth-order SVAR (42) are specified as follows:

$$E\left[(\mathbf{A}_i,\mathbf{B})_{mn}\right]=\begin{array}{l}\vartheta \text{ for } i=1,\ m=n\\ 0 \text{ otherwise}\end{array}\quad,\quad V\left[(\mathbf{A}_i,\mathbf{B})_{mn}\right]=\begin{array}{l}\frac{\lambda^2}{i^2} \text{ for } m=n\\ \frac{\lambda^2}{i^2}\frac{\sigma_m^2}{\sigma_n^2} \text{ otherwise}\end{array} \tag{44}$$

where the values for the first-order autoregressive coefficients ϑ are obtained from the estimates of independent AR(1) processes.

2.4 Posterior mean estimates

Table 2 summarizes the priors and the posterior mean estimates. Panels *a*-*b*-*c*-*d* consider the model economy, the financial sector, the monetary policy and the fiscal policy parameters, respectively. Panels *e* and *f* report the estimates of the 34 parameters defining the persistence and the size of the 26 exogenous stochastic

[30]The autoregressive coefficients ρ_ν and ρ_x denote the persisitency of the stochastic component in the import and export equations, respectively. Analitically, the first component defines a stochastic home bias parameter, and the second a stochastic elasticity of substitution between foreign and domestic goods. The two stochastic components enter the log-linear representation of the model additively, such that they do not influence the empirical identifiability of the preference parameters.

components, respectively[31].

According to the estimated posterior mode standard deviations and the implied pseudo t-values, the structural parameter estimates, aside from ϑ_b, all appear significant for each of the countries being considered. The exogenous innovations are all significant according to their standard errors and a relevant degree of autocorrelation is obtained for the subset of autoregressive processes.

The posterior mean values for the model economy parameters are generally close to the respective modal values and indicate reasonable estimates based on our prior opinions and results in the literature. Evident exceptions are the unconventionally high posterior estimates obtained for the private and public capital adjustment cost parameters ψ^i and ψ^{ig}, on average more than the double of the prior mean values, implying milder investment and capital responses than those obtainable under standard calibration values. Furthermore, the curvature parameter for the capital utilization rate ψ^k is estimated to be very high and distant from the prior in all countries. These results imply slow adjustments on both the investment and the capital utilization sides, thus - other things being equal - high persistence in model dynamics.

TABLE 2a ABOUT HERE

A relevant degree of cross-country heterogeneity is obtained with respect to the parameter defining the fraction of liquidity constrained households ϕ^h, that are quite high for Portugal (0.49), basically in line with the EZ estimates in Coenen and Straub (2005) and Forni et al. (2009) for Italy (0.36), Ireland (0.24) and Spain (0.24) and quite low for Greece (0.13). These differences are expected to affect the size of the fiscal multipliers, since a higher degree of rule-of-thumb behavior is reflected in a more direct link between current income and private consumption, i.e. in the breakdown of Ricardian equivalence (Galí et al. 2007).

The posterior mean estimates of the Calvo parameters in the domestic, import and export sectors, ξ_p^d, ξ_p^m and ξ_p^x, respectively, are generally higher than the prior opinions based on survey evidence and the conventional values used in the literature. This result basically reflects the flat slope of the NKPCs, which is more pronounced than that implied by the joint consideration of the Calvo frequency micro-estimates and of the conventional calibration values for the mark-up (or demand elasticity) parameters[32].

The estimated Armington elasticity η, and in particular η^*, are generally smaller than the prior and denote a differentiated pattern across countries. A similar consideration holds true for the risk premium parameter $\widetilde{\phi}_r$, which is estimated to be slightly above unit only for Spain and Italy, thus ruling out a direct emergence of the forward premium puzzle in the remaining countries.

The labor market parameters show a certain degree of variability across countries, particularly for the union's relative bargaining power parameter ς, estimated to be higher than the conventional value of 0.5 for all countries except Italy (0.34). The posterior mean estimates for the hiring cost parameter κ and the

[31] Mode checks and multivariate M-H convergence plots signal that the estimation process performs correctly for all countries. The mode estimates intersect the log posterior kernel at its maximum for all parameters. The multivariate diagnostics signal that the estimates are stable both within (over replications) and particularly between chains. Posterior densities confirm these encouraging indications, signaling a close to normal shape and a reasonable distance from prior densities (or a more concentrated distribution), signalling that the estimated parameters are empirically identified. These results are available upon request from the authors.

[32] For the countries considered in this study, the introduction of endogenous demand elasticities does not solve the micro-macro dichotomy in the estimate of the NKPC slope coefficients (Eichenbaum and Fisher 2007).

matching function share parameter σ_n are not distant from priors, except for the former parameter in the case of Ireland ($\kappa = 0.032$).

TABLE 2b ABOUT HERE

Concerning the financial sector parameters, the coefficient capturing the elasticity of the government default probability to the debt to GDP ratio λ_b is estimated to be well above the prior in all countries, ranging from a minimum of 0.66 for Spain to a maximum of 1.64 for Portugal. The elasticity to the net foreign assets to GDP ratio λ_a is on average smaller and more in line with the prior, ranging from a minimum of 0.31 for Greece to a maximum of 0.62 for Spain. The estimated shape parameter of private sector default probability function is more homogeneous across countries and on average twice the prior size. A high degree of heterogeneity is estimated for the lending rate adjustment cost parameter κ^b, ranging from a minimum of 1.13 for Portugal to a maximum of 21.5 for Spain. An evaluation of the elasticity of the government and private sector default probabilities (thus of the government bond and lending rate spreads) to the debt and net foreign assets to GDP ratios cannot be directly obtained from these parameters. Table 3 reports the expected variation in the government bond and lending rate spreads consistent with a 20 percentage points temporary increase in the debt to GDP ratio and in the net foreign assets to GDP ratio in the different countries.

TABLE 3 ABOUT HERE

TABLE 2c ABOUT HERE

Considering the estimated monetary policy coefficients adjusted for the break implied by the shift to the single currency, a low degree of policy activism emerges. The size of the policy rate response to inflation ψ_1 is low in all countries, ranging from a minimum of 1.05 for Spain to a maximum of 1.28 for Portugal, whilst the output growth response coefficient ψ_2 ranges from a minimum of 0.05 for Greece to a maximum of 0.12 for Italy. Joint with the estimated high degrees of inertial behavior (the coefficient ρ^R is always well above 0.8), these results indicate a particularly mild monetary policy response to variations in inflation and output, potentially dampening its counter-cyclical effects under standard fiscal expansions.

It is interesting to note that the posterior estimates of the three shift parameters accounting for the monetary policy structural break are negative in all countries being considered, signalling that the shift to a common currency and a centralized authority targeting average EZ inflation and output has implied a reduced degree of monetary policy activism with respect to the single economies' macroeconomic developments[33].

TABLE 2d ABOUT HERE

Finally, the posterior estimates for the fiscal policy coefficients confirm the high degree of inertia on both the expenditure and the revenue sides, with estimated autoregressive coefficients well above the conventional

[33] Detailed results on the monetary policy break estimates are reported in a technical appendix available upon request from the authors.

calibration value of 0.9 (Perotti 2005). It is interesting to note that the posterior estimates for the parameter denoting the sensitivity of the tax rates to the government financial need ψ_τ, even if low and distant from the prior, are basically consistent with the Galì and Perotti (2003) estimates for OECD countries. interestingly, the estimated sensitivities of government consumption and transfers to the financial need (η_{gd} and η_{trd}, respectively) are on average higher and more heterogeneous across countries, with a minimum size close to 0.01 for Ireland and a maximum size close to 0.08 for Greece. The parameter defining the link between long-run expenditure and output levels (η_{gy} and η_{try}) are always not significantly different from unity, such that the hypothesis of balanced growth in the fiscal variables, for the sample being considered, cannot be rejected.

TABLE 2e ABOUT HERE

TABLE 2f ABOUT HERE

3 Policy simulations

In this section we provide a comparative analysis of the country-specific expected effects from the implementation of five financially equivalent contractionary fiscal policies: *i)* a persistent, albeit not permanent, reduction in government consumption; *ii)* an equally persistent reduction in government transfers; *iii)* a reduction in government investment; *iv)* a generalized increase of indirect tax rates (on labor incomes, business profits and capital gains); *v)* an increase in the consumption tax rate. These policies are evaluated by simulating the model stochastically (thus assuming that they are unanticipated) and considering the parameterization obtained at the country-specific posterior mean estimates.

The different simulations are made comparable by calibrating the size of each policy shock to be equivalent to a 1% of GDP on impact and by homogenizing their persistence considering a common memory coefficient of 0.75, consistent with a one year average duration of the policy shock.

By construction, each policy measure implies government budget and debt variations, thus changes in the tax rates and in the structure of public expenditure. However,in order to enhance the understanding of the simulation results, we only consider the estimated systematic components in the revenue equations, i.e., the specific elasticity of the tax rates to the financial need, whilst the expenditure side is assumed to be fully exogenous by setting the elasticities of the expenditure components to the financial need and to GDP to zero.

The policy simulations are performed assuming both a standard environment, i.e. one in which the monetary policy reacts to inflation and output growth deviations from target according to the estimated values of the Taylor rule feedback coefficients, and a recessionary environment in which the economies are operating in a liquidity trap. To implement such a scenario, we calibrate a negative preference shock implying an eight-quarters period non positive equilibrium interest rate for each country, and impose the zero-lower-bound (ZLB) condition.

3.1 Government purchase and direct tax shocks: into the mechanics of the risk channel

Before discussing the results of the specific austerity measures, it is worth providing some details on the dynamics activated by two alternative policy interventions on expenditure and revenues, i.e. a 1% GDP negative government consumption shock and a 1% GDP positive shock to direct taxes (on labor income, business profits and capital gains), depicted in Figures 2 and 3, respectively. The latter multiple shock is obtained considering that the the 1% GDP fiscal contraction is obtained by increasing the specific tax rates according to the estimated policy instruments weights ω^i, $i = n, p, k$.

To clarify the functioning of the transmission mechanics under the hypothesis of a default risk channel, the 20 quarters ahead impulse responses of GDP, the debt level, of the debt to GDP ratio, of the NFA evolution and of the government bond and lending rate spreads are reported. These are normalized such that the GDP response has an interpretation in terms of the dynamic monetary fiscal multiplier (i.e. the expected monetary variation in GDP from a one euro budget variation), the debt to GDP ratio response depicts the deviation from its steady state in terms of GDP percentage points, and the responses of the spreads refer to annualized basic points.

FIGURE 2 ABOUT HERE

Considering the government consumption contraction, a first outcome that merits to be highlighted is the modest variability of the output response across countries, reflecting the low sensitivity of the dynamic multiplier of this measure to the heterogeneity in the estimated parameterization. This is due to the fact that government purchases affect output mainly directly, inducing only second-round effects on price and wage dynamics. The peak response is negative and reached on impact, and denotes a monetary multiplier ranging from values slightly above 1 for Greece, Italy and Spain, to 1.35 for Portugal and above 1.8 for Ireland. These results are fully consistent with the available average European estimates (Coenen and Straub 2005, Forni et al. 2009), and highlight the role played by the degree of activism of the centralized monetary policy, which is estimated to be low in all the peripheral economies in the analysis[34].

In the standard times scenario, there are no evident signals of the operation of a sovereign debt channel, since the size of the country-specific multipliers are basically aligned with those obtainable from equally parameterized country models in which the default risk channel effects are eliminated.

As expected, the fiscal contraction leads to a reduction in the bond level in all countries, signalling that the positive response of government expenditure, due to the rise in unemployment benefits payments, and the negative response of revenues, due to the tax rate cuts implicit to their endogenous specification, are not sufficient to reverse the positive effects of the fiscal contraction on the level of debt.

However, since the fiscal contraction leads to a more than proportional decrease in output, the debt to GDP ratio temporarily increases in all the PIIGS countries, with a dynamic pattern which is substantially dominated by the negative output response. The highest increase of the debt ratio, close to 1.7% of GDP, is obtained on impact for Ireland, consistently with the negative output response; the smallest, close to 0.45%

[34] A common result of monetary models is that they are geneally unable to replicate the SVAR-based evidence on the size of fiscal multipliers, since the standard calibration of monetay policy reaction rules impies an high degree of sterilization of the inflationary and growth-enancing effects of fiscal expansions. This is not the case with our estimated model.

of GDP, is obtained on impact for Spain. Conditional to our model and to the estimated parameterization, fiscal austerity plans implemented with government purchase cuts are thus expected to be self-defeating in the short-term.

In line with the expectations, the NFA response is positive in all countries, with evident cross-country heterogeneity. The effects are stronger in Ireland and Portugal, consistent with the deeper output contraction and, in the case of Ireland, with the higher estimated elasticity coefficient of imports, leading to even deeper reductions in imported goods.

The moderate but positive response of both the interest rate spreads in all countries signals that the improved NFA position relative to GDP is not enough in couterbalancing the pressure on sovereign default risk due to the increase in the debt to GDP ratio. In other terms, the size of the elasticity of default risk and thus of the bond spread to the variation in the debt to GDP ratio is high enough to dominate the counteracting effects implicit in the improvement in the NFA positions.

These results signal that, conditional to a negative government consumption shock, the default risk channel operates in the opposite direction than predicted in the analysis of Corsetti et al. (2013). Moreover, the size of the interest rate spreads response is very limited, signalling that, according to our model estimates, the default risk channel is basically irrelevant. Aside from the role played by the estimated small size of the elasticity of default risk to the macroeconomic fundamentals, the main responsible for these results is the consideration of the debt to GDP ratio in the place of the debt level, whose response to a fiscal contraction is positive for sufficiently large fiscal multipliers.

The effects of a contractionary direct taxes shock are only qualitatively similar to those obtained considering a financially equivalent government consumption reduction. The fiscal contraction has negative and persistent effects on real output for all countries, even if the implicit peak multipliers are substantially smaller than those obtained with the government purchase shock, a result which is basically in line with the abundant SVAR-based empirical literature on fiscal multipliers since the seminal analysis of Blanchard and Perotti (2002). Moreover, the output dynamic multiplier is heterogeneous across countries, mainly because of the different fractions of liquidity constrained households estimated in the different countries. The fraction of rule-of-thumb households is in fact estimated to be particularly low for Greece, reflecting the low correlation between private consumption and current net incomes in the sample. Considering the recent evolution of the Greek economy, it is highly probable that the fraction of liquidity constrained households increased strongly. We have verified that, by including a dummy variable controlling for the recessionary periods, the estimated degree of liquidity constraints increases by nearly 18 percentage points for Greece.

Following the tax rates shock, the debt level decreases temporarily in all countries but Ireland, partly because of the higher unemployment response and the resulting increase in unemployment benefit payments. As a result of the debt and the GDP dynamics, a moderate but persistent surge in their ratio emerges.

Even in the case of a revenue-based fiscal contraction, our results indicate that the hypothesis of expansionary fiscal contractions is not empirically relevant, such that the implementation of austerity plans can be self-defeating in the short to medium term, and that the hypothesis of a sovereign risk channel, if effective, operates in the opposite direction when evaluated conditional to fiscal shocks.

It is interesting to note that, under the tax-based fiscal contraction, the positive response of the net foreign asset position obtained in all countries is always significantly larger than that obtained under the expenditure-based contraction, despite the smaller drop in economic activity. This implies that the response of imports is much stronger, a result signalling that the tax reduction induces a significant variation in the relative price of the domestic production, i.e. a real exchange rate devaluation. The internal devaluation is triggered by the increased tax pressure, implying an immediate contraction of the after tax incomes and of the consumption expenditures of liquidity-constrained households. Even if the resulting decrease in labor supply tends to counterbalance the deflationary pressure, the latter tends to prevail.

Concerning the effects of the fiscal retrenchment on the sovereign default probability on bond and lending rate spreads, the impulse responses clearly show that the contractionary tax policy, similarly to the contractionary expenditure policy, stimulates a moderate increase in the government bond and lending rate spreads.

Two key indications from the analysis of the conditional dynamics emerge: *first*, the relation between sovereign debt, net foreign position and interest rate spreads is rather weak in all the peripheral EZ economies considered in the study, such that the recent surge in government bond and lending rate premia in these countries should be mainly attributed to idiosyncratic factors only loosely related with macroeconomic fundamentals (De Grauwe and Ji 2013); *second*, the hypothesis that - when monetary policy is unconstrained - a sovereign risk channel can mitigate the contractionary effects of fiscal consolidations or even - in a liquidity trap constrained regime - lead to an economic expansion, is not empirically supported when considering a short to medium term perspective, since fiscal contractions are temporarily but persistently self-defeating, irrespective of the policy instrument being considered.

The explanation for the different results of our analysis as compared to those in Corsetti et al. (2013) relies heavily on the measure of indebtness considered in the definition of the default probability. The use of the debt level basically constrains the direction of change of the default probability to the one of the policy. The use of the debt to GDP ratio, which is generally accepted as a more appropriate measure of fiscal fragility, does not impose such a restriction and highlights the role of the size of the fiscal multipliers, determining the direction of the variation in the debt to GDP ratio and thus of the default probability.

3.2 Fiscal contractions in unconstrained and constrained monetary policy regimes

The relative efficacy of alternative fiscal measures in different countries depends both on the different degrees of nominal and wage rigidity and on the potentially different interaction between fiscal and monetary policy regimes.

Considering a fiscal retrenchment, an aggressive monetary policy response is expected to reduce the contractionary output response, given the counteracting effects on consumption and investments of the interest rate drop that follows the induced deflation.

In a situation in which the monetary policy response is particularly loose, or constrained by the presence of a binding ZLB, a restrictive and thus deflationary fiscal policy cannot be accommodated by the automatic response of the monetary authority, since the nominal interest rate cannot be reduced further. As a result, the induced deflation is entirely translated into increased real interest rates, that further depress internal demand and economic activity. In these circumstances, that characterize the present economic environment of most EZ peripheral countries, fiscal multipliers are likely to be maximized (Christiano et al. 2011a, Eggertsson 2011, Eggertsson and Krugman 2012) and fiscal retrenchments can hardly resolve in an economic expansion.

The consideration of a sovereign risk channel mainly operating through the dynamics of the debt to GDP ratio reinforces the latter result, provided that the fiscal contraction's negative effects on output - maximized in a constrained monetary policy regime - lead to the increase of the debt to GDP ratio and thus of the bond and lending rate spreads. The key factor in the sign of the propagation mechanics activated by the presence of a sovereign risk channel is, even in the constrained regime, the size of the fiscal multipliers. Note that their relevance, aside from extreme cases in which the systematic component in the government budget is strongly counter-cyclical, is ruled out when considering that the default probability depends of the evolution of the debt level.

Table 4 compares the peak monetary multipliers of alternative contractionary fiscal policies in both the constrained and the unconstrained monetary policy regimes. Considering a fiscal retrenchment implemented through government consumption cuts, the simulation results indicate that, in all the countries considered in the analysis, the contractionary effects are maximized on impact in the unconstrained regime and one quarter later when the ZLB binds. In the latter case, the fiscal multiplier is significantly increased, ranging from a minimum value close to 1.7 for Greece to a maximum close to 2.6 for Ireland. The country-specific fiscal multipliers of government transfers are much smaller and heterogeneous than those of government consumption, and tend to increase in the constrained monetary policy regime.

Following an equivalent contraction in public transfers, the smallest negative output effect is expected for Greece, given a peak multiplier close to 0.08 in the unconstrained regime and to 0.12 when the ZLB binds, whilst the highest effects are expected for Portugal, provided that the peak multiplier is close to 0.41 in normal times and 0.52 in the liquidity trap regime. The heterogeneity of results basically reflects the different fractions of liquidity constrained households being estimated for the different economies, as a higher degree of rule of thumb behavior implies a closer link with after tax and transfers incomes.

Considering the fiscal multipliers of government investment-based fiscal retrenchments, the simulations signals that the peak effects are expected to realize only after $5-6$ periods, consistent with the estimated high public investment adjustment costs and the logic of public capital accumulation, and that the negative effects on output are smaller than those expected for an equivalent government consumption cut. The implicit fiscal multipliers range from a minimum of 0.35 for Italy in the unconstrained regime to a maximum of 0.77 for Portugal, even in this case reached in the standard times regime. Interestingly, the simulations signal that when the binding ZLB regime leads to a modest increase of the fiscal multipliers only in the case of Italy (0.38) and Spain (0.43), whilst for the other countries a significant drop in size is obtained.

Similar results hold true in all countries for the implicit fiscal multipliers of direct and indirect tax increases. In both cases, the simulation results indicate that, in the monetary policy constrained regime, the multipliers tend to be smaller than in the unconstrained regime. This result is particularly evident in the case of the direct income taxation, for which the lowest normal times fiscal multiplier, obtained for Greece, is halved in the constrained regime (from 0.12 to 0.06), as it is for the highest, obtained for Portugal (from 0.38 to 0.18).

Considering the consumption tax increase, the contraction in fiscal multipliers observed in the binding ZLB environment is on average less strong, except for Portugal, for which the implicit fiscal multiplier changes from a value of 0.28 in the unconstrained regime to a value of 0.14 in the constrained regime.

The economic reason for such a result is that, in the constrained regime, fiscal contractions based on government investment cuts and on tax increases lead to a counteracting inflationary pressure, reducing the increase of the real interest rate that would obtain given the deflation and the fixed policy rate. A public investment cut affects both the demand and the supply sides of the economy, activating a deflationary pressure because of decreased demand, and an inflationary pressure because of decreased supply, thus of increased marginal costs. Our results indicate that the latter effect is high enough to reduce the rise in the response of real interest rate for Greece, Ireland and Portugal, downsizing the implicit fiscal multipliers accordingly. A similar line of reasoning holds also for a general tax increase which, by reducing the after tax incomes, leads to both decreased demand in the fraction of liquidity constrained households and to decreased labor supply, the latter activating a counteracting inflationary pressure in wages, thus in marginal costs and prices. In the constrained regime the latter effect tends to prevail in all countries, and the resulting reduction in the real interest rate response leads to a generalized contraction of the tax multipliers.

On this respect, our empirical results are only marginally consistent with those obtained by Eggertsson (2011), showing that, in a liquidity trap environment, tax cuts can lead to an output contraction[35]. Our results, emerging in an extended structural model setting estimated on country data show that, for the economies considered in this analysis, the transmission mechanics addressed by Eggertsson (2011) is at work, but its strength is not sufficient to reverse the sign of the tax multiplier. As a consequence, the direction in which the default risk channel produces its (modest) effects, continue to be procyclical, i.e. opposite to the one predicted by Corsetti et al. (2013).

4 Conclusions

We develop, estimate and simulate a model characterized by government bond and lending rate spreads originating in the sovereign default risk triggered by internal and foreign debt positions. The consideration of an endogenous default risk channel introduces interesting elements for the conduct of fiscal policy in highly indebted economies, especially when the economy is stuck at the ZLB. In principle, for increasing levels of debt and for small sized fiscal multipliers, a fiscal retrenchment can even be expansionary, given the induced reduction in the domestic and foreign debt positions, triggering a reduction in sovereign and private default risk and thus of the interest rate spreads.

The analysis, developed at the country-level for a selection of peripheral EZ economies (the PIIGS), is based on the simulation of the country-specific responses to financially equivalent contractionary fiscal policies affecting government expenditure and revenues.

Results show that, contrary to some conclusions in the recent literature addressing the role of the sovereign risk channel in determining the size and the sign of the fiscal multipliers, the default risk channel can at best be only marginally effective, since the (unconditional) relation between sovereign debts, net foreign positions and interest rate spreads is rather weak in all the peripheral EZ economies considered in the study.

Furthermore, conditional to fiscal retrenchments, the default risk channel operates in the opposite direction than predicted, since sovereign default risk tends to increase in all the economies being considered, such that the size of the Keynesian multiplier is amplified by the operation of this risk channel. Fiscal contractions lead to temporary but persistent increases in the debt to GDP ratio, hence to rising sovereign and private default probabilities and interest rate spreads. The improvement in the NFA position to GDP ratio, emerging after

[35] Eggertsson (2011) obtain this result in a simplified model setting assuming full Ricardian equivalence. A similar result is obtained by Beqiraj and Tancioni (2014) with an extended estimated model considering rule of thumb behavior in a fraction of househlds. In his comment to the Eggertsson's (2011) paper, Christiano (2011) provides some useful insights and identifies two major ingredients for the deflationary pressure to emerge following a tax cut: *i)* the persistence of the deflationary pressure, i.e. the presence of relevant price rigidities; *ii)* the sensitivity of expenditures to the real interest rate, i.e. the empirical relevance of the Euler consumption equation.

the implementation of the contractionary fiscal policy in all the countries considered in the analysis, is not sufficient to stimulate a reduction in default probabilities and spreads to an extent such that the former effects can be reversed.

Two are the key factors responsible for these results. First, since the estimated elasticity of the observed sovereign risk (spreads) to macroeconomic fundamentals is weak, the variations in bond and lending rates resulting from variations in the degree of fragility of domestic and foreign debt positions cannot be of first order. Second, since the estimated degree of activism of monetary policy is low, the size of the fiscal multipliers is relatively high, such that - jointly with the operation of the systematic component of fiscal policy, fiscal contractions lead to increased the debt to GDP ratios in all the countries considered in the analysis.

The consideration of a liquidity trap environment reinforces our conclusions, since the implicit multipliers of government expenditure are generally increased, whilst the reduction observed for those of government revenues is not sufficient to generate an inversion in the sign of the response of the debt to GDP ratios, ruling out the activation of the counter-cyclical effects from the sovereign default risk channel.

The moderate differences in results observed in the constrained and unconstrained regimes are due to a lack of coordination between fiscal and monetary policy, a result that, according to our country estimates, is not entirely specific to the liquidity trap environment.

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TABLE 1 - DOGMATIC PRIORS: STRUCTURAL PARAMETERS

Parameter	Description	Greece	Ireland	Italy	Portugal	Spain
β	Discount factor	0.994	0.997	0.996	0.998	0.995
α	Production function parameter	0.265	0.220	0.333	0.210	0.220
δ	Capital depreciation rate	0.025	0.025	0.025	0.025	0.025
δ^g	Government capital depreciation rate	0.025	0.025	0.025	0.025	0.025
ν	Import share	0.206	0.656	0.210	0.262	0.202
ρ	Separation rate	0.028	0.042	0.021	0.039	0.061
σ_m	Matching efficiency	0.910	0.200	0.950	0.500	1.500
χ	Labor disutility scale	0.100	1.000	4.000	0.200	0.600
b^u	Unemployment benefit	0.650	0.650	0.630	0.720	0.610
θ_w	Renegotiation wage frequency	0.750	0.800	0.850	0.770	0.750
λ_p^i	Price markups	1.200	1.200	1.200	1.200	1.200
κ_ϵ^i	Demand elasticity	10.00	10.00	10.00	10.00	10.00
ι_p^i	Price indixation	0.000	0.000	0.000	0.000	0.000
μ	Growth rate	0.999	1.007	1.002	1.003	1.002
$\widetilde{\phi}_a$	Exchange rate elasticity to net asset	0.001	0.001	0.001	0.001	0.001
d	Relative government transfers share	1.000	1.000	1.000	1.000	1.000
Λ^l	Interest rate markups	1.025	1.025	1.025	1.025	1.025
$\phi^{s,g}$	Sovreign default shape parameter	20.00	20.00	20.00	20.00	20.00
$\varphi^{s,g}$	Sovreign default scale parameter	0.490	0.565	0.509	0.614	0.759
$\varphi^{s,p}$	Private. default shape parameter	5.000	5.000	5.000	5.000	5.000
ϕ^i	Domestic insurance contribution	0.027	0.022	0.013	0.023	0.011
ϕ^{i*}	Foreign insurance contribution	0.008	0.008	0.008	0.008	0.008
σ_z	Contribution efficiency	0.228	0.621	0.560	0.340	0.461

Notes: The parameters related to "great ratios" and other observable quantities related to steady state values are calibrated considering that the time unit is a quarter. The sector specific parameters denoted by i = d, m, x are assumed to be of equal value.

TABLE 2*a* - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: MODEL ECONOMY

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ξ_p^d	$\mathcal{G}$	$0.69-0.75^*$	0.933	0.892	0.879	0.848	0.924
		(0.10)	[0.927 – 0.939]	[0.875 – 0.911]	[0.870 – 0.888]	[0.832 – 0.865]	[0.916 – 0.933]
ξ_p^m	$\mathcal{G}$	$0.69-0.75^*$	0.856	0.878	0.848	0.925	0.789
		(0.10)	[0.819 – 0.899]	[0.843 – 0.913]	[0.816 – 0.883]	[0.903 – 0.948]	[0.753 – 0.824]
ξ_p^x	$\mathcal{G}$	$0.69-0.75^*$	0.821	0.843	0.820	0.875	0.901
		(0.10)	[0.784 – 0.860]	[0.805 – 0.886]	[0.774 – 0.878]	[0.842 – 0.915]	[0.895 – 0.906]
σ_c	$\mathcal{N}$	2.00	2.074	2.012	1.909	2.024	2.078
		(0.10)	[1.919 – 2.227]	[1.843 – 2.178]	[1.774 – 2.048]	[1.858 – 2.193]	[1.923 – 2.240]
h	$\mathcal{B}$	0.70	0.828	0.905	0.818	0.910	0.845
		(0.10)	[0.791 – 0.866]	[0.872 – 0.940]	[0.784 – 0.853]	[0.876 – 0.941]	[0.814 – 0.877]
ϕ^h	$\mathcal{B}$	0.25	0.127	0.239	0.358	0.490	0.238
		(0.10)	[0.081 – 0.174]	[0.119 – 0.360]	[0.276 – 0.443]	[0.377 – 0.598]	[0.165 – 0.311]
η	$\mathcal{G}$	1.50	1.050	1.514	0.445	0.601	1.092
		(0.40)	[0.865 – 1.218]	[0.855 – 2.167]	[0.313 – 0.580]	[0.438 – 0.764]	[0.914 – 1.273]
η^*	$\mathcal{G}$	1.50	0.526	0.826	0.852	0.527	0.607
		(0.40)	[0.400 – 0.658]	[0.651 – 0.998]	[0.748 – 0.955]	[0.409 – 0.647]	[0.469 – 0.736]
$\widetilde{\phi}_s$	$\mathcal{B}$	0.50	0.827	0.834	0.942	0.883	0.960
		(0.15)	[0.725 – 0.954]	[0.694 – 0.957]	[0.904 – 0.981]	[0.836 – 0.934]	[0.934 – 0.986]
$\widetilde{\phi}_r$	$\mathcal{G}$	1.25	0.948	0.878	1.010	0.886	1.247
		(0.50)	[0.885 – 1.002]	[0.778 – 0.970]	[0.964 – 1.057]	[0.841 – 0.923]	[1.097 – 1.396]
ψ^i	$\mathcal{N}$	5.00	13.04	12.40	11.37	10.80	10.89
		(2.50)	[10.14 – 15.90]	[10.01 – 14.82]	[9.389 – 13.33]	[8.669 – 12.95]	[8.65 – 13.20]
ψ^{ig}	$\mathcal{N}$	5.00	12.30	15.43	15.11	6.765	13.96
		(2.50)	[9.380 – 15.08]	[12.66 – 18.26]	[12.57 – 17.55]	[4.275 – 9.413]	[11.33 – 16.53]
ψ^k	$\mathcal{B}$	0.50	0.987	0.645	0.970	0.972	0.949
		(0.15)	[0.979 – 0.996]	[0.608 – 0.683]	[0.958 – 0.982]	[0.953 – 0.992]	[0.921 – 0.976]
σ_n	$\mathcal{B}$	0.50	0.553	0.571	0.525	0.584	0.501
		(0.10)	[0.447 – 0.671]	[0.427 – 0.707]	[0.373 – 0.690]	[0.450 – 0.712]	[0.332 – 0.662]
ς	$\mathcal{B}$	0.50	0.658	0.780	0.337	0.628	0.571
		(0.10)	[0.582 – 0.736]	[0.720 – 0.841]	[0.245 – 0.426]	[0.559 – 0.706]	[0.484 – 0.660]
κ	$\mathcal{G}$	0.05	0.041	0.034	0.047	0.043	0.050
		(0.01)	[0.028 – 0.055]	[0.024 – 0.044]	[0.032 – 0.062]	[0.032 – 0.056]	[0.034 – 0.065]

Notes: N and B are Normal and Beta distributions, respectively. Posterior mean estimates for the model economy parameters are obtained with 250000 M-H replications on two parallel chains. * denotes the range of values for the country-specific values Druant et al. (2012).

TABLE 2*b* - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: FINANCIAL SECTOR

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ϑ_b	$\mathcal{B}$	0.50	0.201	0.218	0.037	0.270	0.027
		(0.20)	[0.002 − 0.452]	[0.001 − 0.475]	[0.000 − 0.081]	[0.007 − 0.533]	[0.000 − 0.050]
λ_b	$\mathcal{G}$	0.50	1.093	1.627	1.295	1.643	0.664
		(0.25)	[0.668 − 1.502]	[1.153 − 2.079]	[0.823 − 1.765]	[1.219 − 2.061]	[0.363 − 0.961]
λ_a	$\mathcal{G}$	0.50	0.311	0.428	0.429	0.462	0.618
		(0.25)	[0.050 − 0.535]	[0.098 − 0.748]	[0.080 − 0.766]	[0.119 − 0.782]	[0.262 − 0.963]
$\phi^{s,p}$	$\mathcal{N}$	1.00	1.957	1.933	1.959	2.106	1.733
		(0.50)	[1.678 − 2.235]	[1.604 − 2.263]	[1.611 − 2.292]	[1.778 − 2.420]	[1.402 − 2.063]
κ_b	$\mathcal{G}$	3.00	3.389	1.516	5.782	1.131	21.55
		(1.50)	[0.500 − 6.382]	[0.240 − 2.853]	[1.665 − 9.695]	[0.421 − 1.798]	[18.87 − 23.77]

Notes: B, G and N are Beta, Gamma and Normal distributions, respectively. Posterior mean estimates for the financial sector parameters are obtained with 250000 M-H replications on two parallel chains.

TABLE 2*c* - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: MONETARY AUTHORITY

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ρ^R	$\mathcal{B}$	0.75	0.844	0.900	0.884	0.879	0.877
		(0.20)	[0.825 − 0.865]	[0.879 − 0.922]	[0.869 − 0.898]	[0.861 − 0.896]	[0.863 − 0.891]
ψ_1	$\mathcal{N}$	2.00	1.174	1.220	1.115	1.279	1.045
		(0.20)	[1.129 − 1.222]	[1.099 − 1.334]	[1.053 − 1.173]	[1.203 − 1.351]	[1.019 − 1.072]
ψ_2	$\mathcal{B}$	0.10	0.051	0.052	0.123	0.055	0.134
		(0.05)	[0.024 − 0.081]	[0.027 − 0.075]	[0.094 − 0.149]	[0.033 − 0.076]	[0.105 − 0.163]

Notes: B and N are Beta and Normal distributions, respectively. Posterior mean estimates for the monetary authority parameters are obtained with 250000 M-H replications on two parallel chains.

TABLE $2d$ - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: FISCAL AUTHORITY

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ω^c	$\mathcal{B}$	0.25	0.392	0.550	0.223	0.423	0.484
		(0.10)	[0.274 – 0.516]	[0.427 – 0.675]	[0.144 – 0.307]	[0.318 – 0.528]	[0.380 – 0.585]
ω^n	$\mathcal{B}$	0.25	0.604	0.244	0.703	0.580	0.477
		(0.10)	[0.478 – 0.720]	[0.130 – 0.363]	[0.600 – 0.812]	[0.459 – 0.701]	[0.370 – 0.581]
ω^k	$\mathcal{B}$	0.25	0.007	0.205	0.031	0.001	0.008
		(0.10)	[0.003 – 0.011]	[0.096 – 0.309]	[0.010 – 0.051]	[0.000 – 0.001]	[0.003 – 0.012]
ψ_τ	$\mathcal{B}$	0.05	0.013	0.012	0.013	0.019	0.013
		(0.02)	[0.009 – 0.016]	[0.008 – 0.016]	[0.010 – 0.016]	[0.012 – 0.026]	[0.010 – 0.015]
ρ_{τ^c}	$\mathcal{B}$	0.75	0.969	0.977	0.955	0.953	0.979
		(0.15)	[0.944 – 0.995]	[0.961 – 0.995]	[0.919 – 0.991]	[0.918 – 0.987]	[0.963 – 0.996]
ρ_{τ^n}	$\mathcal{B}$	0.75	0.986	0.989	0.988	0.988	0.964
		(0.15)	[0.974 – 0.997]	[0.981 – 0.998]	[0.979 – 0.998]	[0.978 – 0.999]	[0.940 – 0.990]
ρ_{τ^k}	$\mathcal{B}$	0.75	0.975	0.981	0.978	0.987	0.981
		(0.15)	[0.956 – 0.994]	[0.969 – 0.994]	[0.959 – 0.997]	[0.977 – 0.999]	[0.968 – 0.995]
ρ_{τ^p}	$\mathcal{B}$	0.75	0.977	0.972	0.961	0.992	0.970
		(0.15)	[0.960 – 0.995]	[0.951 – 0.993]	[0.931 – 0.993]	[0.985 – 0.999]	[0.947 – 0.993]
ρ_g	$\mathcal{B}$	0.75	0.924	0.958	0.960	0.976	0.981
		(0.15)	[0.881 – 0.966]	[0.932 – 0.982]	[0.931 – 0.991]	[0.959 – 0.995]	[0.966 – 0.998]
ρ_{tr}	$\mathcal{B}$	0.75	0.974	0.973	0.971	0.916	0.984
		(0.15)	[0.953 – 0.995]	[0.960 – 0.986]	[0.953 – 0.990]	[0.870 – 0.960]	[0.971 – 0.999]
η_{gy}	$\mathcal{N}$	1.00	0.927	0.974	1.035	1.038	1.044
		(0.10)	[0.770 – 1.081]	[0.808 – 1.137]	[0.873 – 1.203]	[0.868 – 1.199]	[0.871 – 1.219]
η_{try}	$\mathcal{N}$	1.00	0.999	1.016	1.027	1.022	1.034
		(0.10)	[0.826 – 1.152]	[0.849 – 1.185]	[0.862 – 1.192]	[0.864 – 1.190]	[0.870 – 1.194]
η_{gd}	$\mathcal{B}$	0.05	0.032	0.020	0.020	0.021	0.011
		(0.02)	[0.013 – 0.049]	[0.009 – 0.030]	[0.012 – 0.028]	[0.010 – 0.031]	[0.007 – 0.016]
η_{trd}	$\mathcal{B}$	0.05	0.078	0.063	0.019	0.023	0.017
		(0.02)	[0.041 – 0.114]	[0.048 – 0.077]	[0.012 – 0.026]	[0.011 – 0.034]	[0.010 – 0.023]

Notes: N and B are Normal and Beta distributions, respectively. Posterior mean estimates for the fiscal authority parameters are obtained with 250000 M-H replications on two parallel chains.

TABLE 2e - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: AR(1) COEFICIENTS OF SHOCKS

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ρ_{ξ^a}	$\mathcal{B}$	0.75	0.994	0.942	0.912	0.936	0.924
		(0.15)	[0.989 − 0.999]	[0.926 − 0.960]	[0.895 − 0.930]	[0.914 − 0.957]	[0.910 − 0.938]
ρ_{i^g}	$\mathcal{B}$	0.75	0.904	0.778	0.154	0.193	0.804
		(0.15)	[0.855 − 0.951]	[0.758 − 0.797]	[0.059 − 0.245]	[0.084 − 0.294]	[0.734 − 0.876]
$\rho_{\tilde{\phi}}$	$\mathcal{B}$	0.75	0.736	0.837	0.890	0.982	0.915
		(0.15)	[0.332 − 0.926]	[0.776 − 0.901]	[0.865 − 0.916]	[0.973 − 0.993]	[0.889 − 0.940]
ρ_{q_b}	$\mathcal{B}$	0.75	0.947	0.953	0.906	0.925	0.923
		(0.15)	[0.915 − 0.984]	[0.923 − 0.982]	[0.878 − 0.935]	[0.894 − 0.958]	[0.895 − 0.952]
ρ_{ϱ}	$\mathcal{B}$	0.75	0.933	0.995	0.911	0.955	0.934
		(0.15)	[0.891 − 0.999]	[0.990 − 0.999]	[0.886 − 0.936]	[0.925 − 0.989]	[0.915 − 0.953]
ρ_{ν}	$\mathcal{B}$	0.75	0.966	0.973	0.910	0.943	0.945
		(0.15)	[0.948 − 0.987]	[0.951 − 0.994]	[0.885 − 0.936]	[0.901 − 0.985]	[0.926 − 0.965]
ρ_{x}	$\mathcal{B}$	0.75	0.973	0.982	0.894	0.940	0.904
		(0.15)	[0.965 − 0.983]	[0.968 − 0.996]	[0.866 − 0.923]	[0.888 − 0.989]	[0.880 − 0.927]
ρ_{Λ^l}	$\mathcal{B}$	0.50	0.631	0.863	0.593	0.905	0.840
		(0.20)	[0.520 − 0.742]	[0.799 − 0.932]	[0.473 − 0.718]	[0.860 − 0.953]	[0.780 − 0.917]

Notes: B represent the Beta distributions. Posterior mean estimates for the AR(1) coeficients of shocks are obtained with 250000 M-H replications on two parallel chains.

TABLE 2f - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: S.D. OF SHOCK PROCESSES

	Prior distribution		Posterior mean				
	Density	Mean	Greece	Ireland	Italy	Portugal	Spain
		(s.d.)	[c.i.]	[c.i.]	[c.i.]	[c.i.]	[c.i.]
$\varepsilon_{\tau^n,t}$	$\mathcal{G}^{-1}$	0.01	0.008	0.003	0.005	0.006	0.003
		(2.00)	[0.007 − 0.008]	[0.003 − 0.004]	[0.004 − 0.005]	[0.006 − 0.007]	[0.003 − 0.004]
$\varepsilon_{\tau^p,t}$	$\mathcal{G}^{-1}$	0.01	0.003	0.003	0.003	0.002	0.004
		(2.00)	[0.002 − 0.003]	[0.003 − 0.004]	[0.003 − 0.003]	[0.002 − 0.003]	[0.004 − 0.004]
$\varepsilon_{\tau^k,t}$	$\mathcal{G}^{-1}$	0.01	0.004	0.019	0.007	0.001	0.004
		(2.00)	[0.004 − 0.005]	[0.017 − 0.021]	[0.006 − 0.008]	[0.001 − 0.001]	[0.003 − 0.004]
$\varepsilon_{\tau^c,t}$	$\mathcal{G}^{-1}$	0.01	0.004	0.005	0.002	0.004	0.004
		(2.00)	[0.003 − 0.004]	[0.004 − 0.005]	[0.002 − 0.002]	[0.004 − 0.005]	[0.003 − 0.004]
$\varepsilon_{g,t}$	$\mathcal{G}^{-1}$	0.01	0.025	0.028	0.019	0.024	0.011
		(2.00)	[0.022 − 0.027]	[0.025 − 0.031]	[0.017 − 0.021]	[0.021 − 0.026]	[0.010 − 0.012]
$\varepsilon_{tr,t}$	$\mathcal{G}^{-1}$	0.01	0.079	0.027	0.014	0.021	0.013
		(2.00)	[0.071 − 0.087]	[0.024 − 0.030]	[0.012 − 0.015]	[0.019 − 0.023]	[0.011 − 0.014]
$\varepsilon_{i^g,t}$	$\mathcal{G}^{-1}$	0.1	0.112	0.198	0.994	0.787	0.124
		(2.00)	[0.088 − 0.133]	[0.164 − 0.231]	[0.822 − 1.157]	[0.477 − 1.094]	[0.092 − 0.155]
$\varepsilon_{\xi^a,t}$	$\mathcal{G}^{-1}$	0.01	0.012	0.019	0.010	0.013	0.009
		(2.00)	[0.010 − 0.013]	[0.016 − 0.021]	[0.009 − 0.011]	[0.011 − 0.015]	[0.008 − 0.010]
$\varepsilon_{r,t}$	$\mathcal{G}^{-1}$	0.01	0.003	0.004	0.002	0.002	0.003
		(2.00)	[0.003 − 0.003]	[0.004 − 0.005]	[0.002 − 0.002]	[0.002 − 0.002]	[0.003 − 0.003]
$\varepsilon^d_{p,t}$	$\mathcal{G}^{-1}$	0.50	7.185	2.747	1.309	0.735	2.836
		(2.00)	[5.873 − 8.433]	[1.815 − 3.668]	[1.086 − 1.530]	[0.555 − 0.918]	[2.128 − 3.520]
$\varepsilon^m_{p,t}$	$\mathcal{G}^{-1}$	0.5	3.605	1.744	2.789	12.42	1.565
		(2.00)	[1.749 − 5.686]	[0.739 − 2.655]	[1.535 − 3.923]	[5.287 − 19.68]	[1.019 − 2.082]
$\varepsilon^x_{p,t}$	$\mathcal{G}^{-1}$	0.5	2.998	2.002	1.814	3.048	1.096
		(2.00)	[1.717 − 4.252]	[0.960 − 3.160]	[0.818 − 3.004]	[1.412 − 5.025]	[0.740 − 1.441]
$\varepsilon_{q_b,t}$	$\mathcal{G}^{-1}$	0.01	0.004	0.004	0.002	0.002	0.002
		(2.00)	[0.003 − 0.004]	[0.003 − 0.004]	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.003]
$\varepsilon_{q_i,t}$	$\mathcal{G}^{-1}$	0.5	0.284	0.855	0.208	0.320	0.269
		(2.00)	[0.218 − 0.343]	[0.682 − 1.021]	[0.170 − 0.245]	[0.252 − 0.385]	[0.214 − 0.326]
$\varepsilon_{\widetilde{\phi},t}$	$\mathcal{G}^{-1}$	0.01	0.007	0.003	0.003	0.001	0.002
		(2.00)	[0.002 − 0.016]	[0.002 − 0.004]	[0.002 − 0.003]	[0.000 − 0.001]	[0.002 − 0.003]

Notes: G represent the Gamma distributions. Posterior mean estimates for the standard deviation.of shock processes are obtained with 250000 M-H replications on two parallel chains.

TABLE 2f - (CONTINUED)

	Prior distribution		Posterior mean				
	Density	Mean	Greece	Ireland	Italy	Portugal	Spain
		(s.d.)	[c.i.]	[c.i.]	[c.i.]	[c.i.]	[c.i.]
$\varepsilon_{\xi^c,t}$	$\mathcal{G}^{-1}$	0.01	0.185	0.337	0.122	0.423	0.112
		(2.00)	[0.136 − 0.231]	[0.219 − 0.451]	[0.093 − 0.151]	[0.258 − 0.591]	[0.084 − 0.140]
$\varepsilon_{\xi^n,t}$	$\mathcal{G}^{-1}$	0.01	0.061	0.043	0.013	0.033	0.025
		(2.00)	[0.051 − 0.071]	[0.033 − 0.053]	[0.011 − 0.015]	[0.028 − 0.038]	[0.021 − 0.029]
$\varepsilon_{x,t}$	$\mathcal{G}^{-1}$	0.01	0.037	0.026	0.030	0.024	0.035
		(2.00)	[0.033 − 0.041]	[0.023 − 0.028]	[0.027 − 0.033]	[0.021 − 0.027]	[0.031 − 0.039]
$\varepsilon_{cpi,t}$	$\mathcal{G}^{-1}$	0.01	0.010	0.011	0.007	0.005	0.012
		(2.00)	[0.009 − 0.011]	[0.010 − 0.012]	[0.006 − 0.008]	[0.004 − 0.005]	[0.011 − 0.013]
$\varepsilon_{\nu,t}$	$\mathcal{G}^{-1}$	0.01	0.028	0.032	0.028	0.021	0.033
		(2.00)	[0.025 − 0.031]	[0.028 − 0.035]	[0.025 − 0.031]	[0.019 − 0.024]	[0.029 − 0.037]
$\varepsilon_{\varrho,t}$	$\mathcal{G}^{-1}$	0.01	0.010	0.013	0.007	0.007	0.009
		(2.00)	[0.009 − 0.011]	[0.011 − 0.014]	[0.007 − 0.008]	[0.006 − 0.008]	[0.008 − 0.010]
$\varepsilon^*_{dp,t}$	$\mathcal{G}^{-1}$	0.005	0.006	0.006	0.006	0.006	0.006
		(2.00)	[0.006 − 0.007]	[0.006 − 0.007]	[0.006 − 0.007]	[0.006 − 0.007]	[0.006 − 0.007]
$\varepsilon^*_{y,t}$	$\mathcal{G}^{-1}$	0.005	0.006	0.006	0.006	0.006	0.006
		(2.00)	[0.005 − 0.006]	[0.005 − 0.006]	[0.005 − 0.006]	[0.005 − 0.006]	[0.005 − 0.006]
$\varepsilon^*_{r,t}$	$\mathcal{G}^{-1}$	0.005	0.002	0.002	0.002	0.002	0.002
		(2.00)	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.002]
$\varepsilon^*_{rl,t}$	$\mathcal{G}^{-1}$	0.005	0.001	0.001	0.001	0.001	0.001
		(2.00)	[0.001 − 0.001]	[0.001 − 0.001]	[0.001 − 0.001]	[0.001 − 0.001]	[0.001 − 0.001]
$\varepsilon_{\Lambda^l,t}$	$\mathcal{G}^{-1}$	0.01	0.133	0.184	0.068	0.103	0.079
		(2.00)	[0.117 − 0.149]	[0.164 − 0.204]	[0.059 − 0.077]	[0.092 − 0.114]	[0.071 − 0.088]

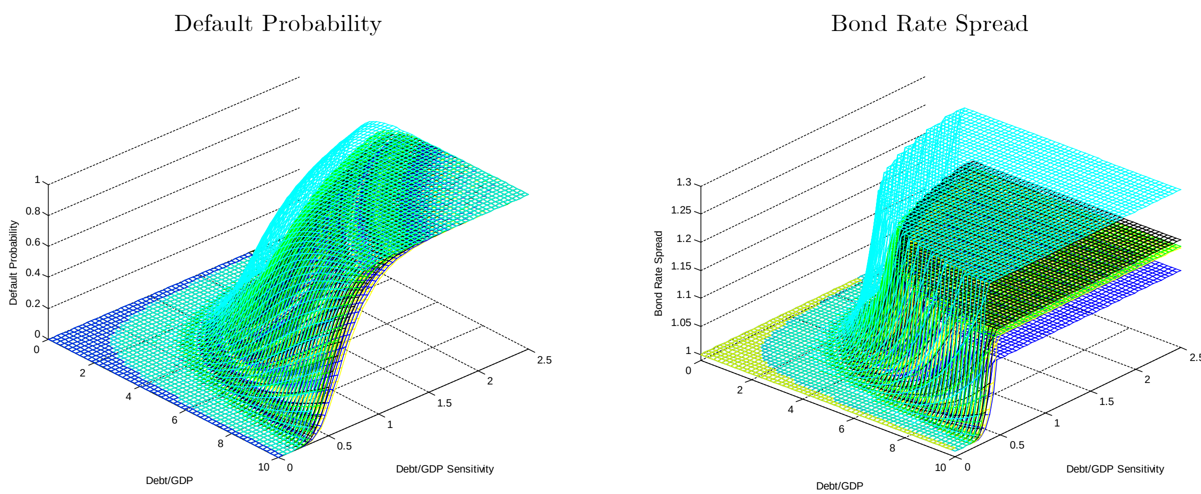
Notes: G represent the Gamma distributions. Posterior mean estimates for the standard deviation.of shock processes are obtained with 250000 M-H replications on two parallel chains.

TABLE 3 - EXPECTED INCREASE IN BOND AND LENDING SPREADS - in basis points

20% Increase in	Spread on	Greece	Ireland	Italy	Portugal	Spain
$\frac{B_t}{Yt}$	r_t^g	213.0	19.6	36.9	39.8	85.4
$\frac{A_t^-}{Yt}$	r_t^g	5.6	1.1	2.3	2.2	23.6
$\frac{B_t}{Yt}$	r_t^l	14.0	1.4	0.6	1.3	1.4
$\frac{A_t^-}{Yt}$	r_t^l	0.4	0.1	0.0	0.1	0.4

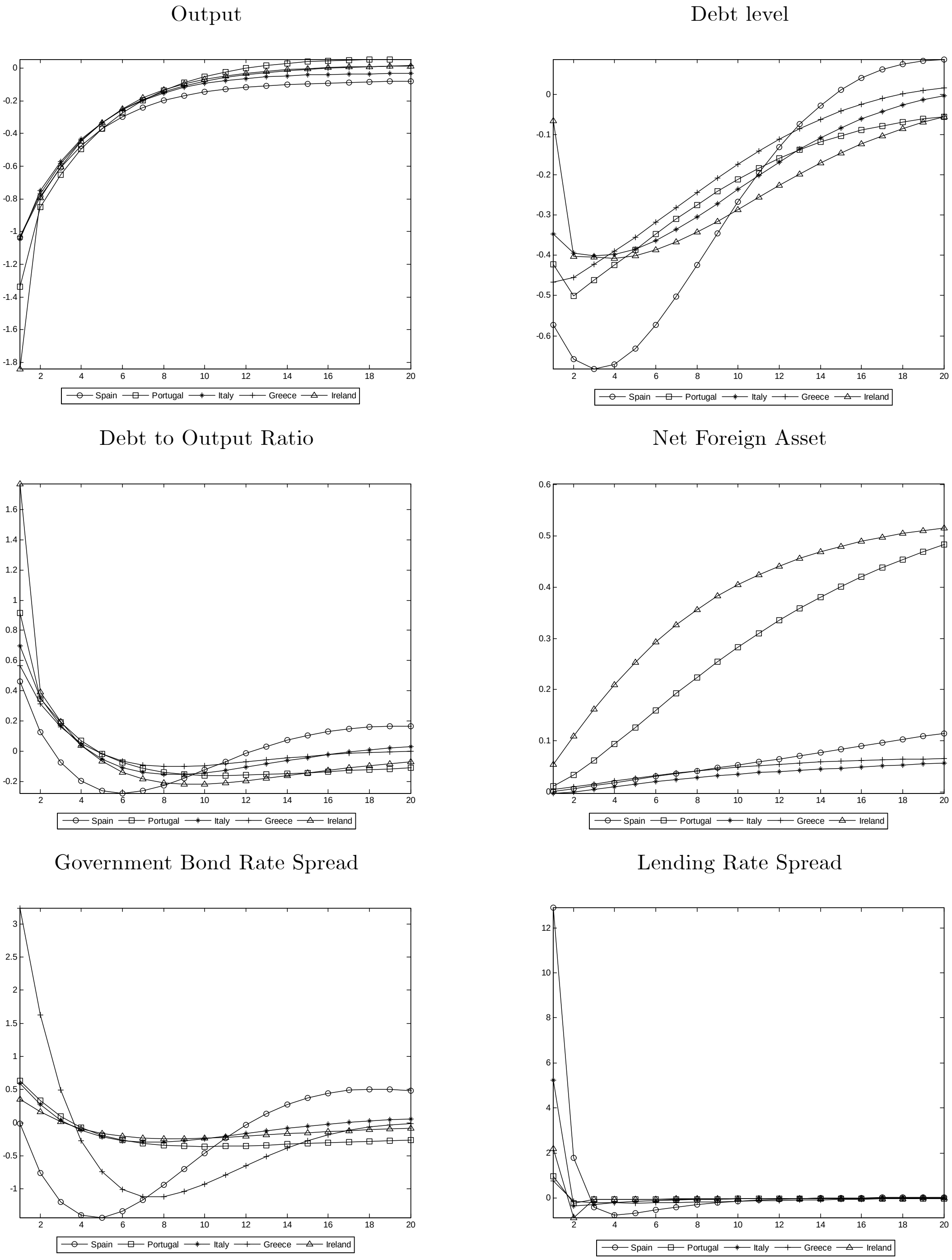
Notes: Interest rate spread are expressed in basis points. The lending rate spread does not consider the mark-up.

FIGURE 1 - DEBT/GDP RATIO, SENSITIVITY PARAMETER, DEFAULT RISK AND BOND RATE SPREAD



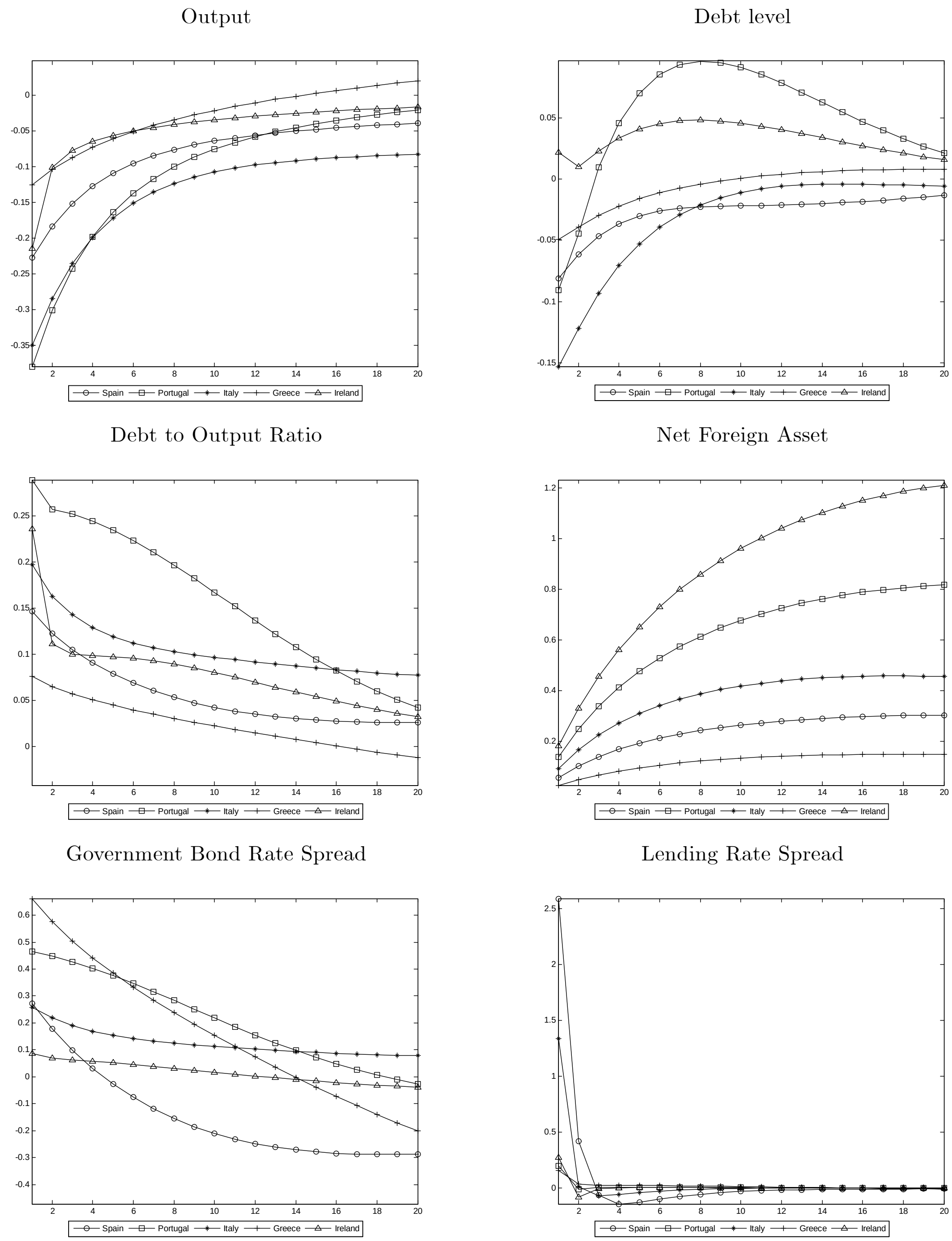
Notes: In the figure the value of the sovreign default probability and interest rate spreads on government bonds are reported.The latter consider a fiscal ceiling based on a maximum value of the service cost equal to the value of output. The black line represent Ireland, the blue Greece, the cylan Spain, green Portugal and yellow Italy. For all the periphery countries fiscal stance binds before default occurs.

FIGURE 2 - RESPONSE TO A 1% GDP GOVERNMENT CONSUMPTION CONTRACTION



Notes: Impulse response of output (Y_t), bond (B_t), bond to output ratio (B_t/Y_t), net foreign asset (A_t),net foreign asset to output ratio (A_t/Y_t), government interest rate spread ($R_t^g - R_t$) and lending interest rate spread ($R_t^l - R_t$) to a one percent GDP government expenditure contraction in the periphery of the eurozone obtained at the posterior mean estimate. Government and lending interest rate spreads are expressed in basis points.

FIGURE 3 - RESPONSE TO A 1% GDP DIRECT TAX INCREASE



Notes: Impulse response of output (Y_t), bond (B_t), bond to output ratio (B_t/Y_t), net foreign asset (A_t),net foreign asset to output ratio (A_t/Y_t), government interest rate spread ($R_t^g - R_t$) and lending interest rate spread ($R_t^l - R_t$) to a one percent GDP direct taxes increase, such as enterprise, capital and labor income tax increases in the periphery of the eurozone obtained at the posterior mean estimate. Government and lending interest rate spreads are expressed in basis points.

TABLE 4 - PEAK FISCAL MULTIPLIERS (quarter) - STANDARD TIMES AND ZLB

Instrument	Multiplier	Greece	Ireland	Italy	Portugal	Spain
Gov. consumption	Stardard Times	1.03 (1)	1.84 (1)	1.05 (1)	1.34 (1)	1.03 (1)
	ZLB	1.75 (2)	2.65 (2)	1.79 (2)	2.39 (2)	1.91 (2)
Gov. transfers	Stardard Times	0.08 (1)	0.12 (1)	0.27 (1)	0.41 (1)	0.17 (1)
	ZLB	0.12 (2)	0.17 (2)	0.44 (2)	0.52 (2)	0.26 (2)
Gov. investment	Stardard Times	0.45 (5)	0.36 (5)	0.35 (5)	0.77 (5)	0.38 (5)
	ZLB	0.33 (6)	0.30 (6)	0.38 (6)	0.52 (6)	0.43 (6)
Direct taxes	Stardard Times	0.12 (1)	0.21 (1)	0.35 (1)	0.38 (1)	0.23 (1)
	ZLB	0.06 (1)	0.18 (1)	0.33 (1)	0.18 (1)	0.19 (1)
Consumption.tax	Stardard Times	0.14 (2)	0.19 (1)	0.27 (1)	0.29 (1)	0.19 (1)
	ZLB	0.12 (2)	0.15 (1)	0.25 (1)	0.14 (1)	0.16 (1)

Notes: The ZLB binds for 8 quarters. The value of the monetary fiscal multiplier is reported.

Evaluating Labor Market Targeted Fiscal Policies in High Unemployment EZ Countries

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Abstract

We consider a distinction between the wage negotiated by newly hired workers and incumbents in a monetary, open economy, search and matching model. We evaluate the efficacy of two labor market targeted fiscal policies, a hiring subsidy and a wage subsidy for new hires of labor, and compare them with that implied by standard fiscal instruments. The model is estimated with Bayesian techniques using data for high unemployment countries of the EZ periphery (Greece, Ireland, Italy, Portugal and Spain). From posterior simulations we show that, except Greece, the labor market policies are not superior to standard fiscal expansions in stimulating economic activity, and their employment-enhancing effects are clearly dominant only in the long term and at the Greece and Ireland's model parameter estimates. The consideration of a liquidity trap environment reinforces these results, showing that expansionary policy actions triggering a deflation can be procyclical when the interest rate zero-lower-bound binds.

JEL classification: E62, H25, H30, J20, C11

Keywords: Wage and hiring subsidies, search and matching, fiscal multiplier, zero lower bound, Bayesian estimation.

Introduction

The recent labor market evolution in the "periphery" of the Euro-zone (EZ), characterized by unprecedented levels of unemployment and youth unemployment rates on average well above 40%, is receiving increasing attention from European economic institutions and governments. The social and political implications of such a labor market performance, basically mirroring the longest and deepest economic downturn even registered since harmonized data began to be recorded, are currently seen as the main threat to the entire European project, making the employment issue one of the declared major European policy challenges. The acknowledgement of the severity of this problem led to formal commitments for action, resulting in a renewed European Employment Strategy (EES), strengthened with the launch of the Employment Package (EP) in April 2012 and, for a more specific target, with the endorsement of the Youth Guarantee (YG) in April 2013, a set of measures targeted to the youth unemployment issue in the most problematic Member States[1].

Some of the policy recommendations within the EP and the YG have already been adopted by the peripheral EZ countries. Greece, Italy, Portugal and Spain have all changed individual dismissal rules, and the collective bargaining regulation has been relaxed in Greece and Spain in favor of company-level renewable agreements. Salary increases have been capped or suspended in all countries of the EZ periphery, whilst hiring and wage (or social contribution) subsidies for new hires of labor have been introduced in Greece and Italy. Other measures are expected to be adopted within the implementation of the YG programme, or through the prospective bilateral Contractual Arrangements with the EU[2].

From the perspective of a macroeconomic analyst, the EP and YG-related measures can be categorized in three main - economically relevant - policy goals: *i)* the reduction of the hiring cost, to enhance the job creation process[3]; *ii)* the reduction of the firing cost, to increase labor market flexibility[4]; *iii)* increase the efficiency of the matching process[5]. Will these policies actually work?

Recent developments in the macroeconomic modelling of monetary economies with frictions, and in particular those addressing the role of imperfect labor markets, provide some guidance in such evaluations. Zanetti (2011), proposes a search and matching model calibrated to UK data to analyze the business cycle implications of unemployment benefits and firing costs. More in the specific of policy evaluation, Faia et al. (2013), by calibrating an open economy labor selection model featuring hiring and firing costs to the available European data, compare the size of the fiscal multiplier resulting from hiring subsidies and short-time work to the fiscal multipliers emerging with equally financed more traditional policies, such as government spending and tax shocks. Both contributions show that labor market institutions and policies play a role in macroeconomic dynamics and that labor market-targeted fiscal instruments can be an effective tool in the management of the

[1] These measures will be partly funded by the EU through the Youth Employment Initiative and by a re-direction European Social Fund resources.

[2] Contractual Arrangements are expected to support the requesting country with policy guidance and financial help in change of structural reforms.

[3] Targeted hiring subsidies, the reduction of the labor tax wedge, wage subsidies for new hires of labor, subsidization of traineeship and apprentienship programmes are the measures devoted to this objective.

[4] The reform of the labor market regulation in the direction of increased internal flexibility, reduced firing costs and width of the collective bargaining process is recommended for the fulfillment of this goal.

[5] In this case the suggested policies include the investment in public employment services to improve the shared information on job opportunities, the anticipation of skill and qualification needs, the cross-border mobility, investments in vocational training and targeted lifelong learning.

short term employment fluctuations.

The economic argument supporting these conclusions is that these policies, by reducing the labor cost, generate consistent improvements on both the demand and supply sides of the economy: on the one hand, the employment expansion increases the level of economic activity; on the other hand, the internal deflation triggers both an interest rate reduction that stimulates private expenditure and an increase in the price competitiveness of the domestic production that improves the foreign net position through increased net exports. Compared to more standard expansionary fiscal policies, the labor market targeted fiscal instruments thus appear robust to the usual criticism addressing the inflationary and distortionary effects of the traditional fiscal measures.

There are however some important questions that need further inspection. *First*, as long as the labor market policies are often targeted to specific sub-groups of the labor force (as it is with some EP and YG-related measures), focusing on policies that affect the general cost of labor can lead to a misleading approximation of the effects of the actual measures within the programmes. *Second*, since policies are targeted to and adopted by specific member countries, it is unclear to what degree a model calibrated to the data of a single country, or to average European data, can approximate the expected effects from the implementation of the same measures in structurally different economic realities. *Third*, it should be recognized that the efficacy of the fiscal stimulus crucially depends on the interaction between fiscal and monetary policy regimes (Christiano et al. 2011a, Eggertsson 2011a,b, Eggertsson and Krugman 2012). In particular, the size of the fiscal multipliers is dampened by the counteracting monetary policy response, generally modeled as targeting inflation and output stabilization. Analyses that do not consider empirically relevant monetary policy reaction rules[6], or the possibility that the fiscal stimulus takes place during a strong recession, i.e. in a neighborhood of a liquidity trap, may produce outcomes that, even if theoretically consistent, can result empirically irrelevant. Such a concern applies also to the analysis of the efficacy of labor market targeted fiscal policies.

In this paper we address these points by simulating the country-specific effects on economic activity and employment from the implementation of two labor market targeted fiscal measures well rooted in the EP-YG programmes: a hiring cost subsidy and a selective wage subsidy targeted to new hires of labor[7]. The expected effects of the labor market policies are then compared to those obtainable from financially equivalent traditional fiscal policies affecting government consumption, transfers and investments on the expenditure side, and labor, consumption, business profits and capital gains taxes on the revenue side.

The different policy options are evaluated using an extended search and matching monetary model estimated with Bayesian techniques on a large set of data for five major EZ peripheral countries, i.e. Greece, Ireland, Italy, Portugal and Spain (the PIIGS). Policy simulations consider both a standard environment in which the domestic economies operate at their full potential and a non standard liquidity-trap environment, with a binding zero lower bound for the nominal interest rate (ZLB). The consistency of the latter scenario with the EZ economic situation is questionable, but likely. The nominal policy rate is still positive in the EZ, but very close to the zero, such that further real interest rate cuts are highly improbable, especially if we

[6]The empirical literature shows that the behavior of the monetary authority is highly inertial, such that the couteracting monetary policy response has moderate effects in the short term Smets and Wouters 2007, Christiano et al. 2011b).

[7]In this respect, the proposed analysis can be considered as an extension of the one developed in the analysis in Zanetti (2011), which focuses on the role of unemployment benefits and firing "taxes", and of the model adopted by Faia et al. (2013), analyzing the size of the fiscal stimulus from hiring subsidies and short-term work relative to other fiscal instruments.

consider the below-target price dynamics and the lack of credible policy commitments to inflate the economy[8].

The model is extended in the design of the labor market structure by considering a distinction between incumbent workers and new entrants in the search and matching framework, such that both government hiring and wage subsidies for newly hired workers can be introduced within the policy instruments set. Such a modification affects both the job creation condition and the Nash bargained wage intertemporally, such that unions/firms are non-neutral in wages/labor costs with respect to choice of new labor hires. Outside this modification, the design of the non Walrasian labor market basically follows Diamond (1982), Mortensen and Pissarides (1994), and Pissarides (2000) for the introduction of hiring costs and matching frictions, and Gertler et al. (2008) and Gertler and Trigari (2009) for the representation of the staggered Nash-wage bargaining between unions and firms.

The proposed model considers some additional features that are functional to the analysis. The small open economy framework, developed along the lines of Adolfson et al. (2007) and Christiano et al. (2011b), in which the foreign sector is described by a structural vector auto-regressive system (SVAR) estimated with Bayesian techniques, allows the evaluation of the effects of the policies on the net foreign position. The rich specification of the fiscal sector, in which we consider unemployment benefits, hiring subsidies and wage subsidies in addition to the standard fiscal instruments describing the expenditure and revenues sides of fiscal models, allows the consideration of a number of alternative fiscal policies. The consideration of a wedge between short and long-term interest rates allows the representation of an interest rate differential between policy and government bond rates that can affect the dynamics of real variables. Moreover, we assume that the public capital stock and investment flow are chosen by a maximizing fiscal player targeting the distance between output and the government financial need.

Our results show that, even if the labor market fiscal measures are an effective tool in stimulating a non jobless expansion, their superiority to alternative and more standard expansionary fiscal policies is questionable. The labor market measures are expected to produce highly heterogeneous effects across countries, depending on the estimated country-specific model structure. Moreover, the expansionary effects on output and employment take place only in the medium to long-run, whilst the impact and short-term effects on economic activity can be recessive for some economies. The comparative analysis shows that, irrespective of the time horizon being considered, a standard expansionary policy based on government consumption dominates any other equivalently financed fiscal intervention in all the countries but Greece.

The analysis shows that these outcomes are explained by three main hindrance factors in the propagation mechanics of the policies: *First,* the high degree of nominal wage rigidity and the role played by the union's relative power in the intertemporal bargaining over the present and expected gains from government subsidization reduce the size of the initial real wage contraction. *Second*, the inertial behavior of the monetary authority response, i.e. the degree to which the interest rate accommodates the internal deflation, leads to a temporary increase in the real interest rate, thus to reduced private consumption and investments. *Third*, the high degree of both nominal and real rigidities rules out a timely response of the real variables once the real interest rate response is back in the negative terrain.

The consideration of a deep recession characterized by a binding ZLB highlights the role played by the

[8] The persistent economic stagnation, the ongoing fiscal consolidation processes and the declared commitment to a continuation of these policies, rule out the feasibility, or credibility, of any inflationary commitment.

monetary policy regime. Results show that, in this situation, the effectiveness of policies based on reduced marginal costs and internal deflations is weakened and delayed, because of the impossibility of accommodating the deflation with a relevant nominal interest rate drop. Such a result holds both for the labor market targeted fiscal policies (hiring and wage subsidies for new hires of labor) and for fiscal expansions based on tax cuts. On the contrary, and in line with the results of a recent literature (Christiano et al. 2011a, Eggertsson 2011a,b, Eggertsson and Krugman 2012), the efficacy of standard inflationary fiscal measures, as are the policies based on increased government expenditure, is increased by the reduced counteracting response of the monetary policy.

The paper is organized as follows: Section one describes the model, focusing in particular on the theoretical extensions implemented in the design of the labor market. Section two provides the details of the Bayesian estimation of the country-specific models. Here we describe the data and their transformations, we address issues of empirical identification, the calibration and the elicidation of priors for the structural model and the Bayesian SVAR parameters, and discuss the posterior estimates. Section three provides a discussion of simulation results, explaining the propagation mechanics in the standard time and binding ZLB environments. Section four concludes.

1 The model

We introduce a number of extensions to the now standard set-up of the NK-DSGE model, characterized by the presence of nominal and real frictions in both good and labor markets (Christiano et al. 2005, Smets and Wouters 2007). *First*, we consider a small open economy framework, developed along the lines of Adolfson et al. (2007) and Christiano et al. (2011b), in which the foreign sector is exogenous with respect the domestic economy and its evolution is described by a structural vector auto-regressive system (SVAR). *Second*, we adopt a rich specification of the fiscal sector, only marginally resembling that proposed in Drautzburg and Uhlig (2011), in which we consider unemployment benefits, hiring subsidies and wage subsidies in addition to the standard fiscal instruments characterizing the expenditure and revenues sides of fiscal models. *Third*, we develop a detailed representation of the non Walrasian labor market, basically following Diamond (1982), Mortensen and Pissarides (1994), and Pissarides (2000) for the introduction of hiring costs and matching frictions, and Gertler et al. (2008) and Gertler and Trigari (2009) for the representation of the staggered Nash-wage bargaining between unions and firms.

As stressed in the introductory section, the major novelty in the design of the labor market structure is the introduction in the model of both government wage and hiring subsidies for newly hired workers, which is obtained by considering a distinction between incumbent workers and new entrants in the search and matching framework. This modification affects both the job creation condition and the Nash bargained wage, such that unions/firms are non-neutral in wages/labor costs with respect to new labor hire choices.

1.1 The labor market

The matching process is described by a standard Cobb-Douglas matching technology:

$$m_t = \sigma_m \upsilon_t^{\sigma_n} u_t^{1-\sigma_n} \tag{1}$$

where σ_m is the matching efficiency parameter, υ_t is the number of vacancies and $u_t = 1 - n_{t-1}$ denotes the unemployment rate once the labor force stock has been normalized to one. The chosen timing in the unemployment relation shows that individuals entering the labor force stock activate their job search immediately, whilst workers that loss their job in t are not able to search for a new one in the same period of the separation event. Given the job filling rate $q_t = m_t/\upsilon_t$ and the job finding rate $s_t = m_t/u_t$, the labor market tightness can equivalently be defined as $\theta_t = \upsilon_t/u_t$ or $\theta_t = s_t/q_t$.

Under the assumption of exogenous separation, the employment law of motion is described by the following dynamic equation

$$n_t = (1-\rho)\, n_{t-1} + m_t \tag{2}$$

where ρ is the separation rate.

1.2 The household

1.2.1 The optimizing household

We consider a continuum of Ricardian households indexed by $j \in [0,1]$ that have access to a complete set of contingent claims, suggested by Galí et al. (2007). This hypothesis ensures that households are homogeneous with respect to consumption and asset holdings choices, thus the notation can be simplified by dropping the j-index. The representative household is assumed to maximize the following lifetime utility function:

$$\max_{C_t^r, B_t^r, B_t^{*r}, K_t^{p,r}, I_t^r, u_t^k} E_0 \sum_{t=0}^{\infty} \beta^t \left[\xi_t^c \frac{(C_t^r - h\widetilde{C}_{t-1})^{1-\sigma_c}}{1-\sigma_c} - \chi_t n_t \right] \tag{3}$$

where C_t^r is a composite consumption index, $h\widetilde{C}_{t-1}$ denotes external habits σ_c is the consumption curvature parameter and $0 \leq n_t \leq 1$ denotes the fraction of household members who are employed. ξ_t^c and χ_t are two preference shocks which are assumed to follow the i.i.d. processes $\xi_t^c = e^{\varepsilon_{\xi^c,t}}$ and $\chi_t = \chi\mu^{(1-\sigma_c)t}\xi_t^n$, respectively, where $\xi_t^n = e^{\varepsilon_{\xi^n,t}}$[9].

Each household purchases consumption and investment goods by means of after tax labor and capital incomes, after tax unemployment benefits, dividends and government transfers. The budget constraint is thus given by:

[9] The peculiar specification of the stochastic scaling factor of labor disutility χ_t is chosen to ensure balanced growth.

$$(1+\tau_t^c)C_t^r + I_t^r + \frac{B_t^r}{P_t R_t^e} + \frac{e_t B_t^{*r}}{P_t R_t^{e*}\Phi(\frac{A_t}{Y_t}, \frac{e_t}{e_{t-1}}, R_t^{e*}-R_t^e, \widetilde{\phi}_t)} = TR_t^r + \frac{B_{t-1}^r}{P_t} + \frac{e_t B_{t-1}^{*r}}{P_t} + (1-\tau_t^n)\left[\frac{W_t}{P_t}n_t + b_t^u(1-n_t)\right]$$
$$+\left\{(1-\tau_t^k)\left[\frac{R_t^k}{P_t}u_t^k - a(u_t^k)\right] + \delta\tau_t^k\right\}K_{t-1}^{p,r} + \frac{\Pi_t^p \mu^t}{P_t} \quad (4)$$

where I_t^r is private investment, $A_t = \frac{e_t B_{t+1}^*}{P_t}$ is the aggregate net foreign asset position of the domestic economy and e_t is the nominal effective exchange rate. B_t^r and B_t^* denote domestic and foreign bond holdings, respectively, P_t is the consumption price index and $R_t^e = R_t q_{b,t}$, $R_t^{e*} = R_t^* q_{b,t}^*$ are the domestic and foreign interest rates on government bonds, where R_t, R_t^* denote the respective policy rates and $q_{b,t}$, $q_{b,t}^*$ are the home and foreign spreads on government bond, respectively. The domestic spread is assumed to follow the AR(1) process $q_{b,t} = \overline{q}_b^{1-\rho_{q_b}} q_{b,t-1}^{\rho_{q_b}} e^{\varepsilon_{q_b,t}}$, whilst the foreign spread is defined within the SVAR system for the foreign variables. $\frac{R_t^k}{P_t}$ is the real return on capital $K_t^{p,r}$, u_t^k and $a\left(u_t^k\right)$ denote the utilization rate and its adjustment cost[10], respectively, and δ is the private capital depreciation rate. $\frac{W_t}{P_t}$ is the real wage and $\frac{\Pi_t^p \mu^t}{P_t}$ define real dividends, where μ denotes the long-run trend growth of labor-augmenting productivity. Government transfers TR_t^r, unemployment benefits $b_t^u = b^u \mu^t$[11] and the tax rates on consumption τ_t^c, on labor income τ_t^n and on capital τ_t^k complete the budget constraint of the Ricardian household. The term $\Phi_t = \Phi(\frac{A_t}{Y_t}, \frac{e_t}{e_{t-1}}, R_t^{e*} - R_t^e, \widetilde{\phi}_t)$ in (4) denotes the risk premium on foreign bond holdings in the modified uncovered interest parity (UIP) equation $E_t\left(\frac{e_{t+1}}{e_t}\right) = \frac{R_t^e}{\Phi_t R_t^{e*}}$, i.e.:

$$\Phi_t = \exp[-\widetilde{\phi}_a\left(\frac{A_t}{Y_t} - \frac{A}{Y}\right) - \widetilde{\phi}_r\left(R_t^{e*} - R_t^e\right) + \widetilde{\phi}_s\left(1 - \frac{e_t}{e_{t-1}}\right) + \widetilde{\phi}_t] \quad (5)$$

where $\widetilde{\phi}_t$ is a time varying shock to the risk premium, which is assumed to follow the AR(1) stochastic process $\widetilde{\phi}_t = \widetilde{\phi}_{t-1}^{\rho_{\widetilde{\phi}}} e^{\varepsilon_{\widetilde{\phi},t}}$ and $\widetilde{\phi}_a$, $\widetilde{\phi}_s$ and $\widetilde{\phi}_r$ are positive elasticities. Our specification ensures the satisfaction of the usual equilibrium requirements (Lundvik 1992, Schmitt-Grohé and Uribe 2001) and adds some flexibility to alternative modified UIP equations adopted in the literature (e.g. Adolfson et al. 2008 and Christiano et al. 2011b). The log-linear representation of the modified UIP is the following:

$$E_t\left(\Delta e_{t+1}\right) = \widetilde{\phi}_s \Delta e_t + \left(1 - \widetilde{\phi}_r\right)\left(R_t^e - R_t^{e*}\right) + \widetilde{\phi}_a\left(A_t - Y_t\right) - \widetilde{\phi}_t$$

were the parameter $\widetilde{\phi}_s$ defines the autoregressive behavior of the expected change in the nominal exchange rate and $\widetilde{\phi}_r \geq 0$ denotes the elasticity to the interest rate differential on bond holdings, allowing for the emergence of the "forward premium puzzle" (for $\widetilde{\phi}_r > 1$), i.e. the negative correlation between interest rate differentials and expected exchange rate variations often observed in empirical trials[12].

[10] The function $a\left(u_t^k\right)$ is assumed to be strictly increasing and convex, with curvature parameter ψ^k. The utilization rate relates effective to physical capital in a standard fashion, i.e. $K_t^r(i) = K_{t-1}^{p,r}(i)u_t(i)$.

[11] In order to ensure long-run balanced growth, b_t^u is assumed to grow at the labor augmenting productivity growth rate μ.

[12] In the modified UIP adopted in Adolfson et al. (2008) the autoregressive component is not independent on the elasticity to the interest rate differential, and the chosen prior does not allow for a direct emergence of the forward premium puzzle. Compared to the specification adopted in Christiano et al. (2011b), our modified UIP adds the autoregressive component.

The law of motion of physical capital is described by the following equation:

$$K_t^{p,r} = (1-\delta)K_{t-1}^{p,r} + q_{i,t}\left[1 - S(\frac{I_t^r}{I_{t-1}^r})\right] I_t^r \tag{6}$$

where $S(\frac{I_t^r}{I_{t-1}^r})$ defines the private investment adjustment cost function, with curvature parameter ψ^i, and $q_{i,t}$ is an investment-specific shock, which is assumed to follow the i.i.d. stochastic process $q_{i,t} = e^{\varepsilon_{q_i,t}}$.

Aggregate demand for type X_t goods, $X_t = (C_t, I_t)$, is obtained as a CES index of domestically produced and imported goods, such that:

$$X_t = \left[(1-\nu)^{\frac{1}{\eta}} \left(X_t^d\right)^{\frac{\eta-1}{\eta}} + \nu^{\frac{1}{\eta}} \left(X_t^m\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{7}$$

where, from households' cost minimization, $X_t^d\,(1-\nu)\left(\frac{P_t^d}{P_t}\right)^{-\eta} X_t$ and $X_t^m = \nu\left(\frac{P_t^m}{P_t}\right)^{-\eta} X_t$ are, respectively, the aggregate available domestic and foreign produced goods, ν denotes the import share parameter and η is the elasticity of substitution between domestic and imported goods. P_t^d and P_t^m denote the price indexes of domestic and imported goods, respectively, such that:

$$P_t = \left[(1-\nu)\left(P_t^d\right)^{1-\eta} + \nu\left(P_t^m\right)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{8}$$

From the first order condition (F.O.C.) for consumption, the following consumption Euler equation is obtained:

$$C_t^r - hC_{t-1}^r = \left[\beta R_t^e \frac{P_t}{P_{t+1}} \frac{(1+\tau_t^c)}{(1+\tau_{t+1}^c)} \frac{\xi_{t+1}^c}{\xi_t^c}\right]^{-\frac{1}{\sigma_c}} \left(C_{t+1}^r - hC_t^r\right) \tag{9}$$

1.2.2 The rule-of-thumb household

We assume that Ricardian and non Ricardian households have the same number of workers,hence:

$$n_t = n_t^r = n_t^{nr} \tag{10}$$

From the budget constraint of the non Ricardian household, the resulting consumption equation is as follows:

$$C_t^{nr} = \frac{1}{(1+\tau_t^c)}\left[Tr_t^{nr} + (1-\tau_t^n)\frac{W_t}{P_t} n_t + (1-\tau_t^n) b_t^u (1-n_t)\right] \tag{11}$$

where it is evident that rule-of-thumbers spend all their net income (from labor, government transfers and unemployment benefits) in consumption goods.

1.2.3 Workers value functions

Let $W_t(w_t)$ be the worker value of being matched to a job evaluated at the wage w_t and U_t be the value of being unemployed at time t. Assuming that the probabilities of wage reoptimization can be different for incumbent workers and hires of new labor, the value of the employment/unemployment states are the following:

$$W_t(w_t) = (1-\tau_t^n)\frac{w_t}{P_t} - \frac{\chi_t}{\Lambda_t} + \beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left[(1-\rho)\left[\gamma_w W_{t+1}(w_t) + (1-\gamma_w)W_{t+1}(w_{t+1}^*)\right] + \rho U_{t+1}\right]\right] \quad (12)$$

$$U_t = (1-\tau_t^n)b_t^u + \beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left[s_{t+1}\left(\theta_w W_{t+1}(w_t) + (1-\theta_w)W_{t+1}(w_{t+1}^*)\right) + (1-s_{t+1})U_{t+1}\right]\right] \quad (13)$$

where γ_w and θ_w are the Calvo parameters defining the probability of being unable to re-optimize the wage in $t+1$ for incumbent workers and for newly matched workers, respectively. Λ_t is the Lagrange multiplier. From equations (12) and (13) the net value of being employed, i.e. the worker' surplus $W_t(w_t) - U_t$, is obtained.

1.3 The intermediate goods sector

Each intermediate firm (i) operates in a perfectly competitive environment. The production technology is as follows:

$$Y_t^i(i) = \xi_t^a \left[\frac{K_{t-1}^g}{\int_0^1 Y_t^i(j)dj}\right]^{\frac{\xi}{1-\xi}} \left[K_t(i)\right]^\alpha \left[\mu^t n_t(i)\right]^{(1-\alpha)} \quad (14)$$

where K_t^g is public capital, α and ξ are the private and public capital shares in production, respectively, and $\xi_t^a = \xi_{t-1}^{a^{\rho_{\xi^a}}} e^{\varepsilon_{\xi^a,t}}$ is an AR(1) process defining the evolution of total factor productivity.

The optimizing firm chooses the optimal quantity of capital by solving the following maximization problem:

$$\max_{K_t(i)} P_t^i(i)\, Y_t(i) - R_t^k(i)\, K_t(i) \quad \text{s.t. } (14)$$

whose re-arranged F.O.C. yields:

$$R_t^k(i) = \alpha P_t^i(i)\frac{Y_t^i(i)}{K_t(i)} \quad (15)$$

where $P_t^i(i)$ is the intermediate sector price index.

A distinction between job values to the firm of newly hired and incumbent workers is introduced. Such a distinction, which - to our knowledge - is new to the literature on models with search and matching frictions, is necessary to evaluate the relative efficacy of two labor market-targeted fiscal instruments: hiring and wage government subsidies. The former basically consists in a reduction of the cost of hiring per vacancy, $\kappa(1-\varphi_t^h)$, the latter in a reduction of the wage cost $w_t(1-\varphi_t^w)$ for new hires of labor, where κ is the hiring cost and φ_t^h, φ_t^w are the hiring and wage subsidies, respectively. Note that in this setting the government wage subsidy for new hires of labor can be considered equivalent to a selective fiscal instrument affecting the direct taxation on the labor income of newly hired workers.

Let $J_t^n(w_t)$ and $J_t^o(w_t)$ be the values to the firm of a job evaluated at the wage w_t for a newly hired and an incumbent worker, respectively:

$$J_t^n(w_t) = (1-\tau_t^p)\left[\zeta_t - (1-\varphi_t^w)\frac{w_t}{P_t^d}\right] + (1-\rho)\beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left(\gamma_w J_{t+1}^o(w_t) + (1-\gamma_w)J_{t+1}^o(w_{t+1}^*)\right)\right] \quad (16)$$

and:

$$J^o_t(w_t) = (1-\tau^p_t)(\zeta_t - \frac{w_t}{P^d_t}) + (1-\rho)\beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left(\gamma_w J^o_{t+1}(w_t) + (1-\gamma_w)J^o_{t+1}(w^*_{t+1})\right)\right] \tag{17}$$

where P^d_t is the domestic price index, τ^p_t denotes the business profits tax rate and $\zeta_t = (1-\alpha)P^i_t Y_t/n_t$ the marginal productivity of labor. By re-arranging equations (16) and (17) yields an alternative specification of $J^n_t(w_t)$:

$$J^n_t(w_t) = J^o_t(w_t) + (1-\tau^p_t)\varphi^w_t \frac{w_t}{P_t} \tag{18}$$

Equation (18) shows that the standard case in the literature, in which the firm does not consider a distinction in the job values of incumbent and newly hired workers, is restored for $\varphi^w_t = 0$.

Given the positions above, the value of a vacancy is the following:

$$J^v_t = -\kappa(1-\varphi^h_t) + q_t\left[\theta_w J^n_t(w_{t-1}) + (1-\theta_w)J^n_t(w^*_t)\right] \tag{19}$$

which resolves in a standard vacancy value equation for $\varphi^h_t = 0$ and $J^n_t = J^o_t = J_t$, i.e. for $\varphi^w_t = 0$.

By imposing the free entry condition, such that $J^v_t = 0$, and considering that a fraction of the hiring and wage cost is financed by the government with subsidies, i.e. $\varphi^h_t > 0$, $\varphi^h_t > 0$, the vacancy posting condition is the following:

$$\begin{aligned}\frac{\kappa(1-\varphi^h_t)}{q_t} &= \left[\theta_w J^n_t(w_{t-1}) + (1-\theta_w)J^n_t(w^*_t)\right] \\ &= \left[\theta_w J^o_t(w_{t-1}) + (1-\theta_w)J^o_t(w^*_t)\right] + (1-\tau^p_t)\varphi^w_t\left[(1-\theta_w)\frac{w^*_t}{P^d_t} + \theta_w\frac{w_{t-1}}{P^d_t}\right]\end{aligned} \tag{20}$$

where an alternative expression in terms of J^o_t is provided for analytical convenience. Note that equation (20) resolves in a standard vacancy posting condition for $\varphi^h_t = 0$ and $\varphi^w_t = 0$. Considering the recursive solution of the value to the firm of an incumbent job position (17), the vacancy posting condition (20) becomes:

$$\begin{aligned}\frac{\kappa(1-\varphi^h_t)}{q_t} &= (1-\tau^p_t)(P^i_t\zeta_t - \frac{w^*_t}{p^d_t}) + (1-\rho)\beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\kappa(1-\varphi^h_{t+1})}{q_{t+1}}\right] \\ &+E_t\left\{(1-\tau^p_{t+1})\left(\frac{w^*_{t+1}}{p^d_{t+1}} - \frac{w^*_t}{p^d_t}\right)\sum_{j=1}^{\infty}\frac{\Lambda_{t+1}}{\Lambda_t}\left[(1-\rho)\beta\gamma_w\right]^j\right\} \\ &-\frac{\theta_w}{\gamma_w}E_t\left\{(1-\tau^p_{t+1})\left(\frac{w^*_{t+1}}{p^d_{t+1}} - \frac{w_t}{p^d_t}\right)\sum_{j=1}^{\infty}\frac{\Lambda_{t+1}}{\Lambda_t}\left[(1-\rho)\beta\gamma_w\right]^j\right\} \\ &+\theta_w\left\{(1-\tau^p_t)(\frac{w^*_t}{p^d_t} - \frac{w_{t-1}}{p^d_{t-1}})E_t\sum_{j=0}^{\infty}\frac{\Lambda_{t+1}}{\Lambda_t}\left[(1-\rho)\beta\gamma_w\right]^j\right\} \\ &-(1-\rho)\beta E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}(1-\tau^p_{t+1})\varphi^w_{t+1}\left[\theta_w\frac{w_t}{p^d_t} + (1-\theta_w)\frac{w^*_{t+1}}{p^d_{t+1}}\right]\right\} \\ &+(1-\tau^p_t)\varphi^w_t\left[\theta_w\frac{w_{t-1}}{p^d_{t-1}} + (1-\theta_w)\frac{w^*_t}{p^d_t}\right]\end{aligned} \tag{21}$$

Compared to the job creation condition in the standard search and matching set-up, equation (21) shows that the wage subsidy influences vacancy posting intertemporally. Present vacancies posted are positively related to the present wage subsidy φ_t^w (last row of equation 21) and negatively related to the loss opportunity of the gains from wage subsidies due to future job openings (second last row of equation 21). The latter loss is proportional to the fraction of surviving workers $(1-\rho)$, i.e. those jobs that will not benefit from the government wage subsidy in the next period, thus the positive contemporaneous effects, other things being equal, are always dominant. Present and future hiring subsidies φ_t^h affect vacancy posting directly. For $\varphi_t^h = 0$ and $\varphi_t^w = 0$, equation (21) resolves in the standard vacancy posting condition.

1.4 Nash wage bargaining

We do not consider a separate Nash wage bargaining scheme for incumbent and newly hired workers on the grounds that the separation rate is exogenous and unions are assumed to be representative of both types of labor. In other terms, since firing is not a control variable for the domestic intermediate firm, an optimal firing strategy distinguishing between incumbents and newly hired workers cannot be implemented[13]. A unique wage is thus Nash-bargained by maximizing the product:

$$\max_{w_t^*} \left[W_t(w_t^*) - U_t\right]^{\varsigma} J_t(w_t^*)^{1-\varsigma} \tag{22}$$

where the parameter ς denotes the union's relative bargaining power and $J_t(w_t^*)$ denotes the aggregate job value to the firm, i.e.:

$$\begin{aligned} J_t(w_t^*) &= \int_0^1 J_t^i(w_t^*)di = \int_0^{\phi_t^o} J_t^o(w_t^*)di + \int_{\phi_t^o}^1 J_t^n(w_t^*)di \\ &= J_t^o(w_t^*) + (1-\phi_t^o)(1-\tau_t^p)\varphi_t^w \frac{w_t^*}{P_t^d} \end{aligned} \tag{23}$$

where $\phi_t^o = (1-\rho)\, n_{t-1}/n_t$ is the share of incumbent workers.

Considering equations (22) and (23) the following F.O.C. is obtained:

$$(1-\varsigma)\,(1-\tau_t^p)\left[W_t(w_t^*) - U_t\right] = \varsigma(1-\tau_t^n)\left[J_t^o(w_t^*) + (1-\phi_t^o)(1-\tau_t^p)\varphi_t^w w_t^* \frac{1}{p_t^d}\right] \tag{24}$$

By substituting the value functions in (24), after some algebra, the equation for the individual real wage

[13] Note that the consideration of an endogenous specification of the firing process along the lines proposed byf the recent literature on search and matching models (Krause and Lubik 2007, Faia et al. 2013) would not change the theoretical consistency of our hypothesis. In fact, in these models the endogenous separation rate is in general conditioned to an exogenous, job-specific, stochastic productivity process, such that the endogeneity would not introduce an additional type-specific control variable to the firm.

is obtained:

$$
\begin{aligned}
w_t^* &= \vartheta_t \left\{ \varsigma \left[\zeta_t + (1-\phi_t^o)\varphi_t^w \frac{w_t^*}{p_t^d} \right] + (1-\varsigma)\left(b_t^u + \frac{\chi_t}{\Lambda_t} \right) \right\} \\
&+ \vartheta_t (1-\varsigma) E_t \left\{ T_{t+1}^n \left[\Delta w_{t+1}^* - \frac{\theta_w}{\gamma_w} \frac{s_{t+1}}{1-\rho} (w_{t+1}^* - w_t) \right] \sum_{j=1}^{\infty} \frac{\Lambda_{t+j}}{\Lambda_t} \left[(1-\rho)\beta\gamma_w \right]^j \right\} \\
&+ \vartheta_t \varsigma E_t \left\{ \left[T_{t+1}^p - \frac{\theta_w}{\gamma_w} \left[T_{t+1}^p - S_{t+1} T_{t+1}^n \right] \right] \Delta \frac{w_{t+1}^*}{p_{t+1}^d} \sum_{j=1}^{\infty} \frac{\Lambda_{t+j}}{\Lambda_t} \left[(1-\rho)\beta\gamma_w \right]^j \right\} \\
&+ \frac{1}{(1-\tau_t^p)} \vartheta_t \varsigma (1-\rho) \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{\kappa(1-\varphi_{t+1}^h)}{q_{t+1}} \left[1 - S_{t+1} \frac{T_{t+1}^n}{T_{t+1}^p} \right] \right\} \\
&+ \vartheta_t \varsigma \beta E_t \left\{ (1-\rho-s_{t+1}) \varphi_{t+1}^w \frac{\Lambda_{t+1}}{\Lambda_t} T_{t+1}^n \left[(1-\theta_w) \frac{w_{t+1}^*}{p_{t+1}^d} + \theta_w \frac{w_t}{p_t^d} - \left(1 - \phi_{t+1}^o \right) \frac{w_{t+1}^*}{p_{t+1}^d} \right] \right\} \\
&- \vartheta_t \varsigma (1-\rho) \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} T_{t+1}^p \varphi_{t+1}^w \left[(1-\theta_w) \frac{w_{t+1}^*}{p_{t+1}^d} + \theta_w \frac{w_t}{p_t^d} \right] \right\}
\end{aligned} \tag{25}
$$

where we have used the transformations $T_t^i = (1-\tau_t^i)/(1-\tau_{t-1}^i)$, for $i = (n,p)$, $S_t = (1-\rho-s_t)/(1-\rho)$, $\vartheta_t \equiv 1/\left[1-\varsigma\left(1-1/p_t^d\right)\right]$, $p_t^d = P_t^d/P_t$, and w_t is the average real wage:

$$
w_t = \frac{m_t}{n_t} \left[\theta_w w_{t-1} + (1-\theta_w) w_t^* \right] + \frac{(1-\rho)\, n_{t-1}}{n_t} \left[\gamma_w w_{t-1} + (1-\gamma_w) w_t^* \right]
$$

Equation (25) shows that, in the presence of a wage subsidy φ_t^w, the real wage is directly related to the marginal product of labor ζ_t, as in the standard model, to the present government wage subsidy for new hires of labor $(1-\phi_t^o)\varphi_t^w w_t^*/p_t^d$, and to the future wage subsidy. The latter affects the present real wage from the perspective of both the firm and the worker expected gains from the measures: *i*) from the perspective of firm's expected gain, the last row of equation (25) shows that the bargained real wage is negatively related to the anticipation of the loss of future (after tax) *firm* gains from wage subsidies, proportional to the fraction of continuing jobs $1-\rho$ - i.e. those not benefiting from wage subsidization - and to the union's relative bargaining power ς, denoting the workers share; *ii*) from the perspective of the workers expected gain, the second last row of equation (25) shows that the anticipation of the loss of future (after tax) *worker* gains from wage subsidies, again proportional to both the fraction of continuing jobs $1-\rho$ and to the relative bargaining power ς, increases the bargained wage, whilst an incentive to reduce the bargained wage comes from the anticipation of the shared (after tax) *worker* gains from the wage subsidization of future hires of new labor s_{t+1}

For reasonable values of the exogenous separation rate ρ and of the union's relative bargaining power ς, the firm's intertemporal incentive to reduce the present bargained wage dominates the union's net intertemporal incentive to increase it, because of the consideration of the gains from the subsidization of future hires of labor, as evident in the terms s_{t+1} and $-\left(1-\phi_{t+1}^o\right) w_{t+1}^*/p_{t+1}^d$ in the second last row of equation (25). Other things being equal, the wage contraction is thus directly related to the size of the separation rate ρ and to the union's relative bargaining power ς. Moreover, the staggered bargaining perspective assumed here allows to highlight that the expected wage subsidy affects the real wage considering the probability of a new hire of labor to re-negotiate the wage.

The introduction of a hiring subsidy φ_t^h negatively affects the present real wage as it directly reduces the expected hiring costs. Considering a firm negotiating a real wage, the incentive for a reduction comes from the anticipation of the loss opportunity of a future reduction in the hiring cost.

Note that, for $\varphi_t^h = 0$ and $\varphi_t^w = 0$, equation (25) resolves in the standard real Nash wage equation.

1.5 The final goods sector: wholesalers and retailers in the domestic, import and export sectors

For expositional convenience, a joint description of the structure of the final good sector, composed of domestic, import and export wholesalers and retailers, is provided.

Domestic wholesale firms buy the homogenous good Y_t^i from domestic intermediate good producers at the price P_t^i, and differentiate the homogeneous product into $Y_t^d(i)$ using a linear technology. Wholesalers sell their goods under monopolistic competition to domestic retailers, who use the differentiated goods $Y_t^d\,(i)$ to produce the composite final good Y_t^d.

Wholesale firms in the import sector buy the homogenous good Y_t^* from foreign retailers at the foreign price P_t^*, and obtain a differentiated good $Y_t^m(i)$. Wholesale importing firms sell their goods under monopolistic competition to import retailers who use the differentiated goods $Y_t^m\,(i)$ to produce the composite final good Y_t^m.

Finally, wholesale export firms buy the homogenous good Y_t^d from domestic retailers at the price P_t^d and produce a differentiated good $Y_t^x(i)$ using a linear technology. Wholesalers in the export sector sell their goods under monopolistic competition to export retailers, who use the differentiated goods $Y_t^x\,(i)$ to produce the composite final good Y_t^x.

We allow for variable demand elasticity in the three sectors, indexed by $k = (d, m, x)$, by assuming a flexible variety aggregator à la Kimball (1995):

$$\left[\int_0^1 G\left(\frac{Y_t^k\,(i)}{Y_t^k}; \lambda_{p,t}^k\right) di\right] = 1$$

such that the domestic retailers demand function for differentiated goods is:

$$Y_t^k\,(i) = Y_t^k G'^{-1}\left[\frac{P_t^k(i)}{P_t^k}\varkappa_{p,t}^k\right] \tag{26}$$

where:

$$\varkappa_{p,t}^k \equiv \int_0^1 G'\left(\frac{Y_t^k(i)}{Y_t^k}; \lambda_{p,t}^k\right)\frac{Y_t^k(i)}{Y_t^k} di$$

The optimization problem of wholesalers firms that are allowed to re-optimize their prices reads:

$$\max_{\widetilde{P}_t^k(i)} E_t \sum_{j=0}^{\infty} \left(\beta \xi_p^k\right)^j \vartheta_{t+j} \left[\widetilde{P}_t^k(i) X_{t,t+j}^k - MC_{t+j}^k\right] Y_{t+j}^k(i)$$

$$\text{s.t. (26) and } \; X_{t,t+j}^k = \begin{cases} 1 & for\ j=0 \\ \Pi_{l=0}^{j} \left(\pi_{t+l-1}^k\right)^{\iota_p^k} \pi_*^{1-\iota_p^k} & for\ s=1,...,\infty \end{cases}$$

where $MC_t^d = P_t^i$, $MC_t^m = e_t P_t^*$ and $MC_t^x = P_t^d / e_t$ are the nominal marginal costs of the domestic, import sector and export sector wholesalers, respectively. The term $\left(\beta \xi_p^k\right)^j \vartheta_{t+j}$ denotes the stochastic discount factor of the firm, where ξ_p^k is the Calvo probability of price adjustment. $\lambda_{p,t}^k = e^{\varepsilon_{p,t}^k}$ are *i.i.d.* stochastic processes defining the time-varying markups[14] and $X_{t,t+j}^k$ denote price indexation functions.

The first order condition for the optimality problem above is given by:

$$E_t \sum_{j=0}^{\infty} \left(\xi_p^k \beta\right)^j \vartheta_{tt+j} Y_{t+j}^k(i) \left[\widetilde{P}_t^k(i) X_{t,t+j}^k + \left(\widetilde{P}_t^k(i) X_{t,t+j}^k - MC_{t+s}^k(i)\right) \frac{1}{G'^{-1}\left(\nu_t^k\right)} \frac{G'\left(\theta_{t+j}^k\right)}{G''\left(\theta_{t+j}^k\right)}\right] = 0 \tag{27}$$

where $\theta_t^k = G'^{-1}\left(\nu_t^k\right)$, $\nu_t^k = \frac{P_t^k(i)}{P_t^k} \varkappa_{p,t}^k$, and the aggregate domestic price indexes read:

$$P_t^k = \left(1-\xi_p^k\right) P_t^k(i) G'^{-1}\left[\frac{P_t^k(i)}{P_t^k} \varkappa_{p,t}^k\right] + \xi_p^k P_{t-1}^k \left(\pi_{t-1}^k\right)^{\iota_p^k} \pi_*^{1-\iota_p^k} G'^{-1}\left[\frac{P_{t-1}^k \left(\pi_{t-1}^k\right)^{\iota_p^k} \pi_*^{1-\iota_p^k}}{P_t^k} \varkappa_{p,t}^k\right] \tag{28}$$

1.6 Government policies

1.6.1 The monetary authority

The Central Bank sets the nominal interest rate $R_t \equiv 1 + r_t$ according to a contemporaneous rule considering inflation, output and output growth deviations from the respective steady state values. The policy instrument is adjusted gradually, giving rise to interest rate smoothing:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\rho^R} \left[\left(\frac{\pi_t}{\overline{\pi}}\right)^{\psi_1} \left(\frac{Y_t}{\overline{Y}}\right)^{\psi_2}\right]^{1-\rho^R} \left(\frac{Y_t}{Y_{t-1}}\right)^{\psi_3} + \epsilon_t^r \tag{29}$$

where ρ^R defines the degree of interest rate smoothing, ψ_1, ψ_2, ψ_3, are the feedback coefficients to CPI inflation π_t[15], the output level Y_t, and output growth, respectively. The stochastic term ϵ_t^r denotes the monetary policy

[14] We assume i.i.d. mark-up shocks in order to enhance the identifiability of the price equations. For a more in dept explanation of this point, see the estimation section below and Giuli and Tancioni (2012).

[15] CPI inflation is obtained as a weighted average considering domestic and imported price variations, i.e.: $\pi_t = \left[(1-\nu)\left(p_t^d \pi_t^d\right)^{1-\eta} + \nu\left(p_t^m \pi_t^m\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$.

shock, which is assumed to be white noise $\epsilon_t^r = e^{\varepsilon_t^r}$. Similar to money-growth rules, implementation of this policy rule does not require knowledge about the natural rate of interest or of the level of potential output, both of which are unobserved[16].

The fact that the countries being considered in this study all joined a common currency and a centralized monetary policy since 1999 (2001 for Greece) implies that, at the estimation stage, a regime break has to be taken into account. To implement such a structural break, we will consider a permanent observed exogeneous shock acting as a multiplicative regime-shift dummy variable on all the four monetary policy coefficients.

1.6.2 The fiscal authority

By expressing government consumption, government transfers, hiring subsidies and unemployment benefits in terms of domestic goods, the government budget constraint in real terms reads:

$$\begin{aligned} & \frac{P_t^d}{P_t}\left[G_t + I_t^g + \varphi_t^h \kappa \upsilon_t + (1-\tau_t^n) b_t^u (1-n_t)\right] + TR_t + \frac{B_{t-1}}{P_t} + \varphi_t^w (1-\phi_t^o)\left[\theta_w w_{t-1} + (1-\theta_w) w_t^*\right] \\ = & \frac{B_t}{P_t R_t q_t^b} + \tau_t^c C_t + \tau_t^n w_t n_t + \tau_t^k \left[r_t^k u_t^k - a(u_t^k) - \delta\right] K_{t-1}^{p,r} + \tau_t^p \left[\zeta_t - w_t + \varphi_t^w (1-\phi_t^o)\left[\theta_w w_{t-1} + (1-\theta_w) w_t^*\right]\right] \end{aligned} \tag{30}$$

where $G_t = G_{t-1}^{\rho_g} Y_t^{(1-\rho_g)\eta_{gy}} D_t^{\eta_{gd}} e^{\varepsilon_{g,t}}$ and $TR_t = TR_{t-1}^{\rho_{tr}} Y_t^{(1-\rho_{tr})\eta_{try}} D_t^{\eta_{trd}} e^{\varepsilon_{tr,t}}$ are the partial adjustment stochastic processes for government expenditures for consumption and transfers, respectively, where D_t denotes the government financial need and $\varepsilon_{g,t}$, $\varepsilon_{tr,t}$ are *i.i.d.* shocks. Finally, φ_t^h and φ_t^w denote the expenditure for hiring and wage subsidies, respectively, described by the partial adjustment processes $\varphi_t^h = \varphi_{t-1}^{h^{\rho_{\varphi h}}} u_t^{(1-\rho_{\varphi h})\eta_{\varphi h}} e^{\varepsilon_{\varphi h,t}}$ and $\varphi_t^w = \varphi_{t-1}^{w^{\rho_{\varphi w}}} u_t^{(1-\rho_{\varphi w})\eta_{\varphi w}} e^{\varepsilon_{\varphi w,t}}$.

From government budget constraint (30) the financial need D_t is obtained:

$$\begin{aligned} D_t \equiv & \frac{P_t^d}{P_t}\left[G_t + I_t^g + \varphi_t^h \kappa \upsilon_t + (1-\tau_t^n) b_t^u (1-n_t)\right] + TR_t + (1-\tau_t^p)\varphi_t^w (1-\phi_t^o)\left[\theta_w w_{t-1} + (1-\theta_w) w_t^*\right] \\ & + \frac{B_{t-1}}{P_t} - \overline{\tau}_t^c C_t - \overline{\tau}_t^n w_t n_t - \overline{\tau}_t^k \left[r_t^k u_t^k - a(u_t^k) - \delta\right] K_{t-1}^p - \overline{\tau}_t^p (\zeta_t - w_t) \end{aligned} \tag{31}$$

A fraction ψ_τ of D_t is financed with distortionary taxation on consumption, labor income, capital and on business profits, such that:

$$\psi_\tau (D_t - D) = (\tau_t^c - \tau^c) C_t + (\tau_t^n - \tau^n) w_t n_t + \left(\tau_t^k - \tau^k\right) K_{t-1}^p \left[r_t^k u_t^k - a\left(u_t^k\right) - \delta\right] + (\tau_t^p - \tau^p)(\zeta_t - w_t) \tag{32}$$

whilst the remaining fraction is financed by issuing government bonds:

$$\frac{B_t - B}{P_t R_t^e} = (1-\psi_\tau)(D_t - D) \tag{33}$$

[16]The hypothesis that the central bank targets trend output instead of the output that would have prevailed in the absence of nominal rigidities has been adopted in the empirical literature (e.g. Del Negro et al. 2007; Adolfson et al. 2007) and is consistent with the main objective of our analysis, which is basically empirical.

We assume that the different tax rates are partially adjusted[17] by choosing the vector of government tax instruments $\boldsymbol{\omega} = \left[\omega^c \omega^n \omega^k \omega^p\right]'$, where $\omega^c + \omega^n + \omega^k + \omega^p = 1$.

$$\omega^c \psi_\tau \left(D_t - D\right) = \left(\overline{\tau}_t^c - \tau^c\right) C_t \tag{34}$$

$$\omega^n \psi_\tau \left(D_t - D\right) = \left(\overline{\tau}_t^n - \tau^n\right) w_t n_t \tag{35}$$

$$\omega^k \psi_\tau \left(D_t - D\right) = \left(\overline{\tau}_t^k - \tau^k\right) \frac{k_{t-1}^p}{\mu} \left[r_t^k u_t^k - a\left(u_t^k\right) - \delta\right] \tag{36}$$

$$\omega^p \psi_\tau \left(D_t - D\right) = \left(\overline{\tau}_t^p - \tau^p\right)\left(\zeta_t - w_t\right) \tag{37}$$

where $\overline{\tau}_t^i$, $i = c, n, k, p$, denotes the systematic component on the revenue side, which relates to the stochastic tax rate considering a first order autoregressive stochastic wedge $\eta_t^{\tau^i}$ denoting the discretionary component, such that $\tau_t^i = \overline{\tau}_t^i \eta_t^{\tau^i}$, with $\eta_t^{\tau^i} = \eta_{t-1}^{\tau^i \rho_{\tau^i}} e^{\varepsilon_{\tau^n,t}}$.

An optimal rule is considered for government investment expnditures. The fiscal authority is assumed to choose the public capital stock K_t^g and public investment I_t^g by maximizing the distance between output Y_t and the financial need, i.e.:

$$\begin{aligned}
&\max_{K_t^g, I_t^g} E_t \sum_{j=t}^{\infty} \beta^{t+j} \frac{\Lambda_{t+j}}{\Lambda_t}\left[Y_{t+j} - D_{t+j}\right] \\
\text{s.t. } Y_t &= (\xi_t^a)^{(1-\xi)} (K_{t-1}^g)^{\xi} (K_t)^{\alpha(1-\xi)} \left[\mu^t n_t\right]^{(1-\alpha)(1-\xi)} \\
K_t^g &= (1-\delta^g) K_{t-1}^g + q_t^{i^g}\left[1 - S^g\left(\frac{I_t^g}{I_{t-1}^g}\right)\right] I_t^g
\end{aligned}$$

where δ^g is the public capital depreciation rate and $S^g(\frac{I_t^g}{I_{t-1}^g})$ denotes the government investment adjustment cost function, with curvature parameter ψ^{ig}. The first order conditions for government capital and investment are, respectively:

$$\beta E_t\left[\left(1-\delta^g\right)\Lambda_{t+1}^{k^g} q_t^{k^g} + \Lambda_{t+1}\xi(\xi_{t+1}^a)^{(1-\xi)}(K_t^g)^{\xi-1}(K_{t+1})^{\alpha(1-\xi)}\left(\mu^{t+1} n_{t+1}\right)^{(1-\alpha)(1-\xi)}\right] - \Lambda_t^{k^g} = 0$$

$$\beta E_t\left[q_{t+1}^{i^g}\Lambda_{t+1}^{k^g} S^{g\prime}\left(\frac{I_{t+1}^g}{I_t^g}\right)\left(\frac{I_{t+1}^g}{I_t^g}\right)^2\right] + \Lambda_t^{k^g} q_t^{i,g}\left[1 - S^g\left(\frac{I_t^g}{I_{t-1}^g}\right) - S^{g\prime}\left(\frac{I_t^g}{I_{t-1}^g}\right)\left(\frac{I_t^g}{I_{t-1}^g}\right)\right] - \frac{P_t^d}{P_t}\Lambda_t = 0$$

where $\Lambda_t^{k^g}$ is the shadow price of government capital and $q_t^{i^g} = q_{t-1}^{i^{g^{\rho_{ig}}}} e^{\varepsilon_{ig,t}}$ is a stochastic process for the government investment-specific shock.

[17] By denoting with $f\left(D_t\right) = \tau_t^i$, $i = c, n, k, p$, the partial adjustment is obtained by assuming the following conditional process for the tax rates: $\tau_t^i = \tau_{t-1}^{i^{\rho_{\tau^i}}} f\left(D_t\right) e^{\varepsilon_t^i}$, where ε_t^i are *i.i.d.* tax rates shocks.

1.7 Model closure

Given the presence of intertemporally optimizing households $j \in [0, 1-\phi^h]$ and of rule-of-thumb households $j \in (1-\phi^h, 1]$, aggregate consumption and government transfers are given by:

$$C_t = \left(1-\phi^h\right) C_t^r + \phi^h C_t^{nr} \tag{38}$$

and

$$TR_t = \left(1-\phi^h\right) TR_t^r + \phi^h TR_t^{nr} \tag{39}$$

where, given $d = TR_t^{nr}/TR_t^r$, the fraction of government transfers to Ricardian and non Ricardian households are, respectively: $TR_t^r(i) = \frac{TR_t}{1+\phi^h(d-1)}$ and $TR_t^{nr}(i) = \frac{dTR_t}{1+\phi^h(d-1)}$.

Since only Ricardian households hold bonds and accumulate capital, aggregate variables are related to the vector of Ricardian-specific variables as follows:

$$X_t = \left(1-\phi^h\right) X_t^r$$

where $X_t = [I_t, K_t^p, K_t, B_t, B_t^*]'$.

Market clearing for the foreign bond market and the final goods market requires that at the equilibrium the following two equations for net foreign assets evolution and aggregate resources are satisfied:

$$\frac{e_t B_{t+1}^*}{\Phi_t R_t^* q_t^{b*}} = e_t P_t^x \left(C_t^x + I_t^x\right) - e_t P_t^* \left(C_t^m + I_t^m\right) + e_t B_t^* \tag{40}$$

and:

$$C_t^d + C_t^x + I_t^d + I_t^x + G_t + I_t^g \leq Y_t - a\left(u_t^k\right) K_{t-1}^p - \kappa_t \upsilon_t \tag{41}$$

where $C_t^x + I_t^x = \left[\frac{P_t^x}{P_t^*}\right]^{-\eta_*} Y_t^*$ are total exports with η_* denoting the foreign demand elasticity parameter[18].

The stationary representation of the model is obtained by scaling the real variables with respect to the trending technology process. The scaled model is then log-linearized around the deterministic steady state, taking into account that the presence of a deterministic term in the productivity growth process affects the coefficients of the dynamic equations.

The resulting log-linearized model is composed of 51 structural equations and of 23 shock processes, of which seven are assumed to be first order autoregressive and the remaining 16 are assumed to be *i.i.d.*. The economic relations are described by 63 structural parameters (including the fiscal and monetary policy rule coefficients), whilst the stochastic component of the model is defined by 30 coefficients (23 for the standard deviations of shocks and seven for the autoregressive coefficients)[19].

[18] At the estimation stage we will also consider an additive stochastic process ϱ_t in the aggregate resources constraint, i.e. a first order autoregressive measurement error $\varrho_t = \varrho_{t-1}^{\rho_\varrho} e^{\varepsilon_{\varrho,t}}$. Such a shock is generally considered in the empirical literature in order to enhance the estimates when these include output and all its components appearing in the model.

[19] We denote as structural parameters those defining preferences, technology, elasticities, real and nominal rigidities in the good and labor markets, as well as the coefficients describing the monetary and fiscal policy reaction rules. The seven autoregressive coefficients are those describing the memory of the technology process around the deterministic trend, of the structural shock on government investments, on exports, the home bias, the uncovered interest parity, the long-term interest rate spread and the memory of a measurement error included in the aggregate constraint.

1.8 The foreign economy

Foreign output (y_t^*), inflation (π_t^*), short and long-term interest rates $\left(r_{s,t}^* \text{ and } r_{l,t}^*, \text{ respectively}\right)$ are exogenous to the variables of the small domestic economy and their evolution is described by a fourth-order structural Bayesian B-VAR, where contemporaneous correlations are defined by the structure of the stochastic component matrix $\mathbf{B}$. Formally:

$$\mathbf{A}(L)\begin{bmatrix} \pi_t^* \\ \Delta y_t^* \\ r_{s,t}^* \\ r_{l,t}^* \end{bmatrix} = \mathbf{B}\begin{bmatrix} \varepsilon_t^{\pi^*} \\ \varepsilon_t^{y^*} \\ \varepsilon_t^{r_s^*} \\ \varepsilon_t^{r_l^*} \end{bmatrix}, \quad \mathbf{A}_0 = \mathbf{I}_4, \quad \boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \mathbf{I}_4) \tag{42}$$

$$\mathbf{B} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}, \quad \mathbf{BB}' = \boldsymbol{\Omega}$$

The assumptions on the contemporaneous correlations matrix $\mathbf{B}$ are consistent with the hypothesis that output and inflation do not respond contemporaneously to the other shocks in the system (Adolfson et al. 2008)[20], and that the long-term interest rate is post-recursive with respect to the short-term interest rate.

The SVAR system adds four linear stochastic equations to the economic and stochastic relations of the domestic economy model, resulting in a total of 78 equations and 27 shocks.

2 Bayesian estimation

The rich parameterization of the model precludes the estimation of the entire parameter space, because of the poor empirical identifiability of medium and large scale DSGE models (Canova and Sala 2009, Iskrev 2010a,b, Koop et al. 2011). Even if log-linearized around the deterministic steady state, these structures are in fact characterized by relevant nonlinearities in parameter convolutions, such that the likelihood generated by the model can be uninformative, i.e. multimodal or flat with respect to some parameter values. On these premises, only the subset of the parameter space that satisfies the theoretical and empirical identification conditions is estimated using the Bayesian method, whilst for the remaining subset we adopt dogmatic priors specified according to the available country-specific evidence and to conventional calibration values.

A Bayesian approach is adopted also for the estimation of the foreign variables SVAR, in this case considering a partially modified Minnesota priors specification approach. The choice of using the Bayesian method for the estimation of the SVAR is based on recent results showing its good properties both within sample and in terms of minimization of the predictive variance of the resulting model (Banbura et al. 2010).

[20] Consistently with the results in Adolfson and Lindé (2011), the over-identifying restriction that output does not respond contemporaneously to the price shock is not rejected by the data at the standard 5% criterion.

2.1 Data issues and measurement equations

To enhance the empirical identification of the widest fraction of the structural parameters space, we use a large set of domestic and foreign quarterly variables to estimate the country-specific models.

Considering the domestic economies, 21 observables are considered: (log differences of) of real per capita GDP[21] $\left(\Delta y_t^{obs}\right)$, consumption $\left(\Delta c_t^{obs}\right)$, investment $\left(\Delta i_t^{obs}\right)$, imports $\left(\Delta m_t^{obs}\right)$, exports$\left(\Delta x_t^{obs}\right)$, the real wage $\left(\Delta w_t^{obs}\right)$, real government expenditures for consumption $\left(\Delta g_t^{obs}\right)$, investment $\left(\Delta i_t^{g,obs}\right)$ and transfers $\left(\Delta tr_t^{obs}\right)$; the direct tax rate on labor income $\left(\tau_t^{n,obs}\right)$, on business profits $\left(\tau_t^{p,obs}\right)$, on capital $\left(\tau_t^{k,obs}\right)$ and the indirect tax rate on consumption $\left(\tau_t^{c,obs}\right)$; the unemployment rate $\left(u_t^{obs}\right)$, the (quarterly) rates of change of the price deflators for consumption $\left(\pi_t^{c,obs}\right)$, import $\left(\pi_t^{m,obs}\right)$, export $\left(\pi_t^{x,obs}\right)$ and for the domestic sector $\left(\pi_t^{y,obs}\right)$; the nominal effective exchange rate $\left(e_t^{obs}\right)$, the (quarterly) short and long-term interest rate $\left(r_{s,t}^{obs}\text{ and } r_{l,t}^{obs}\text{, respectively}\right)$, the latter approximated by the 10-years government bond rate. Because of the lack of time series data for hiring and wage subsidies $\varphi_t^h$and φ_t^w, the partial adjustment processes defining their evolution over time are pinned down at the estimation stage. All real variables are referred to the base-year 2005.

Considering the variables for the foreign sector, the log difference of real output $\left(y_t^{*,obs}\right)$ is obtained from the real world output index (base-year 2005) and short and long-term interest rates $\left(r_{s,t}^{*,obs}\text{ and } r_{l,t}^{*,obs}\text{, respectively}\right)$ are obtained as weighted averages of the corresponding figures for the US and the EMU area, with weights given by the relative importance of the two economic areas in domestic capital movements. The foreign price deflator $\left(\pi_t^{*,obs}\right)$ is obtained from the real effective exchange rate definition equation using observed data on domestic inflation, the nominal and the real effective exchange rates. A total of 25 variables is thus considered in the country-specific estimates[22].

All data are taken from official sources and cover the period 1980:1-2012:4[23]. Real variables of the private domestic sector, their deflators and the nominal short and long-term interest rates are taken from the OECD-Economic Outlook database. Nominal and real effective exchange rate indexes, defined at the base-year 2005, and real world output index (2005 = 100) are taken from the IMF-International Financial Statistics database. Data for government expenditures and revenues are, for the quarterly frequency, from the IMF Government Financial Statistics database and, for the yearly frequency, from the OECD-Tax Statistics database and from the IMF Finance Statistics Yearbook [24].

Before linking the observed variables to the theoretical counterparts, some of the latter are transformed in order to get full consistency with the statistical definitions. In particular, the transformations take into

[21] Per capita variables are obtained considering the labor force as the normalizing variable.

[22] To the best of our knowledge, the use of such a high number of observables in the estimates is unprecedented in the literature on empirical DSGE models.

[23] Because of the lack of quarterly time series prior to 1990 for Ireland and to 2000 for Greece, quadratic interpolation methods are applied to yearly observations to obtain the quarterly figures 1980:1-1989:4 and 1980:1-1999:4 for Ireland and Greece, respectively.

[24] Even in this case, since quarterly data are available only after 1999:1, adjustments to changing definitions and quadratic interpolation methods are applied to yearly observations in order to obtain the quarterly frequency for the preceding time span. A detailed description of the data manipulation is provided in a technical appendix of the paper, available upon request from the authors

account that, differently to the statistical aggregates, consumption and investment in the theoretical model are composites of domestic and imported goods and output also includes the hiring cost and that related to changes in the capital utilization rate.

Further transformations are needed in order to make the data consistent with the theoretical steady states and in particular with the model property of balanced growth (μ), a theoretical prediction which is not supported by the evidence in all the countries being considered, in particular for export and import shares. More specifically, the positive/negative excess trends in real variables are removed by considering sample deviations from the steady state output growth rate μ in the measurement equations of all the real variables in the system, such that the theory-consistent stationary great ratios are restored.

Formally, considering the vector of real per capita variables $\mathbf{x}_t = (c_t,\, i_t,\, m_t,\, x_t,\, w_t,\, g_t,\, i_t^g,\, tr_t,\, y_t^*)$, of tax rates $\boldsymbol{\tau}_t = \left(\tau_t^n,\, \tau_t^p,\, \tau_t^k,\, \tau_t^c\right)$, of inflation rates $\boldsymbol{\pi}_t = (\pi_t^c,\, \pi_t^m,\, \pi_t^x,\, \pi_t^y,\, \pi_t^*)$, of short and long-term interest rates $\mathbf{r}_{s,t} = \left(r_{s,t},\, r_{s,t}^*\right)$ and $\mathbf{r}_{l,t} = \left(r_{l,t},\, r_{l,t}^*\right)$, the 25 measurement equations linking the linearized model variables to the respective observables read as follows:

$$\begin{bmatrix} \Delta y_t^{obs} \\ \Delta \mathbf{x}_t^{obs} \\ \boldsymbol{\tau}_t^{obs} \\ u_t^{obs} \\ \boldsymbol{\pi}_t^{obs} \\ \mathbf{r}_{s,t}^{obs} \\ \mathbf{r}_{l,t}^{obs} \\ e_t^{obs} \end{bmatrix} = \begin{bmatrix} \widetilde{y}_t - \widetilde{y}_{t-1} + \log \mu \\ \widetilde{\mathbf{x}}_t - \widetilde{\mathbf{x}}_{t-1} + \log \mu + \log \boldsymbol{\mu}_{xy} \\ \widetilde{\boldsymbol{\tau}}_t + \boldsymbol{\tau} \\ \widetilde{u}_t + u \\ \widetilde{\boldsymbol{\pi}}_t + \log \boldsymbol{\pi} \\ \widetilde{\mathbf{r}}_{s,t} - \log \overline{\boldsymbol{\beta}}^{(.,*)} + \log \boldsymbol{\pi}^{(c,*)} \\ \widetilde{\mathbf{r}}_{l,t} - \log \overline{\boldsymbol{\beta}}^{(.,*)} + \log \boldsymbol{\pi}^{(c,*)} + \mathbf{q}_b^{(.,*)} \\ \widetilde{e}_t + \log e \end{bmatrix} \tag{43}$$

where the coefficients μ_{xy} denote the excess trend (or excess growth rate) of each observed generic real per capita variable in $\mathbf{x}_t^{obs}$ from the real per capita GDP growth rate, μ. $\boldsymbol{\tau}$, $-\log \overline{\boldsymbol{\beta}}$, $\boldsymbol{\pi}$, $\mathbf{q}_b$ and s denote the (steady state) tax rates, the domestic and foreign real interest rates, the inflation rates, the domestic and foreign long-term interest rate spreads, and the nominal effective exchange rate, respectively, and u denotes the steady state unemployment rate.

2.2 Calibrated parameters

Calibrated values are chosen taking into account both sample and extraneous evidence when informative for the theoretical parameters, and conventional values when such information is missing.

We impose 27 dogmatic priors on the 63-dimensional structural parameters space. Absent country-specific information, 18 structural parameters are fixed to common values across countries. These are the steady-state mark-up coefficients λ_p^d, λ_p^m and λ_p^x, fixed to the conventional value of 1.2, consistent with prior demand elasticities for domestic, import and export sector firms equal to 6, the Kimball endogenous demand elasticity parameters κ_ϵ^d, κ_ϵ^m and κ_ϵ^x, fixed to the conventional value of 10 (Eichenbaum and Fisher 2007, Smets and Wouters 2007), the parameter defining the fraction of newly hired workers that are unable to re-optimize the wage period by period θ_w, fixed to 0.5, consistent with the hypothesis of a two quarters average duration of the new wage contract, the parameter defining the fraction of government transfers to Ricardian and non

Ricardian households d, fixed to 1, consistent with an hypothesis of equally distributed transfers, the four parameters defining the partial adjustment processes of hiring and wage subsidies φ_t^h and φ_t^w, fixed to zero at the estimation stage, i.e. $\rho_{\varphi^h} = \rho_{\varphi^w} = \eta_{\varphi^h} = \eta_{\varphi^w} = 0$, the three parameters defining the partial indexation mechanism for the domestic, import and export sectors , i.e. ι_p^d, ι_p^m and ι_p^x, respectively, all fixed to zero in order to allow for an interpretation of the (observed) frequency of price changes in terms of (theoretical) price re-optimization[25], the exchange rate sensitivity to the net foreign assets to GDP ratio $\widetilde{\phi}_a$, fixed to the arbitrary small value of 1^{-3}([26]) and the private and government capital depreciation rates, δ and δ^g, respectively, both fixed to the conventional value of 0.025.

The remaining 9 dogmatic priors for structural parameters are fixed considering country-specific evidence. These are the trend growth parameter μ, fixed considering the sample growth rate of per capita GDP, the discount factor β, calibrated considering the country-specific trend growth and the average real interest rate, the home bias parameter $(1-\nu)$, fixed according to the country-specific sample evidence on the import share, the separation rate ρ, fixed to the country estimates provided by Hobijn and Sahin (2009), the parameter defining the frequency of wage re-optimization of incumbent workers γ_w, fixed to the country estimates provided in Druant et al. (2012), and the parameter defining the unemployment benefit b^u, fixed according to the country-specific replacement rates provided in the OECD-LFS data base (Christoffel et al. 2009). The private capital share α, the matching efficiency parameter σ_m and the labor disutility scale parameter χ are calibrated such that the labor share, the unemployment rate and the job finding rate steady-state values evaluated at the prior parameterization match the sample counterparts for each country[27].

Finally, the coefficients in the system of measurement equations (43), i.e. those in the vector of deviations from GDP trend $\boldsymbol{\mu}_{xy}$, in the vectors of tax rates $\boldsymbol{\tau}$, of inflation rates $\boldsymbol{\pi}$, of domestic and foreign real interest rates and bond rate spreads, $-\log \overline{\boldsymbol{\beta}}$ and $\mathbf{q}_b$, respectively, and the long-run nominal effective exchange rate e, are fixed to the respective sample means.

The seven exclusion restrictions for the identification of the foreign variables' SVAR, i.e. the zero restriction for b_{12}, b_{13}, b_{14}, b_{21}, b_{23}, b_{24} and b_{34} add further seven dogmatic priors. Table 1 summarizes the common and country-specific dogmatic priors adopted in model estimation for the structural parameters.

TABLE 1 ABOUT HERE

2.3 Priors for estimated parameters

The subset of (35) structural model parameters who is not affected by evident identification problems, the 29 coefficients defining the stochastic component (the *i.i.d.* hiring and wage subsidy shocks are pinned down at the estimation stage) and the 73 coefficients of the SVAR (nine for the elements of the $\mathbf{B}$ matrix and 64 for

[25] Under the hypothesis of indexation, prices are changed period by period, ruling out any intepretation of the observed frequencies of price changes in terms of frequencies of price re-optimizations.

[26] Such a small value ensures the satisfaction of the stability conditions (Lundvik 1992, Schmitt-Grohé and Uribe 2001) while minimizing the exchange rate persistence induced by its "technical" relation with the NFA evolution.

[27] Sample data for the job finding rate are obtained by elaborating the information in the OECD Labor Force Survey data-base series "Unemployment by duration".

the vector autoregressive component) are estimated with the Bayesian method[28].

Outside the Calvo price parmeters, the prior distributions are common across countries and are specified following the standard practice: *i)* the shape of the probability density functions is the gamma and the inverted gamma for parameters theoretically defined over the $\mathbb{R}^+$ range, the beta for parameters defined in a $[0-1]$ range and the normal for priors on parameters theoretically defined over the $\mathbb{R}$ range; *ii)* prior means and standard deviations are defined on the basis of sample information (when available), or considering the results of previous analyses[29]. In order to enhance the estimation of parameters subject to weak empirical identifiability, informative priors are adopted such that a certain degree of curvature in the log-kernel is obtained.

The prior means for the Calvo parameters of the domestic, import and export sectors, (ξ_p^d, ξ_p^d ξ_p^d, respectively) are specified according to the country-specific micro-evidence provided in Druant et al. (2012)[30], i.e. 0.71 for Greece, 0.75 for Ireland, 0.69 for Portugal and 0.70 for Italy and Spain. Since the available information does not distinguish across sectors, we adopt a relatively high value for the prior standard deviation, equal to 0.1. A weak gamma-distributed prior with mean 1.5 and standard deviation 0.4 is adopted for the import and export Armington elasticities η and η^* (Adolfson et al. 2008, Christiano et al. 2011b).

Considering the modified UIP equation, the autoregressive coefficient $\widetilde{\phi}_s$ is assumed to be beta-distributed with prior mean 0.25 and prior s.d. 0.15, whilst for the country risk adjustment coefficient $\widetilde{\phi}_r$ we basically follow Christiano et al. (2011b), assuming a (more) diffuse gamma distribution with prior mean 1.25 and prior s.d. 0.5.

The private and public investment adjustment cost parameters ψ^i and ψ^{ig} are assumed to be normally distributed around a prior mean of 5 with a prior s.d. of 2, and the utilization rate curvature parameter ψ^k is assumed to be beta-distributed with prior mean 0.5 and prior s.d. 0.15 (Christiano et al. 2011b).

Concerning the preference parameters, the consumption curvature parameter σ_c is assumed to be normally-distributed with a prior mean of 2 and a prior s.d. of 0.1, whilst the external habits parameter is assumed to be beta-distributed and centered around 0.7 with a prior s.d. of 0.1. The prior for the fraction of liquidity constrained households is rather diffuse, with mean 0.25 and s.d. 0.10[31].

Considering the labor market-specific parameters, a relatively weak beta-distributed prior with mean 0.5 and s.d. 0.15 is assumed for the matching function share parameter σ_n and the union's relative bargaining power parameter ς. The prior for the hiring cost parameter κ is assumed to be gamma-distributed with mean 0.05 and s.d. 0.01, a prior mean value consistent with a hiring cost to GDP ratio $\frac{\kappa \upsilon}{Y}$ close to 1%.

Concerning the monetary policy parameters, the interest rate smoothness coefficient ρ^R is assumed to be beta-distributed with prior mean 0.5 and prior s.d. 0.2, the inflation response parameter ψ_1 is assumed to

[28] Operationally, posterior modes are obtained by maximizing the log-posterior kernel (resulting from the prior distribution and the conditional distribution approximated by the Kalman filter) with respect to the model parameters, and posterior distributions are obtained from the Metropolis-Hastings Monte Carlo Markov chain (MCMC) numerical integration algorithm. Two chains of 500k iterations are considered.

[29] The standard practice of considering results from previous studies is not free of limitations, since the validity domain of prior evidence is not independent of the model being considered.

[30] The Kimball curvature, Calvo and mark-up (or demand elasticity) parameters are not separately identifiable, as testified by the results of preliminary identification checks at the prior values (Iskrev 2010a,b). We adopt the standard practice of fixing the Kimball and mark-up parameters to ensure the empirical identification of the estimated Calvo parameters.

[31] The preference parameters, even if separately identifiable in our setting, are not fully variation-free. The choice of a relatively tight prior for the consumption curvature parameter enhances the identifiability of the other parameters.

be normally distributed with prior mean 2 and s.d. 0.2, whilst the output and output growth sensitivity parameters ψ_2 and ψ_3 are assumed to be beta-distributed with prior means (s.d.) of 0.1 (0.05) and 0.25 (0.1), respectively. The four shift parameters accounting for the monetary policy structural break in the smoothness coefficient and in the feedback coefficients are assumed to be normally distributed with zero prior mean and s.d. equal to 0.2.

Considering the fiscal policy parameters, a beta-distributed prior with mean 0.75 and s.d. 0.15 is adopted for the autoregressive components ρ_{τ^c}, ρ_{τ^n}, ρ_{τ^k} and ρ_{τ^k} in the tax rates partial adjustment equations, and ρ_g, ρ_{tr} in the government consumption and transfers equations, respectively. For the coefficients denoting the sensitivity of these expenditure components to output, η_{gy} and η_{try}, an informative and normally distributed prior with mean 1 and s.d. 0.1 is adopted, consistent with the hypothesis of long-run balanced growth of public expenditures. A weakly informative beta-distributed prior with mean 0.05 and s.d. 0.02 is chosen for the parameters η_{gd} and η_{trd}, defining the sensitivity of public consumption and transfers to the government financial need. The latter prior is equivalent to that chosen for the sensitivity of the tax rates to the financial need ψ_τ, basically following the calibration value adopted in Drautzburg and Uhlig (2011). Finally, a weakly informative beta-distributed prior with mean 0.25 and s.d. 0.10 is adopted for the tax instruments ω^c, ω^n and ω^k, whilst ω^p is restricted to be equal to $1-\left(\omega^c+\omega^n+\omega^k\right)$.

Considering the stochastic component of the models, the prior opinions for the autoregressive coefficients of the seven persistent shock processes (i.e., ρ_{ξ^a}, ρ_{i^g}, $\rho_{\bar{\phi}}$, ρ_{q_b}, ρ_{ϱ}, ρ_ν and ρ_x) are commonly described by a weakly informative beta-distributed prior with mean 0.75 and s.d. 0.15[32]. For the standard errors of the 25 innovations, we assume a prior mean of 0.01 with two degrees of freedom for all shocks, except those multiplying convolutions of parameters whose values are outside the $\left[10^{-1},\ 10\right]$ range, that are scaled accordingly.

The prior opinions on the estimated structural parameters are summarized in the first column of the result Table 2 (panels a-e).

The elicidation of priors for the foreign variables' SVAR is based on the partially modified Minnesota priors approach (Doan et al. 1984, Litterman 1986, Sims and Zha 1998) suggested by Banbura et al. (2010). Accordingly, priors are specified consistently with the hypothesis of independent AR(1) processes (random walks for variables close to non-stationarity), with prior variabilities decreasing in the power of the lag order of the SVAR i (net of an overall shrinkage parameter λ, calibrated according to the number of variables in the system) and scaled considering the variables' error variance ratios σ_m^2/σ_n^2, the latter approximated by the estimated residuals of univariate autoregressive representations. Formally, the prior moments for the 73 coefficients of the fourth-order SVAR (42) are specified as follows:

$$E\left[(\mathbf{A}_i,\mathbf{B})_{mn}\right]=\begin{array}{l}\vartheta \text{ for } i=1,\ m=n\\ 0 \text{ otherwise}\end{array}\quad,\quad V\left[(\mathbf{A}_i,\mathbf{B})_{mn}\right]=\begin{array}{l}\frac{\lambda^2}{i^2}\text{ for } m=n\\ \frac{\lambda^2}{i^2}\frac{\sigma_m^2}{\sigma_n^2}\text{ otherwise}\end{array}\tag{44}$$

where the values for the first-order autoregressive coefficients ϑ are obtained from the estimates of independent AR(1) processes.

[32]The autoregressive coefficients ρ_ν and ρ_x denote the persisitency of the stochastic component in the import and export equations, respectively. Analitically, the first component defines a stochastic home bias parameter, and the second a stochastic elasticity of substitution between foreign and domestic goods. The two stochastic components enter the log-linear representation of the model additively, such that they do not influence the empirical identifiability of the preference parameters.

2.4 Posterior mean estimates

Table 2*a*-*b*-*c*-*d*-*e* report the prior and the posterior mean estimates. Panel *a, b* and *c* contain the estimates of 37-dimensional parameters space for the model economy. the monetary policy and the fiscal policy coefficients, respectively. Panel *d* and *e* report the estimates of the 30 parameters defining the persistence and size of the 25 exogenous stochastic components, respectively[33].

According to the estimated posterior mode standard deviations and the implied pseudo *t*-values, the structural parameter estimates all appear significant for each of the countries being considered. Concerning the stationary disturbances, we obtain a high degree of autocorrelation for all the autoregressive shock processes. The exogenous innovations are all significant according to their standard errors.

The posterior mean values for the model economy parameters are generally close to the respective modal values and indicate reasonable estimates based on our prior opinions and results in the literature. Evident exceptions are the.unconventionally high posterior estimates obtained for the private and public capital adjustment cost parameters ψ^i and ψ^{ig}, on average more than the double of the prior mean value, implying milder investment and capital responses than those obtainable under standard calibration values.

The curvature parameter for the capital utilization rate ψ^k is estimated to be very high and distant from the prior for Greece (0.99), Italy (0.97) and Spain (0.96), and very low for Ireland (0.15). These numbers are expected to be reflected in the model dynamics, since a higher curvature parameter indicates less room for quick adjustments relying on the variation of the utilization rate of capital, thus more persistence.

TABLE 2a ABOUT HERE

A relevant degree of cross-country heterogeneity is obtained with respect to the parameter defining the fraction of liquidity constrained households ϕ^h, estimated to be quite high for Portugal (0.36) and Italy (0.34), and quite low for Greece (0.14) and Spain (0.12). These differences are expected to affect the size of the fiscal policy multipliers, as long as a higher degree of rule-of-thumb behavior is reflected in a more direct link between current income and private consumption, i.e. in the breakdown of Ricardian equivalence.

The posterior estimates of the Calvo parameters in the domestic, import and export sectors, ξ_p^d, ξ_p^m and ξ_p^x, respectively, are somewhat higher than the prior opinions based on survey evidence and the conventional values used in the literature. The high posterior estimates basically reflect the flat slope of the NKPCs, which is more pronounced than that implied by the joint consideration of the Calvo frequency micro-estimates and of the conventional calibration values for the mark-up (or elasticity) parameters[34].

The estimated Armington elasticities η and η^* are generally smaller than the prior and denote a differentiated pattern across countries. A similar consideration holds true for the risk premium parameter $\widetilde{\phi}_r$, which

[33] Mode checks and multivariate M-H convergence plots signal that the estimation process performs correctly for all countries. The mode estimates intersect the log posterior kernel at its maximum for all parameters. The multivariate diagnostics signal that the estimates are stable both within (over replications) and particularly between chains. Posterior densities confirm these encouraging indications, signaling a close to normal shape and a reasonable distance from prior densities. These results are available upon request from the authors.

[34] Such a result shows that, for the countries considered in this study, the introduction of endogenous demand elasticities does not solve the micro-macro dichotomy in the estimate of the NKPC slope coefficients (Eichenbaum and Fisher 2007).

is estimated to be below unity for all countries, ruling out a direct emergence of the forward premium puzzle.

The labor market specific parameters show a certain degree of variability across countries, in particular for the union's relative bargaining power parameter ς, estimated to be higher than the conventional value of 0.5 for all countries except Italy (0.37). The posterior mean estimates for the hiring cost parameter κ and the matching function share parameter σ_n are not distant from priors, except for the former parameter in the case of Portugal ($\kappa = 0.023$) and for the latter parameter in the case of Ireland ($\sigma_n = 0.314$).

TABLE 2b ABOUT HERE

TABLE 2c ABOUT HERE

Considering the estimated monetary policy coefficients adjusted for the break implied by the shift to the single currency, relevant differences emerge across countries. The size of the policy rate response to inflation is quite high for Greece (1.8), close to a conventional parameterization for Spain (1.4), and quite low for the remaining countries (between 1.2 and 1.06). Joint with the estimated high degrees of inertial behavior (the coefficient ρ^R is always well above 0.8), these results indicate, with the exception of Greece, a mild monetary policy response to variations in inflation and output, potentially dampening its counter-cyclical effects under standard fiscal expansions and its pro-cyclical effects in the case of fiscal policies targeted to a reduction of the labor cost and inflation.

It is interesting to note that the posterior estimates of the four shift parameters accounting for the monetary policy structural break are negative and sizeable in all countries being considered, signalling that the shift to a common currency and a centralized authority targeting average EZ inflation and output has implied a reduced degree of monetary policy activism with respect to the single economies macroeconomic developments[35].

TABLE 2d ABOUT HERE

Finally, the posterior estimates for the fiscal policy coefficients confirm the high degree of inertia on both the expenditure and the revenue sides, with estimated autoregressive coefficients well above the conventional calibration value of 0.9 (Perotti 2005). It is interesting to note that the posterior estimates for the parameter denoting the sensitivity of the tax rates to the government financial need ψ_τ, even if low and distant from the prior, are basically consistent with the Galì and Perotti (2003) estimates for OECD countries. The estimated sensitivities of government consumption and transfers to the financial need (η_{gd} and η_{trd}, respectively) are on average higher and more heterogeneous across countries, with a size ranging from 0.01 for Ireland to 0.06 for Greece. The parameter defining the link between long-run expenditure and output levels (η_{gy} and η_{try}) are always not significantly different from unity, such that the hypothesis of balanced growth in the fiscal variables cannot be rejected.

[35] Detailed results on the monetary policy break estimates are reported in a technical appendix available upon request from the authors.

TABLE 2e ABOUT HERE

3 Policy simulations

In this section we provide a comparative analysis of the country-specific expected effects from the implementation of the two alternative labor market targeted policies. These are obtained by simulating the model considering the parameterization obtained at the country-specific posterior mean estimates.

The policy simulation exercise is developed along two main lines: *i).*a persistent, albeit not permanent, reduction in the labor cost of newly hired workers through transitory wage subsidies, financed with public resources equivalent to 1% of GDP; *ii)* a transitory reduction in hiring costs through structural LM reforms, for an equivalent amount of resources. The persistence coefficients of the shocks are set to 0.75, consistent with a one year average duration of the policy shock.

Even though the mathematical implementation of measure *ii)* is straightforward in our model, its calibration to the resources being devoted is highly problematic. In order to circumvent these implementation problems, and possibly optimistically, we assume that, given the estimated equilibrium hiring cost parameter (which is not observed), the structural measures are expected to induce a reduction of this specific cost on impact for an amount equivalent to the public financing of the measure.

We assume that the measures are backed by national resources, so that they necessarily imply fiscal financing, i.e, public budget and debt variations through tax rate and expenditure changes, expenditure restructuring and bonds issuing. In order to enhance the understanding of the simulation results, we only consider the estimated systematic components in the revenue equations, i.e., the specific elasticity of tax rates to the financial need, whilst the expenditure side is assumed to be fully exogenous by setting the elasticities of the expenditure components to the financial need and to GDP to zero.

The results from the labor market targeted policy simulations are then compared with those obtainable from the implementation of equally financed fiscal policy measures based on increased expenditures in government consumption, transfers and investments and on decreased tax pressure on labor incomes, business profits, capital gains and consumption. The different simulations are made comparable by calibrating the size of each policy shock to be equivalent to a 1% of GDP on impact and by homogenizing their persistence to the one adopted for the simulation of the labor market targeted fiscal measures.

The same policy simulations are then repeated considering that the economies are operating in a neighborhood of the liquidity trap. To implement such an environment, we calibrate a negative preference shock implying an eight-quarters period non positive equilibrium interest rate for each country, and impose the zero-lower-bound (ZLB) condition.

3.1 The effects of the policies in standard times

Figures 1 and 2 depict the expected effects from government expenditure shocks on hiring costs and wage subsidization for new hires of labor in the PIIGS, respectively. For simplicity, only the responses of GDP and of the unemployment rate are reported. These are normalized such that the GDP response has an interpretation in terms of the dynamic monetary fiscal multiplier (i.e. the expected monetary variation in GDP from a 1 euro budget variation), whilst the unemployment rate response has an interpretation in terms of percent deviation from the steady-state unemployment rate.

FIGURE 1 ABOUT HERE

FIGURE 2 ABOUT HERE

A first outcome that merits to be highlighted is the very high variability of results across countries for both measures, signalling the operation of very different transmission mechanisms. Considering the hiring subsidy, the peak output multiplier and the peak percent reduction in unemployment range, respectively, from a maximum of 3.4 and -2% for Greece, to a minimum of approximately 0.3 for the output in Ireland and of -0.3% for unemployment in Italy. Qualitatively similar results hold for the wage subsidy, for which the highest peak effects are obtained for Greece (4.1 the output peak multiplier, -2.5% the peak reduction in unemployment), and the lowest for Ireland in the case of the output multiplier (0.2) and for Italy in the case of the maximum unemployment reduction (-0.3%).

To understand the economic reasons behind these outcomes, it is worth fixing two points that are common to both the labor market targeted measures. First, the impact effect on output is negative for all countries but Greece and that on unemployment is negligible. Second, the measures are expected to produce positive effects on output and employment only in the medium to long-term (on average, the peak response is reached after 16 periods, i.e. four years), with the sole exception of the unemployment response for Ireland, reaching its peak after three periods.

The negative output response observed in all countries but Greece on impact is mainly related to the delayed real wage contraction, due to the nominal wage rigidity, and to the temporary increase in the real interest rate, due to the weak monetary policy reaction to the deflation stimulated by the real wage contraction. The resulting increase in the real interest rate leads to a temporary drop in private expenditures (consumption and investment), whilst the dampened real wage contraction, which is not compensated by a quick and significant increase in employment, tends to depress private consumption in the fraction of liquidity constrained households. The positive net export response stimulated by the devaluation of the real exchange rate is not sufficient to outweigh the contraction in the internal demand components. The fact that Greece is the country for which the strongest real wage contraction and the highest degree of monetary policy activism are obtained explains great part of the fact that for this country the expansionary effects take place even on impact, consistently with the result and the mechanics discussed in Faia et al. (2013)[36].

FIGURE 3 ABOUT HERE

[36] We have verified that, by setting the inflation response coefficient to 1.2 in the Taylor rule and lowering the estimated elasticity of import to the value being estimated for the export elasticity (0.67), the responses of output and employment are more aligned with those obtained for the other countries. The output impact response becomes negative, whilst the peak output and unemployment multipliers are strongly reduced (1.4 and -0.97%)

Figures 3 and 4, for the hiring and wage subsidy shocks, respectively, report the impulse responses of the real wage and of the real interest rate, together with the dynamics of the relative contributions to the output response of private expenditures and net exports[37].

The induced real wage contraction is at the root of the transmission mechanisms of the policies being considered. The size and the persistence of this effect depend on the mechanics established by equation (25), showing the relevance of the degree of nominal wage rigidity, as well as the emergence of both contemporaneous and intertemporal factors in the wage bargaining process

Considering the introduction of a wage subsidy, the first row of equation (25) shows that, for a given degree of nominal wage rigidity, the bargained real wage is directly related to the present wage subsidy, weighted by the fraction of new hires of labor. The contemporaneous effects are thus dominated by the intertemporal effects, driving the bargained wage in the opposite direction. In fact, and as expected from the discussion in section (2.4), given the country-specific calibrated values for the separation rate ρ, and the estimated union's relative bargaining power parameter ς, the firm's intertemporal incentive to reduce the present bargained wage always dominates the union's net intertemporal incentive to increase it. The different real wage responses in the countries being considered basically reflect the cross-country heterogeneity in these two labor market parameters and the different degrees of nominal wage rigidity.

Considering the introduction of a hiring subsidy, the mechanics of the wage contraction is immediately evident in the third last row of equation (25), showing that the subsidy reduces the present bargained real wage because of the anticipation of the loss opportunity of a future reduction in the hiring cost.

The delayed output and employment peak effects of the labor market targeted policies are due to, on the one hand, the high degree of both nominal and real rigidities and, on the other, to the inertial behavior of the monetary authority. The nominal wage rigidity dampens the speed of the wage contraction, as well as the estimated high degrees of price rigidity, that reduces the size and delays the resulting price deflation.

FIGURE 4 ABOUT HERE

On the real terrain, the estimated high degrees of external habits h introduce a strong memory component in private consumption behavior, which is not compensated by a sufficiently quicker response of private and public investment, because of the high private and public capital adjustment costs (defined by the estimated size of parameters ψ^i and ψ^{ig}), and of the degree of rigidity in varying its utilization.rate (defined by the estimated size of parameter ψ^k). The latter real rigidity,which is estimated to be particularly low for Ireland, explains great part of the quicker positive response in employment obtained for this country.

Concerning the relative effects of the two labor market policies, the simulations indicate that, except Greece, the expected effects from the introduction of hiring subsidies are slightly stronger than those from an equally financed wage subsidization. This result is due to the stronger real wage contraction stimulated by the hiring cost subsidy shock.

Table 3 shows that, compared to more standard expansionary fiscal policies increasing public spending or reducing the tax pressure, the labor market targeted fiscal policies prove less efficient in providing a timely

[37] The relative contribution to the output variation of private domestic expenditures (consumption and investment) and of net exports are obtained by weightening the variables' impulse responses by the respective steady state ratios to output.

(impact) stimulus to economic activity in all countries being considered. Except Greece, the fiscal multipliers are maximized both on impact and at the peak response with a government consumption shock. Even considering a wasteful expenditure, for these countries the range of values for the estimated impact and peak monetary multipliers are within 1 and 2.

TABLE 3 ABOUT HERE

It is interesting to compare the effects from hiring costs and newly hired workers' wage subsidization with those from a general labor tax reduction. The latter produces the peak output response on impact in all economies, even if the size of the multiplier is highly heterogeneous across countries, basically reflecting the estimated fraction of liquidity constrained households[38] The reason for the quicker effects is that, since the tax cut affects the (larger) fraction of incumbent workers, the reduction in the labor tax pressure immediately increases the current after tax real income, stimulating consumption in the fraction of liquidity constrained households and labor supply. The increase in labor supply tends to counterbalance the inflationary pressure activated by the increased private consumption expenditure. Thus, because of the resulting economic expansion, private investment also increases. The negative net export response, due to the slightly reduced competitiveness of the domestic production from increased domestic prices, is not sufficient to reverse the sign of the response in output.

The impact reduction in unemployment stimulated the labor market targeted measures (Table 4) dominates that obtainable from the alternative measures only in the case of Ireland, whilst the expected peak effects are stronger than those obtainable with a government consumption expansion for Greece and Ireland, basically equivalent for Portugal and weaker for Italy and Spain.

The main responsible for the relatively high values of the government expenditure employment multiplier is again the estimated inertial behavior of the monetary policy. When faced with an expansionary and inflationary policy, the smoothed response of the nominal interest rate tends to downsize the counteracting effects of the monetary policy stabilization response, whilst it provides weak accommodation to policies relying mainly on the dynamics activated by wage and price deflations, as it is in the case of the wage and hiring costs subsidization policies.

To summarize: *i)* the labor market targeted policies lead in general to a higher degree of heterogeneity of results across countries than that resulting from standard fiscal policies (in particular government consumption expenditures); *ii)* aside Greece, their growth-enhancing effects are always inferior than those obtainable from government consumption expenditure; *iii)* even if the employment effects can be superior than those of the alternative fiscal policies, their potential is reached only with a significant delay.

These results signal that, even if the labor market targeted policies reduce the labor cost both directly and indirectly, whereas standard fiscal expansions based on government expenditure lead to an increase in the real wage that tends to counterbalance the employment-enhancing effects of the economic expansion, these

[38] The fraction of rule-of-thumb households is in fact estimated to be particularly low for Spain and Greece, reflecting the low correlation between private consumption and current net incomes in the sample. Considering the recent evolution of the Greek and Spanish economies, it is highly probable that the fraction of liquidity contrained households increased strongly. We have verified that, by including a dummy variable controlling for the recessionary periods, the estimated degree of liquidity constraints increases by 0.14 points for Spain and 0.18 points for Greece.

mechanisms are not strong enough to make the labor market targeted policies a set of instruments to be preferred to more standard fiscal policies, especially under a business cycle management perspective.

It is worth highlighting that, under the small open economy assumption adopted in this study, the estimated effects of the labor market targeted policies are likely to be maximized, since we cannot control for the situation in which the same policy is adopted in the foreign economy. It would be interesting to evaluate to which degree their generalized adoption in a highly integrated single currency area has the same efficacy.

TABLE 4 ABOUT HERE

3.2 The effects of the policies in a liquidity trap

The analysis developed so far has shown that the relative efficacy of the alternative measures in the different countries depends both on the different degrees of nominal and wage rigidity and on the interaction between fiscal and monetary policy regimes. In particular, an aggressive monetary policy increases the expected effects of fiscal measures targeted to induce a price deflation through the reduction of the labor cost, and dampens those of policies stimulating the general economic activity, because of their inflationary implications.

The fact that the labor market targeted fiscal policies being evaluated are expected to be implemented in economies operating well below their potential, as is the case of the countries considered in this study, suggests to extend the analysis to the situation of a binding ZLB. In these circumstances, a deflationary fiscal policy cannot be accommodated by the automatic response of the monetary authority, since the nominal interest rate cannot be reduced further (Eggertsson et al. 2014)[39]. On the contrary, an expansionary and inflationary fiscal policy, until it does not succeed in taking the economy out of the liquidity trap, will not face the same counteracting effects originating in the stabilizing response of the monetary policy during standard times (Christiano et al. 2011a, Eggertsson 2011a,b, Eggertsson and Krugman 2012). Tables 5 and 6 replicate, for a below potential-liquidity trap economic environment, the information on the fiscal multipliers and on the employment effects of the alternative policies provided by Tables 3 and 4 for the economis operating at thei potential output levels. Since strongly negative output multipliers are often found, one row reporting the peak negative multiplier is added in Table 5.

The consideration of a liquidity trap environment affects the efficacy of the labor market targeted fiscal policies in different directions in the short and in the long term. Considering the hiring cost subsidization policy, the short-term output multipliers are significantly negative in all countries but Greece, (between -0.04 for Spain and -2.6 for Portugal), whilst the long-term peak output multipliers are increased and delayed further (between 0.5 for Ireland and 3.2 for Greece). Qualitatively similar results are obtained considering the subsidization of the wage of the new hires of labor, for which the short term multipliers are again negative (between -0.03 for Spain and -2.5 for Portugal), whilst in the long run their peak values are confirmed to be increased (between 0.4 for Ireland and 5.2 for Greece). The employment effects are instead always positive, even if the stronger peak employment reduction is in general delayed further as compared to the standard time simulations.

[39] Eggertsson et al. (2014), by simulating a monetary model calibrated to average EZ data, show that a permanent reduction in product and labor market markups (a structural policy in authors' terms), can have contractionary short term effects when the economy is in a liquidity trap.

The transmission mechanics explaining these results is the same described for the simulations assuming a not binding ZLB environment. Even in this case, the subsidization policy generates a deflation through the real wage contraction. The main difference here is that, for the eight periods in which the ZLB binds, the monetary authority cannot accommodate the policy with a nominal interest rate reduction, such that the resulting increase in the real interest rate is of the same size of the price deflation. The transitory but sizeable negative output response amplifies the real wage contraction and the deflation during the liquidity trap period.

As the economy recovers, the monetary authority decreases the policy rate by a larger amount than in a not binding ZLB environment, because of the stronger deflation, and firms are willing to hire more workers, because of the stronger real wage contraction. This justifies the expansion following the transitory but persistent depression activated by the labor market policies.

Notwithstanding the amplified and delayed long run output responses, and with the exception of Greece, the labor market targeted policies are confirmed to be inferior to a fiscal policy expansion based on government consumption. As expected, the output and employment effects of fiscal expansions based on government expenditures are significantly increased, with the peak government consumption output multipliers in the range $1.7 - 3.3$, and the unemployment reduction within -0.8% and -1.3%. When the ZLB binds, the counteracting response of the monetary authority does not take place until the economy is out of the liquidity trap. In this circumstance, the real interest rate tends to decrease with the increased inflation, adding a positive private expenditure response to the government stimulus.

TABLE 5 ABOUT HERE

TABLE 6 ABOUT HERE

It is interesting to note that, under a binding ZLB, fiscal expansions based on tax rate cuts are counterproductive in all countries in the short term, and basically ineffective in the long run. This result is only apparently surprising. On the one hand, a labor tax cut increases the after tax current income, leading to both increased labor supply and to increased consumption demand in the fraction of liquidity constrained households. On the other, the increased labor supply induces a real wage and thus marginal cost contraction, activating a deflationary pressure. Since only a minor fraction of households are liquidity constrained, the deflation stimulated by the reduced tax pressure prevails such that, given the fixed policy rate, an increase in the real interest rate emerges, leading to reduced private expenditures[40].

[40] The mechanics behind this result has been explained in detail by Eggertsson (2011a) in a simplified model setting assuming full Ricardian equivalence. In his comment to the Eggertsson's (2011a) paper, Christiano (2011) provides some useful insights and identifies two major ingredients for the deflationary pressure to emerge following a tax cut: *i)* the persistence of the deflationary pressure, i.e. the presence of relevant price rigidities; *ii)* the sensitivity of expenditures to the real interest rate, i.e. the empirical relevance of the Euler consumption equation. Our results, emerging in an extended structural model setting estimated on country data, provide evidence in support to Eggertsson's result giving an empirical assesment of both key factors.

4 Conclusions

We develop, estimate and simulate a model characterized by a detailed representation of the non Walrasian labor market. We introduce both government hiring and wage subsidies for newly hired workers, obtained by considering a distinction between incumbent workers and new entrants in the search and matching framework, in order to formalize a modification affecting both the job creation condition and the Nash bargained wage, such that unions/firms are non-neutral in wages/labor costs with respect to new hires of labor.

The analysis, developed at the country-level for a selection of peripheral EZ economies (the PIIGS), is based on the simulation of the country-specific response of output and employment to a general hiring shock and a wage subsidy shock targeted to new hires of labor only, and on their comparison with the expected effects from financially equivalent fiscal policies affecting government expenditure and revenues. Results show that, contrary to some conclusions in the recent literature and the policy recommendations within the European EP and YG programmes, the labor market targeted fiscal measures, in a short term perspective, are not superior to more standard fiscal instruments in the management of the business cycle. The analysis also indicates that, even in a longer term perspective and aside Greece, the output multiplier of government consumption is higher than that from hiring costs and newly hired workers' subsidization. Considering the employment effects, these policies prove to be clearly superior to more standard fiscal expansions only in the long term and at the Greece and Ireland model parameter estimates.

The consideration of a liquidity trap environment reinforces these conclusions, as both output and employment multipliers of government expenditures are significantly increased. On the contrary - and with the exception of Greece - the output multiplier of the labor market targeted measures are strongly negative in the short term, and their peak effects are reached with an increased delay as compared with the standard environment simulations.

These results basically highlight the importance of the fiscal-monetary policy coordination in the business cycle management, an option which might be out of reach during a deep recession.

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TABLE 1 - DOGMATIC PRIORS: STRUCTURAL PARAMETERS

Parameter	Description	Spain	Greece	Ireland	Italy	Portugal
β	Discount factor	0.995	0.994	0.997	0.996	0.999
α	Production function parameter	0.220	0.265	0.220	0.333	0.210
δ	Capital depreciation rate	0.025	0.025	0.025	0.025	0.025
δ^g	Government capital depreciation rate	0.025	0.025	0.025	0.025	0.025
ν	Import share	0.340	0.335	0.920	0.281	0.350
ρ	Separation rate	0.061	0.028	0.042	0.021	0.039
σ_m	Matching efficiency	1.150	0.650	0.300	0.600	0.250
χ	Labor disutility scale	0.800	0.300	1.000	4.070	0.200
b^u	Unemployment benefit	0.610	0.650	0.650	0.630	0.720
γ_w	Renegotiation frequency incumbent workers	0.750	0.750	0.800	0.850	0.770
θ_w	Renegotiation frequency new workers	0.500	0.500	0.500	0.500	0.500
φ^j	Labor subsidies	0.000	0.000	0.000	0.000	0.000
λ_p^i	Price markups	1.200	1.200	1.200	1.200	1.200
κ_ϵ^i	Demand elasticity	10.00	10.00	10.00	10.00	10.00
ι_p^i	Price indixation	0.000	0.000	0.000	0.000	0.000
μ	Growth rate	1.002	0.999	1.007	1.002	1.003
$\widetilde{\phi}_a$	Exchange rate elasticity to net asset	0.001	0.001	0.001	0.001	0.001
d	Relative government transfers share	1.000	1.000	1.000	1.000	1.000
ρ_{φ^j}	Labor subsidies autoregressive parameters	0.000	0.000	0.000	0.000	0.000
η_{φ^j}	Labor subsidies partial adjustment parameters	0.000	0.000	0.000	0.000	0.000

Notes: The parameters related to "great ratios" and other observable quantities related to steady state values are calibrated considering that the time unit is a quarter. The sector specific parameters denoted by i = d, m, x are assumed, as for the wage and hiring subsidy j = w, h, to be of equal value.

TABLE 2*a* - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: MODEL ECONOMY

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ξ_p^d	$\mathcal{G}$	$0.69 - 0.75^*$	0.894	0.905	0.877	0.844	0.873
		(0.10)	[0.865 − 0.923]	[0.884 − 0.926]	[0.867 − 0.887]	[0.822 − 0.866]	[0.861 − 0.884]
ξ_p^m	$\mathcal{G}$	$0.69 - 0.75^*$	0.906	0.842	0.840	0.900	0.837
		(0.10)	[0.876 − 0.937]	[0.815 − 0.868]	[0.802 − 0.877]	[0.873 − 0.929]	[0.797 − 0.885]
ξ_p^x	$\mathcal{G}$	$0.69 - 0.75^*$	0.822	0.850	0.808	0.847	0.790
		(0.10)	[0.784 − 0.864]	[0.807 − 0.904]	[0.759 − 0.861]	[0.816 − 0.880]	[0.748 − 0.833]
σ_c	$\mathcal{N}$	2.00	1.961	1.864	1.983	1.921	2.017
		(0.10)	[1.799 − 2.121]	[1.705 − 2.029]	[1.845 − 2.124]	[1.766 − 2.071]	[1.849 − 2.179]
h	$\mathcal{B}$	0.70	0.821	0.801	0.822	0.762	0.905
		(0.10)	[0.782 − 0.859]	[0.755 − 0.848]	[0.785 − 0.862]	[0.705 − 0.819]	[0.883 − 0.928]
ϕ^h	$\mathcal{B}$	0.25	0.137	0.252	0.343	0.361	0.123
		(0.10)	[0.081 − 0.187]	[0.158 − 0.346]	[0.251 − 0.438]	[0.280 − 0.445]	[0.049 − 0.191]
η	$\mathcal{G}$	1.50	0.941	1.432	0.439	0.667	0.663
		(0.40)	[0.764 − 1.112]	[0.807 − 2.017]	[0.299 − 0.569]	[0.480 − 0.847]	[0.490 − 0.837]
η^*	$\mathcal{G}$	1.50	0.626	0.893	0.851	0.700	0.374
		(0.40)	[0.502 − 0.747]	[0.751 − 1.043]	[0.723 − 0.980]	[0.571 − 0.830]	[0.247 − 0.497]
$\widetilde{\phi}_s$	$\mathcal{B}$	0.25	0.494	0.644	0.872	0.876	0.876
		(0.15)	[0.390 − 0.613]	[0.514 − 0.779]	[0.767 − 0.966]	[0.816 − 0.939]	[0.802 − 0.953]
$\widetilde{\phi}_r$	$\mathcal{G}$	1.25	0.612	0.692	0.958	0.598	0.751
		(0.50)	[0.517 − 0.706]	[0.575 − 0.806]	[0.880 − 1.027]	[0.467 − 0.721]	[0.667 − 0.842]
ψ^i	$\mathcal{N}$	5.00	13.01	7.90	11.81	8.86	10.73
		(2.50)	[13.20 − 15.65]	[5.12 − 10.67]	[9.74 − 13.90]	[6.85 − 10.86]	[8.48 − 12.88]
ψ^{ig}	$\mathcal{N}$	5.00	12.92	13.43	15.08	5.34	13.49
		(2.50)	[10.21 − 15.65]	[10.84 − 16.04]	[12.63 − 17.53]	[2.99 − 7.57]	[10.74 − 16.18]
ψ^k	$\mathcal{B}$	0.50	0.988	0.148	0.971	0.461	0.957
		(0.15)	[0.981 − 0.996]	[0.107 − 0.189]	[0.959 − 0.982]	[0.347 − 0.566]	[0.935 − 0.980]
σ_n	$\mathcal{B}$	0.50	0.494	0.314	0.559	0.541	0.481
		(0.10)	[0.374 − 0.613]	[0.189 − 0.438]	[0.418 − 0.708]	[0.413 − 0.664]	[0.303 − 0.664]
ς	$\mathcal{B}$	0.50	0.724	0.762	0.367	0.842	0.606
		(0.10)	[0.659 − 0.794]	[0.685 − 0.841]	[0.274 − 0.455]	[0.783 − 0.902]	[0.525 − 0.691]
κ	$\mathcal{G}$	0.05	0.053	0.045	0.043	0.024	0.052
		(0.01)	[0.037 − 0.068]	[0.032 − 0.058]	[0.029 − 0.057]	[0.018 − 0.030]	[0.034 − 0.069]

Notes: N and B are Normal and Beta distributions, respectively. Posterior mean estimates for the model economy parameters are obtained with 250000 M-H replications on two parallel chains. * denotes the range of values for the country-specific values Druant et al. (2012).

TABLE 2*b* - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: MONETARY AUTHORITY

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ρ^R	$\mathcal{B}$	0.50	0.888	0.896	0.909	0.830	0.908
		(0.20)	[0.869 − 0.905]	[0.878 − 0.915]	[0.894 − 0.925]	[0.809 − 0.852]	[0.897 − 0.920]
ψ_1	$\mathcal{N}$	2.00	1.80	1.10	1.23	1.06	1.42
		(0.20)	[1.58 − 2.02]	[1.03 − 1.16]	[1.09 − 1.36]	[1.02 − 1.10]	[1.19 − 1.65]
ψ_2	$\mathcal{B}$	0.10	0.061	0.021	0.017	0.010	0.008
		(0.05)	[0.037 − 0.086]	[0.011 − 0.031]	[0.002 − 0.032]	[0.003 − 0.016]	[0.001 − 0.014]
ψ_3	$\mathcal{B}$	0.25	0.063	0.064	0.119	0.055	0.084
		(0.10)	[0.030 − 0.096]	[0.045 − 0.085]	[0.093 − 0.147]	[0.036 − 0.075]	[0.042 − 0.125]

Notes: N and B are Normal and Beta distributions, respectively. Posterior mean estimates for the monetary authority parameters are obtained with 250000 M-H replications on two parallel chains.

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TABLE 2c - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: FISCAL AUTHORITY

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ω^c	$\mathcal{B}$	0.25	0.399	0.438	0.238	0.420	0.494
		(0.10)	[0.276 − 0.514]	[0.296 − 0.576]	[0.150 − 0.320]	[0.315 − 0.525]	[0.383 − 0.608]
ω^n	$\mathcal{B}$	0.25	0.595	0.375	0.690	0.580	0.470
		(0.10)	[0.477 − 0.717]	[0.240 − 0.515]	[0.580 − 0.800]	[0.459 − 0.701]	[0.355 − 0.581]
ω^k	$\mathcal{B}$	0.25	0.007	0.159	0.034	0.001	0.009
		(0.10)	[0.003 − 0.011]	[0.057 − 0.252]	[0.011 − 0.055]	[0.000 − 0.002]	[0.003 − 0.014]
ψ_τ	$\mathcal{B}$	0.05	0.014	0.018	0.013	0.021	0.013
		(0.02)	[0.009 − 0.017]	[0.012 − 0.024]	[0.009 − 0.016]	[0.014 − 0.028]	[0.010 − 0.016]
ρ_{τ^c}	$\mathcal{B}$	0.75	0.962	0.967	0.953	0.956	0.982
		(0.15)	[0.933 − 0.990]	[0.947 − 0.989]	[0.916 − 0.992]	[0.922 − 0.992]	[0.969 − 0.998]
ρ_{τ^n}	$\mathcal{B}$	0.75	0.981	0.988	0.988	0.990	0.968
		(0.15)	[0.968 − 0.995]	[0.979 − 0.998]	[0.979 − 0.998]	[0.981 − 0.999]	[0.945 − 0.993]
ρ_{τ^k}	$\mathcal{B}$	0.75	0.980	0.968	0.979	0.987	0.982
		(0.15)	[0.964 − 0.997]	[0.955 − 0.982]	[0.962 − 0.998]	[0.976 − 0.999]	[0.969 − 0.996]
ρ_{τ^p}	$\mathcal{B}$	0.75	0.978	0.971	0.958	0.990	0.972
		(0.15)	[0.963 − 0.995]	[0.949 − 0.994]	[0.927 − 0.992]	[0.982 − 0.999]	[0.951 − 0.993]
ρ_g	$\mathcal{B}$	0.75	0.976	0.953	0.966	0.964	0.971
		(0.15)	[0.949 − 0.999]	[0.926 − 0.980]	[0.938 − 0.993]	[0.943 − 0.984]	[0.954 − 0.988]
ρ_{tr}	$\mathcal{B}$	0.75	0.949	0.965	0.980	0.911	0.972
		(0.15)	[0.923 − 0.975]	[0.950 − 0.980]	[0.966 − 0.995]	[0.866 − 0.956]	[0.958 − 0.986]
η_{gy}	$\mathcal{N}$	1.00	0.985	0.958	1.02	1.05	1.06
		(0.10)	[0.819 − 1.15]	[0.793 − 1.12]	[0.860 − 1.20]	[0.888 − 1.23]	[0.893 − 1.23]
η_{try}	$\mathcal{N}$	1.00	0.994	1.03	1.01	1.02	1.00
		(0.10)	[0.829 − 1.16]	[0.868 − 1.20]	[0.850 − 1.17]	[0.858 − 1.18]	[0.842 − 1.17]
η_{gd}	$\mathcal{B}$	0.05	0.028	0.030	0.019	0.016	0.016
		(0.02)	[0.015 − 0.041]	[0.013 − 0.046]	[0.010 − 0.028]	[0.006 − 0.025]	[0.010 − 0.021]
η_{trd}	$\mathcal{B}$	0.05	0.056	0.098	0.018	0.024	0.023
		(0.02)	[0.023 − 0.089]	[0.070 − 0.125]	[0.011 − 0.025]	[0.013 − 0.036]	[0.016 − 0.030]

Notes: N and B are Normal and Beta distributions, respectively. Posterior mean estimates for the fiscal authority parameters are obtained with 250000 M-H replications on two parallel chains.

TABLE 2d - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: AR(1) COEFICIENTS OF SHOCKS

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
ρ_{ξ^a}	$\mathcal{B}$	0.75	0.949	0.934	0.915	0.911	0.954
		(0.15)	[0.927 − 0.973]	[0.918 − 0.950]	[0.890 − 0.942]	[0.889 − 0.934]	[0.936 − 0.973]
ρ_{i^g}	$\mathcal{B}$	0.75	0.913	0.838	0.154	0.194	0.847
		(0.15)	[0.868 − 0.953]	[0.751 − 0.928]	[0.059 − 0.245]	[0.088 − 0.296]	[0.761 − 0.929]
$\rho_{\tilde{\phi}}$	$\mathcal{B}$	0.75	0.887	0.843	0.888	0.897	0.881
		(0.15)	[0.846 − 0.931]	[0.800 − 0.889]	[0.836 − 0.942]	[0.843 − 0.951]	[0.812 − 0.954]
ρ_{q_b}	$\mathcal{B}$	0.75	0.873	0.910	0.874	0.905	0.927
		(0.15)	[0.846 − 0.900]	[0.876 − 0.945]	[0.838 − 0.910]	[0.877 − 0.933]	[0.900 − 0.955]
ρ_{ϱ}	$\mathcal{B}$	0.75	0.972	0.902	0.758	0.971	0.945
		(0.15)	[0.953 − 0.992]	[0.857 − 0.949]	[0.657 − 0.857]	[0.952 − 0.992]	[0.909 − 0.985]
ρ_{ν}	$\mathcal{B}$	0.75	0.956	0.976	0.928	0.918	0.963
		(0.15)	[0.932 − 0.981]	[0.964 − 0.988]	[0.891 − 0.965]	[0.864 − 0.971]	[0.940 − 0.986]
ρ_{x}	$\mathcal{B}$	0.75	0.987	0.962	0.885	0.928	0.899
		(0.15)	[0.983 − 0.991]	[0.947 − 0.977]	[0.827 − 0.950]	[0.871 − 0.993]	[0.852 − 0.946]

Notes: B represents the Beta distribution. Posterior mean estimates for the AR(1) coeficients of shocks are obtained with 250000 M-H replications on two parallel chains.

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TABLE 2e - PRIOR DISTRIBUTIONS AND POSTERIOR MEAN ESTIMATES: S.D. OF SHOCK PROCESSES

	Prior distribution		Posterior mean				
	Density	Mean (s.d.)	Greece [c.i.]	Ireland [c.i.]	Italy [c.i.]	Portugal [c.i.]	Spain [c.i.]
$\varepsilon_{\tau^n,t}$	$\mathcal{G}^{-1}$	0.01	0.008	0.003	0.005	0.006	0.003
		(2.00)	[0.007 – 0.008]	[0.003 – 0.003]	[0.004 – 0.005]	[0.006 – 0.007]	[0.003 – 0.004]
$\varepsilon_{\tau^p,t}$	$\mathcal{G}^{-1}$	0.01	0.003	0.003	0.003	0.003	0.004
		(2.00)	[0.002 – 0.003]	[0.003 – 0.004]	[0.003 – 0.003]	[0.002 – 0.003]	[0.004 – 0.004]
$\varepsilon_{\tau^k,t}$	$\mathcal{G}^{-1}$	0.01	0.004	0.019	0.007	0.001	0.004
		(2.00)	[0.004 – 0.005]	[0.017 – 0.021]	[0.006 – 0.008]	[0.001 – 0.001]	[0.003 – 0.004]
$\varepsilon_{\tau^c,t}$	$\mathcal{G}^{-1}$	0.01	0.004	0.005	0.002	0.004	0.004
		(2.00)	[0.003 – 0.004]	[0.004 – 0.005]	[0.002 – 0.002]	[0.004 – 0.005]	[0.003 – 0.004]
$\varepsilon_{g,t}$	$\mathcal{G}^{-1}$	0.01	0.026	0.028	0.019	0.024	0.011
		(2.00)	[0.023 – 0.028]	[0.025 – 0.031]	[0.017 – 0.021]	[0.021 – 0.026]	[0.010 – 0.012]
$\varepsilon_{tr,t}$	$\mathcal{G}^{-1}$	0.01	0.080	0.027	0.014	0.021	0.013
		(2.00)	[0.072 – 0.087]	[0.024 – 0.030]	[0.013 – 0.015]	[0.019 – 0.023]	[0.011 – 0.014]
$\varepsilon_{i^g,t}$	$\mathcal{G}^{-1}$	0.1	0.161	0.225	0.985	1.104	0.123
		(2.00)	[0.118 – 0.203]	[0.140 – 0.305]	[0.759 – 1.213]	[0.696 – 1.542]	[0.074 – 0.171]
$\varepsilon_{\xi^a,t}$	$\mathcal{G}^{-1}$	0.01	0.012	0.019	0.010	0.014	0.008
		(2.00)	[0.011 – 0.014]	[0.017 – 0.021]	[0.009 – 0.011]	[0.012 – 0.016]	[0.007 – 0.009]
$\varepsilon_{r,t}$	$\mathcal{G}^{-1}$	0.01	0.003	0.005	0.002	0.002	0.003
		(2.00)	[0.003 – 0.003]	[0.004 – 0.005]	[0.002 – 0.002]	[0.002 – 0.002]	[0.003 – 0.003]
$\varepsilon^d_{p,t}$	$\mathcal{G}^{-1}$	0.5	2.139	2.240	1.123	0.703	0.668
		(2.00)	[1.655 – 2.605]	[1.636 – 2.854]	[0.909 – 1.335]	[0.579 – 0.827]	[0.518 – 0.806]
$\varepsilon^m_{p,t}$	$\mathcal{G}^{-1}$	0.5	2.324	1.128	2.063	2.299	2.113
		(2.00)	[1.638 – 3.014]	[0.787 – 1.461]	[1.509 – 2.619]	[1.691 – 2.903]	[1.454 – 2.790]
$\varepsilon^x_{p,t}$	$\mathcal{G}^{-1}$	0.5	2.001	1.512	0.889	1.104	1.096
		(2.00)	[1.320 – 2.658]	[0.920 – 2.046]	[0.595 – 1.161]	[0.817 – 1.378]	[0.740 – 1.441]
$\varepsilon_{q_b,t}$	$\mathcal{G}^{-1}$	0.01	0.004	0.004	0.002	0.002	0.002
		(2.00)	[0.004 – 0.004]	[0.003 – 0.004]	[0.002 – 0.002]	[0.002 – 0.002]	[0.002 – 0.002]
$\varepsilon_{q_i,t}$	$\mathcal{G}^{-1}$	0.5	0.230	0.819	0.215	0.157	0.252
		(2.00)	[0.186 – 0.274]	[0.678 – 0.960]	[0.178 – 0.250]	[0.125 – 0.190]	[0.209 – 0.295]
$\varepsilon_{\tilde{\phi},t}$	$\mathcal{G}^{-1}$	0.01	0.003	0.003	0.003	0.003	0.003
		(2.00)	[0.002 – 0.004]	[0.002 – 0.003]	[0.002 – 0.004]	[0.002 – 0.003]	[0.002 – 0.004]

Notes: G represents the Gamma distribution. Posterior mean estimates for the standard deviation.of shock processes are obtained with 250000 M-H replications on two parallel chains.

TABLE 2e - (CONTINUED)

	Prior distribution			Posterior mean			
	Density	Mean	Greece	Ireland	Italy	Portugal	Spain
		(s.d.)	[c.i.]	[c.i.]	[c.i.]	[c.i.]	[c.i.]
$\varepsilon_{\xi^c,t}$	$\mathcal{G}^{-1}$	0.01	0.249	0.292	0.127	0.299	0.200
		(2.00)	[0.171 − 0.323]	[0.215 − 0.366]	[0.091 − 0.164]	[0.189 − 0.408]	[0.132 − 0.270]
$\varepsilon_{\xi^n,t}$	$\mathcal{G}^{-1}$	0.01	0.097	0.037	0.014	0.050	0.031
		(2.00)	[0.076 − 0.118]	[0.029 − 0.045]	[0.012 − 0.016]	[0.042 − 0.057]	[0.026 − 0.037]
$\varepsilon_{x,t}$	$\mathcal{G}^{-1}$	0.01	0.039	0.026	0.030	0.025	0.036
		(2.00)	[0.035 − 0.043]	[0.023 − 0.029]	[0.027 − 0.034]	[0.023 − 0.028]	[0.032 − 0.040]
$\varepsilon_{cpi,t}$	$\mathcal{G}^{-1}$	0.01	0.010	0.009	0.006	0.004	0.009
		(2.00)	[0.009 − 0.011]	[0.008 − 0.010]	[0.006 − 0.007]	[0.004 − 0.004]	[0.008 − 0.010]
$\varepsilon_{\nu,t}$	$\mathcal{G}^{-1}$	0.01	0.030	0.029	0.029	0.022	0.031
		(2.00)	[0.027 − 0.034]	[0.026 − 0.032]	[0.026 − 0.032]	[0.020 − 0.025]	[0.028 − 0.034]
$\varepsilon_{\varrho,t}$	$\mathcal{G}^{-1}$	0.01	0.012	0.011	0.007	0.007	0.008
		(2.00)	[0.011 − 0.013]	[0.010 − 0.012]	[0.006 − 0.008]	[0.006 − 0.008]	[0.007 − 0.008]
$\varepsilon^*_{dp,t}$	$\mathcal{G}^{-1}$	0.005	0.006	0.006	0.006	0.006	0.006
		(2.00)	[0.006 − 0.007]	[0.006 − 0.007]	[0.006 − 0.007]	[0.006 − 0.007]	[0.006 − 0.007]
$\varepsilon^*_{y,t}$	$\mathcal{G}^{-1}$	0.005	0.006	0.006	0.006	0.006	0.006
		(2.00)	[0.005 − 0.006]	[0.005 − 0.006]	[0.005 − 0.006]	[0.005 − 0.006]	[0.005 − 0.006]
$\varepsilon^*_{r,t}$	$\mathcal{G}^{-1}$	0.005	0.002	0.002	0.002	0.002	0.002
		(2.00)	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.002]	[0.002 − 0.002]
$\varepsilon^*_{rl,t}$	$\mathcal{G}^{-1}$	0.005	0.001	0.001	0.001	0.001	0.001
		(2.00)	[0.001 − 0.001]	[0.001 − 0.001]	[0.001 − 0.001]	[0.001 − 0.001]	[0.001 − 0.001]

Notes: G represents the Gamma distribution. Posterior mean estimates for the standard deviation.of shock processes are obtained with 250000 M-H replications on two parallel chains.

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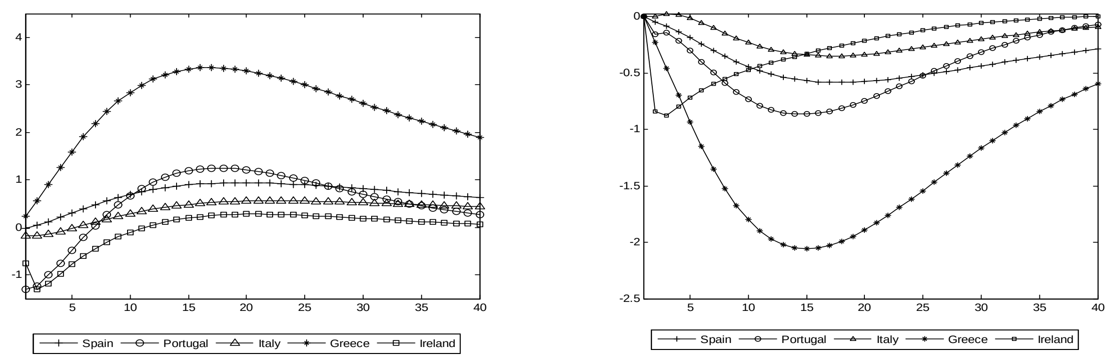
FIGURE 1 - RESPONSE TO A 1% OF GDP HIRING COSTS REDUCTION

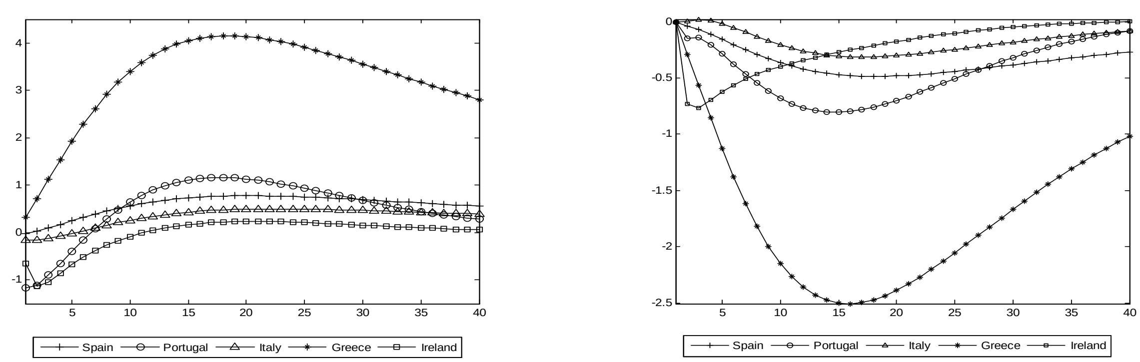
GDP (monetary multiplier) | Unemployment Rate (% deviation from s.s.)



Notes: Impulse response of output (Y_t) and unemployment (u_t) to a one percent shock in hiring cost reduction in the periphery of the eurozone obtained at the posterior mean estimate.

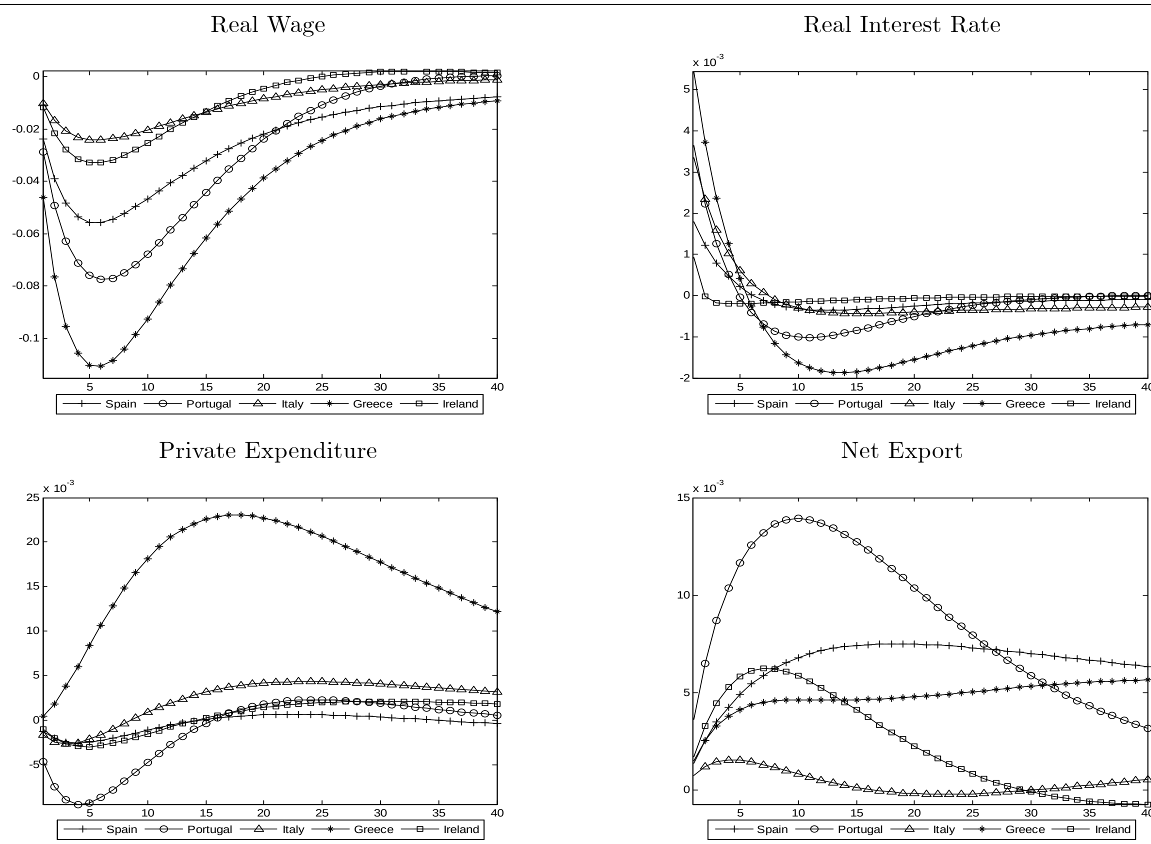
FIGURE 2 - RESPONSE TO A 1% OF GDP WAGE SUBSIDIZATION OF NEWLY HIRED WORKERS

GDP (monetary multiplier) | Unemployment rate (% deviation from s.s.)



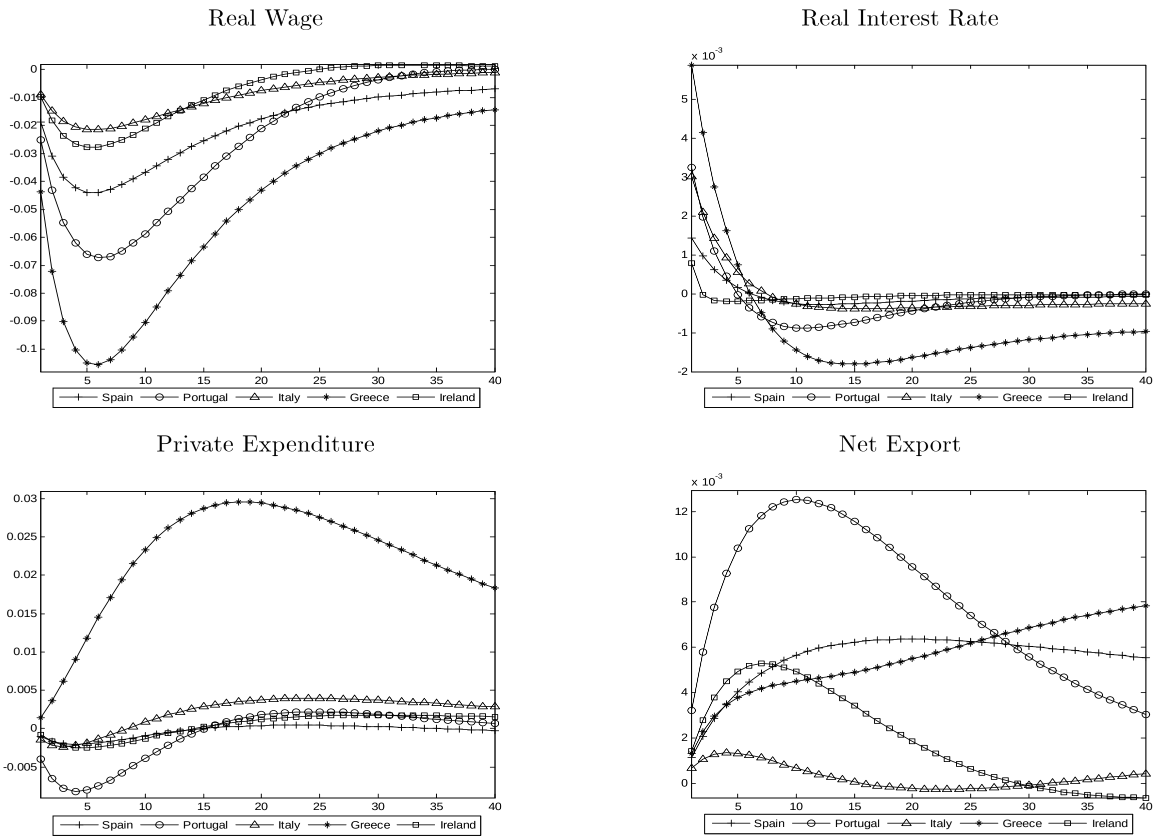
Notes: Impulse response of output (Y_t) and unemployment (u_t) to a one percent shock in wage subsidization of newly hired workers in the periphery of the eurozone obtained at the posterior mean estimate. The variables are expressed in terms of percent deviations from the steady states.

FIGURE 3 - RESPONSE TO A 1% OF GDP HIRING COSTS REDUCTION



Notes: Impulse response of real wage (w_t), real interest rate (R_t), private expenditure (C_t) and net export ($X_t - M_t$) to a one percent shock in hiring cost reduction in the periphery of the eurozone obtained at the posterior mean estimate. The variables are expressed in terms of percent deviations from the steady states.

FIGURE 4 - RESPONSE TO A 1% OF GDP WAGE SUBSIDIZATION OF NEWLY HIRED WORKERS



Notes: Impulse response of real wage (w_t), real interest rate (R_t), private expenditure (C_t) and net export ($X_t - M_t$) to a one percent shock in wage subsidization of newly hired workers in the periphery of the eurozone obtained at the posterior mean estimate. The variables are expressed in terms of percent deviations from the steady states.

TABLE 3 - FISCAL MULTIPLIERS - STANDARD TIMES

Instrument	Multiplier	Greece	Ireland	Italy	Portugal	Spain
Hiring subsidy	Impact	0.23	−0.76	−0.18	−1.30	−0.02
	Peak (quarter)	3.36 (17)	0.28 (21)	0.56 (22)	1.24 (18)	0.94 (19)
Wage subsidy	Impact	0.31	−0.66	−0.16	−1.17	−0.02
	Peak (quarter)	4.15 (18)	0.23 (21)	0.50 (22)	1.16 (18)	0.78 (20)
Gov. consumption	Impact	1.00	2.04	0.98	1.60	1.00
	Peak (quarter)	1.00 (1)	2.04 (1)	0.98 (1)	1.60 (1)	1.00 (1)
Gov. transfers	Impact	0.08	0.20	0.22	0.31	0.07
	Peak (quarter)	0.08 (1)	0.20 (1)	0.22 (1)	0.31 (1)	0.07 (1)
Gov. investment	Impact	0.20	0.31	0.15	0.55	0.18
	Peak (quarter)	0.47 (6)	0.52 (5)	0.34 (5)	1.07 (5)	0.42 (5)
Wage.tax	Impact	0.11	0.24	0.29	0.37	0.09
	Peak (quarter)	0.11 (1)	0.24 (1)	0.29 (1)	0.37 (1)	0.09 (1)
Profit.tax	Impact	0.01	0.07	−0.18	0.03	−0.01
	Peak (quarter)	0.10 (17)	0.11 (2)	0.60 (21)	0.23 (20)	0.61 (19)
Capital gains.tax	Impact	0.01	0.03	0.02	0.02	0.01
	Peak (quarter)	0.03 (7)	0.05 (5)	0.04 (6)	0.04 (5)	0.03 (6)
Consumption.tax	Impact	0.12	0.27	0.23	0.40	0.08
	Peak (quarter)	0.12 (2)	0.27 (1)	0.23 (1)	0.40 (1)	0.09 (2)

Notes: Fiscal multipliers on output (Y_t) in standard times for the PIIGS countries are reported for different potential government instruments. In order to get a clear view, not only for their value on impact, the peak of fiscal multipliers and the time, in brackets, in whitch it is realized is also reported.

TABLE 4 - UNEMPLOYMENT EFFECTS - STANDARD TIMES

Instrument	Multiplier	Greece	Ireland	Italy	Portugal	Spain
Hiring subsidy	Impact	−0.23	−0.84	0.00	−0.15	−0.05
	Peak (quarter)	−2.06 (15)	−0.88 (3)	−0.35 (17)	−0.86 (15)	−0.58 (18)
Wage subsidy	Impact	−0.29	−0.73	0.00	−0.15	−0.04
	Peak (quarter)	−2.51 (16)	−0.77 (3)	−0.31 (17)	−0.80 (15)	−0.48 (18)
Gov. consumption	Impact	−0.74	−0.40	−0.75	−0.80	−0.70
	Peak (quarter)	−0.74 (2)	−0.40 (2)	−0.75 (2)	−0.80 (2)	−0.70 (2)
Gov. transfers	Impact	−0.06	−0.04	−0.17	−0.16	−0.05
	Peak (quarter)	−0.06 (2)	−0.04 (2)	−0.17 (2)	−0.16 (2)	−0.05 (2)
Gov. investment	Impact	−0.15	−0.10	−0.12	−0.35	−0.13
	Peak (quarter)	−0.26 (5)	−0.13 (4)	−0.18 (5)	−0.51 (4)	−0.21 (5)
Wage.tax	Impact	−0.08	−0.04	−0.22	−0.18	−0.06
	Peak (quarter)	−0.08 (2)	−0.04 (2)	−0.22 (2)	−0.18 (2)	−0.06 (2)
Profit.tax	Impact	−0.01	0.11	−0.02	0.06	−0.04
	Peak (quarter)	−0.06 (15)	−0.02 (17)	−0.38 (16)	−0.21 (17)	−0.38 (17)
Capital gains.tax	Impact	−0.01	−0.01	−0.01	−0.01	−0.01
	Peak (quarter)	−0.02 (5)	−0.02 (4)	−0.02 (4)	−0.02 (5)	−0.02 (5)
Consumption.tax	Impact	−0.09	−0.06	−0.18	−0.21	−0.06
	Peak (quarter)	−0.09 (2)	−0.07 (3)	−0.18 (2)	−0.21 (2)	−0.06 (2)

Notes: Fiscal multipliers on unemployment (u_t) in standard times for the PIIGS countries are reported for different potential government instruments. In order to get a clear view, not only for their value on impact, the peak of fiscal multipliers and the time, in brackets, in whitch it is realized is also reported.

TABLE 5 - FISCAL MULTIPLIERS - ZLB BINDS FOR 8 PERIODS

Instrument	Multiplier	Greece	Ireland	Italy	Portugal	Spain
Hiring subsidy	Impact	0.20	−0.50	0.04	−1.30	−0.03
	Peak + (quarter)	3.20 (18)	0.52 (22)	1.07 (23)	2.48 (19)	1.83 (21)
	Peak - (quarter)	–	−2.41 (3)	−0.17 (4)	−2.58 (3)	−0.04 (2)
Wage subsidy	Impact	0.27	−0.66	−0.16	−1.18	−0.02
	Peak + (quarter)	7.23 (21)	0.44 (23)	0.91 (24)	2.32 (19)	1.52 (21)
	Peak - (quarter)	–	−2.44 (3)	−0.49 (3)	−2.55 (2)	−0.03 (2)
Gov. consumption	Impact	1.00	2.05	0.98	1.60	1.00
	Peak + (quarter)	1.75 (2)	3.33 (2)	1.72 (2)	2.52 (2)	1.76 (2)
	Peak - (quarter)	−0.04 (23)	−0.08 (26)	–	−0.18 (22)	–
Gov. transfers	Impact	0.08	0.20	0.22	0.32	0.07
	Peak + (quarter)	0.14 (2)	0.31 (2)	0.38 (2)	0.49 (2)	0.12 (2)
	Peak - (quarter)	−0.01 (19)	−0.01 (22)	–	−0.04 (21)	−0.00 (40)
Gov. investment	Impact	0.20	0.31	0.15	0.55	0.18
	Peak + (quarter)	0.95 (6)	1.12 (5)	0.68 (6)	2.37 (5)	0.87 (6)
	Peak - (quarter)	–	–	–	−0.28(25)	–
Wage.tax	Impact	−0.11	−0.24	−0.29	−0.37	−0.09
	Peak + (quarter)	0.01 (22)	0.01 (27)	–	0.05 (22)	0.00 (40)
	Peak - (quarter)	−0.19 (2)	−0.39 (2)	−0.52 (2)	−0.58 (2)	−0.16 (2)
Profit.tax	Impact	−0.01	0.07	0.19	−0.03	0.00
	Peak + (quarter)	−0.01 (1)	0.18 (3)	0.51 (3)	0.38 (5)	0.00 (2)
	Peak - (quarter)	−0.18 (19)	−0.07 (9)	−1.09 (23)	−0.48 (21)	−0.08 (20)
Capital gains.tax	Impact	−0.11	−0.03	−0.01	−0.02	−0.01
	Peak + (quarter)	0.01(21)	–	–	0.01(27)	–
	Peak - (quarter)	−0.19(2)	−0.12(6)	−0.07(6)	−0.09(6)	−0.06(7)
Consumption.tax	Impact	−0.12	−0.27	−0.23	−0.40	−0.08
	Peak + (quarter)	0.03(30)	0.02(29)	–	0.08(23)	0.01(40)
	Peak - (quarter)	−0.25(3)	−0.49(2)	−0.45(2)	−0.68(2)	−0.17(2)

Notes: Fiscal multipliers on output (Y_t) in ZLB times for the PIIGS countries are reported for different potential government instruments. In order to get a clear view, not only for their value on impact, the peak of fiscal multipliers and the time, in brackets, in whitch it is realized is also reported. The timing of the exit from the ZLB is endogenously determined by implementing the non-negativity constraint along with Taylor-rule.

TABLE 6 - UNEMPLOYMENT EFFECTS - ZLB BINDS FOR 8 PERIODS

Instrument	Multiplier	Greece	Ireland	Italy	Portugal	Spain
Hiring subsidy	Impact	−0.21	−0.91	−0.17	−0.15	−0.04
	Peak (quarter)	−1.98 (16)	−1.76 (3)	−0.73 (18)	−1.73 (16)	−1.15 (19)
Wage subsidy	Impact	−0.26	−0.73	0.01	−0.14	−0.04
	Peak (quarter)	−4.84 (19)	−1.41 (3)	−0.61 (18)	−1.61 (16)	−0.95 (19)
Gov. consumption	Impact	−0.74	−0.40	−0.76	−0.80	−0.70
	Peak (quarter)	−1.24 (3)	−0.79 (3)	−1.32 (3)	−1.32 (3)	−1.22 (3)
Gov. transfers	Impact	−0.15	−0.04	−0.17	−0.16	−0.05
	Peak (quarter)	−0.10 (3)	−0.07 (3)	−0.29 (3)	−0.26 (3)	−0.08 (3)
Gov. investment	Impact	−0.15	−0.10	−0.12	−0.36	−0.13
	Peak (quarter)	−0.52 (6)	−0.29 (4)	−0.36 (5)	−1.15 (4)	−0.44 (6)
Wage.tax	Impact	0.08	0.05	0.23	0.18	0.06
	Peak (quarter)	−0.01 (21)	−0.01 (18)	−0.02 (27)	−0.03 (19)	−0.00 (36)
Profit.tax	Impact	0.01	0.11	0.01	−0.05	0.00
	Peak (quarter)	0.01 (2)	−0.04 (17)	−0.15 (4)	−0.14 (4)	0.00 (2)
Capital gains.tax	Impact	0.08	0.01	0.01	0.01	−0.01
	Peak (quarter)	−0.01 (21)	−0.01 (22)	−0.01 (20)	−0.02 (25)	−0.01 (25)
Consumption.tax	Impact	0.09	0.06	0.18	0.21	0.06
	Peak (quarter)	−0.01 (28)	−0.02 (20)	0.03 (35)	−0.05 (21)	−0.01 (40)

Notes: Fiscal multipliers on unemployment (u_t) in zlb times for the PIIGS countries are reported for different potential government instruments. In order to get a clear view, not only for their value on impact, the peak of fiscal multipliers and the time, in brackets, in whitch it is realized is also reported. The timing of the exit from the ZLB is endogenously determined by implementing the non-negativity constraint along with Taylor-rule.

Agents Heterogeneity in the Theory of Search and Matching

Abstract

The introduction of heterogeneous consumers in general equilibrium models is a useful and powerful assumption from both the theoretical and empirical perspectives. In this paper we show that most of the analyses considering such an assumption are characterized by somehow strong assumptions which make the apparent heterogeneity illusory in many respects. We relax some of the commonly adopted hypotheses in the labor market dimension that seem to be crucial in the previous literature, by considering type-specific workers, and show that substantial differences emerge in model dynamics. These differences are shown to be relevant not only for the labor market-specific dynamics but also for that of real and monetary variables.

JEL classification: E52, J64, E24, E32, E31.

Keywords: Heterogeneity, Type-Specific Worker, Labor Market,Search, Busines Cycle.

1 Introduction

Since the seminal work of Campell and Mankiw (1989), a large body of literature has considered the role of rule-of-thumb/non-asset holders/liquidity constrained (heterogeneous) households. The assumption of heterogeneous households enhances the explanation of some stylized facts of macroeconomic dynamics. Farther, the abundant literature addressing the efficacy of fiscal policy in monetary models highlights the need of considering heterogeneous agents in order to reconcile the theoretical predictions to the existing empirical evidence, often consistent with the breakdown of the Ricardian equivalence result. The need for models accounting for deep agent heterogeneity has been emphasized by Mankiw (2000), who underlines the fact that an empirically-relevant model of fiscal policy needs a particular sort of heterogeneity, including a reepresentation of the type-specific behavior of both low and high-wealth households.

Questioning which among habit persistence, nonseparability between consumption and leisure and rule-of -thumb consumers accounts better for the predictability of consumption growth, Kiley (2010) shows support for rule-of-thumb behavior and little support for nonseparability between consumption and leisure.

Using a slightly different definition, but similar reasons for introducing heterogeneity, Bilbije and Straub (2013a, 2013b) argue that introducing limited asset market participation, i.e. asset and non-asset holders, is crucial in explaining the U.S. macroeconomic performance and monetary policy before the 1980s and their changes thereafter. The consideration of limited asset market participation in their theoretical model, explains why a loose Fed policy in the pre-1980 years was consistent with equilibrium determinacy and minimization of macroeconomic volatility. They also provide empirical evidence consistent with this hypothesis and study the relative merits of structural changes and shocks for reproducing the so called "conquest of the Great Moderation".

The crucial importance of heterogeneity is also emphasized by Guvenen (2006) that, by allowing for the presence of two types of agents, stockholders and non-stockholders, reconciles two opposing views about the elasticity of intertemporal substitution (EIS).

Based on the evidence that consumption rises in response to an increase in government consumption spending Gali, Lopez-Salido and Valles (2007) (henceforth GLV) extend the standard new

Keynesian model to allow for the presence of rule-of-thumb consumers, an hypothesi which lies at the heart of the paper results. They show how the interaction of the latter with sticky prices and deficit financing can account for the existing evidence on the effects of government spending.

Mertens and Ravn (2011) evaluate the extent to which a DSGE model can account for the impact of tax policy shocks. They estimate the response of macroeconomic aggregates to anticipated and unanticipated tax shocks in the US and find that unanticipated tax cuts have persistent expansionary effects on output, consumption, investment and hours worked. As in Campbell and Mankiw (1989) and GLV, Mertens and Ravn consider rule-of-thumb consumption behavior, which allows for a significantly better replication of the empirical response of nondurables consumption to changes in taxes, in particular for the absence of a strong consumption response to expected tax cuts.

In order to estimate the effects of fiscal policy in the Euro area, Forni Monteforte Sessa (2009) introduce a fraction of non-Ricardian agents in a monetary general equilibriun model. Estimation results point to a significant share of non-Ricardian agents and to the prevalence of mild Keynesian effects of fiscal policy.

The crucial importance of introducing rule-of-thumb consumers into a dynamic model is emphasized, also, by Boscá, Doménech and Ferri (2011). The authors conclude that the introduction of rule-of-thumb consumers allows for a deeper comprehension of the effects of shocks on some key macroeconomic variables and on their interaction, also improving the capability of the labor market search model in reproducing some of the stylized facts characterizing the US labour market. Kriwoluzky (2012) uses a dynamic model with consumer heterogeneity in the same spirit of GLV, i.e. optimizing and rule-of-thumb consumers, and find that the response of private consumption is significantly negative on impact, rises and becomes significantly positive two quarters after the realization of the policy shock.

By incorporating households heterogeneity in the form of limited asset market participation in a dynamic general equilibrium model, Bilbije (2008) finds out that, while "moderate" participation rates strengthen the role of monetary policy, low enough participation causes an inversion of results dictated by conventional wisdom. The slope of the "IS" curve changes its sign, the "Taylor principle" is inverted, welfare-maximizing discretionary monetary policy requires a passive policy rule and the effects and propagation of shocks are changed.

Taking up from the work of Bilbije (2008), Motta and Tirelli (2012) demonstrate that the limited asset market participation has potentially strong policy implications when the central bank is the sole policymaker, but a well-made system of automatic fiscal stabilizers dampens the undesirable effects of limited asset market participation. Bilbije, Meier and Müller (2008) estimate the structural parameters of a dynamic stochastic general equilibrium model featuring limited asset market participation suggesting that most of the changes in fiscal policy transmission are accounted for by increased asset market participation and the more active monetary policy of the Volcker–Greenspan period.

The key behind the main insights of the Natvik (2009) study, that government consumption may render the Taylor principle insufficient as a condition for equilibrium determinacy and that the interest rate may have to respond far more aggressively than one for one to inflation when the government share is large, is that some households, referred to as rule-of-thumb consumers, have no access to financial markets but consume their entire disposable income each period. Colciago (2011) paper instead, show that the non standard results, obtained by the introduction of rule-of-thumb consumers, can be restored to the standard one when, together with non-asset holders, nominal wage stickiness is introduced.

Rule-of thumb-consumption has been incorporated also in important quantitative tools for policy analysis, such as in Erceg, Guerrieri and Gust (2006, 2009), Coenen *et al.* (2008), Corsetti, *et al.* (2010), Furlanetto (2011), Coenen *et al.* (2013).

Freedman *et. al.* (2010), instead, complaining that most part of the earlier analyses tended to focus on the short-run to medium-run effects of the fiscal stimulus, employ a modeling framework considering liquidity-constrained households that is suitable for analyzing not only the short-run but also the longer-run results of permanent changes in saving rates, and that is also suitable for jointly simulating a wide array of realistic fiscal and monetary policy measures.

Starting from the empirical evidence that consumption volatility is negatively correlated with the size of the government, Andrés, Doménecha and Fatás (2008) explore a variation of classical business cycle model in which they introduce rule-of-thumb consumers and find out that consumption volatility is in fact reduced when the government size increases.

Drautzburg and Uhlig (2011), in quantifying the fiscal multipliers in response to the American

Recovery and Reinvestment Act and extending a benchmark model in order to allow for credit-constrained households, find out that the multiplier is sensitive to the fraction of transfers given to credit-constrained households.

These results are confirmed by Farhi and Werning (2013). The authors, providing an explicit solution for government spending multipliers, find out that the interplay between the increase in future spending by hand-to-mouth agents, the inflation that it generates, and the current and future spending decisions of optimizing agents is, clearly, extremely potent and can generate very large multipliers.

Instead, the New Neoclassical Synthesis model of Canzoneri, Cumby and Diba (2006), augmented for the presence of rule-of-thumb consumers, fails to assign a significant role to fiscal and demand shocks generally.

Consumer heterogeneity, even if in a different form, is also considered in the works of Curdia and Woodford (2009), Eggertsson and Krugman (2012) and Corsetti *et. al.* (2013).

In order to analyze policy issues in the presence of credit spreads, Curdia and Woodford (2009) and, more recently, Corsetti *et. al.* (2013), also introduce consumer heterogeneity, which assumes crucial importance for their results.

Eggertsson and Krugman (2012) note that making some agents debt-constrained is a surprisingly powerful assumption for letting Fisherian debt deflation, the possibility of a liquidity trap, the paradox of thrift and toil, Keynesian-type multipliers, and a rationale for expansionary fiscal policy all emerge naturally from the model.

The list of relevant studies relying on the introduction of agent heterogeneity now considered is decisively not exhaustive. There are a lot of works related to this topic that, for pure space reasons, we do not mention here but deserve the same attention.

The point that we rise in this paper is that most of these works are in fact characterized only by a limited degree of heterogeneity. More specifically, we argue that agents heterogeneity is generally limited to the consumption dimension. The minority of works that try to deal with heterogeneity also in labor supply, beside the fact that they assume a unique wage for different types of agents, rely on some other strong assumptions used in the aggregation process making the former an illusory labor supply heterogeneity.

Our interest here is to show how, and to which degree, the consideration of a limited heterogeneity is transmitted in a serious limitation of the static and dynamic properties of the models that rely on these commonly adopted hypotheses. In order to do so, we assume heterogeneity in both the consumption and labor dimensions by considering a micro-founded theory of the labor market under agents heterogeneity.

Technically, we start from the work of Mortensen and Pissarides (1994) and relax the assumption of the same union that makes different types of households enjoy (suffer) the same wage and suffer (enjoy) the same unemployment rate.

Furthermore, by introducing a staffing agency in the model, we relax the common practice of pooling optimizing and rule-of-thumb households, on the grounds that it not only gives rise to different static and dynamic results, but also leads to a second-best Nash bargained wage.

A further assumption that we relax is the equality between the composition of household types that populate the economy and the coposition of labor and staffing agencies, on the grounds that there is no economic reason, outside model tractability, to adopt such a homogeneity hypothesis for a composition that in reality is driven by profit choices.

From a static perspective, we show that in the proposed model, consumers are not only different in consumption behavior but also in the equilibrium wage, in the equilibrium labor supply, and more generally in all the labor market variables. From the perspective of the dynamic model properties, we show that the extended heterogeneity yields some new insights and rises some doubts about the relevance of results on fiscal and monetary policy effectiveness addressed by the previous literature.

The paper is organized as follows. Section one describes the model, Section two describes the model properties by settig-up a calibration experiment, Section three concludes.

2 The Model

In order to allow for heterogeneity in the labor market we introduce staffing agencies in a model with search and matching frictions in the labor market.

The framework is a variation of the Mortensen and Pissarides search and matching model (Mortensen and Pissarides 1994; Pissarides 2000). The main difference is that we allow for full labor market heterogeneity and introduce a staffing agency which supplies labor to the intermediate good producing firms in outsourcing.

2.1 Households

As in Gali *et al.* (2007), the economy is populated by a continuum of households indexed by $\iota \in [0,1]$. A fraction $\iota \in [0, 1-\upsilon]$ of households enjoys unlimited access to capital markets, so its members substitute consumption intertemporally. We use the term "Ricardians" or "intertemporally optimizing households" to refer to this subset of households. The remaining fraction $\iota \in [1-\upsilon, 1]$ do not have access to capital markets, so its members not owning any asset or having any liability cannot use their wealth to smooth consumption over time. Both types of workers supply labor to the staffing agencies in a frictional, search and matching, labor market.

2.1.1 Intertemporally Optimizing Households

The intertemporally optimizing household chooses consumption c_t^o, investment i_t^o, capital k_t^o, government bond b_t^o and utilization rate of capital u_t to maximize the following utility function

$$E_t \sum_{s=0}^{\infty} \beta^s \left[\log\left(c_{t+s}^o - h^o c_{t+s-1}^o\right) - \varkappa^o \frac{h_{t+s}^{o\,1+\sigma}}{1+\sigma} n_{t+s}^o \right] \tag{1}$$

where h^o is the degree of habit persistence, n_t^o is the fraction of members of the optimizing household that are working and h_t^o is the intensity with which each worker works.

Let τ_t be the lump sum tax, Π_t the lump sum profits, $b_t^{u,o}$ the unemployment benefit, u_t the capital utilization rate, $a(\cdot)$ the strictly increasing and strictly convex cost function of varying capacity utilization, p_t the nominal price level, r_t the quarterly nominal interest rate, and r_t^k the rental rate of effective capital. Then the household budget constraint is:

$$c_t^o + i_t^o + \frac{b_t^o}{p_t r_t} + \tau_t \leq \frac{w_t^o h_t^o n_t^o}{p_t} + (1 - n_t^o)\, b_t^{u,o} + \frac{b_{t-1}^o}{p_t} + \left[\frac{r_t^k}{p_t} u_t - a(u_t)\right] k_{t-1}^{p,o} + \frac{\Pi_t}{p_t} \tag{2}$$

The physical capital $k_t^{p,o}$ evolves according to the following law of motion:

$$k_t^{p,o} = (1-\delta)k_{t-1}^{p,o} + q_t^i \left[1 - S(\frac{i_t^o}{i_{t-1}^o})\right] i_t^o \tag{3}$$

whilst capital services are related to the physical stock of capital $k_t^{p,o}$ by:

$$k_t^o = u_t k_t^{p,o} \tag{4}$$

where δ is the depreciation rate of capital, $S(\frac{i_t^o}{i_{t-1}^o})$ represents investment adjustment costs, and q_t^i denotes the stochastic marginal efficiency of investment, described by the first order autoregressive process $q_t^i = q_{t-1}^{i\rho_{q^i}} e^{\varepsilon_{q^i,t}}$.

The optimizing household choose the set of processes $\{c_t^o, i_t^o, k_t^o, b_t^o, u_t\}_{t=0}^{\infty}$ given the set of processes $\{p_t, r_t, n_t^o, \tau_t, w_t^o, h_t^o\}_{t=0}^{\infty}$ in order to maximize the sum of discounted utilities subject to (2). The following optimality conditions holds:

$$[c_t^o] : \lambda_t^o = \frac{1}{\left(c_t^o - h^o c_{t-1}^o\right)} \tag{5}$$

$$[b_t^o] : \lambda_t^o = \beta r_t \frac{\lambda_{t+1}^o}{p_{t+1}/p_t} \tag{6}$$

$$[k_t^{p,o}] : q_t^k = \beta \frac{\lambda_{t+1}^o}{\lambda_t^o} \left[\frac{r_{t+1}^k}{p_{t+1}} u_{t+1} - a(u_{t+1}) + (1-\delta) q_{t+1}^k\right] \tag{7}$$

$$[i_t^o] : 1 = q_t^i q_t^k \left[1 - S(\frac{i_t^o}{i_{t-1}^o}) - S'(\frac{i_t^o}{i_{t-1}^o})(\frac{i_t^o}{i_{t-1}^o})\right] + \beta q_{t+1}^i q_{t+1}^k \frac{\lambda_{t+1}^o}{\lambda_t^o} S'\left(\frac{i_{t+1}^o}{i_t^o}\right)\left(\frac{i_{t+1}^o}{i_t^o}\right)^2 \tag{8}$$

$$[u_t] : \frac{r_t^k}{p_t} = a'(u_t) \tag{9}$$

where λ_t^o is the marginal utility of income, whereas q_t^k represents the shadow price of a unit of physical capital, i.e. Tobin's Q.

2.1.2 Liquidity Constraint Households

The liquidity constrained households can neither save nor borrow and hence cannot benefit from the access to the capital markets. Their consumption expenditure is determined by the specific liquidity constraint:

$$c_t^l \leq \frac{w_t^l h_t^l n_t^l}{p_t} + \left(1 - n_t^l\right) b_t^{u,l} - \tau_t \tag{10}$$

From the maximization problem faced by the liquidity constrained household:

$$\max E_t \sum_{s=0}^{\infty} \beta^s \left[\log\left(c_{t+s}^l - h^l c_{t+s-1}^l\right) - \varkappa^l \frac{h_{t+s}^{l^{1+\sigma}}}{1+\sigma} n_{t+s}^l \right] \tag{11}$$

subject to (10), the marginal utility of consumption for liquidity constrained households is obtained:

$$\lambda_t^l = \frac{1}{\left(c_t^l - h^l c_{t-1}^l\right)} \tag{12}$$

where h^l is the degree of habit persistence in consumption of liquidity constrained households. Though the liquidity constrained households are not allowed to use their income to smooth consumption over time, they take into account the fact that a matching today will, with some probability, be continued in the future, providing labor income to be spent to consume tomorrow.

2.2 The Labor Market

Every period, each staffing agency i operating in the labor market j posts $\nu_{i,t}^j$ vacancies and employs $n_{i,t}^j$ workers. The number of job matches $m_{j,t}$ in labor market j depends on the matching technology, which is assumed of the form:

$$m_t^j = \theta_m^j \left(u_t^j\right)^{\theta^j} \left(\nu_t^j\right)^{1-\theta^j} \tag{13}$$

where $\nu_t^j = \int_0^1 \nu_{i,t}^j di$ and $u_t^j = 1 - n_{t-1}^j$, and $n_t^j = \int_0^1 n_{i,t}^j di$ are the total number of vacancies, the unemployed and the employed workers in labor market of type j, respectively, θ_m^j denotes the matching efficiency and θ^j captures the elasticity of the matching function with respect to unemployment. In period t, the probability that a firm fills a vacancy in the labor market j is denoted by $q^j = m_t^j/\nu_t^j$, whilst $s_t^j = m_t^j/u_t^j$ denotes the probability that an unemployed worker j finds a job. Finally, at the beginning of each period t, new hires enter the employment stock, and at the end of each period a fraction of workers loses the job with probability $1-\rho_t^j$, where:

$$\rho_t^j = \rho_m^j \rho_a^j \left(1 - \frac{n_{j,t}^{a,i}}{n_t^{a,j}}\right) \tag{14}$$

denotes the survival probability of an employment relationship until the next period, $1-\rho_a^j$ is the staffing agency exit probability from labor market j, and $\left(1 - n_{j,t}^{a,i}/n_t^{a,j}\right)$ denotes the time-varying probability of a staffing agency operating in market j of not moving in market i. Consequently, the total employment for staffing agencies operating in the labor market j is:

$$n_{i,t}^j = \left(\rho_t^j + x_{i,t}^j\right) n_{i,t-1}^j. \tag{15}$$

2.3 Staffing Agencies

In order to relax the assumption of labor homogeneity adopted in the literature, and to shed some light on how labor heterogeneity affects the behavior of a worker, we introduce the staffing agencies. These supply labor to intermediate goods firms in a homogenous, perfectly competitive, labor market.

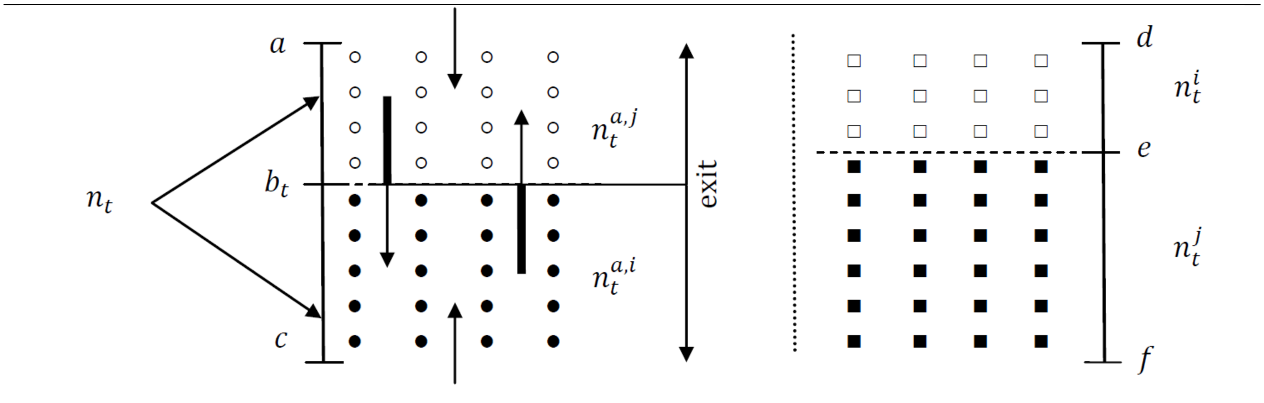
The labor market is populated by a continuum of staffing agencies indexed, as the intermediate goods producers, by $i \in [0,1]$. The staffing agencies operating in the labor market are of two types, $j = o, l$. The former operates in the optimizing households labor market and the latter in the liquidity constrained households labor market.

The total number of staffing agencies operating in the labor market j, $n_t^{a,j}$, evolves according to

$$n_t^{a,j} = \rho_a^j \left[\rho_m^j \left(1 - \frac{n_{j,t-1}^{a,i}}{n_{t-1}^{a,j}}\right) n_{t-1}^{a,j} + n_{e,t-1}^{a,j} + \rho_a^i \rho_m^i \left(1-\psi_{t-1}\right) n_{i,t-1}^{a,j}\right] \tag{16}$$

where ${}_{e,t}^{a,j}$ and $n_{j,t-1}^{a,i}$ are the mass of new staffing agencies entering in the labor market j and the mass of staffing agencies who move from labor market j into labor market i, respectively; ψ_t is the fraction of staffing agencies that, once leaving the labor market j and not reaching the labor market i, exit the market.

FIGURE 1.- LABOR MARKET DYNAMICS AND STAFFING AGENCIES



Once the job request n_t is made by the intermediate goods producer firm, it will be captured, with time-varying probability:

$$\omega_t = \frac{a - b_t}{a - c} = \frac{n_t^{a,j}}{n_t^{a,i} + n_t^{a,j}} \tag{17}$$

by the staffing agencies operating in the labor market j, whilst it will be captured with time-varying probability $1 - \omega_t$ by the staffing agencies operating in the labor market i.

In the light of the labor market mechanics specified above, the total employment in the labor market j is:

$$n_t = \int_0^1 \int_\iota n_t^j(i)\ di\ d\iota$$

Let $\mathcal{F}_{i,t}^j$ be the value of the staffing agency of type i operating in the j type labor market:

$$\begin{aligned}
\mathcal{F}_{i,t}^j\left(w_{i,t}^j, n_{i,t-1}^j w_{i,t}^i, n_{i,t}^i\right) \quad = \quad & \left(\frac{w_{i,t}}{p_t} - \frac{w_{i,t}^j}{p_t}\right) h_{i,t}^j n_{i,t}^j - \frac{\kappa_t^j}{2}\left(x_{i,t}^j\right)^2 n_{i,t-1}^j \\
& + \beta\rho_a^j E_t \frac{\lambda_{t+1}^o}{\lambda_t^o}\left(1 - \frac{n_{j,t}^{a,i}}{n_t^{a,j}}\right)\mathcal{F}_{i,t+1}^j\left(w_{i,t+1}^j, n_{i,t}^j, w_{i,t+1}^i, n_{i,t+1}^i\right) \\
& + \beta\rho_a^j\rho_a^i E_t \frac{\lambda_{t+1}^o}{\lambda_t^o}\frac{n_{j,t}^{a,i}}{n_t^{a,j}}\frac{q_{t+1}^i}{n_{t+1}^{a,i}}\mathcal{F}_{i,t+1}^i\left(w_{i,t+1}^i, n_{i,t}^i, w_{i,t+1}^j, n_{i,t+1}^j\right) \\
& - f_m^j\left[w_t^i h_t^i + \beta\rho_a^i E_t \frac{\lambda_{t+1}^o}{\lambda_t^o}\left(1 - \frac{n_{i,t+1}^{a,j}}{n_{t+1}^{a,i}}\right)\frac{\kappa_t^i}{2}\left(x_{i,t+1}^i\right)^2\right]
\end{aligned} \tag{18}$$

where

$$x^j_{i,t} = \frac{q^j_{i,t}\nu^j_{i,t}}{n^j_{i,t-1}} \tag{19}$$

defines the hiring rate, κ^j_t denotes the hiring cost and $w_{i,t}$ is the cost of labor services paid by the intermediate good producer to the staffing agency for one unit of labor intensity. Since the staffing agencies supply labor services in a perfectly competitive market, $w_{i,t}$ is the same for all agencies and hence taken as given. As before, the discount factor for the staffing agency $\beta\frac{\lambda^o_{t+1}}{\lambda^o_t}$ equals the discount factor for the intertemporally optimizing household satisfying the assumption on the ownership structure of the economy.

In order to explore, by micro-foundation, the dynamics of the labor market we allow for a non zero endogenous time-varying probability of movement, $n^{a,i}_{j,t}/n^{a,j}_t$, from one labor market to the other for the staffing agencies.

Once a new agency decides to enter, or an incumbent agency j decides to leave, for pure profit reasons, the labor market j in order to access the labor market i, a positive time-varying probability of posting a vacancy $1/n^{a,i}_t$ is faced. Moving from one labor market to the other is costly. The sunk movement cost, prior to entry, is defined as a share f^j_m of the staffing agency's j total costs.

Every period t, each staffing agency i optimally demands labor at the intensive margin in the labor market j until the worker's j marginal cost equals the staffing agency's i marginal benefit:

$$\frac{w_{i,t}}{p_t} = \varkappa^l \frac{h^{j^\sigma}_{t+s}}{\lambda^j_t}. \tag{20}$$

In the labor market j, the staffing agency's optimization problem is to choose n^j_t, by setting x^j_t, to maximize the value function (18) subject to the employment evolution equation (15). The first-order necessary condition is:

$$\kappa^j_t x^j_{i,t} = \left(\frac{w_{i,t}}{p_t} - \frac{w^j_{i,t}}{p_t}\right) h^j_{i,t} + \beta\rho^j_a \left(1 - \frac{n^{a,i}_{j,t}}{n^{a,j}_t}\right) E_t \frac{\lambda^o_{t+1}}{\lambda^o_t}\left[\rho^j_{t+1}\kappa^j_{t+1}x^j_{i,t+1} + \frac{\kappa^j_{t+1}}{2}\left(x^j_{i,t+1}\right)^2\right] \tag{21}$$

Let $J^j_{i,t}\left(w^j_{i,t}\right) = \partial F^j_{i,t}\left(w^j_{i,t}, n^j_{i,t-1}\right)/\partial n^j_{i,t}$ be the surplus that a staffing agency i bargaining in period t enjoys from a match with an individual worker of type j, given by:

$$
\begin{aligned}
J_{i,t}^{j}\left(w_{i,t}^{j}\right) &= \left(\frac{w_{i,t}}{p_t}-\frac{w_{i,t}^{j}}{p_t}\right)h_{i,t}^{j}-\beta\rho_a^{j}E_t\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}\left(1-\frac{n_{j,t+1}^{a,i}}{n_{t+1}^{a,j}}\right)\frac{\kappa_{t+1}^{j}}{2}\left(x_{i,t+1}^{j}\right)^{2} \\
&\quad +\beta\rho_a^{j}E_t\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}\left(1-\frac{n_{j,t+1}^{a,i}}{n_{t+1}^{a,j}}\right)\left[\rho_{t+1}^{j}+x_{i,t+1}^{j}\right]J_{i,t+1}^{j}\left(w_{i,t+1}^{j}\right). \qquad (22)
\end{aligned}
$$

The mass of new staffing agencies entering in the labor market j, $n_{e,t}^{a,j}$, and the mass of staffing agencies who move from labor market j into labor market i, $n_{j,t-1}^{a,i}$, are determined, respectively, by the free entry condition:

$$
\beta\rho_a^{j}\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}\frac{1}{n_{t+1}^{a,j}}q_{t+1}^{j}J_{t+1}^{j}\left(w_{t+1}^{j}\right)=f_e^{j}\left[w_t^{j}h_t^{j}+\beta\rho_a^{j}\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}\left(1-\frac{n_{j,t+1}^{a,i}}{n_{t+1}^{a,j}}\right)\frac{\kappa_t^{j}}{2}\left(x_{i,t+1}^{j}\right)^{2}\right] \qquad (23)
$$

and the free movement condition:

$$
\begin{aligned}
\beta\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}J_{t+1}^{j}\left(w_{t+1}^{j}\right) &= \rho_a^{i}\beta\left(1-\psi_t\right)\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}q_{t+1}^{i}\frac{1}{n_{t+1}^{a,i}}J_{t+1}^{i}\left(w_{t+1}^{i}\right) \\
&\quad -f_m^{i}\left(1-\psi_t\right)\left[w_t^{j}h_t^{j}+\beta\rho_a^{j}\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}\left(1-\frac{n_{j,t+1}^{a,i}}{n_{t+1}^{a,j}}\right)\frac{\kappa_t^{j}}{2}\left(x_{i,t+1}^{j}\right)^{2}\right] \qquad (24)
\end{aligned}
$$

Due to time-to-build, once entered in the labor market, the entry and movement sunk costs, defined as a share f_e^{j} and f_m^{j} of the staffing agency's j total costs $w_t^{j}h_t^{j}+\beta\rho_a^{j}\lambda_{t+1}^{o}/\lambda_t^{o}\left(1-n_{j,t+1}^{a,i}/n_{t+1}^{a,j}\right)\kappa_t^{j}/2\left(x_{i,t+1}^{j}\right)^{2}$, respectively, are paid in t, whilst the staffing agencies become active in the labor market j in $t+1$.

2.4 Firms

The production sector is populated by a representative final good producer and a continuum of intermediate goods producers indexed by $i \in [0,1]$, characterized by staggered price setting as described by Calvo (1983).

2.4.1 Final Good Producer

The final good producer buys the differentiated intermediate goods $y_{i,t}$ from the intermediate goods producers, produces the composite homogenous good y_t as in Kimball (1995):

$$\int_0^1 \Gamma\left(\frac{y_{i,t}}{y_t}; \epsilon_t^p\right) di = 1 \tag{25}$$

and re-sells it to consumers in a perfectly competitive market. The Kimball aggregator $\Gamma(.)$ is a strictly concave and increasing function, such that $\Gamma(1; \epsilon_t^p) = 1$. ϵ_t^p is a stochastic component hitting the aggregator function, or a shifter o, and is described by the first order autoregressive process $\epsilon_t^p = \epsilon_{t-1}^{p\rho_{\epsilon^p}} e^{\varepsilon_{\epsilon^p,t}}$.

The optimization problem of the final good producer is:

$$\max_{Y_t, Y_{it}} p_t y_t - \int_0^1 p_{i,t} y_{i,t} di \tag{26}$$

subject to (25), where $p_{i,t}$ and p_t are the prices of intermediate and final goods respectively. From the first order condition for $y_{i,t}$ and y_t, the demand for input i is given by:

$$y_{i,t} = y_t \Gamma'^{-1}\left[\frac{p_{i,t}}{p_t}\int_0^1 \Gamma'\left(\frac{y_{i,t}}{y_t}\right)\frac{y_{i,t}}{y_t} di\right] \tag{27}$$

2.4.2 Intermediate Goods Producers

In the intermediate goods sector there is a continuum of monopolistic suppliers indexed by $i \in [0, 1]$. The intermediate goods producer rent capital services $k_{i,t}$ and hire labor $h_{i,t}$ in a perfectly competitive market to produce the intermediate good i using the following technology

$$y_{i,t} = \epsilon_t^a k_{i,t}^{\alpha} \left[\mu^t h_{i,t}\right]^{1-\alpha} - \mu^t \phi \tag{28}$$

where $0 < \alpha < 1$ and $\phi > 1$ denotes the fixed cost of production. The intermediate good producer i chooses capital services $k_{i,t}$ and labor $h_{i,t}$ by minimizing the firm's total time t costs given by $r_t^k k_{i,t} + w_{i,t} h_{i,t}$, subject to: (28). From the minimization programme, the following optimality conditions holds:

$$k_{i,t} = \frac{\alpha}{1-\alpha}\frac{w_{i,t}}{r_t^k}h_{i,t} \tag{29}$$

and:

$$mc_{i,t} = \frac{r_t^k w_{i,t}^{1-\alpha}}{\alpha^\alpha \left[\mu^t \left(1-\alpha\right)\right]^{1-\alpha} \epsilon_t^a} \tag{30}$$

where $mc_{i,t}$ is the marginal cost of firm i, which equals the Langrange multiplier associated with the production function.

The price-setting problem of the intermediate firms follows Calvo (1983). In any period t every intermediate firm i faces a random probability $\left(1-\zeta_p\right)$ to re-optimize its price. The re-optimized price is denoted by $p_{i,t}^*$. With a probability ζ_p, the firm is not allowed to re-optimize and indexes its price to an average of current and past inflation $\prod_{l=1}^{s} \overline{\pi}^{1-\gamma_p}\pi_{t+l-1}^{\gamma_p}$. It follows that from equations (25) and (27) the aggregate price index can be expressed as:

$$p_t = \left(1-\zeta_p\right) p_{i,t}\Gamma'^{-1}\left(\frac{p_{i,t}}{p_t}\varkappa_t\right) + \zeta_p \overline{\pi}^{1-\gamma_p}\pi_{t-1}^{\gamma_p}p_{t-1}\Gamma'^{-1}\left(\frac{\overline{\pi}^{1-\gamma_p}\pi_{t-1}^{\gamma_p}p_{t-1}}{p_t}\varkappa_t\right) \tag{31}$$

where:

$$\varkappa_t = \int_0^1 \Gamma'\left(\frac{y_{i,t}}{y_t}\right)\frac{y_{i,t}}{y_t}di$$

Under Calvo-style pricing with partial indexation, the problem of the i-th re-optimizing intermediate goods producer is to choose a target price $p_{i,t}^*$ to maximize the stream of discounted profits:

$$E_t \sum_{s=0}^{\infty} \zeta_p^s \beta^s \frac{\lambda_{t+s}^o p_t}{\lambda_t^o p_{t+s}} \left[p_{i,t}^* \prod_{l=1}^{s} \overline{\pi}^{1-\gamma_p}\pi_{t+l-1}^{\gamma_p} - mc_{i,t+s}\right] y_{i,t+s}$$

subject to the demand curve given by (27). The nominal discount factor for firms $\beta^s \frac{\lambda_{t+s}^o p_t}{\lambda_t^o p_{t+s}}$ equals the discount factor for the intertemporally optimizing households satisfying the assumption on the ownership structure of the economy.

The optimality condition for the target price is:

$$\sum_{s=0}^{\infty} \zeta_p^s \beta^s \frac{\lambda_{t+s}^o p_t}{\lambda_t^o p_{t+s}} y_{i,t+s} \left[p_{i,t}^* \prod_{l=1}^{s} \overline{\pi}^{1-\gamma_p}\pi_{t+l-1}^{\gamma_p} + \left(p_{i,t}^* \prod_{l=1}^{s} \overline{\pi}^{1-\gamma_p}\pi_{t+l-1}^{\gamma_p} - mc_{i,t+s}\right)\Xi_{t+s}\right] = 0 \tag{32}$$

where:

$$\Xi_t = \frac{1}{\Gamma'^{-1}\left(\frac{p_{i,t}}{p_t}\varkappa_t\right)} \frac{\Gamma'\left[\Gamma'^{-1}\left(\frac{p_{i,t}}{p_t}\varkappa_t\right)\right]}{\Gamma''\left[\Gamma'^{-1}\left(\frac{p_{i,t}}{p_t}\varkappa_t\right)\right]}$$

Finally, the log-linearization of (31) and (32) yields the familiar equation relating the dynamics of inflation to movements in real marginal costs.

2.5 Labor Contract

Staffing agencies and workers bargain over the surplus of their match in shares determined by the exogenous bargaining power η. As in Gertler and Trigari (2009), we allow for some degree of wage stickiness in the model introducing staggered Nash bargaining. We assume that in any period t every household j faces a random probability $(1-\zeta_w)$ to be able to bargain the wage $w^j_{*,t}$, and with probability ζ_w she will start working at the nominal hourly wage of the existing contract in t, partially indexed to inflation $w^j_{i,t}\overline{\pi}^{1-\gamma_w}\pi^{\gamma_w}_{t-1}$. Accordingly, the average nominal wage w^j_t evolves according to the following equation:

$$w^j_t = (1-\zeta_w)\, w^j_{*,t} + \zeta_w \int_0^1 w^j_{i,t-1}\overline{\pi}^{1-\gamma_w}\pi^{\gamma_w}_{t-1} \frac{\rho^j_m + x^j_{i,t}}{\rho^j_m + x^j_t} \frac{n^j_{i,t}}{n^j_t} di. \tag{33}$$

Let $W^j_{i,t}\left(w^j_{i,t}\right)$ be the worker value function, given by:

$$W^j_{i,t}\left(w^j_{i,t}\right) = \frac{w^j_{i,t}}{p_t} h^j_{i,t} - \varkappa^j \frac{{h^j_t}^{1+\sigma}}{1+\sigma} n^j_t + \beta \frac{\lambda^j_{t+1}}{\lambda^j_t}\left[\rho^j W^j_{i,t+1}\left(w^j_{i,t+1}\right) + \left(1-\rho^j\right) U^j_{t+1}\right], \tag{34}$$

where the nominal wage $w^j_{i,t+1}$ is:

$$w^j_{i,t+1} = \begin{cases} w^j_{*,t+1} & \text{with probability } 1-\zeta_w \\ w^j_t \overline{\pi}^{1-\gamma_w}\pi^{\gamma_w}_t & \text{with probability } \zeta_w \end{cases} \tag{35}$$

Let the value of being unemployed U^j_t be given by:

$$U^j_t = b^j_t + \beta \frac{\lambda^j_{t+1}}{\lambda^j_t}\left[s^j_{t+1} W^j_{x,t+1} + \left(1 - s^j_{t+1}\right) U^j_{t+1}\right] \tag{36}$$

where $W^j_{x,t}$ is the period t value function of a new worker of type j who does not know which staffing agency she is matched with:

$$W^j_{x,t} = \int_0^1 W^j_{i,t}\left(w^j_{i,t}\right) \frac{x^j_{i,t} n^j_{i,t-1}}{x^j_t n^j_{t-1}}.$$

In the light of the above definitions, the contract nominal wage $w^j_{*,t}$ is chosen to maximize the Nash product given by the joint surplus of a match over the worker's and staffing agency's outside options:

$$\left[W^j_{i,t}\left(w^j_{i,t}\right) - U^j_t\right]^{\eta^j} \left[J^j_{i,t}\left(w^j_{i,t}\right)\right]^{1-\eta^j} \tag{37}$$

subject to the nominal wage equation (35).

Finally, the optimal wage equation $w^j_{*,t}$ is obtained from the optimal sharing rule:

$$\eta^j \left.\frac{\partial W^j_{i,t}\left(w^j_{i,t}\right)}{\partial w^j_{i,t}}\right|_{w^j_{i,t}=w^j_{*,t}} J^j_{i,t}\left(w^j_{*,t}\right) = -\left(1-\eta^j\right) \left.\frac{\partial J^j_{i,t}\left(w^j_{i,t}\right)}{\partial w^j_{i,t}}\right|_{w^j_{i,t}=w^j_{*,t}} \left[W^j_{i,t}\left(w^j_{*,t}\right) - U^j_t\right]. \tag{38}$$

given the unemployed, worker's, and staffing agency's value functions, equation (36), (34), and (22), respectively.

2.6 Aggregation, Monetary and Fiscal Policy, and Resource Constraint

Given the assumption on the types of households that populate the economy, the aggregate per-capita level of household key quantity variable $x_t(\iota)$ is:

$$x_t = \int_0^1 x_t(\iota) d\iota = \int_0^{1-\upsilon} x^o_t d\iota + \int_{1-\upsilon}^1 x^l_t d\iota$$

for $x_t(\iota) = [c_t(\iota), k^p_t(\iota), k_t(\iota), i_t(\iota), b_t(\iota)]$ and

$$\begin{aligned} x_t &= \int_0^1 \int_0^1 x_t(i,j)\, didj \\ &= \int_0^1 \int_0^1 \int_0^1 x_t(\iota, i, j) d\iota didj = \int_0^1 \int_0^1 \int_0^{1-\upsilon} x^o_t(i,j)\, d\iota didj + \int_0^1 \int_0^1 \int_{1-\upsilon}^1 x^l_t(i,j)\, d\iota didj \end{aligned}$$

for $x_t(\iota, i, j) = n_t(\iota, i, j)$.

Government purchases the final public consumption good as a fraction of total output, g_t, makes unemployment benefit payments to households, $b^u(1-n_t)$, issues bonds to refinance its outstanding debt, b_t, and levies lump-sum taxes, τ_t. The fiscal authority's period-by-period budget constraint is then given by:

$$g_t + b^u(1-n_t) + b_{t-1} = \tau_t + \frac{b_t}{r_t} \tag{39}$$

where τ_t and g_t are exogenously determined, and assumed to be described by the first order autoregressive processes $\tau_t = \tau_{t-1}^{\rho_\tau} e^{\varepsilon_{\tau,t}}$ and $g_t = g_{t-1}^{\rho_g} e^{\varepsilon_{g,t}}$, respectively, and $b^u(1-n_t) = (1-\upsilon)\, b^{u,o}(1-n_t^o) + \upsilon b^{u,l}\left(1-n_t^l\right)$.

The monetary authority adopts the standard augmented Taylor-type rule for the nominal interest rate

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\rho_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\rho_y}\right]^{1-\rho_r} \varepsilon_t^r \tag{40}$$

where r and π are the equilibrium values of the gross nominal interest and inflation rate respectively and ε_t^r is the zero-mean *i.i.d.* monetary policy shock.

Finally, we close the model with the economy's aggregate resource constraint given by:

$$\begin{aligned} y_t &= c_t + i_t + g_t + \int_0^1 \frac{\kappa_t(\iota)}{2} \int_0^1 \left[x_t(i,\iota)\right]^2 n_{t-1}(i,\iota)\, di d\iota + a(u_t)\, k_{t-1}^p \\ &\quad + \int_0^1 f_e(\iota) \int_0^1 \left[w_t^j h_t^j + \beta \rho_a^j \frac{\lambda_{t+1}^o}{\lambda_t^o} \left(1 - \frac{n_{j,t+1}^{a,i}(i,\iota)}{n_{t+1}^{a,j}(i,\iota)}\right) \frac{\kappa_{t+1}^j}{2} \left[x_{t+1}(i,\iota)\right]^2\right] n_{e,t+1}^a(i,\iota)\, di\ d\iota \\ &\quad + (1-\psi_t) \int_0^1 f_m(\iota) \int_0^1 \left[w_t^j h_t^j + \beta \rho_a^j \frac{\lambda_{t+1}^o}{\lambda_t^o} \left(1 - \frac{n_{j,t+1}^{a,i}(i,\iota)}{n_{t+1}^{a,j}(i,\iota)}\right) \frac{\kappa_{t+1}^j}{2} \left[x_{t+1}(i,\iota)\right]^2\right] n_{j,t+1}^{a,i}(i,\iota)\, di\ d\iota \end{aligned}$$

where y_t is the final good quantity defined in equation (25).

2.7 Model Properties

2.7.1 Calibration

The model is calibrated to be consistent with quarterly U.S. time series and cross-sectional data, whilst we consider conventional values when such information is missing. The calibrated parameters values are summarized in table 1. In order to better capture the effects from the consideration

TABLE. 1.–PARAMETER VALUES IN SIMULTAIONS OF THE MODEL

Discount factor	β	.995
Capital depreciation rate	δ	.025
Capital share in production	α	.33
Habit in consumption parameter	h	.71
Elasticity of labor supply	σ^j	1.85
Liquidity constraint households share	υ	.50
Workers' separation rate	ρ^j	.09
Elasticity of matches to unemployment	θ^j	.72
Workers' bargaining power	η^j	.72
Matching function constant	θ^j_m	.30
Disutility of labor parameter	$\varkappa^j$	20.00
Staffing agency exit probability	ρ^j_a	.01
Entry cost	f^j_e	.75
Movement cost	f^j_m	.25

Notes: Parameters related to "great ratios" and other observable quantities related to steady state values are calibrated considering that the time unit is a quarter. The type specific parameters denoted by j = o, r are assumed to be of equal value in order to capture better all the differencies due to non calibration.

of agents heterogeneity in both the consumption and labor market dimensions, and to allow the comparability of results with those in the existing literature considering consumer heterogeneity only, we consider the same parameters values for both optimizing and liquidity constrained households.

The discount factor β is set to be consistent with a steady-state real interest rate of 1 percent, the capital depreciation rate is assumed to depreciate at the rate of 10 percent per year, hence δ is fixed at 0.025, the Cobb–Douglas production function parameter α is set at 0.33. Additional parameters are: the external habit parameter h, set at 0.71, as estimated by Smets and Wouters (2007), the inverse of the Frisch elasticity σ^j, set at 1.85 based on Chetty *et al.* (2011), and the share of liquidity constrained households υ, fixed at 0.5, consistently with the estimates in Campbell and Mankiw (1989).[1]

Considering the labor market model district, the search and matching-specific parameters are: the separation rate ρ^j is set at 0.09 based on evidence provided by Shimer (2007) for the US quarterly

[1] In estimating the Frisch elasticity, Christiano *et al.* (2012), choose a prior based on the microevidence provided by McCurdy (1981). Such a calibration is not legal given that in McCurdy the hours of work are chosen freely by the worker, whilst in Christiano *et al.* (2012) hours are choosen unilateraly and efficently by the firm.

worker separation rate, and adjusted for quarterly job destruction via firm exit evidence reported in Samaniego (2008) and based on Davis and Haltiwanger (1992), the elasticity of matches to unemployment θ^j is fixed at 0.72 as suggested by the estimates reported in Shimer (2005a), the workers' bargaining power η^j is set at 0.72 in order to satisfy the Hosios' efficiency conditions (see Hosios (1990)). The last two parameters of the standard search and matching model, the matching function constant θ_m^j and the scaling parameter for disutility of labor $\varkappa^j$ are set, respectively, at 0.3 and 20, i order to match the average job-finding and unemployment rates, respectively.

Finally, the staffing agency parameters are: the entry and movement costs share f_e^j and f_m^j set at 0.75 and 0.25 respectively, while the staffing agency exit probability ρ_a^j, are set to 0.01, a mean value based on the work of Campbell (1998), Hopenhayn and Rogerson (1993) and Broda and Weinstein (2010), which coincide with the findings in Davis and Haltiwanger (1992).

2.7.2 Results

In order to study whether macroeconomic fluctuations affect different agents differently and whether heterogeneity in turn affects macroeconomic fluctuations, we examine the behavior of the model considering a technology shock as the exogenous driving force. For comparison and simplicity, we report in figure 1 the responses for both the full-heterogeneity model, solid line, and the limited-heterogeneity model, dashed line, of key aggregate macroeconomic variables.

The full-heterogeneity model is consistent with the fact that different types of agents are not only paid differently but also work differently, both in the intensive and in the extensive sense, and hence suffer/enjoy different unemployment rates as well as different wages. In the limited-heterogeneity model, instead, we consider the heterogeneity in consumption and employment but do not extend such differences to the wage, which remains the same for different types of agents.

In the limited-heterogeneity case, in which the type-specific agents are paid the same wage, it can be easily noticed that the response of aggregate employment to a positive technology shock, n_t, is overstated. The excess response of aggregate employment leads to an excess response not only of output, y_t, and investment, i_t, but also of key monetary variables, such as inflation π_t and the interest rate r_t.

In contrast to the inflation and interest rate response, which, by immediately reverting, experience only a relatively sharp rise on impact, employment and output share a hump-shaped response.

On the contrary, in the full-heterogeneity model, where for different types of agents different wage and different labor supply and demand are considered, the smoothed and moderate response of aggregate employment is entirely due to the different responses to the technology shock of wage and labor of different types of households, with the heterogeneity in labor reflected in both the intensive and extensive margins.

Faithful to the behavior of employment, the output follows a relatively smoothed and moderate response in the wake of the technology shock. Furthermore, the same smoothed and moderate response are obtained also for investment and the monetary variables, inflation and interest rate.

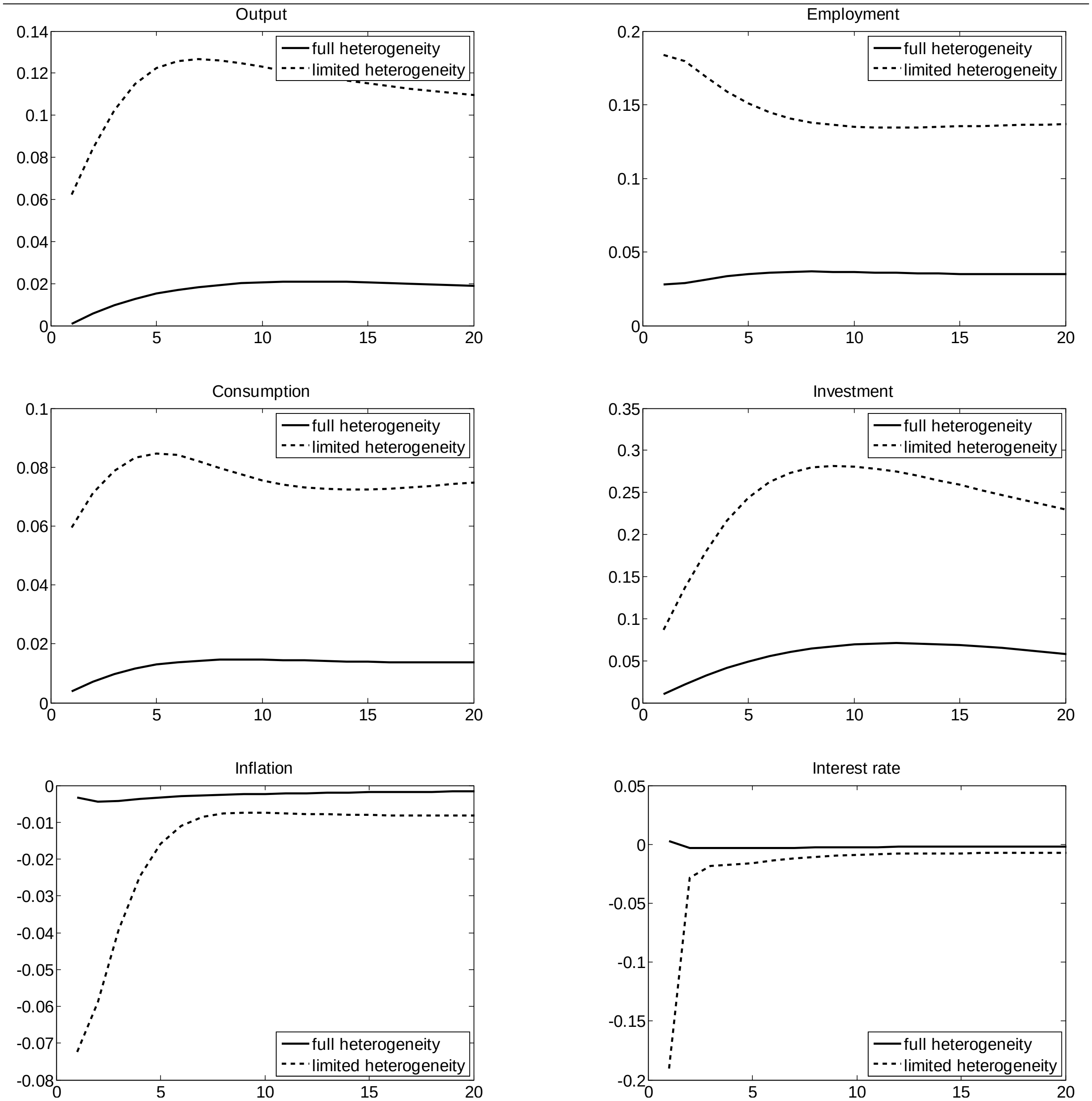
In order to get the intuition of the differences in the dynamic responses for the key macroeconomic variables and to have a clear view of the results presented above, figure 2 presents the impulse responses of both types of households for the key macroeconomic type-specific variables. The solid and dotted line in each graph illustrate the response of liquidity and non-liquidity constraint workers, respectively.

Differently from the standard literature, it can be easily noted how different, in a heterogeneity microfounded model, the response of the key macroeconomic variables are for the two types of workers in the wake of an increase in total factor productivity.

The strongly different responses of employment for the liquidity and non-liquidity constrained workers are the result of a strongly different response of their wages, being influenced by and influencing the high heterogeneity in the responses of the labor market variables. The heterogeneous responses of the full-heterogeneity model are reflected in the excess output response in the limited-heterogeneity model, where the type-specific response of wages are not considered. More precisely, the shortcut of the equal response for the wage of liquidity constrained and unconstraint workers, minimizes the distance of the response of employment of the former type from the response of employment of the latter type. Given that the response of employment of the non-liquidity constraint worker is overstated, the substantial rise in output emerges in the limited heterogeneity model.

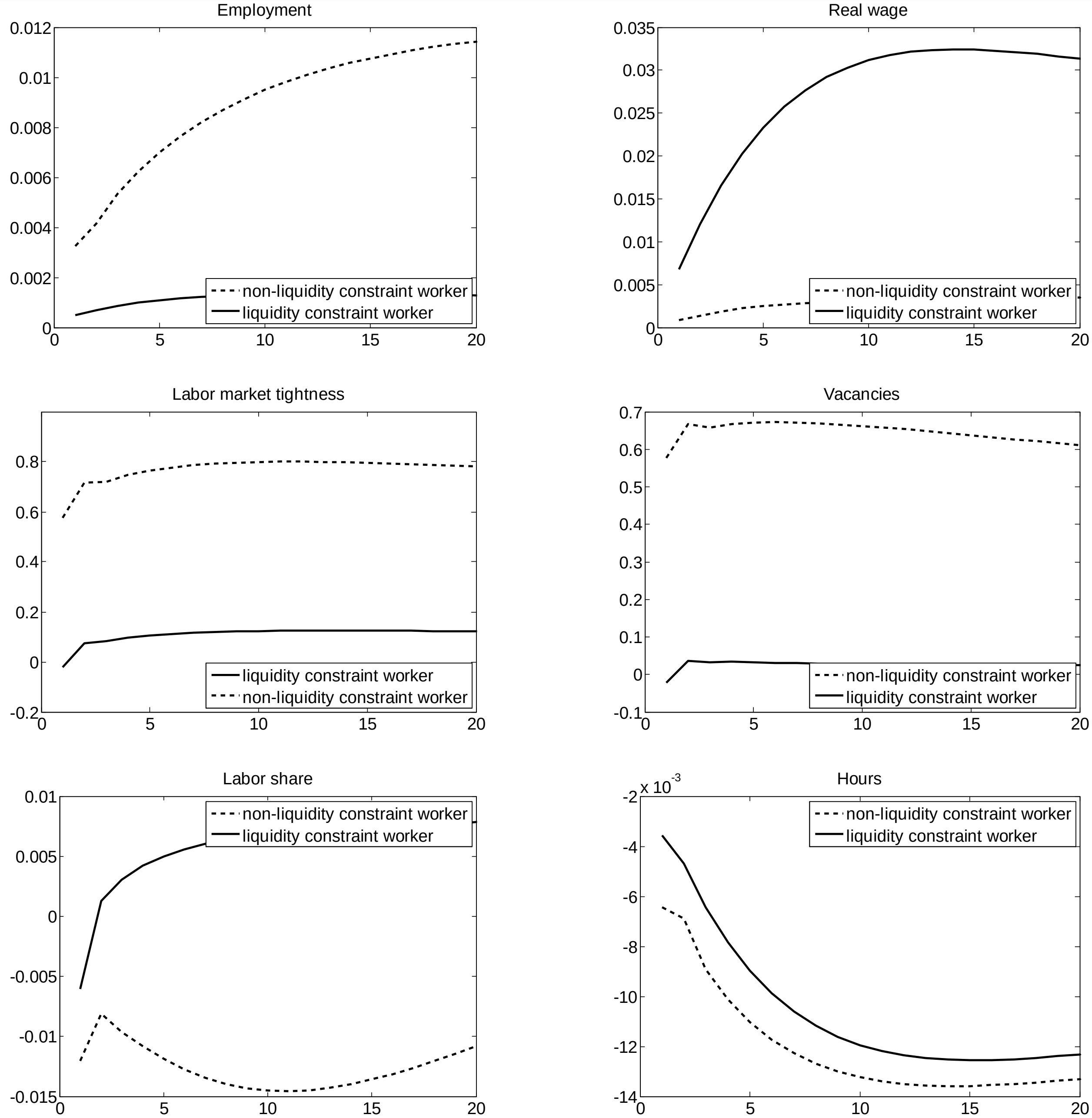
By contrast, in the model with full heterogeneity, the substantially different responses of wages, reflected in a moderate response of total employment (by definition a convex combination of the two strongly different responses of type-specific employment) result in a relatively moderate response of

FIGURE 2.- IMPULSE RESPONSES TO A TECHNOLOGY SHOCK: KEY AGGREGATE VARIABLES



Notes: The figure shows impulse response of output (y_t), employment (n_t), private expenditure (c_t), investment (i_t), inflation (π_t) and interest rate (r_t) to a one percent shock in total factor productivity. Solid and dashed lines represent the full heterogeneity and limited heterogeneity models respectively. The variables are expressed in terms of percent deviations from the steady states.

FIGURE 3.- IMPULSE RESPONSES TO A TECHNOLOGY SHOCK: TYPE-SPECIFIC VARIABLES



Notes: The figure shows impulse response of type-specific employment (n_t^j), real wage (w_t^j), labor market tightness (θ_t^j), vacancies (ν_t^j), labor share ($w_t^j h_t^j n_t^j / y_t$) and hours (h_t^j) to a one percent shock in total factor productivity. Solid and dashed lines represent the dynamic responses of liquidity and non-liquidity constraint workers respectively. The variables are expressed in terms of percent deviations from the steady states.

output.

As it can be easily noted, there is substantial difference in the dynamics of key macroeconomic and labor-specific variables when a microfounded, full heterogeneity model is, somehow, polluted by some homogeneity assumptions. What seems to be interesting, and troubling for the validity of previous analyses, is the fact that the effects of the different responses are experienced not only by the labor market variables but also by the real and monetary variables.

2.8 Conclusions

We have modified the Mortensen and Pissarides model of unemployment dynamics to allow for deep heterogeneity in the labor market. By micofounding the labor market, strongly different results emerge for the different type-specific labor market variables.

Contrary to what is commonly assumed in the literature, not only the steady state solutions, but also the dynamics of the model is affected, since the two labor-types are quantitatively different with respect to key variables defining the labor market dynamics, such as the real wage, unemployment, the labor market tightness and vacancies, and also qualitatively different for few of them, the dynamics of the labor share among others.

A distinguishing feature of our analysis is that, in trying to microfound the distinction of the two types of household-workers we are able to capture some relevant differences in the steady state and in dynamic properties of both type-specific and key aggregate macroeconomic variables.

We suspect that the practice of not considering a full heterogeneity model puts into serious doubt the validity of the results obtained so far in the research on these issues, namely the role of liquidity-constrained or rule-of-thumb agents in various areas where they are introduced. We leave these issues for further research.

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To my family