FiMod – A Model for Fiscal Policy Simulations*

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This paper develops a medium-scaled dynamic, stochastic, general equilibrium (DSGE) model for fiscal policy simulations. Relative to existing models of this type, our model incorporates a two-country monetary union structure, which makes it ideally suited to simulate fiscal measures by relatively large countries in a currency area. We also provide a notable degree of disaggregation on the government expenditures side, by explicitly distinguishing between (productivity-enhancing) public investment, public purchases and the public sector wage bill. Finally, we consider a labor market characterized by search and matching frictions, which allows to analyze the response of equilibrium unemployment to fiscal measures. In order to illustrate some of its applications, and motivated by recent policy debate in the Euro Area, we calibrate the model to Spain and the rest of the area and simulate a number of fiscal consolidation scenarios. We find that fiscal consolidation is the least damaging (in terms of output and employment losses) when achieved by reducing the public sector wage bill and/or by increasing (indirect) taxation, whereas it is most damaging when carried out by cutting public investment.

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1 Introduction

The recent crisis has obliged governments around the world to put in place ambitious fiscal stimulus plans and the ensuing fiscal consolidation (or "exit") strategies in order to assure fiscal stability. The latter issue is moving center stage in current public debates. In order to bring fiscal balances back on track, fiscal authorities mainly have the possibility of increasing taxes and/or cutting public spending. But which taxes should be increased? Which spending components should be cut? All across Europe, countries such as Germany, Greece, Portugal, Spain and others have put forward consolidation plans that include cuts in public employment, public wages and public investment as well as increases in VAT and labor tax rates. Which consequences can we expect from these measures on, among others, output, unemployment or international competitiveness? What are the short-run costs and long-run benefits of such measures? In this paper, we present "*FiMod – A (DSGE-) **Mod**el for **Fi**scal Policy Simulations* ", a dynamic, stochastic, general equilibrium (DSGE) model jointly developed by Banco de España and Deutsche Bundesbank staff in order to address exactly such kind of questions.

DSGE models provide a reliable tool for evaluating alternative policy measures. For this reason, fiscal policy analysis in DSGE models has gained momentum recently. The applications of such models include the assessment of temporary versus permanent fiscal stimulus, the assessment of structural changes in public tax and spending policy, the analysis of fiscal multipliers and the role of private demand as well as fiscal policy's interaction with monetary policy (in particular, at the zero-lower bound). Without completeness, relevant studies include Galí and Monacelli (2008), who analyze optimal fiscal and monetary policy in a currency union; Coenen et al. (2008), who simulate structural tax reforms based on the European Central Bank's New Area Wide Model (NAWM; Christoffel et al. 2008); Boscá et al. (2009a, 2009b, 2010), who analyze several policy measures based on the REMS model, which is used by the Spanish Ministry of Finance; Colciago et al. (2009), who assess the role of automatic stabilizers in a monetary union; Christiano et al. (2009), Cogan et al. (2009) and Hall (2009), all of which analyze fiscal multipliers; and Eggertsson (2009) and Erceg and Lindé (2010), who assess fiscal policy at the zero-lower bound. Freedman et al. (2009) address the question of potential short-run benefits and long-run costs of fiscal deficits, while Coenen et al. (2010a, 2010b) and Hebous (2010) provide a comprehensive overview of the effects of fiscal policy stimulus in structural models. Several institutions and authors, including some of the ones mentioned above, are working on improving their models in order to be better able to picture relevant fiscal policy features.[1]

Our DSGE model for fiscal policy analysis contributes to the literature in two important ways. First, the model incorporates a two-country monetary union structure. This makes it ideally suited to analyze fiscal policy measures by large countries in a monetary union, as is the case of Germany, France, Italy or Spain inside the European Monetary Union (EMU). The two-country structure allows to consider the spillover effects of fiscal actions in one country to the other, and vice versa. Most of the models mentioned above focus either on large economies with an independent monetary policy reaction function, or on small open

[1] For example, members of the European System of Central Banks (ESCB) are conducting fiscal policy simulations in their DSGE models such as the Bank of Portugal in PESSOA (see, for example, Almeida et al., 2010), the Bank of Finland in Aino (e.g. Kilponen and Ripatti, 2005) and the European Central Bank in the EAGLE-model (see Gomes et al., 2010). Also, the EU Commission is further activating their Quest III-model to conduct fiscal policy analyses (see Ratto et al., 2009).

economies that do not influence the rest of the world. Second, we provide a notable degree of disaggregation on the fiscal expenditures side. In particular, we explicitly distinguish between public investment and public consumption; the latter in turn is divided between public purchases and the public sector wage bill. Each of these components has a distinct effect on the rest of the economy. The model thus allows to simulate specific measures that have been implemented recently in a number of European countries, such as cuts in public sector wages and/or employment, and reductions in public investment. Fiscal expenditures are completed with a number of transfers to the private sector, including unemployment benefits and lump-sum subsidies. On the fiscal revenues side, the model considers also a wide range of taxes, including taxes on consumption, labor income, returns on bond holdings and on physical capital, and social security contributions. Finally, our model incorporates the modern theory of equilibrium unemployment by introducing search and matching frictions in the labor market, along the lines of Pissarides (2000).[2] This allows us to study the effects of various fiscal actions on unemployment. Following Galí et al. (2007), we also assume the existence of rule-of-thumb (RoT) households; this gives rise to imperfect unemployment insurance and thus justifies the existence of a government-financed unemployment insurance system.

For the purpose of illustration, we calibrate the home country in the model to Spain and the foreign country to the rest of the EMU. We then use the calibrated model to simulate some of the measures recently implemented or announced by the Spanish fiscal authorities. In particular, we simulate reductions in public sector wages and public employment. Since the public wage bill is a component of public consumption, it is interesting to compare the resulting effects to those stemming from a reduction in public purchases, the component that most closely resembles the usual definition of 'government consumption' in DSGE models. We also analyze a decrease in public investment, which differs from public consumption in that the stock of public capital (for example, infrastructures) has a beneficial effect on private sector productivity. Regarding the fiscal revenues side, we simulate increases in VAT and labor tax rates. In order to make all these measures comparable, we calibrate the change in each fiscal instrument so as to produce an (ex-ante) reduction in the primary deficit to GDP ratio of half a percentage point. All measures are assumed to be permanent, which allows us to assess both short-run and long-run effects. Furthermore, we assume that the long-run fiscal saving resulting from lower interest payments on outstanding debt is used to reduce lump-sum taxes, which are assumed to be levied on Ricardian households only. By avoiding long-run changes in distortionary taxes, we can isolate the pure effects of each fiscal instrument on the economy.[3]

Our results indicate that different fiscal consolidation strategies have different effects of production and employment. A reduction in productivity-enhancing government spending (i.e. in public investment) is relatively more harmful in terms of output, unemployment, international competitiveness and private consumption than a comparable decrease in public consumption – not only in the short but also in the long-run. Regarding the latter, we find reductions in public sector wages and/or employment to be generally preferable to cuts in public purchases, as the former measures have positive spillover effects on the private sector

[2]Here we follow Boscá et al. (2010), who are to our knowledge the first to have incorporated search and matching frictions in a medium-scale DSGE model for fiscal policy simulations.

[3]However, for the purpose of illustration we also present an alternative simulation in which the VAT rate is increased according to the design just described, but the saving in interest payments is used to cut labor income taxes in the long-run.

via reductions in labor costs and, at the same time, do not have a direct effect on aggregate consumption demand.[4] Regarding taxation, we find that an increase in the labor income tax rate is relatively effective in reducing the debt-to-GDP ratio, while having only small negative effects on output, employment and international competitiveness. Notice that in a standard search and matching framework, unlike in neoclassical models of the labor market, labor taxation does not affect labor supply per se, which is vertical at the level of the labor force; however, it does raise wage claims by matched workers and hence the resulting wage agreements. Our results suggest that the bargaining process in a matching framework partially dampens the effects of labor taxation on labor hours (employment) and production. Finally, we find that an increase in consumption taxes has no long-run effects on production, employment and wages, even though it does generate short-run losses as expected. The reason for the long-run neutrality of VAT is that it does not affect workers' match surplus (unlike in the case of wage income taxes). As a result, permanent changes in VAT produce a redistribution in consumption from rule-of-thumb to Ricardian households, while leaving long-run aggregate consumption unchanged. Simulating the same decrease in the VAT rate and using the proceeds to cut social security contributions – a measure that has was called "fiscal devaluation"by some economists, was conducted in Germany in 2007 and is under discussion in several EMU member countries –, we find that such a measure may favor the Spanish economy (including output, employment, international competitiveness, and the fiscal balance), while the spillovers to the rest of EMU are rather small.

The rest of this paper is organized as follows. The model is presented in section 2. Section 3 valuates the impact of the policy measures announced by the Spanish government. We also focus on the comparison of a reduction in public employment and public wages, respectively, to a decrease in public purchases (the way a cut in public consumption has conventionally been modelled so far). Furthermore, we differentiate between short and long-run effects. In Section 4, we present an analysis in which long-run proceeds of increasing VAT are used to cut social security contributions and we simulate a pre-announced temporary increase in government purchases followed by a belated financing through labor taxes. Section 5 concludes.

2 The model

This section presents the details of *FiMod*, a dynamic stochastic general equilibrium framework which is especially suitable for the analysis of fiscal policy issues. It is currently calibrated for Spain in the European Monetary Union (EMU). However, it can easily be recalibrated to fit the characteristics of any other monetary union economy. The calibration strategy is also detailed at the end of this section.

We consider a two-country monetary union in which we normalize population size to unity, of which $\omega \in (0,1)$ live in the home country (Spain), while the remaining $(1-\omega)$ live in the foreign country (rest of EMU). Throughout the paper, quantity variables will be expressed in per capita terms, unless otherwise indicated; aggregate quantities can easily be obtained by multiplying per capita quantities by each country's population. Both regions are modeled analogously, while we allow structural parameters to differ. Each country is

[4] Of course, our analysis is valid only insofar as public sector wage cuts do not induce workers to no longer search for jobs in the public sector and/or cuts in public employment do not impede provision of public services that cannot be produced by the private sector (or only at prohibitively large costs).

inhabited by households who consume home and foreign consumption goods and supply labor. Only a fraction of households can buy and sell assets (in particular, physical capital, domestic government debt and international bonds), while the rest is liquidity-constrained and behaves in a non-Ricardian fashion. The analysis by Galí et al. (2007) suggests that breaking Ricardian equivalence is important to generate realistic impulse response functions of private consumption following a fiscal shock. Both types of household also enjoy utility from government services.

Private production is split in three sub-sectors. Retailers operate in a competitive manner by buying intermediate goods varieties at the price set by the intermediate goods producers, bundle these into a final good and sell the latter to the home and foreign market. We assume that there is no price discrimination between the two markets. Intermediate goods producers use labor services and private capital as production inputs. Cost minimization determines the amounts of each input used per firm. As sellers of differentiated products, intermediate goods-producing firms enjoy monopolistic power and are thus able to set their nominal price, which they do in a staggered manner following Calvo (1983). Furthermore, the stock of public capital (infrastructures, etc.) enters the private production function and thus increases private sector productivity. Finally, a sector of labor firms search for unemployed workers in a frictional labor market, hire them, produce labor services and sell these to the intermediate goods sector for a perfectly competitive price. Except for the frictional labor market structure, the production sector is similar to Smets and Wouters (2003, 2007) or Christiano et al. (2005) and can thus be considered standard.

The labor market is characterized by search and matching frictions, in the tradition of Pissarides (2000). This implies that it takes time for unemployed workers and vacant jobs to be matched, which generates involuntary unemployment. We assume that both private firms and the government search in the same pool of unemployment, which means that unemployed individuals may find a job in either of the two sectors. Wages in the private sector are set in a staggered manner along the lines of Bodart et al. (2006), Christoffel et al. (2009) and de Walque et al. (2009). The wage bargaining is undertaken by a union. The public sector wage and employment levels are autonomously set by the government as in Quadrini and Trigari (2007), Afonso and Gomes (2008) or Gomes (2009).

The government is split into monetary and fiscal policy. The monetary authority sets the nominal area-wide reference interest rate (i.e. the ECB rate) according to a Taylor-type rule that responds to area-wide inflation and output. Fiscal policy is conducted autonomously in each country. National fiscal authorities finance themselves with taxes on consumption, wage income and returns on capital and bond investments, as well as with social security contributions and lump-sum taxes. Furthermore, each fiscal authority can issue public debt. On the other hand, each government spends in privately-produced consumption and investment goods, public sector wages, unemployment benefits, lump-sum subsidies, and interest payments on outstanding debt.

We will start by describing the household sector in section 2.1. Then, we turn to the production sector in section 2.2, while section 2.3 details the labor market description. Fiscal authorities are described in section 2.4, followed by a description of international linkages in section 2.5 where we also detail the monetary policy rule. In section 2.5.3, we derive the missing equilibrium conditions, while the calibration strategy is explained in section 2.6.

2.1 Households

Following Galí et al. (2007), we assume that each country is populated by a share $(1-\mu)$ of optimizing households who have unrestricted access to capital markets and are therefore able to substitute consumption intertemporally. The remaining share $\mu \in [0,1)$ of households is considered to be liquidity-constrained in the sense that they can neither save nor borrow and, thus, consume all their labor income in each period, i.e. they behave in a non-Ricardian fashion. This household type has become known as 'rule-of-thumb' household in the literature. Each household has a continuum of members of size one. The welfare function of each type of representative household is given by

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \cdot \epsilon_t^c \cdot u_t \left(c_t^i, c_{t-1}^i, \tilde{g}_t \right) \right\}, \tag{1}$$

where E_t is the expectations operator conditional on time-t information, c_t^i denotes household consumption of final goods, and the superscripts $i = o, r$ denote optimizing and rule-of-thumb households, respectively. The variable $\tilde{g}_t$ is government services produced by public employees, which is taken as given by private households. The instantaneous utility function is given by

$$u \left(c_t^i, c_{t-1}^i, \tilde{g}_t \right) = \begin{cases} \frac{\left[c_t^i - h \cdot c_{t-1}^i \right]^{1-\sigma_c} - 1}{1-\sigma_c} + \zeta \cdot \frac{\tilde{g}_t^{1-\sigma_c} - 1}{1-\sigma_c}, & \sigma_c > 0, \sigma_c \neq 1 \\ log \left[c_t^i - h \cdot c_{t-1}^i \right] + \zeta \cdot log[\tilde{g}_t], & \sigma_c = 1 \end{cases} . \tag{2}$$

The parameter σ_c is the coefficient of relative risk aversion (equal to the inverse of the intertemporal elasticity of substitution), h denotes the degree of habit formation in consumption, ϵ_t^c is an AR(1) preference shifter common to all households, and $\zeta > 0$ is a parameter capturing the relative valuation of public consumption in the households' utility function.

Inside each household, its members may be employed in the public sector, in the private sector, or unemployed. We assume full consumption insurance within the household, as in Andolfatto (1996) or Merz (1995). This holds both for Ricardian and rule-of-thumb households. In this regard, our specification of rule-of-thumb households differs somewhat from Galí et al. (2007); see also Boscá et al. (2009a, 2009b, 2010) for a more detailed explanation. However, the level of unemployment affects the disposable income of rule-of-thumb households, such that they still face a true income risk from employment fluctuations.

We assume that both countries trade consumption and investment goods as well as international nominal bonds. Trade in goods is modelled as follows. The consumption basket of a type-i household in the home country is given by

$$c_t^i = \left(\frac{c_{At}^i}{\omega + \psi} \right)^{\omega+\psi} \left(\frac{c_{Bt}^i}{1-\omega-\psi} \right)^{1-\omega-\psi},$$

where c_{At}^i and c_{Bt}^i are consumption of goods produced in country A (home) and B (foreign), respectively, and ψ is a parameter capturing the degree of home bias in consumption. Cost

minimization by the household implies,

$$\frac{c^i_{At}}{c^i_{Bt}} = \frac{\omega+\psi}{1-\omega-\psi}\frac{P_{Bt}}{P_{At}},$$

where P_{At} and P_{Bt} are the *producer price indexes* (PPI) in countries A and B, respectively. From now onwards, let

$$p_{Bt} \equiv \frac{P_{Bt}}{P_{At}}$$

denote the *terms of trade*. Analogously, production technologies make use of a combination of investment goods produced in both countries. The basket of investment goods (which are assumed to be owned by type-o households only) is given by

$$I^o_t = \left(\frac{I^o_{At}}{\omega+\psi}\right)^{\omega+\psi}\left(\frac{I^o_{Bt}}{1-\omega-\psi}\right)^{1-\omega-\psi},$$

where I^o_{At} and I^o_{Bt} are investment in goods produced in country A and B, respectively. Again, cost minimization implies that

$$\frac{I^o_{At}}{I^o_{Bt}} = \frac{\omega+\psi}{1-\omega-\psi}p_{Bt}.$$

The above equations imply that nominal expenditure in consumption and investment goods equal $P_{At}c^i_{At} + P_{Bt}c^i_{Bt} = P_t c^i_t$ and $P_{At}I^o_{At} + P_{Bt}I^o_{Bt} = P_t I^o_t$, respectively, where

$$P_t = (P_{At})^{\omega+\psi}(P_{Bt})^{1-\omega-\psi}$$

is the corresponding *consumer price index* (CPI). Notice that $P_t = P_{At}\cdot p_{Bt}^{1-\omega-\psi}$. Therefore, CPI inflation is given by

$$\pi_t = \pi_{At}\left(\frac{p_{Bt}}{p_{Bt-1}}\right)^{1-\omega-\psi},$$

where $\pi_{At} \equiv P_{At}/P_{At-1}$ is PPI inflation in country A.

2.1.1 Optimizing households

In order to calculate households' optimal choices, we first have to describe the budget constraints they are facing. Each optimizing households' real labor income (gross of taxes) is given by $w^p_t n^{p,o}_t + w^g_t n^{g,o}_t$, where w^p_t is the average real wage in the private sector (to be derived later), w^g_t is the real wage in the government sector, and $n^{p,o}_t$ and $n^{g,o}_t$ are the number of type-o household members employed in the private and government sector, respectively. Wages are taxed by the government at rate τ^w_t. When unemployed, the household member receives unemployment benefits κ^B. Consumption expenditures are taxed at rate τ^c_t. The household can invest in physical capital k^o_t, which earns a real rental rate r^k_t and depreciates at rate δ^k. Returns on physical capital (net of depreciation allowances) are taxed at rate τ^k_t. The latter can be seen as a proxy for corporate taxes, as private investment decisions are assumed to be made by households. The optimizing household can also purchase nominal government bonds B^o_t, which pay a gross nominal interest rate R_t. Returns on government bonds are taxed at the rate τ^b_t. Finally, optimizing households can hold international nomi-

nal bonds, D_t^o. In order to ensure stationarity of equilibrium, we follow Schmitt-Grohé and Uribe (2003) and assume that home agents pay a risk-premium (on top of the area-wide nominal policy rate, which we denote by R_t^{ecb}) that increases with the country's net foreign asset position. In particular we assume that the nominal interest rate paid or received by home investors is given by $R_t^{ecb}\exp(-\psi_d d_t/Y_t)$, with $\psi_d > 0$, where $d_t \equiv D_t/P_{At}$, D_t is the home country's nominal net foreign asset position and $(-)\, d_t/Y_t$ is the ratio of net foreign debt over output. We assume for simplicity that trade in international bonds is not taxed. Taking these elements together, the budget constraint of the representative optimizing households in real terms reads

$$\begin{aligned}(1+\tau_t^c)c_t^o + I_t^o + \frac{B_t^o + D_t^o}{P_t} \quad + \quad & \frac{T_t}{1-\mu} = \frac{\Pi_t}{P_t} + \left((1-\tau_t^k)r_t^k + \tau_t^k\delta^k\right)k_{t-1}^o + \frac{R_{t-1}B_{t-1}^o}{P_t} \\ & + \frac{R_{t-1}^{ecb}e^{-\psi d_{t-1}/Y_{t-1}}D_{t-1}^o}{P_t} - \tau_t^b\frac{(R_{t-1}-1)\,B_{t-1}^o}{P_t} + \frac{Sub_t}{1-\mu} \\ & + (1-\tau_t^w)\left(w_t^p n_t^{p,o} + w_t^g n_t^{g,o}\right) + (1-n_t^{p,o}-n_t^{g,o})\kappa^B,\end{aligned} \tag{3}$$

where Π_t are nominal per capita profits from firms (which are assumed to be owned by the optimizing households) redistributed in a lump-sum manner, and T_t and Sub_t are lump-sum taxes and subsidies, respectively. The law of motion of private physical capital is given by

$$k_t^o = (1-\delta^k)k_{t-1}^o + \left[1 - S\left(I_t^o/I_{t-1}^o\right)\right]I_t^o, \tag{4}$$

where $S\left(I_t^o/I_{t-1}^o\right) = \frac{\kappa_I}{2}\left(I_t^o/I_{t-1}^o - 1\right)^2$ represents investment adjustment costs (see Christiano et al., 2005; for a discussion). Maximizing (1) given (2) subject to equations (3) and (4) yields the following standard first-order conditions,

$$\text{for } c_t^o\text{:} \quad \lambda_t^o = \frac{\epsilon_t^c\cdot\left[c_t^o - h\cdot c_{t-1}^o\right]^{-\sigma_c} - \beta\cdot h\cdot E_t\left\{\epsilon_{t+1}^c\cdot\left[c_{t+1}^o - h\cdot c_t^o\right]^{-\sigma_c}\right\}}{(1+\tau_t^c)}\,, \tag{5}$$

$$\text{for } B_t^o\text{:} \quad \lambda_t^o = \beta\cdot E_t\left\{\lambda_{t+1}^o\cdot\frac{R_t\cdot(1-\tau_{t+1}^b)+\tau_{t+1}^b}{\pi_{t+1}}\right\}\,, \tag{6}$$

$$\text{for } k_t^o\text{:} \quad Q_t = \beta\cdot E_t\left\{\frac{\lambda_{t+1}^o}{\lambda_t^o}\left[(1-\delta^k)Q_{t+1} + (1-\tau_{t+1}^k)\cdot r_{t+1}^k + \tau_{t+1}^k\cdot\delta^k\right]\right\}\,, \tag{7}$$

$$\text{for } I_t^o\text{:} \quad 1 = Q_t\left[1 - S\left(I_t^o/I_{t-1}^o\right) - I_t^o\cdot S'\left(I_t^o/I_{t-1}^o\right)\right] + \beta\cdot E_t\left\{\frac{\lambda_{t+1}^o}{\lambda_t^o}Q_{t+1}\frac{{I_{t+1}^o}^2}{I_t^o}S'\left(I_{t+1}^o/I_t^o\right)\right\}\,, \tag{8}$$

$$\text{for } D_t^o\text{:} \quad \lambda_t^o = \beta R_t^{ecb}\cdot e^{-\psi_2 d_t/Y_t}\cdot E_t\left\{\frac{\lambda_{t+1}^o}{\pi_{t+1}}\right\}, \tag{9}$$

where λ_t^o is the Lagrange multiplier on equation (3) and $Q_t\cdot\lambda_t^o$ is the Lagrange multiplier on equation (4). Therefore, λ_t^o represents the marginal utility of real income, whereas Q_t represents the shadow real price of a unit of physical capital, i.e. Tobin's Q. Optimality additionally requires that the No-Ponzi condition on wealth is satisfied, which we assume to hold henceforth.

2.1.2 Non-Ricardian households

As non-Ricardian households can neither save nor borrow, their budget constraint simplifies to

$$(1+\tau_t^c)c_t^r = (1-\tau_t^w)\left(w_t^p n_t^{p,r} + w_t^g n_t^{g,r}\right) + (1-n_t^{p,r}-n_t^{g,r})\kappa^B, \tag{10}$$

which determines rule-of-thumb consumption, c_t^r. The corresponding marginal utility of consumption for rule-of-thumb households is, thus, given from maximizing (1) for $i = r$ subject to (2) and (10), that is,

$$\lambda_t^r = \frac{\epsilon_t^c \cdot \left[c_t^r - h \cdot c_{t-1}^r\right]^{-\sigma_c} - \beta \cdot h \cdot E_t\left\{\epsilon_{t+1}^c \cdot \left[c_{t+1}^r - h \cdot c_t^r\right]^{-\sigma_c}\right\}}{(1+\tau_t^c)} \ . \tag{11}$$

2.1.3 Aggregation

Given the above description, consumption per capita in the home country equals the weighted average of consumption for each household type, i.e.

$$C_t = (1-\mu)\cdot c_t^o + \mu \cdot c_t^r. \tag{12}$$

For future reference, per capita domestic demand for the home country's and the foreign country's consumption good equal

$$C_{At} = (1-\mu)\, c_{At}^o + \mu c_{At}^r,$$

$$C_{Bt} = (1-\mu)\, c_{Bt}^o + \mu c_{Bt}^r,$$

respectively. For the quantity variables that exclusively concern optimizing households, per capita amounts are given simply by

$$k_t = (1-\mu)k_t^o,$$

$$\frac{B_t}{P_t} = (1-\mu)\frac{B_t^o}{P_t},$$

$$I_t = (1-\mu)I_t^o,$$

$$D_t = (1-\mu)D_t^o.$$

$$I_{At} = (1-\mu)\, I_{At}^o,$$

$$I_{Bt} = (1-\mu)\, I_{Bt}^o,$$

Employment aggregation will be described in the labor market section.

2.2 Production

The retail and intermediate goods sectors of the economy are similar to Smets and Wouters (2003, 2007) or Christiano et al. (2005), with the exception that labor services are not hired directly from the households but from a sector of firms that produce homogenous labor services in the manner of Christoffel at al. (2009) or de Walque et al. (2009). It is the latter firms that hire workers and bargain over wages with them. In this subsection, we focus on

the retail and intermediate goods sectors, postponing the description of the labor market to the next subsection.

2.2.1 Retailers

There is a measure-ω continuum of firms in the retail (or final good) sector. Each retail firm purchases a variety of differentiated intermediate goods, bundle these into a final good and sell the latter under perfect competition. We assume that the law of one price holds within the union, which means that the price of the home country's final good is the same in both countries and equal to P_{At}. The maximization problem of the representative retail firm reads

$$\max_{\{y_t(j)\}_{j=0}^{1}} P_{At}Y_t - \int_0^{\omega} P_{At}(j)\tilde{y}_t(j)dj, \tag{13}$$

where

$$Y_t = \left(\int_0^{\omega} \left(\frac{1}{\omega}\right)^{1/\epsilon} \tilde{y}_t(j)^{(\epsilon-1)/\epsilon} dj \right)^{\epsilon/(\epsilon-1)}, \ \epsilon > 1, \tag{14}$$

is the retailer's production function, $\tilde{y}_t(j)$ is the retailer's demand for each differentiated input $j \in [0, \omega]$, and $P_{At}(j)$ is the nominal price of each input. The first-order condition for each input $j \in [0, \omega]$ reads

$$\tilde{y}_t(j) = \left(\frac{P_{At}(j)}{P_{At}} \right)^{-\epsilon} \frac{Y_t}{\omega}. \tag{15}$$

Combining the latter with (13) and the zero profit condition, we obtain that the producer price index in the home country must equal

$$P_{At} = \left(\int_0^{\omega} \frac{1}{\omega} P_{At}(j)^{1-\epsilon} dj \right)^{1/(1-\epsilon)}.$$

Notice that, since there are ω retail firms, total demand for each intermediate input equals

$$\omega \tilde{y}_t(j) \equiv y_t(j) = \left(\frac{P_{At}(j)}{P_{At}} \right)^{-\epsilon} Y_t. \tag{16}$$

2.2.2 Intermediate goods

Firms in the intermediate goods sector have mass ω. Each producer $j \in [0, \omega]$ produces according to the following technology,

$$y_t(j) = \epsilon_t^a \cdot \left(k_{t-1}^g\right)^{\eta} \cdot \left[\tilde{k}_t(j)\right]^{\alpha} \cdot \left[l_t(j)\right]^{(1-\alpha)}, \tag{17}$$

where $\alpha \in [0, 1]$ is the elasticity of output with respect to private capital, $l_t(j)$ denotes the demand for labor services, $\tilde{k}_t(j)$ is the demand for capital services and ϵ_t^a is an AR(1) TFP process. Also, k_{t-1}^g is the public capital stock available in period t, which is determined by the government and is assumed to be productivity-enhancing; the parameter $\eta \in [0, 1)$ measures how influential public capital is on private production. Intermediate goods firms acquire labor and capital services in perfectly competitive factor markets at real (CPI-deflated) prices

x_t and r_t^k, respectively. In period t, nominal profits of firm j, $\Pi_t^{whole}(j)$, in real terms are thus given by

$$\frac{\Pi_t^{whole}(j)}{P_t} = \frac{P_{At}(j)}{P_t} y_t(j) - x_t \cdot l_t(j) - r_t^k \cdot \tilde{k}_t(j). \tag{18}$$

Cost minimization subject to (17) implies the following factor demand conditions,

$$r_t^k = mc_t \cdot \alpha \cdot \frac{y_t(j)}{\tilde{k}_t(j)}, \tag{19}$$

$$x_t = mc_t \cdot (1-\alpha) \cdot \frac{y_t(j)}{l_t(j)}, \tag{20}$$

where mc_t is the real (CPI-deflated) marginal cost common to all intermediate good producers.[5]

We assume that intermediate goods firms set nominal prices à la Calvo (1983). Each period, a randomly chosen fraction $\theta_P \in [0,1)$ of firms cannot re-optimize their price. A firm that has the chance to reoptimize its price in period t chooses the nominal price $P_{At}(j)$ that maximizes

$$E_t \sum_{k=0}^{\infty} (\beta\theta_P)^k \frac{\lambda_{t+k}^o}{\lambda_t^o} \left[\frac{P_{At}(j)}{P_{t+k}} - mc_{t+k} \right] y_{t+k}(j), \tag{21}$$

subject to $y_{t+k}(j) = \left(P_{At}(j)/P_{At+k}\right)^{-\epsilon} Y_{t+k}$. The first-order condition is given by

$$E_t \sum_{k=0}^{\infty} (\beta\theta_P)^k \frac{\lambda_{t+k}^o}{\lambda_t^o} \left[\frac{\tilde{P}_{At}}{P_{t+k}} - \frac{\epsilon}{\epsilon-1} mc_{t+k} \right] \left(\frac{\tilde{P}_{At}}{P_{At+k}} \right)^{-\epsilon} Y_{t+k} = 0, \tag{22}$$

where $\tilde{P}_{At}$ is the optimal price chosen by all period-t price setters. The law of motion of the price level is given by

$$P_{At} = \left[\theta_P \left(P_{At-1}\right)^{1-\epsilon} + (1-\theta_P) \left(\tilde{P}_{At}\right)^{1-\epsilon} \right]^{1/(1-\epsilon)}, \tag{23}$$

or equivalently,

$$1 = \theta_P \left(\frac{1}{\pi_{At}} \right)^{1-\epsilon} + (1-\theta_P) \tilde{p}_t^{1-\epsilon},$$

where $\tilde{p}_t \equiv \tilde{P}_{At}/P_{At}$ is the relative (PPI-deflated) optimal price.

2.3 The labor market

Labor firms hire workers from the household sector in order to produce homogenous labor services, which they sell to intermediate goods producers at the perfectly competitive price

[5] Notice that constant returns to scale in private capital and labor, together with perfectly competitive input prices, imply that the ratios $y_t(j)/\tilde{k}_t(j)$ and $y_t(j)/l_t(j)$ are equalized across firms. Combining (17), (19) and (20), the common real marginal cost can be expressed as

$$mc_t = \frac{1}{\epsilon_t^a \cdot \left(k_{t-1}^g\right)^{\eta}} \cdot \left(\frac{x_t}{1-\alpha} \right)^{1-\alpha} \cdot \left(\frac{r_t^k}{\alpha} \right)^{\alpha}.$$

x_t. This modelling strategy follows Christoffel et al. (2009) or de Walque et al. (2009). We keep the conventional assumption of the Pissarides (2000) framework that each labor firm can at most hire one worker. The production function of each labor firm is linear in the number of hours worked by its employee, which is fixed at the level $\bar{h}$. Therefore, the total per capita supply of labor services is given by

$$L_t = N_t^p \cdot \bar{h}, \tag{24}$$

where N_t^p is the rate of private-sector employment. Equilibrium in the market for labor services requires that $\omega \cdot N_t^p \cdot \bar{h} = \int_0^\omega l_t(j)dj$. In what follows, we will specify the matching process and flows in the labor market, vacancy creation and (private) wage determination. Government wages and employment are autonomously chosen by the fiscal authority (see section 2.4).

2.3.1 Matching process and labor market flows

As already described, we consider a model in which the worker can be in one of three states: (i) unemployed, (ii) employed in the public sector, or (iii) employed in the private sector. Unemployment is the residual state in the sense that a worker whose employment relationship ends flows back into unemployment. Unemployed workers look for job opportunities. They find them either in the public sector (with superscript g for government employment) or in the private sector (with superscript p). Workers do not direct search to either the public or the private sector and are, thus, matched randomly. In this sense, the matching process differs slightly from other papers incorporating public employment in a matching framework (as, for example, Quadrini and Trigari, 2007; Afonso and Gomes, 2008; or Gomes, 2009). We apply the three state labor market structure of, for example, Albrecht et al. (2009). While we follow this approach for simplicity, it should be noted that this assumption does not affect the results qualitatively.

Let us denote sector-specific per capita employment in period t by N_t^f, where $f = p, g$ stands for private and public (i.e. government) employment, respectively.[6] The total employment rate is then given by $N_t^{tot} = N_t^p + N_t^g$, while the unemployment rate is given by

$$U_t = 1 - N_t^{tot}. \tag{25}$$

Following Blanchard and Galí (2008), we assume that the hiring round takes place at the beginning of each period, and that new hires start producing immediately. We also assume that workers dismissed at the end of period $t-1$ start searching for a new job at the beginning of period t. Therefore, the pool of searching workers at the beginning of period t is given by

$$\tilde{U}_t = U_{t-1} + s^p N_{t-1}^p + s^g N_{t-1}^g.$$

[6] Note that, as we work with household type-specific (un)employment rates for each sector in the households' budget constraints (see equations (3) and (10)), we basically have to aggregate employment in order to obtain total (per capita) employment levels across public and private employment. This is done in an analogously to the aggregation of consumption decisions (see section 2.1.3; again implying that capital letters indicate aggregate levels). Thus, aggregated per capita employment levels in each sector are given by $N_t^f = (1-\mu) \cdot n_t^{f,o} + \mu \cdot n_t^{f,r}$. Noting that dismissal and (re-)employment probabilities are equal across household types, we have that $N_t^f = n_t^{f,o} = n_t^{f,r}$; see also Moyen and Stähler (2009) for details.

The matching process is governed by a standard Cobb-Douglas aggregate matching function for each sector $f = p, g$,

$$M_t^f = \kappa_e^f \cdot \left(\tilde{U}_t\right)^{\varphi^f} \cdot \left(v_t^f\right)^{(1-\varphi^f)}, \tag{26}$$

where $\kappa_e^f > 0$ is the sector-specific matching efficiency parameter, $\varphi^f \in (0,1)$ the sector-specific matching elasticity and M_t^f the number of new matches formed in period t resulting from the total number of searchers and the number of sector-specific vacancies v_t^f.[7] The probability for an unemployed worker to find a job in sector f can thus be stated as $p_t^f = M_t^f / \tilde{U}_t$, while the probability of filling a vacancy is given by $q_t^f = M_t^f / v_t^f$. We assume a constant separation rate in each sector, denoted by s^f. The law of motion for sector-specific employment rates is therefore given by

$$N_t^f = \left(1 - s^f\right) \cdot N_{t-1}^f + p_t^f \cdot \tilde{U}_t, \tag{27}$$

for $f = g, p$. Thus, employment in sector f today is given by yesterday's employment that has not been destroyed plus newly created matches in that sector.

2.3.2 Asset value of jobs and wage bargaining

Because of search frictions, formed matches entail economic rents. Firms and workers bargain about their share of the overall match surplus. In order to describe the bargaining process we first have to derive the asset value functions for workers and firms. We assume staggered bargaining of nominal wages along the lines of Bodart et al. (2006). In particular, each period a randomly chosen fraction θ_w of continuing firms cannot renegotiate wages, while a fraction θ_w^n of newly created firms does not bargain over wages and simply pays the average nominal wage of the previous period. Letting $\tilde{W}_t^p$ denote the nominal wage negotiated in period t, the value function of a firm that renegotiates in that period is given by

$$\begin{aligned} J_t\left(\tilde{W}_t^p\right) &= E_t \sum_{k=0}^{\infty} \left\{ \left[\beta \cdot (1 - s^p) \cdot \theta_w\right]^k \cdot \frac{\lambda_{t+k}^o}{\lambda_t^o} \cdot \left[\bar{h} \cdot x_{t+k} - (1 + \tau_{t+k}^{sc}) \cdot \frac{\tilde{W}_t^p}{P_{t+k}} \right] \right\} \\ &\quad + (1 - \theta_w) \cdot E_t \sum_{k=1}^{\infty} \left\{ \left[\beta \cdot (1 - s^p)\right]^k \cdot \theta_w^{k-1} \cdot \frac{\lambda_{t+k}^o}{\lambda_t^o} \cdot J_{t+k}\left(\tilde{W}_{t+k}^p\right) \right\}, \end{aligned} \tag{28}$$

where τ_t^{sc} is the social security contribution rate. Therefore, the value of the firm is the discounted profit flow in those future states in which it is not allowed to renegotiate (the term on the right-hand side in the first line of equation 28), plus its continuation value should it have the chance to reoptimize in the next period (the term in the second line).[8] For new jobs where firm and worker do not bargain, the nominal wage equals last period's average

[7] Note that, with the representation above (equation (26)), we are able to calibrate the matching functions across sectors differently. In the case $\varphi^g < \varphi^p$ (the strategy which we will follow), vacancies are relatively more important than the pool of unemployment in the government sector. We believe this is a plausible assumption.

[8] Details on how to derive equation (28) can be found in Christoffel et al. (2009) and de Walque et al. (2009) or sent upon request. An analogous proceeding holds for the workers' side described below.

nominal wage, W_{t-1}^p, and the value of the job equals

$$J_t\left(W_{t-1}^p\right) = J_t\left(\tilde{W}_t^p\right) - E_t \sum_{k=0}^{\infty} \left\{ \left[\beta \cdot (1-s^p) \cdot \theta_w\right]^k \cdot \frac{\lambda_{t+k}^o}{\lambda_t^o} \cdot (1+\tau_{t+k}^{sc}) \cdot \frac{W_{t-1}^p - \tilde{W}_t^p}{P_{t+k}} \right\}.$$

Free entry into the vacancy posting market drives the expected value of a vacancy to zero. Under our assumption of instantaneous hiring, real vacancy posting costs κ_v^p must equal the time-t vacancy filling probability, q_t^p, times the expected value of a filled job in period t,

$$\frac{\kappa_v^p}{q_t^p} = (1-\theta_w^n) \cdot J_t\left(\tilde{W}_t^p\right) + \theta_w^n \cdot J_t\left(W_{t-1}^p\right), \tag{29}$$

where we take into account that the wage of the newly-created job may be optimally bargained with probability $1-\theta_w^n$.

We can now derive the asset value functions of workers. In particular, we are interested in the value of the job in excess of the value of being unemployed, i.e. the worker's match *surplus*. Since different household types use different stochastic discount factors, we must distinguish between the surplus for an optimizing and a rule-of-thumb household. For a worker belonging to a type-i household, the surplus value of a job in a renegotiating firm is given by

$$\begin{aligned} H_t^{i,p}\left(\tilde{W}_t^p\right) &= E_t \sum_{k=0}^{\infty} \left\{ \left[\beta \cdot (1-s^p) \cdot \theta_w\right]^k \cdot \frac{\lambda_{t+k}^i}{\lambda_t^i} \cdot \left[(1-\tau_{t+k}^w) \cdot \frac{\tilde{W}_t^p}{P_{t+k}} - oo_{t+k}^{i,p} \right] \right\} \\ &\quad + (1-\theta_w) \cdot E_t \sum_{k=1}^{\infty} \left\{ \left[\beta \cdot (1-s^p)\right]^k \cdot \theta_w^{k-1} \cdot \frac{\lambda_{t+k}^i}{\lambda_t^i} \cdot H_{t+k}^{i,p}(\tilde{W}_{t+k}^p) \right\}, \end{aligned} \tag{30}$$

for $i = o, r$, where

$$oo_t^{i,f} \equiv \kappa^B + \beta(1-s^f) E_t \frac{\lambda_{t+1}^i}{\lambda_t^i} \left\{ p_{t+1}^g H_{t+1}^{i,g} + p_{t+1}^p \left[(1-\theta_w^n) H_{t+1}^{i,p}\left(\tilde{W}_{t+1}^p\right) + \theta_w^n H_{t+1}^{i,p}\left(W_t^p\right) \right] \right\}, \tag{31}$$

represents the outside option of a type-i worker employed in sector $f = p, g$ at time t. The latter is the sum of unemployment benefits, κ^B, and the expected value of searching for a job in the following period, where p_{t+1}^f is the probability of finding a job in sector $f = p, g$. Conditional on landing on a private-sector job ($f = p$), the surplus value for the worker is contingent on whether the firm is allowed to bargain (in which case the worker receives $\tilde{W}_{t+1}^p$) or not (in which case she receives today's average wage, W_t^p). In new jobs where the wage is not optimally bargained, the surplus value enjoyed by type-i workers is given by

$$H_t^{i,p}\left(W_{t-1}^p\right) = H_t^{i,p}\left(\tilde{W}_t^p\right) + E_t \sum_{k=0}^{\infty} \left\{ \left[\beta \cdot (1-s^p) \cdot \theta_w\right]^k \cdot \frac{\lambda_{t+k}^i}{\lambda_t^i} \cdot (1-\tau_{t+k}^w) \cdot \frac{W_{t-1}^p - \tilde{W}_t^p}{P_{t+k}} \right\}.$$

Let $H_t^{i,g}$ denote the surplus value of a government job for a type-i worker. As wages there

are autonomously set by the fiscal authority, the asset value function simplifies to

$$H_t^{i,g} = (1-\tau_t^w)w_t^g - oo_t^{i,g} + \beta(1-s^g)E_t\left\{\frac{\lambda_{t+1}^i}{\lambda_t^i}\cdot H_{t+1}^{i,g}\right\}, \tag{32}$$

where w_t^g is the real wage paid by the government. The only influence of staggered wage setting in the private sector on the asset value of public employees operates through the outside option of public sector workers, $oo_t^{i,g}$, given by (31) for $f = g$. Given the asset value functions of firms and workers, we are now in a position to describe the wage bargaining game.

As already mentioned above, we assume unionized wage bargaining following Boscá et al. (2009a, 2009b, 2010).[9] The unions's utility is the average utility of its members. More precisely, it is the weighted average of the surplus of optimizing and rule-of-thumb workers, which we denote by

$$\Omega_t \equiv (1-\mu)H_t^{o,p}\left(\tilde{W}_t^p\right) + \mu H_t^{r,p}\left(\tilde{W}_t^p\right).$$

This implies that the union wants to maximize its members' gain from employment over unemployment, as in the formulation by Oswald (1993). We assume Nash bargaining between the firm and the union, where the union's bargaining power parameter is given by $\xi \in [0,1)$. The joint maximization problem is therefore given by

$$\max_{\tilde{W}_t^p} \; [\Omega_t]^{\xi}\left[J_t\left(\tilde{W}_t^p\right)\right]^{1-\xi}. \tag{33}$$

The resulting sharing rule is given by

$$\Omega_t = \frac{\xi}{1-\xi}\cdot\frac{E_t\sum_0^{\infty}\left\{\left((1-\mu)\frac{\lambda_{t+k}^o}{\lambda_t^o}+\mu\frac{\lambda_{t+k}^r}{\lambda_t^r}\right)\left[\beta(1-s^p)\theta_w\right]^k\frac{(1-\tau_{t+k}^w)}{P_{t+k}}\right\}}{E_t\sum_0^{\infty}\left\{\frac{\lambda_{t+k}^o}{\lambda_t^o}\left[\beta(1-s^p)\theta_w\right]^k\frac{(1+\tau_{t+k}^{sc})}{P_{t+k}}\right\}}\cdot J_t\left(\tilde{W}_t^p\right), \tag{34}$$

which states that the share of the matching surplus the worker receives depends on the union's bargaining power and (the expected evolution of) labor taxes, prices and type-specific stochastic discount factors. Solving equation (34) for $\tilde{W}_t^p$ by using the corresponding asset value functions gives the optimal wage bargained in period t. Finally, we derive the average real wage in the private sector, $w_t^p \equiv W_t^p/P_t$. The latter evolves according to

$$w_t^p = \frac{(1-s^p)N_{t-1}^p}{N_t^p}\left[(1-\theta_w)\tilde{w}_t^p + \theta_w\cdot\frac{w_{t-1}^p}{\pi_t}\right] + \frac{M_t^p}{N_t^p}\left[(1-\theta_w^n)\tilde{w}_t^p + \theta_w^n\cdot\frac{w_{t-1}^p}{\pi_t}\right], \tag{35}$$

where $\tilde{w}_t^p \equiv \tilde{W}_t^p/P_t$ is the real optimally bargained wage, $w_{t-1}^p/\pi_t = W_{t-1}^p/P_t$ is the real value of yesterday's average nominal wage at today's prices, and we have taken into account that new and continuing jobs pay the optimally bargained wage with probabilities $1-\theta_w^n$ and $1-\theta_w$, respectively. Equation (35) can also be expressed as $w_t^p = (1-\gamma_t)\tilde{w}_t^p + \gamma_t\cdot w_{t-1}^p/\pi_t$,

[9] Assuming individual bargaining between each worker with the firm does not change the steady-state results at all. But it (slightly) changes the magnitude of wage evolution across the cycle. This is due to the fact that rule-of-thumb households discount differently. The effects are very small, however, and, therefore, we decided to stick to the assumptions made by Boscá et al. (2009a, 2009b, 2010).

where $\gamma_t \equiv \theta_w + (M_t^p/N_t^p) \cdot (\theta_w^n - \theta_w)$ (see also Blanchard and Galí, 2007, who propose a similar equation for real wage rigidity).

2.4 Fiscal authorities

The real (CPI-deflated) per capita value of end-of-period government debt, $b_t \equiv B_t/P_t$, evolves according to a standard debt accumulation equation,

$$b_t = \frac{R_{t-1}}{\pi_t} b_{t-1} + PD_t,$$

where PD_t denotes real (CPI-deflated) per capita primary deficit. The latter is given by per capita fiscal expenditures minus per capita fiscal revenues,

$$\begin{aligned} PD_t &= \left[\frac{G_t}{p_{Bt}^{1-\omega-\psi}} + \kappa^B U_t + Sub_t \right] \\ &\quad - \left[(\tau_t^w + \tau_t^{sc}) \left[w_t^p N_t^P + w_t^g N_t^g \right] + \tau_t^b \frac{R_{t-1} - 1}{\pi_t} b_{t-1} + \tau_t^c C_t + \tau_t^k (r_t^k - \delta^k) k_{t-1} + T_t \right], \end{aligned} \tag{36}$$

where G_t denotes per capita government spending in goods and services expressed in PPI terms (hence the correction for the CPI-to-PPI ratio, $P_t/P_{At} = p_{Bt}^{1-\omega-\psi}$). Government spending in goods and services is in turn the sum of government demand for privately-produced consumption and investment goods (which we will henceforth refer to as 'public purchases' and 'public investment', respectively) and the public sector wage bill (gross of social security contributions). Following standard practice, we assume full home-bias in public purchases and public investment, such that their nominal price is equal to the home country PPI, P_{At}.[10] Letting C_t^g and I_t^g denote real per capita public purchases and public investment, respectively, we have the following nominal relationship: $P_{At} G_t = P_{At} \left(C_t^g + I_t^g \right) + (1 + \tau_t^{sc}) P_t w_t^g N_t^g$. Dividing by P_{At} and using $P_t/P_{At} = p_{Bt}^{1-\omega-\psi}$, we obtain

$$G_t = C_t^g + I_t^g + \left[(1 + \tau_t^{sc}) w_t^g N_t^g \right] p_{Bt}^{1-\omega-\psi}. \tag{37}$$

Given public investment, the stock of public physical capital evolves as follows,

$$k_t^g = (1 - \delta^g) k_{t-1}^g + I_t^g, \tag{38}$$

where we assume that the public capital stock depreciates at rate δ^g (which may potentially deviate from the private-sector depreciation rate).

The government therefore has six instruments on the revenue side: the tax rate on wage income, τ_t^w, on consumption, τ_t^c, on bond returns, τ_t^b, on capital returns, τ_t^k, the social security contribution tax rate, τ_t^{sc}, and lump-sum taxes, T_t. It also has five instruments on the expenditures side: public purchases, C_t^g, public investment, I_t^g, public sector wages, w_t^g, public employment, N_t^g, and lump-sum subsidies, Sub_t. For each of these fiscal instruments,

[10] Full home bias in public consumption and investment is assumed for simplicity and can be justified by the fact that, for OECD countries, there is evidence for strong home bias in government procurement, much over and above that observed in private consumption (see, for example, Trionfetti, 2000; and Brulhart and Trionfetti, 2004).

we assume a rule of the form

$$\frac{X_t}{\bar{X}} = \left(\frac{X_{t-1}}{\bar{X}}\right)^{\rho_X} \cdot \left(\frac{b_{t-\tilde{t}}}{\omega^b Y^{tot}_{t-\tilde{t}}} p^{1-\omega-\psi}_{Bt-\tilde{t}}\right)^{(1-\rho_X)\phi_X} \cdot \exp\left(\epsilon^X_t\right), \tag{39}$$

where $X_t \in \{C^g_t, I^g_t, w^g_t, N^g_t, Sub_t, \tau^w_t, \tau^{sc}_t, \tau^b_t, \tau^c_t, \tau^k_t, T_t\}$, $\bar{X}$ is a long-run target, ρ_X is a smoothing parameter, $b_{t-\tilde{t}} p^{1-\omega-\psi}_{Bt-\tilde{t}} / Y^{tot}_{t-\tilde{t}}$ is the ratio of public debt over GDP in period $t-\tilde{t}$ (where Y^{tot}_t is the home country's per capita GDP in terms of PPI, to be defined below), ω^b is a long-run target for the debt ratio, ϕ_X measures the responsiveness of the instrument to deviations in the debt ratio from its long-run target, and ϵ^X_t is an iid shock. For C^g_t and I^g_t, the long-run target is a certain weight of steady-state GDP: $\bar{C}^g = \omega_{Cg}\bar{Y}^{tot}$, $\bar{I}^g = \omega_{IG}\bar{Y}^{tot}$. For public sector wages and employment, the long-run targets are, respectively, a premium over private-sector wages and a share of total employment in the steady state: $\bar{w}^g = \omega_{wg}\bar{w}^p$, $\bar{N}^g = \omega_{ng}\bar{N}^{tot}$. In order to guarantee stability in the debt ratio, for *at least* one instrument the coefficient ϕ_X must be non-zero (positive for revenue instruments, negative for expenditure instruments). Notice however that it generally suffices to assume a small and inertial responsiveness of the chosen instrument(s) to deviations in the debt ratio.[11]

2.5 The foreign country block, international linkages and union-wide monetary policy

In this section, we will describe some structural relationships corresponding to the foreign country block, point out the international linkages via trade in goods and foreign assets, and describe the union-wide monetary policy rule.

2.5.1 The foreign country

We use asterisks to denote decisions made by foreign agents as well as structural parameters in the foreign country. The latter is modelled analogously to the home country. For this reason, here we discuss only some structural relationships, while the full set of equations corresponding to the foreign country are shown in the Appendix.

The consumption basket of foreign households is given by

$$c^{i*}_t = \left(\frac{c^{i*}_{At}}{\omega - \psi^*}\right)^{\omega-\psi^*} \left(\frac{c^{i*}_{Bt}}{1-\omega+\psi^*}\right)^{1-\omega+\psi^*},$$

for $i = o, r$, where c^{i*}_{At} and c^{i*}_{Bt} denote consumption by foreign type-i households of goods produced in country A (home) and B (foreign), respectively, while ψ^* captures the degree of home bias in foreign households' preferences. The foreign country's investment basket is

[11] The literature on optimal fiscal policy derives two stylized results. First, it seems preferable to move fiscal instruments by a small amount permanently to service a new higher level of debt, rather than change them by a large amount on a temporary basis to return debt to its initial level (see, for example, Schmitt-Grohé and Uribe, 2007, Kirsanova and Wren-Lewis, 2007, and Canzoneri et al., 2008, among others). This finding can be related to the tax smoothing argument (see Barro, 1979, and Lucas and Stokey, 1983). Second, mild countercyclical policy responses have a stabilizing and welfare-enhancing effect (see also Leith and Wren-Lewis, 2007, Straub and Tchakarov, 2007, or Galí and Monacelli, 2008).

analogously defined. The corresponding consumer price index in the foreign country (which is used as numeraire by households and firms in that country) is given by

$$P_t^* = P_{At}^{\omega-\psi^*} P_{Bt}^{1-\omega+\psi^*} = P_{Bt}\left(\frac{1}{p_{Bt}}\right)^{\omega-\psi^*}.$$

Therefore, the foreign country's consumer price inflation evolves according to

$$\pi_t^* \equiv \frac{P_t^*}{P_{t-1}^*} = \pi_{Bt}\left(\frac{p_{Bt-1}}{p_{Bt}}\right)^{\omega-\psi^*},$$

where $\pi_{Bt} \equiv P_{Bt}/P_{Bt-1}$ is producer price inflation in the foreign country. The PPI itself evolves according to

$$P_{Bt} = \left(\int_0^{1-\omega} \frac{1}{1-\omega} P_{Bt}(j)^{1-\epsilon^*} dj\right)^{1/(1-\epsilon^*)} = \left[\theta_P^*\left(\pi_{t-1}^{\gamma_P^*} \cdot P_{Bt-1}\right)^{1-\epsilon^*} + (1-\theta_P^*)\left(\tilde{P}_{Bt}\right)^{1-\epsilon^*}\right]^{1/(1-\epsilon^*)},$$

where $\tilde{P}_{Bt}$ is the common nominal price chosen by the foreign country's price-setters in period t. Also, the nominal interest rate paid/received by the foreign country's nationals on international bonds equals $R_t^{ecb}\exp\left(-\psi d_t^*/Y_t^*\right)$, where $(-)\, d_t^*/Y_t^*$ is the foreign country's ratio of net foreign debt over output.

2.5.2 International linkages

As already mentioned, international linkages between the two countries in real terms result from trade in goods and services as well as international bonds. These issues are reflected in the current account of each economy. The home country's net foreign asset position, expressed in terms of PPI, evolves according to

$$d_t = \frac{R_{t-1}^{ecb} \cdot e^{-\psi d_{t-1}/Y_{t-1}}}{\pi_{At}} \cdot d_{t-1} + \underbrace{\frac{1-\omega}{\omega}\left(C_{At}^* + I_{At}^*\right) - p_{Bt}\left(C_{Bt} + I_{Bt}\right)}_{=\text{Trade balance}}, \tag{40}$$

where $(1-\omega)\left(C_{At}^* + I_{At}^*\right)/\omega$ are real per capita exports and $p_{Bt}\left(C_{Bt} + I_{Bt}\right)$ are real per capita imports. Zero net supply of international bonds implies

$$\omega d_t + (1-\omega)\, p_t^B d_t^* = 0. \tag{41}$$

Finally, terms of trade $p_{Bt} = P_{Bt}/P_{At}$ evolve according to

$$p_{Bt} = \frac{\pi_{Bt}}{\pi_{At}} p_{Bt-1}. \tag{42}$$

2.5.3 Equilibrium in goods markets and GDP

Market clearing implies that private per capita production in the home and foreign country, Y_t and Y_t^* respectively, is used for private and public consumption as well as public and

private investment demand,

$$Y_t = C_{At} + I_{At} + C_t^g + I_t^g + \frac{1-\omega}{\omega}\left(C_{At}^* + I_{At}^*\right),$$

$$Y_t^* = C_{Bt}^* + I_{Bt}^* + C_t^{g*} + I_t^{g*} + \frac{\omega}{1-\omega}\left(C_{Bt} + I_{Bt}\right).$$

Consistently with national accounting, each country's GDP is the sum of private-sector production and government production of goods and services. The latter is measured at input costs, that is, by the gross government wage bill. Let Y_t^{tot} and $Y_t^{tot,*}$ denote real (PPI-deflated) per capita GDP in the home and foreign country, respectively. We then have

$$Y_t^{tot} = Y_t + (1+\tau_t^{sc}) w_t^g N_t^g p_{Bt}^{1-\omega-\psi}, \tag{43}$$

$$Y_t^{tot,*} = Y_t^* + (1+\tau_t^{sc*}) w_t^{g*} N_t^{g*} p_{Bt}^{-(\omega-\psi^*)}, \tag{44}$$

where in (44) we have used $P_t^*/P_{Bt} = p_{Bt}^{-(\omega-\psi^*)}$.

2.5.4 Monetary authority

We assume that the area-wide monetary authority has its nominal interest rate, R_t^{ecb}, respond to area-wide CPI inflation and output (both in deviations from steady state) according to a simple Taylor rule,

$$\frac{R_t^{ecb}}{\bar{R}^{ecb}} = \left(\frac{R_{t-1}^{ecb}}{\bar{R}^{ecb}}\right)^{\rho_R} \left\{ \left[\left(\frac{\pi_{t-1}}{\bar{\pi}}\right)^{\omega} \left(\frac{\pi_{t-1}^*}{\bar{\pi}}\right)^{1-\omega} \right]^{\phi_\pi} \left[\left(\frac{Y_{t-1}^{tot}}{\bar{Y}^{tot}}\right)^{\omega} \left(\frac{Y_{t-1}^{*,tot}}{\bar{Y}^{*,tot}}\right)^{1-\omega} \right]^{\phi_y} \right\}^{(1-\rho_R)} \exp\left(\epsilon_t^R\right),$$

where ρ_R is a smoothing parameter, ϕ_π and ϕ_y are the monetary policy's stance on inflation and output gap deviations, respectively, and ϵ_t^R is an iid shock. This completes the model description. We now turn to the model calibration.

2.6 Calibration

We calibrate our model to quarterly frequencies. We calibrate the home country (A) to the Spanish economy and the foreign country (B) to the rest of the European Monetary Union. We set the home country size to $\omega = 0.10$, which roughly corresponds to Spain's population share in the EMU. Our remaining calibration strategy is to, first, set key steady-state ratios, including the ratios of various expenditure categories over output, equal to their real world counterparts. These ratios are summarized in Tables 1 and 2 for the home (i.e. Spain) and foreign (i.e. rest of EMU) countries, respectively. While calibrating the steady-state ratios is based on observed data, we have, second, chosen the remaining structural parameters of our model (i) with the aim of reproducing the above steady-state ratios and (ii) following recent literature. A summary can be found in Table 3. Note that we assume most parameters to be equal in the home and foreign country unless explicitly stated differently. With these ratios and parameters at hand, we are then able to derive the deterministic steady state of our model. We note in passing that we are able to derive the corresponding steady-state solutions for all variables analytically.

2.6.1 Steady-state ratios and targeted parameters

Normalizing EMU's GDP to unity, i.e. $\bar{Y}^{tot*} = 1$, we can set Spain's per capita GDP to about $\bar{Y}^{tot} = 1.05$.[12] For the steady-state ratios in the home and foreign country, we mainly refer to national accounts data from 1999 to 2008. The data comes from the European Commission (*AMECO* and *Public Finance Report – 2010*) and Eurostat (*NEW CRONOS*). From the data, we set the steady-state shares of different government spending-to-GDP ratios according to Table 1. Furthermore, the shares of government granted subsidies-to-GDP and debt-to-GDP are set according to this data.[13]

Table 1: Targeted values (home country Spain)

Target	Symbol	Value
PPI inflation	$\bar{\pi}_A$	1.0000
Current account	$\bar{d} = -\bar{d}^*$	0.0000
(Average) Labor tax rate	$\bar{\tau}^w$	0.1622
Bond tax rate	$\bar{\tau}^b$	0.1622
VAT rate	$\bar{\tau}^c$	0.0762
Social security contribution rate	$\bar{\tau}^{sc}$	0.1555
Capital tax rate	$\bar{\tau}^k$	0.1806
Unemployment rate	$\bar{U}$	0.1113
Fraction of publ. employment	$fracpub = \frac{\bar{N}^g}{1-\bar{U}}$	0.1872
Pub. sector wage premium	$wageprem$	1.0592
Vacancy filling rate (private)	$\bar{q}^p$	0.7000
Vacancy filling rate (public)	$\bar{q}^g$	0.8000
Per capita GDP	$\bar{Y}^{tot}$	1.0500
Gov. SS spending	$\omega^G = \bar{G}/\bar{Y}^{tot}$	0.2131
Gov. SS purchases	$\omega^{Cg} = \bar{C}^g/\bar{Y}^{tot}$	0.0756
Gov. SS investment	$\omega^{Ig} = \bar{I}^g/\bar{Y}^{tot}$	0.0355
SS debt-to-GDP ratio (annualized)	$\omega^d = \bar{B}/(4\bar{Y}^{tot})$	0.4831
SS subsidy-to-GDP ratio	$\omega^s = \bar{Sub}/\bar{Y}^{tot}$	0.1543
Replacement ratio	$rrs = \frac{\kappa^B}{(1-\bar{\tau}^w)\bar{w}}$	0.3780

Source: Original data from European Commission, Eurostat and OECD, own calculations for the ratios and implicit tax rates; normalization as described in the main text.

Regarding the tax rates, we have calculated them as average implicit tax rates according to the following procedure: we take the government revenues rom a specific tax and divide it by its corresponding base. This is done for all tax rates except for Spain's personal income tax rate, $\bar{\tau}^w$ (which in the model includes social security contributions by workers), and the tax rate on returns from public debt $\bar{\tau}^b$: the latter is set equal to the former, which in turn is based on calculations by Argimón et al. (2007) using Spanish fiscal micro data.[14]

[12] As in latest Eurostat release *http://epp.eurostat.ec.europa.eu/cache/ITY_ PUBLIC/1-18022010-AP/EN/1-18022010-AP-EN.PDF* for EU27.

[13] As $\bar{Sub}$ is defined in terms of CPI and $\bar{Y}^{tot}$ in PPI, we have to transform it according to $\bar{Sub} = \omega^s \cdot \bar{Y}^{tot} \left(1/\bar{p}_B\right)^{1-\omega-\psi}$, which we neglect in the table for convenience.

[14] Hence, we ignore a tax reform of 2007 under which income from interest payments from public debt and similar instruments are separated from the rest of the taxpayer's tax base, and taxed at the marginal rate of 18%. However, the implicit tax rate (including all kinds of reductions, deductions, etc.) is probably much

According to Spain's *Encuesta de Población Activa* (EPA), an official labor force survey, the unemployment rate in Spain from 1999 to 2008 averaged $\bar{U} = 11.13\%$, while the fraction of public to total employment averaged $fracpub = 18.72\%$. For rest of EMU, we find $\bar{U}^* = 8.44\%$ and $fracpub^* = 18.14\%$. According to national accounts, the Spanish average wage premium in the public sector is 5.92%, which is also in line with Afonso and Gomes (2008). For the rest of EMU, we follow Afonso and Gomes (2008) and Gomes (2009) and set the wage premium to 3.75% (see also Fernández-de-Córdoba et al., 2009, for a discussion).

The OECD calculates replacement ratios for different types of households (see *www.oecd.org/els/social/workincentives*) depending on their relative income and other characteristics. It calculates a "short-run" replacement ratio (average replacement ratio enjoyed in the first 12 months of the unemployment spell) and a "long-run" replacement ratio (replacement ratio in the 60th month of benefit receipt).[15] Giving equal weights to all the different groups, we have that the sample averages for Spain in the period 2001-2008 are 69.4% (short-term) and 36,5% (long-term). In our model, the unemployment benefit is constant for as long as the person remains unemployed, so it is basically an annuity. We combine the two empirical rates in the following way. A person that remains forever unemployed enjoys an annuity value equal to

$$(1-\beta)[\kappa^B + \beta\kappa^B + \beta^2\kappa^B + ...] = (1-\beta)\kappa^B/(1-\beta) = \kappa^B,$$

where κ^B is unemployment benefits. We can now consider a scheme hat pays 'κ^{Bs}' ('short run' benefits) for the first 4 quarters and 'κ^{Bl}' ('long-run' benefits) forever after. The annuity value of such a scheme is

$$\begin{aligned}
\kappa^B &= (1-\beta)[\kappa^{Bs} + \beta\kappa^{Bs} + \beta^2\kappa^{Bs} + \beta^3\kappa^{Bs} + \beta^4\kappa^{Bl} + \beta^5\kappa^{Bl} + ...] \\
&= (1-\beta)[\kappa^{Bs} + \beta\kappa^{Bs} + \beta^2\kappa^{Bs} + \beta^3\kappa^{Bs}] + (1-\beta)\beta^4[\kappa^{Bl} + \beta\kappa^{Bl} + ...] \\
&= (1-\beta)[1+\beta+\beta^2+\beta^3]\kappa^{Bs} + \beta^4\kappa^{Bl}.
\end{aligned}$$

Considering that κ^B equals the steady-state after-tax wage times a replacement ratio rrs, $\kappa^B = rrs(1-\bar{\tau}^w)\bar{w}^p$, we would therefore assign a weight of β^4 to the lung-run replacement ratio ($\kappa^{Bl}/(1-\bar{\tau}^w)/\bar{w}^p = 36.5\%$) and the rest to the short-run replacement ratio ($\kappa^{Bs}/(1-\bar{\tau}^w)/\bar{w}^p = 69.4\%$). Calibrating the discount factor to $\beta = 0.99$, we obtain $rrs = \left(1-\beta^4\right)69.4\% + \beta^4 36.5\% = 37.8\%$. For the rest of EMU, an analogous procedure yields $rrs^* = 41.60\%$. Following Christoffel et al. (2009), we set the vacancy-filling probabilities in the private and public sector to $\bar{q}^p = \bar{q}^{p,*} = 0.7$ and $\bar{q}^g = \bar{q}^{g,*} = 0.8$, respectively.

We normalize steady-state PPI inflation rates to one, $\bar{\pi}_A = \bar{\pi}_B = 1$, which in turn implies $\bar{\pi} = \bar{\pi}^* = 1$. Furthermore, we set net foreign asset positions to zero, $\bar{d} = \bar{d}^* = 0$, implying trade balance between both regions in the steady state. The calibration for the foreign country is performed following a similar strategy and is summarized in Table 2.

2.6.2 Other parameter values

We set the Calvo parameter θ_P to 0.75, which implies that nominal prices are fixed on average for four quarters. This is calibrated somewhere in the middle of the range typically reported

lower, so it is sensible to set it equal to the personal income tax rate (as it was the case before 2007).

[15] See also Moyen and Stähler (2009) for a more detailed description of such a two-tier unemployment insurance scheme typical in Europe.

Table 2: Targeted values (rest of EMU)

Target	Symbol	Value
(Average) Labor tax rate	$\bar{\tau}^{w*}$	0.2225
Bond tax rate	$\bar{\tau}^{b*}$	0.1267
VAT rate	$\bar{\tau}^{c*}$	0.0995
Social security contribution rate	$\bar{\tau}^{sc*}$	0.1706
Capital tax rate	$\bar{\tau}^{k*}$	0.0704
Unemployment rate	$\bar{U}^*$	0.0844
Fraction of publ. employment	$fracpub^* = \frac{\bar{N}^{g*}}{1-\bar{U}^*}$	0.1814
Pub. sector wage premium	$wageprem^*$	1.0375
Vacancy filling rate (private)	$\bar{q}^{p*}$	0.7000
Vacancy filling rate (public)	$\bar{q}^{g*}$	0.8000
Per capita GDP	$\bar{Y}^{tot*}$	1.0000
Gov. SS spending	$\omega^{G*} = \bar{G}^*/\bar{Y}^{tot*}$	0.2256
Gov. SS purchases	$\omega^{Cg*} = \bar{C}^{g*}/\bar{Y}^{tot*}$	0.0985
Gov. SS investment	$\omega^{Ig*} = \bar{I}^{g*}/\bar{Y}^{tot*}$	0.0238
SS debt-to-GDP ratio (annualized)	$\omega^{d*} = \bar{B}^*/(4\bar{Y}^{tot*})$	0.6896
SS subsidy-to-GDP ratio	$\omega^{s*} = \bar{Sub}^*/\bar{Y}^{tot*}$	0.2126
Replacement ratio	$rrs^* = \frac{\kappa^{B*}}{(1-\bar{\tau}^{w*})\bar{w}^*}$	0.41600

Source: Original data from European Commission, Eurostat and OECD, own calculations for the ratios and implicit tax rates; normalization as described in the main text.

in the literature. Coenen et al. (2008) and Smets and Wouters (2003) estimate an average price duration for optimal price setting of ten quarters using full information Bayesian estimation techniques, while Del Negro et al. (2005) only report an average price duration of three quarters. Micro-data for the euro area on price setting reports relatively low price durations with a median of around 3.5 quarters (i.e. close to one year; see Alvarez et al., 2006; for a summary of more recent micro-evidence). The steady-state mark-up of intermediate goods producers over marginal cost is set at 10 percent, implying that $\epsilon = 11$. Regarding nominal wage stickiness, Christoffel et al. (2009), Colciago et al. (2008) and de Walque et al. (2009) find a rather high degree of stickiness for wages on existing jobs. We opt for a middle value of these studies and set $\theta_w = 0.83$. According to de Walque et al. (2009), newly created jobs face a somewhat higher wage flexibility, but are still tied to existing (previous period's) wages. Hence, we choose $\theta_w^n = 0.7$.[16]

Regarding preference parameters, we choose standard values: $\beta = 0.99$, $\sigma_c = 2$ and $h = 0.85$ (see, for example, Smets and Wouters, 2003; or Coenen et al., 2008). The home bias parameter in each country is set such that the share of domestically-produced goods in total private consumption expenditure equals its empirical counterpart, 66% in Spain and 93% in the rest of EMU, yielding $\psi = 0.56$ and $\psi^* = 0.03$. For the fraction of liquidity constraint consumers, we choose $\mu = 0.25$ following Coenen and Straub (2005). The latter is a conservative choice, given that the range of estimates in the literature goes up to 45% (see Forni et al., 2009). Mostly, the share of RoT-consumers is chosen to engineer a moderate

[16] De Walue et al. (2009) find this by matching their model to fit US data. To us, it seems reasonable that the tie of new jobs' wages to existing wages may be even higher in Europe due to a higher degree of collective wage bargaining.

Table 3: Baseline parameter calibration

Parameter	Symbol	Value	Parameter	Symbol	Value
Relative size of home country	ω	0.100	Preferences		
			Share of RoT consumers	μ	0.250
Shock persistence			Discount rate	β	0.992
Technology shock	ρ_a	0.900	Risk aversion	σ_c	2.000
Gov. purchase shock†	ρ_{C_g}	0.900	Habits in consumption	h	0.850
Pub. employment shock	ρ_{ng}	0.900	Home bias	ψ; ψ^*	0.56; 0.03
Pub. wages shock†	ρ_{wg}	0.750	SS consumption shock	$\bar{\epsilon}^c$	1.000
Pub. investment shock†	ρ_{I_g}	0.500			
Preference shock	ρ_c	0.900	Trade in internat. bonds		
			Risk premium parameter	$\psi_2 = \psi_2^*$	0.010
Monetary policy					
Smoothing	ρ_R	0.900	Production		
Stance on inflation	ϕ_π	1.500	Priv. capital depreciation	δ^k	0.025
Stance on output gap	ϕ_y	0.500	Pub. capital depreciation	δ^g	0.025
			Priv. capital share in prod.	α	0.300
Fiscal policy			Pub. capital influence in prod.	η	0.100
Lump-sum tax smoothing	ρ_T	0.750	Adjustment cost parameter	κ_I	2.480
Capital tax smoothing	ρ_k	0.900			
SSC smoothing	ρ_{sc}	0.900	Labor market		
VAT smoothing†	ρ_c	0.900	Matching elasticity (private)	φ^p	0.500
Bond tax smoothing	ρ_b	0.900	Matching elasticity (public)	φ^g	0.300
Labor tax smoothing†	ρ_w	0.900	Separation rate (public)	$s^g = (1/2)s^p$	0.020
Stance on debt (lump-sum tax)	ϕ_T	0.200	Separation rate (private)	s^p	0.040
Stance on debt (cap. tax)	ϕ_k	0.000			
Stance on debt (SSC)	ϕ_{sc}	0.000			
Stance on debt (VAT)	ϕ_c	0.000			
Stance on debt (bond tax)	ϕ_b	0.000			
Stance on debt (lab. tax)	ϕ_w	0.000			
Stance on debt (gov. purchases)	ϕ_{C_g}	0.000			
Price and wage stickiness					
Calvo parameter (prices)	θ_P	0.750			
Market power (markup)	ϵ	11.000			
Calvo parameter (existing wages)	θ_w	0.830			
Calvo parameter (new wages)	θ_w^n	0.700			

Notes: Parameter values chosen as described in the main text. Fiscal instrument used is lump-sum tax (hence, fiscal policy's stance on debt deviations zero for other fiscal instruments) and home and foreign country parameters are equal (both true unless indicated differently for some simulations in the main text). Shock persistence and smoothing set to zero for the long-run simulations when indicated by † implying an immediate change.

crowding in of private consumption after a government expenditure shock, in line with evidence reported from a VAR by Gali et al. (2007).

According to Schmitt-Grohé and Uribe (2003), it is sufficient to chose a rather small value for the risk premium parameter on international bonds in order to generate a stable equilibrium. So we opt for $\psi_d = \psi_d^* = 0.01$. For the monetary policy rule, we chose coefficients associated with a classical Taylor rule (see Taylor, 1993; as well as Woodford, 2001, for a discussion).

On the production side, we set $\alpha = 0.3$ to generate a private capital share in production of about one third. Capital, both public and private, depreciates at rate $\delta^g = \delta^p = 0.025$. These are standard values in the literature; see, for example, Cooley and Prescott (1995) or Burda and Weder (2002). We choose $\eta = 0.1$ on a somewhat arbitrary basis, as there are no reliable estimates available for the elasticity of private sector production with respect to public capital. It should be noted that, not surprisingly, this parameter is crucial for how harmful a decrease in public investment is to the whole system. While the qualitative findings do not change with the value of η, the quantitative findings do to a certain extent. The investment adjustment cost parameter is chosen to be $\kappa_I = 2.48$ in line with Schmitt-Grohé and Uribe (2005). On the labor market, following Petrongolo and Pissarides (2001), we set the matching elasticity in the private sector to the standard value of $\varphi^p = 0.5$. We, further, follow Afonso and Gomes (2008) in setting $\varphi^g = 0.3 < \varphi^p$ which implies that vacancies are relatively more important for the matching process in the public sector than unemployment. For the separation rates, we chose $s^p = 0.06$ in line with Christoffel et al. (2009) which is also close to the values in Boscá et al. (2009a, 2009b, 2010). Again, we follow Afonso and Gomes (2008) and Gomes (2009) who find that $s^g = 1/2 \cdot s^p$.

The remaining parameters are calculated in order to replicate the steady-state ratios mentioned above. This yields corresponding values for private-sector and public-sector matching efficiency κ_e^p and κ_e^g, union bargaining power ξ, private-sector vacancy posting costs κ_v^p and unemployment benefits κ^B (equal to the targeted replacement rate times the steady-state after-tax real wage) as well as the corresponding foreign country counterparts.[17]

3 Main analysis

In this section, we describe the main analysis conducted in this paper. In order to do so, we first describe the simulation design and, then, discuss the results.

3.1 Simulation design

The main focus of our paper is to analyze short and long-run effects of permanent changes in a number of fiscal instruments that are aimed at achieving fiscal consolidation. Along the lines of recent actions taken or announced by the Spanish government, the instruments we consider are public wages, public employment, government purchases and public investment on the expenditure side, as well as VAT and labor income tax rates on the revenue side. In order to make them comparable, we calibrate the change in each fiscal instrument such that the primary deficit to GDP ratio falls by half a percentage point *ex ante*, that is, holding

[17] Note that, for this baseline, we get $\xi = 0.2149$ and $\xi^* = 0.2266$ which implies that the condition of Hosios (Hosios, 1990) is not satisfied. As we do not conduct a welfare analysis in this paper, this is not influential for our results.

constant everything other than the instrument being changed. For simplicity, we assume that at the time of the fiscal change the economy is in steady state. Therefore, when calculating ex-ante effects, all variables are set equal to their baseline steady state values. The primary deficit to GDP ratio is given by

$$PD_t^{ratio} = \frac{PD_t}{Y_t^{tot}} \cdot p_{Bt}^{1-\omega-\psi}, \tag{45}$$

where primary deficit PD_t is defined in equation (36). Notice that, since PD_t and Y_t^{tot} are expressed in terms of CPI and PPI, respectively, we adjust the ratio of both variables by the CPI-to-PPI ratio, $P_t/P_{At} = p_{Bt}^{1-\omega-\psi}$. From equation (45), the change in primary deficit required to bring about a half percentage point reduction in the deficit ratio ex-ante is given by

$$d(PD) = -0.005 \cdot \bar{Y}^{tot} \left(1/\bar{p}_B\right)^{1-\omega-\psi}, \tag{46}$$

where bars denote baseline steady state values. From the definition of real primary deficit, equation (36), we can then calculate the necessary change in the corresponding fiscal instrument. In the case of a change in consumption taxes, ceteris paribus the change in primary deficit equals $d(PD) = -d(\tau^c)\bar{C}$. Combining this with (46), we then have

$$d(\tau^c) = 0.005 \cdot \left(\frac{\bar{p}_B^{1-\omega-\psi} \bar{C}}{\bar{Y}^{tot}} \right)^{-1},$$

where $(\bar{p}_B^{1-\omega-\psi}\bar{C})/\bar{Y}^{tot}$ is the share of private consumption in GDP. In the case of a change in wage income taxes, similar calculations yield

$$d(\tau^w) = 0.005 \cdot \left(\frac{\bar{p}_B^{1-\omega-\psi} \bar{N}^{tot} \bar{w}}{\bar{Y}^{tot}} \right)^{-1},$$

where $(\bar{p}_B^{1-\omega-\psi}\bar{w}\bar{N}^{tot})/\bar{Y}^{tot}$ is the labor share of GDP and $\bar{w} \equiv \left(\bar{N}^p/\bar{N}^{tot}\right)\bar{w}^p + \left(\bar{N}^g/\bar{N}^{tot}\right)\bar{w}^g$ is the economy-wide average real wage. For PPI-deflated expenditure instruments, the required percentage change is given by $d(X)/\bar{X} = -0.005\left(\bar{X}/\bar{Y}^{tot}\right)^{-1}$, for $X = C^g, I^g$. Finally, the required percentage changes in public wages or public employment are given by

$$\frac{d(X)}{\bar{X}} = -0.005 \left(\frac{\bar{p}_B^{1-\omega-\psi} \left(1+\bar{\tau}^{sc}\right) \bar{w}^g \bar{N}^g}{\bar{Y}^{tot}} \right)^{-1},$$

for $X = w^g, N^g$.

We assume that the changes are conducted immediately. However, given the flow-structure on the labor market, we have to assume a gradual decrease to its new value for a drop in public employment (implied by a positive persistence parameter, see Table 3). Given that, because of labor market regulations, public employment cannot be reduced immediately in praxis either, we believe this to be a realistic feature of our model.

As discussed in the description of the fiscal block, in order to guarantee stability of public debt at least one fiscal instrument must eventually react to deviations of the public debt ratio from a long-run target; that is, in the set of fiscal rules described by (39), for at least

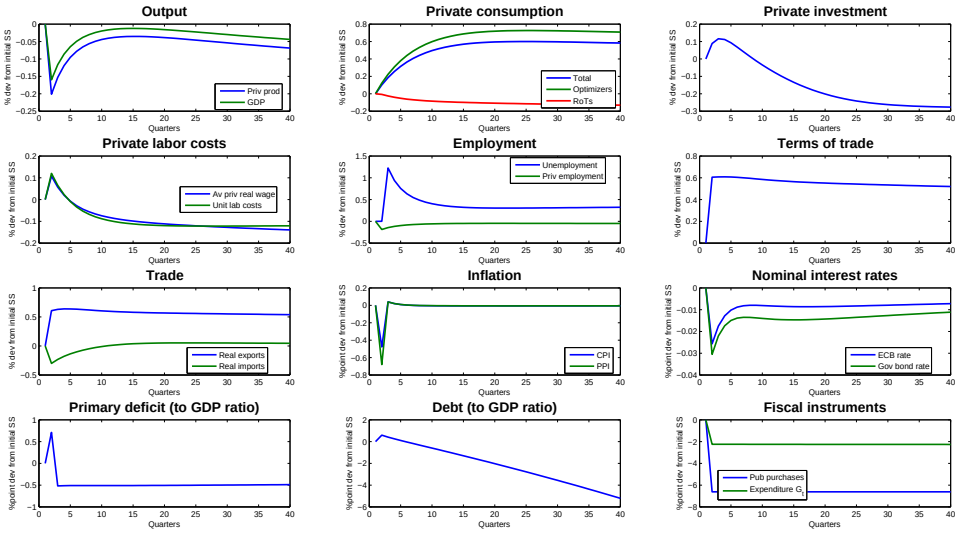
one instrument X we must have $\phi_X \neq 0$. We assume lump-sum taxes to be that instrument (i.e. we set $\phi_T > 0$). Since the latter are levied on Ricardian households only, this strategy allows us to avoid any additional distortionary effects stemming from the endogenous fiscal rule and thus isolate the pure effects of each fiscal instrument. The long-run change in lump-sum taxes reported in Table 4 can thus be interpreted as the fiscal authorities' long-run saving in interest rate payments allowed for by fiscal consolidation. We assume that lump-sum taxes react to the change in the debt ratio with a 10-year delay (i.e., $\tilde{t} = 40$ in equation 39), so as to isolate the short-run response of public deficit and debt from the fiscal rule.

3.2 Expenditure components

We start our analysis by having a look at the rather familiar effects of permanent reduction in government purchases $\bar{C}^g$. While our model is able to differentiate between different public consumption components, this corresponds to how reductions in government consumption are traditionally analyzed in conventional models. We see in Figure 1 that lower government purchases reduce private output and, thus, GDP. Remember that the entire cut in public purchases takes place immediately so there is no gradual change. Hence, there is an immediate and rather large drop in private production and, thus, GDP due to lower public demand. Optimizers increase consumption because of the positive wealth effect induced by expected future tax decreases associated to the lower level of government spending today (and, thus, lower levels of debt tomorrow). The increase in private demand alleviates the drop in public demand and private production as well as GDP increase when optimizers start to consume more. As in Galí et al. (2007), liquidity-constrained households, however, decrease consumption because they are not subject to the positive wealth but only suffer the income loss due to the negative wage effect (which they spend entirely each period). Because optimizers make up three quarters of total population, aggregate consumption increases on impact (and some time thereafter). Nevertheless, as the negative wage effects keeps on reducing income and, thus, consumption of liquidity-constrained consumers, this effect is compensated for such that private production and, thus, GDP eventually fall again. The fall in aggregate demand makes firms, first, decrease prices generating deflationary pressure and, second, makes them lower private production implying less labor and capital demand. Thus, private employment falls. The rise in unemployment makes it less likely for unemployed workers to find a job which reduces their reservation wage (i.e. their fall-back utility) and, thus, wages. Lower wages imply a decrease in unit labor costs defined as the real private sector wage bill divided by real private production. The short increase of unit labor costs on impact is due to staggered wage setting and the relatively large drop of private output on impact. Lower production also implies a fall in capital demand and, thus, investment eventually. The temporary increase in investment can be explained by the fact that firms initially substitute labor by capital due to the fact that the initial increase in unit labor costs induced by staggered wage setting tends to increase the rise in the real interest rate. The drop in prices and the eventual drop in unit labor costs improve the terms of trade which yields an increase in real exports as home country products become relatively cheaper. This, however, makes the level of real imports fall initially. A higher aggregate level of national private consumption eventually overcompensates for this because higher consumption is associated with an increased demand for foreign goods as well. The fiscal balances improve as can be noticed by the decrease in both the primary deficit-to-GDP and the debt-to-GDP ratios. The initial increase is due to the fact that the denominator of the ratios sharply decreases

on impact, while the nominator gradually adapts. In the discussion on fiscal multipliers, the effects just described are, generally, understood to typically accompany public spending multipliers (see, among others, Cogan et al. 2009; Coenen et al., 2010a; and Hebous, 2010). We see in Table 4 and the corresponding section, however, that, when talking about the size of (long-run) fiscal spending multipliers, it matters which spending component we actually consider.

Figure 1: Permanent reduction in home government purchases



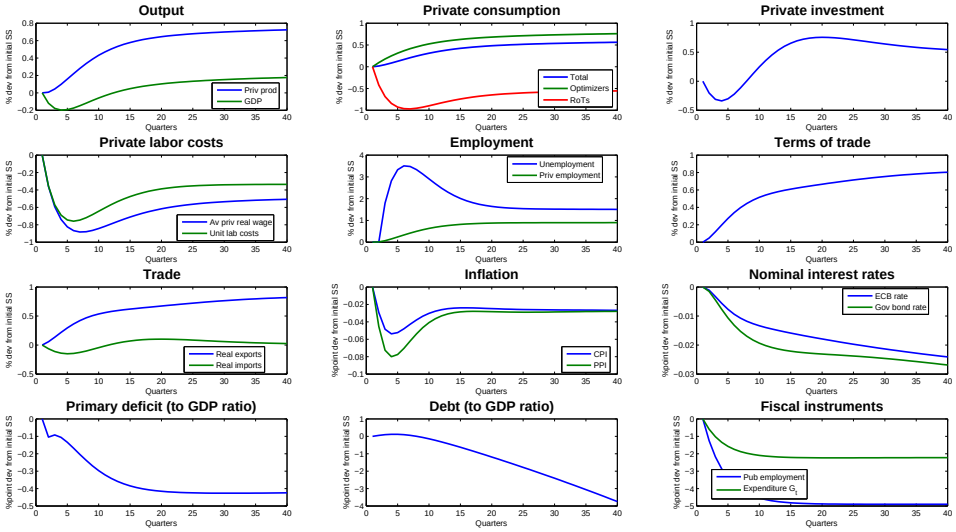
Notes: Transition dynamics of selected home country variables following a permanent reduction in government purchases. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios, respectively).

The spending component not only influences the size of the "final" fiscal multiplier but also affects the dynamics of the system. Figure 2 summarizes the dynamic effects of a cut in public employment for selected variables.[18] We note that, while the effects on private consumption and fiscal balances tend to be quite similar, there are notable differences in the dynamics of private production, GDP, employment and private investment. Furthermore, all the effects differ in size. This is because the two measures – even though both decreasing public consumption – produce different adjustment paths. Reducing the level of public employment implies an increase in unemployment and, thus, a decrease in the probability for unemployed workers finding a job in both the public and also the private sector. This yields a reduction in average private sector wages and, thus, unit labor costs immediately. Lower unit labor costs allow firms to cut prices which improves the terms of trade, fosters demand for Spanish goods in the rest of EMU and, thus, increases exports. In contrast to a cut in government purchases, higher (also export-driven) private demand without a loss of public demand makes private firms increase production. They do so by increasing private employ-

[18] Please remember that, because of the labor market flow structure, we have to presume a gradual decrease in public employment while, for all other instruments, the change is instantaneous. However, this is not the source of the different effects in the long-run.

ment and, eventually, higher private capital input. The initial slump in investment can be explained by the rise of the real interest rate due to the fall in nominal interest rates and in inflation, the latter being stronger because the central bank focusses on the union-wide inflation rate and output gap. Higher private employment and production, however, augment marginal productivity of capital and, eventually, compensates for this effect generating an increase in private investment. Because of lower private wages, less public employment and an increase in unemployment, consumption of RoT households falls, while it increases for optimizers and, thus, on the aggregate level. The effects can be explained in analogy to the above description for a cut in public purchases which also holds for the evolution of imports. The most significant difference between both measures is the fact that, when reducing public employment, private production increases while it decreases when decreasing government purchases. Another noteworthy issue is the fact that GDP falls when shedding public employment. The effect on private production is mainly due to the wage reduction just described. The effect on GDP is due to the definition of real GDP itself, namely the sum of private production and government production (the latter measured by the government wage bill). The latter falls when dismissing public sector workers. Because private production increases along the transition path, so does GDP eventually. This increase is, however, not sufficient to compensate for the loss of public production in the long-run (see also Table 4). We should bear in mind, however, that this is basically a matter of definition because public sector production is measured by its inputs (according to national accounting). Perhaps more important is the positive spillover effects that this measure has on private sector output and employment, which differ from the effects of a cut in public purchases.

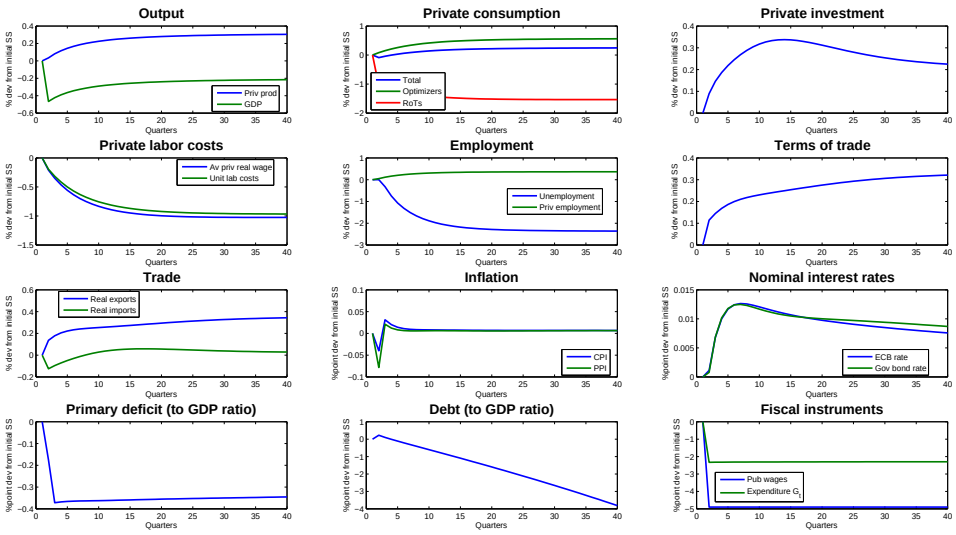
Figure 2: Permanent reduction in home government employment



Notes: Transition dynamics of selected home country variables following a permanent reduction in public employment. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios, respectively).

Besides reducing the public sector wage bill by shedding public employees, the government can also decide to cut public wages. The effects of this measure are shown in Figure 3. Cutting public sector wage payments reduces private sector wage claims and, thus, unit labor costs. Under this measure, the workers' fall-back utility is, however, not influenced by a lower probability of finding a job in the public or the private sector, but by the fact that, when having found a job in the public sector, the corresponding gain is less. This seems to affect private sector wage negotiations more than a reduction in public employment as we can see that private wages decrease somewhat more. Again, it allows firms to cut prices which improves the terms of trade and fosters exports to the rest of EMU. The higher demand for Spanish goods is produced with more employment and higher capital inputs, the latter increasing investment. Furthermore, as there are no workers laid off in this scenario, the increase in private employment now significantly reduces unemployment. Regarding the consumption reaction of liquidity-constrained consumers, the reduction in unemployment is not sufficient to compensate for the reduction in public and private sector wages, while, again, consumption for optimizing households increases yielding a rise in aggregate consumption. Therefore, we find a cut in public sector wages to be beneficial for private sector output and for both private sector and total employment. Again, GDP falls because it is defined as the sum of private output plus the public sector wage bill (both in terms of PPI). The positive output effect cannot compensate for the negative wage effect this time. However, more important may be the positive spillover effects that this measure has on private sector output and employment again.

Figure 3: Permanent reduction in home government wages



Notes: Transition dynamics of selected home country variables following a permanent reduction in public wages. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios, respectively).

Another deficit-reducing measured recently approved in Spain is an important cut in public investment. The model-simulated effects from such a measure can be seen in Fig-

ure 4. A decrease in public investment impacts the economy through two different angles. While the reduction for public investment demand as such affects the economy in an analogous way as the reduction in public purchases discussed in Figure 1, the cut in public investment additionally affects private sector productivity. In this respect, the cut in public investment acts similar to a permanent (but lagged) negative productivity shock. The latter implies a larger reduction in private sector employment, a larger rise in unemployment and, thus, a larger decrease in private wage claims (because of the fallen probability of finding a job there) compared to the situation of a government purchases cut. Hence, the reduction in consumption of RoT households is also larger and more persistent. The positive wealth effect of a reduction in government spending as such is still present for optimizing households in this situation, which is the reason we see a small increase in their and in the aggregate consumption levels initially. However, because marginal productivity of capital falls on its transition to the new steady state, optimizing households are induced to front-load investment and, thus, decrease consumption. This can also explain the somewhat puzzling behavior of private investment. Owing to the permanent decline in public investment, and the corresponding expected decrease in the marginal productivity in the future, unconstrained households bring forward their investment, which leads to the substantial increase of private investment in the short-run. In the long-run, however, the reduction of public investment has also a negative long-run impact on private investment because of the declined productivity. This channel is absent following a reduction in government purchases alone leading private investment to immediately fall then (see Figure 1). Furthermore, we see that the decrease in private sector wages is not sufficient to compensate for the fall in productivity and, thus, unit labor costs increase. Only on impact do they fall. This implies that, only on impact, firms can reduce prices which improves terms of trade and fosters exports, while this is reversed from about quarter four onward implying a worsening of international competitiveness. Because of an increase in Spain's CPI inflation, nominal interest rates slightly increase as well. The primary deficit-to-GDP and the debt-to-GDP ratios increase on impact and, then, fall. This is, again, due to the relatively large and persistent fall in GDP which is not accompanied by an equally large fall in expenditures on impact. It should be noted here that the magnitude of all the effects are sensitive to how influential public capital is for private production; the parameter η in the private production function, equation (17); see also Straub and Tchakarov (2007) for a more detailed discussion.

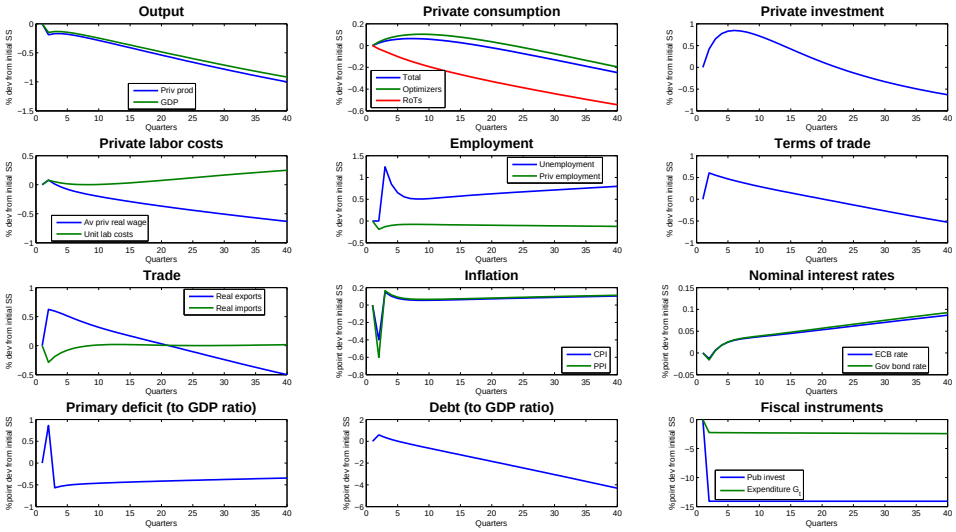
Drawing some preliminary conclusions from the above analysis, we see that, when considering government expenditures to be the instrument used, it matters which spending component is cut. Not surprisingly, a reduction in productivity-enhancing government spending seems rather harmful in terms of output (also in the long-run, see Section 3.4), while decreasing public consumption seems to be less harmful in terms of production losses. This especially holds when such a reduction in public consumption is able to decrease unit labor costs and augment international competitiveness via the labor market. In our model, this is the especially case when reducing the public sector wage bill, which can positively influence private sector production as well as total employment.

3.3 Revenue components

Using the revenue side to decrease the level of government debt, in this section, we analyze the effects of an increase in labor taxation and the VAT rate.

Figure 5 shows the effects of a permanent increase in the labor tax rate. An increase

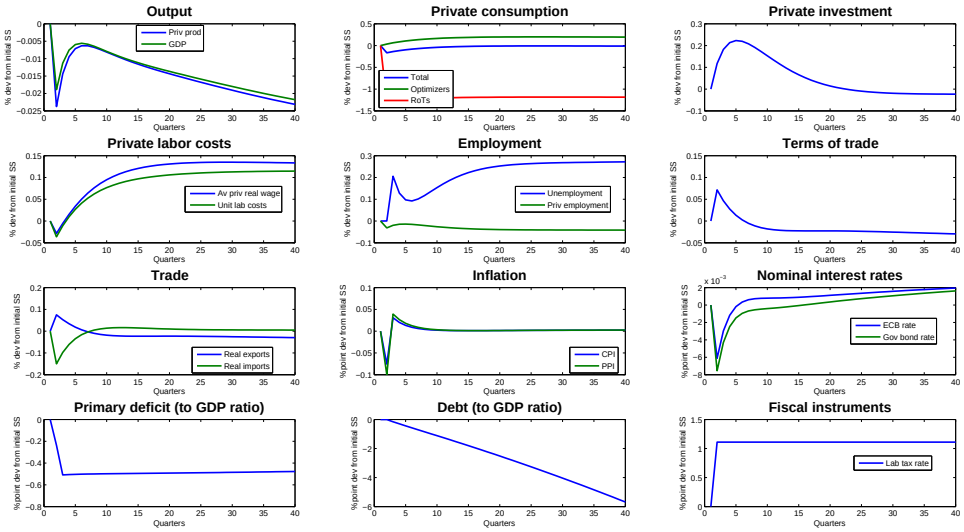
Figure 4: Permanent reduction in home government investment



Notes: Transition dynamics of selected home country variables following a permanent reduction in government investment. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios, respectively).

in the labor tax rate implies a decrease in the take-home pay which yields a large fall in the consumption of RoT households. Optimizing households cannot compensate for this drop on impact even though they slightly increase consumption because of the positive wealth effect associated to the higher labor tax rate today and, thus, lower debt levels tomorrow. Less demand yields a drop in private production and, thus, GDP which implies a fall in employment (hence, an increase in unemployment). Furthermore, firms reduce before-VAT prices on impact. Increasing unemployment generally leads to a fall in wages in matching models *ceteris paribus*. However, the increase in unemployment - implying a lower re-employment probability and, thus, reduced wage claims by workers - does, in the medium to long-run, not (over-) compensate the fact that workers claim higher wages because taxation has increased (by more than re-employment opportunities have fallen). Thus, workers want to be compensated for this loss in take-home pay by demanding higher wages, at least partly. Hence, unit labor costs increase in the medium and long-run after the drop on impact which eventually makes home country products relatively more expensive, reduces exports and deteriorates the terms of trade. Even though the real interest rate increases because inflation falls by more on impact than nominal interest rates increase, private investment increases on impact and, then, in the long-run falls below its initial steady-state level. The reason is that due to lower production marginal productivity of capital falls on its transition to the new steady state and optimizing households are induced to front-load investment similar to the effect that has been described for a decrease in public investment. The front-loading relatively decreases consumption of optimizers and, hence, additionally reduces the positive wealth effect.

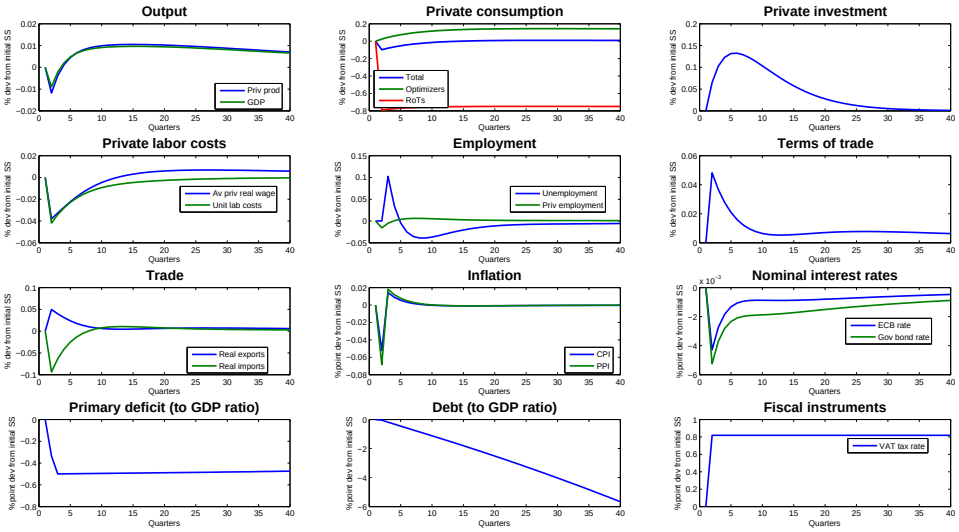
Figure 5: Labor taxes



Notes: Transition dynamics of selected home country variables following a permanent increase in the labor tax rate. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios as well as the tax rate itself).

The effects of a permanent increase in the VAT rate are pictured in Figure 6. Augmenting VAT sets in train some of the mechanisms described above. As goods and services become more expensive, liquidity-constrained consumers will reduce consumption, while optimizing households slightly increase it due to the wealth effect. This implies a reduction in demand and a drop in output, yielding lower labor demand and an increase in unemployment. However, and contrary to the case of the rise in labor income taxes, the fall in the VAT rate produces a reduction in average wages in the private sector, a decrease in unit labor costs and, thus, improvements in the terms of trade and exports. This is due to the fact that VAT does not directly influence workers' match surplus and hence their wage claims. Private investment increases even though the real interest rate slightly increases because of an analogous effect as described for the labor income tax simulation. The magnitude of the effects, however, are smaller compared to those following a rise in labor income taxation. Another difference is that wage claims will not overshoot the initial steady-state level and, thus, terms of trade will not worsen compared to the initial situation (even though they do not really improve, either). Generally speaking, changes in the VAT have no effect on the main aggregates in the long-run. This is due to the fact that the VAT rate, τ_t^c, affects only (i) the government budget constraint, (ii) households' marginal utility of real income, λ_t^i ($i = o, r$), and (iii) rule-of-thumb consumption demand. Since marginal utilities enter the equilibrium conditions as ratios of the form $\lambda_{t+1}^i / \lambda_t^i$, in the steady state such an effect disappears. Also, while rule-of-thumb consumption certainly falls, this is exactly compensated by an equal increase in the consumption of Ricardian households, thus leaving total consumption unchanged. Nevertheless, the dynamic simulations show that the effects on some variables in the transition path can be considered sizeable (for example, consumption).

Figure 6: Value added taxes



Notes: Transition dynamics of selected home country variables following a permanent increase in the VA tax rate. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios as well as the tax rate itself).

3.4 Summary of long-run effects

The long-run effects of the permanent changes in the various fiscal instruments discussed above are summarized in Table 4. We also present the results of implementing all the measures simultaneously as this is what is currently discussed in Spain. In order to allow for a fair comparison, we assume that the total ex ante change in the primary deficit is still equal to half a percentage point when simultaneously applying all measures. The table presents percentage deviation from the initial steady state for selected variables (percentage point deviations for any X-to-GDP ratio, inflation, interest rates and tax rates). The magnitude of the decrease in lump-sum taxes can be interpreted as the fiscal authority's long-run benefit due to the long-run savings on interest payments. These savings could alternatively be used for increasing any other expenditure component (or decrease distortionary taxation) in the long-run. To avoid additional distortionary effects and hence isolate the pure effects of each fiscal instrument, the entire long-run benefit is tucked into lump-sum taxation.

The following findings stand out. A permanent cut in public investment to reduce the primary deficit-to-GDP ratio and, thus, debt seems to be harmful but not helpful – at least under our assumption that public capital enhances private sector productivity. A cut in public investment primarily affects the economy via a reduction in private productivity and, thus, eventually implies a decrease in output (private production as well as GDP), private investment, international competitiveness and consumption as already described in the dynamics section. The negative impact on the economy is, generally, largest when using this measure. Furthermore, it is the measure with the smallest impact on the fiscal balances as can be seen by the relatively small reduction in the debt-to-GDP ratio. Another interesting aspect regarding a cut in public investment is that this measure seems to be the only

one that has significant long-run price effects feeding through to lasting and relatively large changes in the corresponding interest rates. This is mainly due to the fact that the fall in productivity increases unit labor costs and, thus, induces firms to raise prices. Notice also that the consumption of optimizing households falls only for this measure while it increases for all the other ones. The positive wealth effect that this type of household still faces is, thus, overcompensated for by the fall in productivity.

As a further assessment of how damaging this measure may be, we can compare the last two columns of Table 4. In the second-to-last column, we analyze the effects of implementing all measures simultaneously, while, in the last column, all measures except the reduction in public investment are implemented.[19] We see that the effects of a cut in public investment pretty much dominate the arena. While, in the last column, key variables such as private sector output and total unemployment move in the direction policy-makers would hope for, the opposite holds for the second-to-last column in which the measure of reducing public investment is included.

Regarding the different components of government consumption, our model simulation indicates that the decrease in government purchases is more efficient than cuts in government wages or employment in terms of reducing the debt-to-GDP ratio. This is, however, associated by a fall in private production and GDP. The fall in government demand for Spanish goods cannot be compensated for by the slight increase in national and international private demand (the latter resulting from the improvements in the terms of trade as described in Section 3.2). We should note, again, at this point that this may change when the long-run benefits are not used to reduce lump-sum taxes but other distortionary taxes. As is also stressed in Coenen et al. (2010b), the long-run benefits of fiscal consolidation depends to a large extent on what is done with the additional proceeds resulting from lower interest payments on outstanding debt. Nevertheless, as one has to specify what is done with these proceeds when simulating fiscal policy measures – and we want to analyze the isolated effect of the corresponding instrument alone – using the proceeds to decrease lump-sum taxes seems the fairest alternative as they do not influence the system ulteriorly. Still, even when using the lump-sum assumption, we see that a reduction in either public employment or public wages – both being part of government consumption as it is conventionally modelled – generate positive private production multipliers, not only in the long-run but also in the short-run. For a detailed description, also of the differences in magnitude, see section 3.2.

[19] Note that the aggregate change when implementing all the measure (or all excluding public investment, respectively) still amounts to half a percentage point in primary deficit ex ante. The short-run effects and transition paths of the corresponding simulation are relegated to the appendix as it is basically a combination of the effects described in the two previous subsections.

	Gov. Purchases		Public wages		Labor tax		All	
		Gov employment		Public Invest		VAT		All (excl Igt)
Real priv output	-0.13	0.77	0.32	-2.12	-0.04	0.00	-0.18	0.19
Real GDP	-0.10	0.22	-0.20	-1.97	-0.03	0.00	-0.32	-0.02
Real priv consumption	0.51	0.62	0.26	-1.10	-0.03	0.00	0.07	0.27
Consumption optimizer	0.63	0.83	0.58	-1.08	0.18	0.13	0.23	0.47
Consumption RoT	-0.17	-0.51	-1.53	-1.18	-1.19	-0.75	-0.86	-0.83
Private investment	-0.28	0.48	0.20	-1.52	-0.02	0.00	-0.17	0.08
Priv average real wage	-0.18	-0.46	-1.01	-1.41	0.12	0.00	-0.46	-0.30
Real Unit Labour Cost	-0.12	-0.33	-0.97	0.53	0.12	0.00	-0.12	-0.26
Unemployment	0.37	1.48	-2.37	1.31	0.28	0.00	0.17	-0.05
Private employment	-0.06	0.90	0.36	-0.20	-0.04	0.00	0.16	0.23
Terms of trade	0.47	0.86	0.34	-1.78	-0.04	0.00	-0.01	0.32
Exports	0.49	0.88	0.36	-1.79	-0.04	0.00	0.01	0.34
Imports	0.03	0.02	0.03	-0.01	0.00	0.00	0.02	0.01
CPI inflation	0.00	-0.03	0.00	0.19	0.00	0.00	0.02	-0.01
ECB rate	0.00	-0.03	0.00	0.20	0.00	0.00	0.02	-0.01
Bond rate	-0.01	-0.04	0.01	0.22	0.00	0.00	0.02	-0.01
Lump-sum tax	-3.40	-3.07	-2.44	-1.22	-3.37	-3.36	-2.84	-3.13
Debt to GDP ratio	-5.27	-4.76	-3.82	-1.94	-5.22	-5.21	-4.42	-4.85
dCgt	-6.61	0.00	0.00	0.00	0.00	0.00	-1.10	-1.32
dngt	0.00	-4.90	0.00	0.00	0.00	0.00	-0.82	-0.98
dwgt	0.00	0.00	-4.90	0.00	0.00	0.00	-0.82	-0.98
dIgt	0.00	0.00	0.00	-14.08	0.00	0.00	-2.35	0.00
dtaut	0.00	0.00	0.00	0.00	1.11	0.00	0.19	0.22
dVAT	0.00	0.00	0.00	0.00	0.00	0.82	0.14	0.16

Table 4: Long-run results

Some additional insights regarding the effects of cuts in the different expenditure components are worth emphasizing. First, when decreasing the level of public employment, we identify a long-run increase in unemployment even though private employment significantly increases as well. This is due to the fact that, even in the long-run, the private sector is not able to fully absorb the release in public sector employees (which is described in more detail in Section 3.2).[20] Second, we see that all the expenditure-side measures affect the labor market directly by decreasing average real wage payments in the private sector. And, third, RoT-households always experience a fall in consumption, which implies that, indeed, the aggregate real labor income is lower than it was in the initial steady-state situation. Optimizing households seem to benefit because of the wealth effect reducing their lump-sum tax payments. Therefore, it is also clear that fiscal consolidation on the expenditure side, even when generating short and long-run benefits and not directly aiming a cutting transfers, generates re-distribution among the different household types.

Regarding consolidation on the revenue side, we see that both an increase in the rates of labor taxation and VAT seem to be equally efficient in terms of fiscal consolidation. In the long-run, VAT hardly influences the rest of the economy as already described in Section 3.3. It merely generates re-distribution of consumption between optimizing and liquidity-constrained households. After all, the latter type decreases consumption by 0.75% because of the tax increase, while the wealth effect dominates for optimizers. Compared to DSGE models with conventional labor markets, an increase in labor taxes has a fairly small effect on the real side of the economy, which is due to the fact that the wage bargaining structure partially dampens the effects of such taxes on firms' labor costs (also explained in more detail in Section 3.3 already). Nevertheless, though very small, the effects tend to be negative on output, employment, investment and international competitiveness.

Summing up, a reduction in public wages and employment, a decrease in government purchases as well as increases in VAT and labor tax rates seem to be promising in order to lower the debt-to-GDP ratio as well as to improve international competitiveness. A cut in public investment seems to be less desirable due to their effects on private sector productivity – unless what is declared to be investment so far is not productivity-enhancing and rather belongs to public purchases in terms of our model. We should also note that aggregate real wage payments decrease in most circumstances. This primarily hits RoT-households' consumption, even though none of the measures directly tackles re-distribution itself.

4 Additional analyses

In this section, we conduct a number of simulations in order to illustrate some additional model applications. First, closely related to the discussion in the previous section, we simulate the situation in which the VAT rate is permanently increased in order to decrease social security contributions. Hence, we do not use lump-sum taxes to sap the proceeds resulting from savings on interest payments on outstanding debt, but adjust instead a distortionary fiscal instrument such as social security contributions. Such a measure is discussed in several countries (and has partly been carried out in Germany in 2007) and is interpreted as a way of performing "fiscal devaluation" inside a monetary union. Second, we simulate a credibly

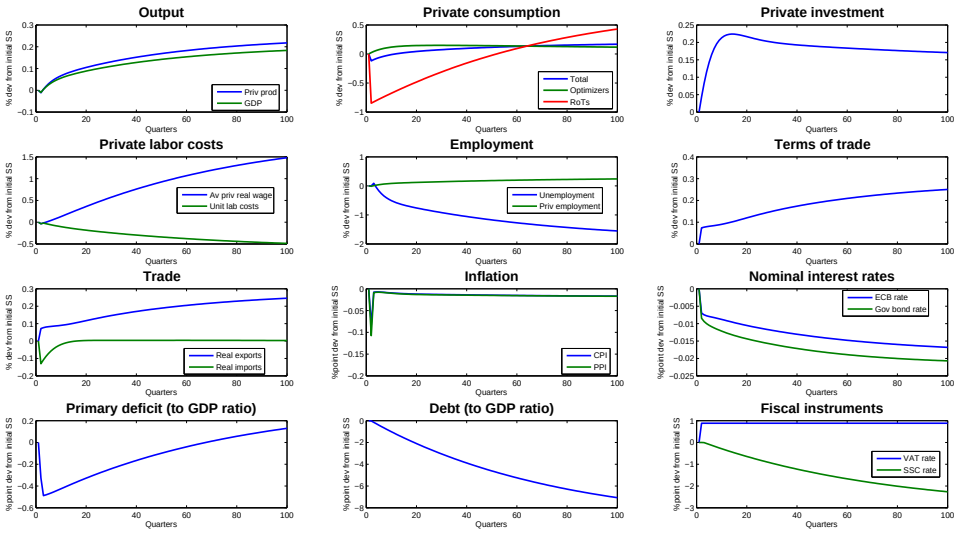
[20] But we also not, however, that the increase in unemployment is quite small as it is given in percentage deviations. Assuming, for example, an unemployment rate of 10% initially, the increase in unemployment by 1.48% given in Table 4 implies a new steady-state unemployment rate of 10.148%.

announced temporary measure to increase government purchases for three years but start taking care of the financing only one year after the spending hike is over.

4.1 Simulating fiscal devaluation

It is well-known that the structure of taxation differs significantly between European countries. Some rely more on direct taxation, while others use indirect taxation such as the consumption tax in our model to finance government expenditures. There is an ongoing debate on whether output and employment prospects of a country can be improved by shifting the tax structure from direct (i.e. labor/income) to indirect (i.e. consumption) taxation; see European Commission (2008). Germany has been criticized for improving its international competitiveness at the cost of other member states by increasing the VAT rate by three percentage points while simultaneously lowering the social security contributions in 2007. It has to be noted, however, that revenues resulting from only one percentage point of the VAT increase were used to lower social security contributions, the rest was used for consolidation purposes.

Figure 7: Effects of fiscal devaluation (Spain)

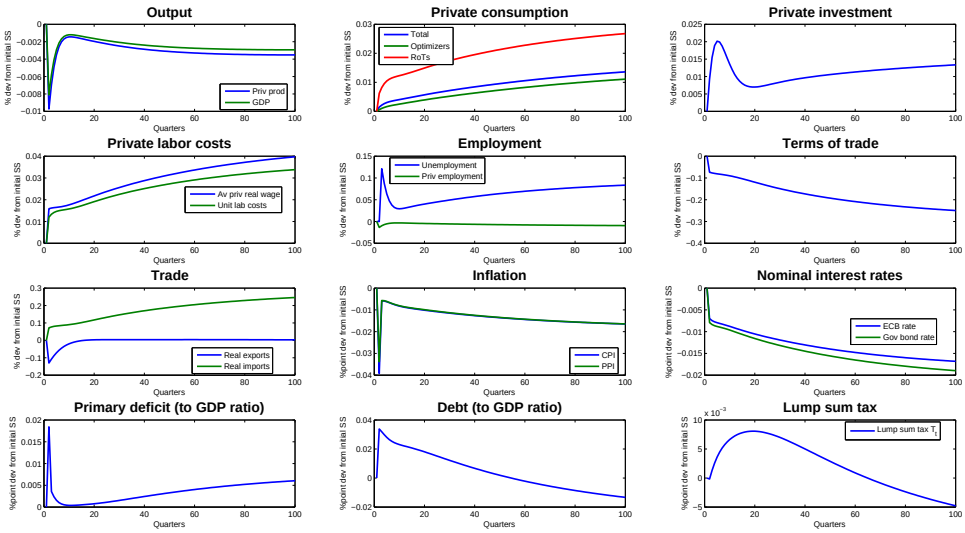


Notes: Transition dynamics of selected home country variables following a permanent increase in the VAT rate to reduce social security contributions. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios as well as the tax rate itself).

In *FiMod*, we simulate the effects that occur when a similar policy measure is conducted in Spain. We assume that the VAT rate is permanently increased such that the primary deficit-to-GDP ratio is decreased by half a percentage point ex ante as described in Section 3.1. Instead of using the savings in interest payments on outstanding debt to decrease lump sum taxes, we now reduce social security contributions in the home country (Spain). Social security contribution immediately adapt to the deviations of the targeted debt-to-GDP ratio. This implies that, as the debt-to-GDP ratio decreases, social security contribution do

so as well. In terms of our model, we assume that, in the home country (Spain), the fiscal instrument used are social security contributions with $\rho_{\tau^{sc}} = 0$ (no smoothing) and $\phi_{\tau^{sc}} = 1$ (high stance on deviations of debt from target); see equation (39). The foreign country (rest of EMU), still uses lump sum taxes as fiscal instrument. Figure 7 shows the transitional dynamics of selected variables in Spain, while Figure 8 shows the same transitional dynamics in the rest of EMU in order to analyze spillovers. Long-run effects are summarized in Table 5.

Figure 8: Effects of fiscal devaluation (rest of EMU)



Notes: Transition dynamics of selected home country variables following a permanent increase in the VAT rate to reduce social security contributions. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios as well as the tax rate itself).

Before describing the effects, we have to note that the exercise should be considered as an illustrative example for what *FiMod* predicts to happen when Spain conducts this measure. As has been shown by Lipińska and von Thadden (2009), the effects – especially the spillovers to the other country – depend considerably on the size of the home country, on the speed of adjustment in other fiscal variables, on the monetary policy associated with such a measure and on whether the shift is anticipated or not. We abstract from a detailed robustness analysis as the issue is not the main focus of our paper. Interested readers are, however, referred to Lipińska and von Thadden (2009).

We see in Figure 7 that the increase in the VAT rate in Spain induces RoT-households to consume less, which is not surprising as consumption goods become more expensive. Anticipating the positive wealth effect already described, optimizers immediately increase consumption. Output blips only on impact and, then steadily increases until it reaches the new steady-state value. The reason is that private demand in the home country as well as exports eventually increase. As the increase in VAT is used to reduce decrease social security contributions, this reduces unit labor costs inducing firms to employ more workers. Lower

unemployment increases the workers' fall-back position in the bargaining process making them demand higher wages. Higher wages and less unemployment eventually increases RoT-households' consumption. Lower unit labor costs allows firms to reduce prices which increases the terms of trade and fosters exports because, in relative terms, Spanish goods become cheaper. This reduces imports on impact but, as aggregate consumption demand eventually increases – also for foreign goods –, imports stay more or less unaffected in the long-run. Higher production and more employment increases marginal capital productivity and, thus, private investment. The drop in prices makes the central bank lower interest rates. The fiscal position of Spain, especially the debt-to-GDP ratio, improves even though social security rates are decreased.[21]

	Spain	**Rest of EMU**
Real priv output	0.25	-0.0030
Real GDP	0.21	-0.0025
Real priv consumption	0.20	0.0181
Consumption optimizer	0.07	0.0155
Consumption RoT	0.86	0.0315
Private investment	0.15	0.0162
Priv average real wage	2.01	0.0466
Real Unit Labour Cost	-0.63	0.0387
Unemployment	-1.90	0.0970
Private employment	0.29	-0.0109
Terms of trade	0.29	-0.2901
Exports	0.29	-0.0035
Imports	0.00	0.2874
CPI inflation	-0.02	-0.0189
ECB rate	-0.02	-0.0216
Bond rate	-0.02	-0.0132
Debt to GDP ratio	-9.44	0.0000
dssct	-3.04	0.0000
dVAT	0.88	0.0000

Table 5: Long-run effects of fiscal devaluation conducted in Spain

The rest of EMU is influenced by the measure conducted in Spain mainly through two channels, which can be retraced in Figure 8. First, monetary policy reduces the monetary policy rate and, second, trade is affected because Spain has improved its international competitiveness (i.e. exports to Spain fall while imports from Spain increase). On the one hand, output in the rest of EMU falls as Spain reduces private demand for foreign goods. On the other hand, the ECB rate is reduced, which decreases the real interest rate in the rest of EMU and fosters private capital investments there, increasing output. The latter effect is not strong enough to compensate the first. As we can see, the effects are relatively small, which tends to hold for the other variables as well.[22] The fall in output implies a rise in unit labor

[21] Note that this is partly due to the simulation design. As we did not change the long-run target for the social security contribution rate $\bar{\tau}^{sc}$ nor the targeted debt-to-GDP ratio ω^b, the rule itself (and its parameters) influences the final social security rate and, thus, the final debt-to-GDP ratio in the new steady-state. One could change the simulation design such that a differently determined final steady-state social security rate and/or debt-to-GDP ratio is reached. This influences the long-run equilibrium and also the dynamics potentially. As the question of fiscal devaluation is not the main focus of our paper, however, we neglect a more detailed analysis of this issue.

[22] Note, however, that the magnitude especially changes when increasing home country size.

costs and a reduction of private employment which, naturally, yields an increase in unemployment. Because of a fall in the real interest rate, firms substitute capital for labor as can be seen by the increase in private investment. This, in turn, increases the marginal productivity of labor. As wages result to be a weighted average of marginal productivity of labor, which increases, and the fall-back position of workers, which decreases, the overall effect on wages is ambiguous. We can see that, in our baseline calibration, the fall-back position effect is dominated by the increase in marginal productivity yielding an increase in wages (and, thus, a further increase in unit labor costs) making competitiveness of the rest of EMU fall compared to the Spanish economy. Consumption of RoT-households also increases because the wage increase is strong enough to compensate for the increase in unemployment making aggregate labor income increase. The fiscal position in the rest of EMU deteriorates on impact but, because of higher revenues from VAT and labor income, seems to improve again eventually.

Our simulation suggests that, in the long-run, the shift in the Spanish tax structure by relying more on indirect taxation and decreasing social security contributions primarily improves Spain's economic situation, while the effects on the rest of EMU are generally very small – but negative in terms of output and employment (see Table 5). So, for a (relatively small) single country, fiscal devaluation as just described fosters economic prospects according to our model. However, we must again stress that the effects are sensitive to country size, the precise simulation design and the parametrization of the fiscal rule(s). A more profound analysis of this question, also in our model, is certainly interesting but is beyond the scope of our paper. We should also bear in mind that the simulations shown here do not include strategic interaction of the rest of EMU-countries with policy measures conducted in Spain – an issue that certainly becomes the more important the larger the economy conducting fiscal devaluation is.

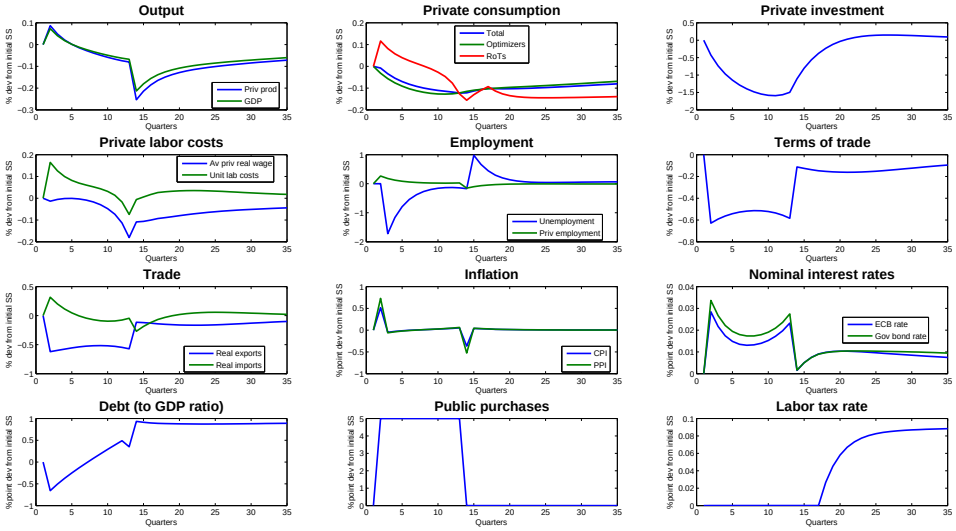
4.2 Simulating announced policy measures

In this subsection, we analyze a credibly announced (and performed) temporary increase in government purchases C_t^g by 5% for three years (i.e. 12 quarters) which is financed by an increase in labor taxes exerted only one year after the spending measure has been expired (i.e. after four years). We have parameterized the labor tax rule with $\rho_{\tau^w} = 0.7$ (some degree of persistence) and $\phi_{\tau^w} = 0.3$ (a significant stance on debt deviations). The steady state is not changed in this simulation. The dynamics for selected variables can by retraced in Figure 9.

The increase in public purchases increases aggregate demand and, thus, output and GDP. Higher demand (temporarily) increases prices which lowers the terms of trade and reduces exports. Furthermore, optimizing households decrease consumption because of an anticipated negative wealth effect by expecting higher taxes in the future. As higher output is produced by more private employment (implying a fall in unemployment), RoT-households increase consumption. Aggregate consumption demand eventually falls, however. Hence, the boost in public demand and, thus, output, is eventually overcompensated by the crowding out of national and international private demand for Spanish goods. This becomes especially obvious because we see that imports increase. Anticipating the decrease in output and private capital productivity, optimizers decrease capital investment. This can also explain the fact that wages eventually fall. Note, however, that because of staggered wage setting and the improvement of the workers' fall-back position due to higher re-employment chances, the impact reaction of real wages is not enough to avoid an increase in unit la-

bor costs. The debt-to-GDP ratio decreases on impact as private output and GDP increase. This is, however, overcompensated by two effects eventually. First, private output and GDP ultimately fall as we have just described. Second, because government purchases are deficit-financed, the level of debt increases additionally implying an increase in interest payments on outstanding debt. We see exactly the opposite effects when public purchases are decreased to their initial level again.

Figure 9: Simulating announced measures



Notes: Dynamics of selected home country variables following a temporary increase in public purchases by 5% financed by a delayed increase in labor taxation. Shows percentage deviations from initial steady state (percentage point deviations for interest rates, inflation and X-to-GDP ratios as well as the tax rate itself).

Still, there are some effects that should be highlighted. As the level of debt is higher when government purchases are decreased again, the debt-to-GDP ratio tends to stay high. This is only slowly taken care of when the increase in the labor tax rate induced by the fiscal policy rule takes place. The tax increase does not affect the economy to a large extent, because it was pre-announced and already taken into consideration by all economic agents, with one exception. We see that consumption of RoT-households drops as soon as the labor tax rate is increased. This is because the tax hike reduces their take-home pay and, as they have no chance to save and borrow, they must reduce their level of consumption (by assumption, so to they). In the end, all variables move back to the initial steady-state levels.

5 Conclusions

In this paper, we develop a dynamic stochastic general equilibrium (DSGE) model of a two-country monetary union economy with a comprehensive fiscal block. Our model is primarily aimed at simulating the effects of fiscal policy measures by relatively large countries (such as Germany, France, Italy or Spain) in a monetary union such as the Euro Area. We provide

a notable degree of disaggregation on the fiscal expenditures side, explicitly distinguishing between (productivity-enhancing) public investment, public purchases, and the public sector wage bill. We also consider a wide range of taxes on the fiscal revenues side. The model incorporates various other realistic features such as frictional labor markets and equilibrium unemployment, staggered price setting and wage bargaining in the private sector, liquidity-constrained households, habit formation, and investment adjustment costs. It is calibrated for Spain and the rest of the Euro Area, but it can easily be re-calibrated for other member states.

Inspired by recent fiscal actions and announcements in Spain, we simulating a number of policy measures aimed at achieving fiscal consolidation. We find that using cuts in public investment is likely to rather hurt than benefit the economy in the short as well as in the medium and long-run, while cuts in public consumption seem to be more desirable as they tend to affect the private labor market positively. This is especially the case when the reduction in public consumption is achieved by cutting public sector wages or employment, because the resulting worsening of private-sector workers' outside option makes them accept lower wages. This contributes to an increase in production, investment, employment, international competitiveness and aggregate private consumption.

Furthermore, we find that, in a matching labor environment, increases in labor of consumption taxes do not seem to affect production and output as much as they do in conventional models incorporating a Walrasian labor market. We also show that a shift of direct to indirect tax-financing of government expenditures can improve Spain's competitiveness while its effects on the rest of EMU are rather small.

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