Essays on fiscal policy

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Preface

This thesis consists of three chapters. The first chapter makes use of a New-Keynesian framework to analyze the effects of introducing the public sector in a small open economy, for which a different degree of home-bias for the private and the public sector will be assumed. Once it has been proven that this introduction does not fundamentally vary the original results of the Galí-Monacellli (2005) model, a sensitivity analysis of the effects of such introduction will be made in a setting with different exchange-rate regimes and different degrees of openness. The second chapter develops a DSGE model which features incomplete asset markets, domestic debt denominated either in domestic or foreign currency, a risk premium on such debt and simple feedback rules. We find that in this setting a positive government spending shock leads to expansionary effects on output when exchange rates are allowed to adjust. This effect is reinforced by the real depreciation caused by such policy especially in the case in which debt is denominated in foreign currency. This is not the case under fixed exchange rates, then also under a peg effects are, as expected, quite similar under both currency denominations of debt. The third chapter was written together with

Stefan Niemann[1] and Paul Pichler[2]. In it fiscal policy is introduced into a sovereign debt model with endogenous default costs to examine the implications for the determination of the output costs of default. We find that the quantitative properties of the output costs of default, and their dependence on primitives such as the elasticity of labor supply, are distinctly different depending on the margin of fiscal adjustment. The consideration of fiscal policy thus has potentially important implications for the quantitative properties of models of sovereign debt and default.

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Chapter 1

Fiscal policy and home-bias analysis in a New-Keynesian framework

Introduction

The Euro-area is the latest experiment in regional integration. Its main drawback is directly related to the optimum currency area's theory, elaborated by Mundell (1961). Following Eichengreen (1990, 1993) Europe is not as good an example of an optimum currency area as the United States because the degree of integration in the US is much greater than it is still in the Euro-area. A fundamental difference has to do with fiscal policy. Although Mundell did not originally take into account fiscal policy, subsequent contributions of authors such as Kenen (1993), Eichengreen (1990) or Sala-i-Martín (1992) highlight the importance of this policy tool within a monetary union. In the absence of flexible exchange rates and without domestic monetary policy, member countries are left with the fiscal policy to be used as a stabilization tool when shocks hit the economy if such shocks have asymmetric effects or are country-specific. When a federal government exists, like in the US, then, once the shock hits the economy it is rapidly absorbed by this institution through a system of transfers across states that will counteract such shock. However within the Euro-area there is not yet such an institution.

The European public procurement law might help to improve these shortcomings within the Euro-area. Public procurement refers to the process by which public authorities at any level hire work or acquire goods and/or services from private firms. It is an important component of public spending and has a sizeable impact on a country's final demand. Within the European Union it accounts for 19% of GDP. The importance of this policy instrument has been stressed by the European Commission in the *Strategy for the upgrade of the single market*[1] of October 2015 where it was stated that: '*In 2014, the EU adopted a major overhaul of the EU procurement framework, simplifying procedures, making the rules more flexible and adapting them to better serve other public policies, in particular innovation.This was aimed at making public procurement more efficient and strategic, fulfilling the principles of transparency and competition to the benefit of both public*

[1]European Commission, Upgrading the Single Market: more opportunities for people and business, COM(2015) 550 final, available at http://ec.europa.eu/DocsRomm/documents/14007

purchasers and economic operators, in particular". As stated, the core principles of EU public procurement are transparency, equal treatment, open competition and sound procedurial management. They are designed to achieve a competitive, open and well regulated procurement market. This is essential to increase the efficiency of public funds, most of all after the Great Recession, when public budgets of member countries have been reduced. Thus it can be expected that this law increases the purchase by domestic governments of, at least, goods and services from firms located in other member countries. Unfortunately up-to-date there is no procurement data on bids won by non-domestic firms within the European Union or the Euro-zone, so we cannot contrast our theoretical findings.

This chapter analyzes, within a New-Keynesian DSGE framework, the effects of the public sector having a different degree of home-bias from that of the private sector. We start by comparing such a model with the Gali and Monacelli (2005) model for a small open economy with no public sector and that of Payne and Uren (2014), which includes the public sector in the model. The introduction of the public moderates the response of output to changes in interest rates and, thus, the monetary policy will lose effectiveness. This comes from fiscal authorities ensuring a certain level of spending in each period, regardless of the potential changes in the interest rates, which limits the response of aggregate demand to those same changes. Including a fiscal sector with a specific degree of home-bias implies that the strength of the responses to a shock to government spending in the local economy depends on the degree of openness of each sector (private and public) and the type of exchange-rate regime. An increased degree of openness ensures that a government spending shock has less asymmetric effects, as these are shared more evenly with the rest of the economies within the monetary union.

The following section highlights the literature related to the subject at hand. Section 3 develops the theoretical model of a different degree of home-bias for the private and the public sector. Section 4 describes the calibration process for the model using the Spanish economy as a benchmark for the Euro-area. Then section 5 compares the model developed in Section 3 with the special case in which the degree of home-bias is assumed to be equal for both the private and the public sector (Payne and Uren's approach) and with the Galí-Monacelli (2005) model. This exercise accounts for the effects of including fiscal policy into the model. Then a series of sensibility analysis over fiscal policy are undertaken: A comparison between the effects of a government spending shock in a fixed or flexible exchange-rate framework, its effects depending on the degree of home-bias and on the trade elasticity. This section closes with an analysis of the welfare implications in terms of lifetime utility. Finally section 6 focuses on the effects of a shock to foreign government spending to analyze the effects of fiscal spillovers from the rest of the world.

Literature review

Obstfeld and Rogoff (1995) were the first to include nominal rigidities such as monopolistic competition and sticky prices into and RBC framework, creating in this way a New-Keynesian model for a small open economy.This model also includes a public sector in which public purchases implies a composite that aggregates across all the differentiated foreign and domestic goods, however government purchases were modelled just as private consumption. Ganelli (2005) uses a similar setting in which again public consumption can be a composite of domestic and foreign goods; but also the public and private sectors are now allowed to differ in their price elasticities. This affects the macroeconomic interdependence across countries under asymmetric shocks.[2]

Galí and Monacelli (2005) offer a very tractable framework in which to base the analysis of such fiscal policy shocks as it contemplates realistic features such as nominal rigidities and monopolistic competition in an open economy, and is rich enough to properly analyze the effects, not only in terms of the main economic variables, but also in terms of the spillover effects of such policies to the rest of the world. Furlanetto (2006) builds upon the previous model introducing the fiscal sector and confirms the main findings of the Mundell-Fleming-Dornbush model- all of them in line with the analysis of this chapter as well. Fiscal multipliers on output are low (below one) and decreasing in the degree of openness, positive spending shocks lead to an increase in interest rates through an endogenous monetary policy and this in turn leads to the appreciation of the exchange rates. The impact of such policies being always higher under fixed exchange rates. Payne and Uren (2014) use the same setting. They conclude that the introduction of a fiscal sector implies that the response of the output-gap to changes in interest rates will be moderated and, thus, the monetary policy will lose effectiveness.

[2] Lane and Ganelli (2003) offer a survey on how fiscal policy has been introduced in the NOEM literature.

This comes from the fact that fiscal authorities will ensure a certain level of spending in each period, regardless of the potential changes in the interest rates, which will limit the response of aggregate demand to those same changes. Then they quantify to what extent shocks to the economy differ in their effects on an economy depending on the type of exchange regime it holds and conclude that output fluctuations are lower under flexible exchange rates.

Regarding the importance of the degree of openness, Faia and Monacelli (2008) analyze the effects of the degree of home-bias in private consumption after a productivity shock, on the exchange rate and find that exchange rate volatility is decreasing in openness. Di Giogio et al. (2016) perform a similar exercise now taking into account the degree of home-bias of the public sector and conclude that, after a government spending shock, such home-bias in combination with an endogenous monetary policy, leads to an appreciation of the exchange rate, and that such appreciation has a direct correlation to the degree of home bias. Our analysis, developed in a similar setting, has similar results.

Blanchard et al. (2016) focus on the spillover effects of a shock to government spending in a currency union from the core to the pheriphery. In their model a crowd-in effect in the pheriphery leads to increased welfare in this area. We imitate this analysis by looking at the effects of a shock to foreign government spending on the domestic economy and find opposite results. Only in the case of a flexible exchange with high degree of public openness is the domestic economy better off and never in an scenario of fixed exchange-rates irregardless of the degree of openness of the government sector.

The model

The model presented below is based on an extension of the Galí-Monacelli (2005). The world economy consists of a small open economy and the rest of the world. Each economy is populated by infinitely lived agents. The small economy is also populated by firms that face a Calvo-price setting restriction. Also every period only a certain percentage of firms can adjust their prices to expected changes in the economic fundamentals. Finally there exists a fiscal and monetary authority.

In this chapter we will aim at accounting for the effects of having a different degree of openness for the private and the public sector respectively. Thus the definition of the aggregate price level of the economy, determined as the CPI index, will change slightly with respect to the previous models' specifications. Here it will be assumed that different prices for private and public goods exist. Thus the aggregate price level will be defined as:

$$P_t = \left[\left(P_t^C\right)^{1-s_G} \left(P_t^G\right)^{s_G} \right] \quad (1.1)$$

being s_G the steady-state government-spending to total-output ratio. Thus $(1 - s_G)$ will determine the ratio of private consumption to output and, thus, these two measures approximate the size of each sector in the economy. Then prices for private and public consumption are defined as a combination of domestic and foreign prices:

$$P_t^C = \left[(1-\alpha) \left(P_{H,t}^C\right)^{1-\eta} + \alpha \left(P_{F,t}^C\right)^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

$$P_t^G = \left[(1-z)\left(P_{H,t}^G\right)^{1-\eta} + z\left(P_{F,t}^G\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

being P_t^C the aggregate price for private consumption, defined as the sum of domestic $\left(P_{H,t}^C\right)$ and foreign prices $\left(P_{F,t}^C\right)$, and being P_t^G the aggregate price for public spending. The parameters $\alpha \in [0,1]$ and $z \in [0,1]$ represent the degree of openness for the private and the public sector respectively, also $\eta > 0$ measures the elasticity of substitution between domestic and foreign goods. Finally log-linearizing the previous formula around the steady state yields:

$$p_t \equiv (1-\xi)p_{H,t} + \xi p_{F,t} \tag{1.2}$$

where $\xi = \alpha - s_G(\alpha - z)$.

The world economy is modelled as a continuum of small open economies along the unit interval. Since each economy is of measure zero, its domestic policy decisions do not have any impact on the rest of the world. Furthermore they have identical preferences, technology and market structure. They only differ in their productivity shocks.

Household behaviour

Within the small open economy there is a representative household that behaves following a utility function of the form:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}\right] \tag{1.3}$$

which depends upon C, consumption, and N, labour input, and where β is the discount factor, σ is the inverse of the intertemporal elasticity of substitution and φ is the inverse of the Frisch labour elasticity.

Here consumption represents an index of nationally-produced, $C_{H,t}$, and foreign-imported goods, $C_{F,t}$, - defined specifically in the Appendix to this chapter- of the form:

$$C_t \equiv \left((1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{1.4}$$

The household faces a constraint:

$$P_t C_t + E_t \left[Q_{t+1} D_{t+1} \right] \leqslant D_t + W_t N_t + T_t \tag{1.5}$$

for $t = 0, 1, 2, \ldots$,where P is the CPI, Q_{t+1} is the stochastic discount factor common to all countries, D_{t+1} is the pay-off at time $t+1$ of a portfolio held at time t and . Lastly on the right-hand side (RHS) W_t is the nominal wage and T_t denotes lump-sum taxes/transfers.

Then maximizing the utility function in (1.3) with respect to consumption and labour and subject to the budget constraint above, it yields:

$$C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{1.6}$$

$$\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) = Q_{t,t+1} \tag{1.7}$$

Finally taking logs:

$$w_t - p_t = \sigma c_t + \varphi n_t \tag{1.8}$$

$$c_t = E_t \left[c_{t+1} \right] - \frac{1}{\sigma} \left(i_t - E_t \left[\pi_{t+1} \right] - \rho \right) \tag{1.9}$$

These two first-order conditions represent the labour supply optimality condition and the Euler equation respectively. Also i_t is the nominal interest rate, π_t is the inflation rate and $\rho = -\log(\beta)$ is the time-discount rate.

Government

The public sector in this model purchases a quantity G_t following the same logic as households' consumption , thus it can choose to purchase domestic and/or foreign goods - Definitions of domestic and foreign government spending can be found in the Appendix:

$$G_t \equiv \left((1-z)^{\frac{1}{\eta}} G_{H,t}^{\frac{\eta-1}{\eta}} + z^{\frac{1}{\eta}} G_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{1.10}$$

The government faces a budget constraint of the form:

$$\int_0^1 P_{H,t}(j) G_{H,t}(j) dj + \int_0^1 \int_0^1 P_{i,t}(j) G_{i,t}(j) dj di \leq T_t \tag{1.11}$$

so government spending must not exceed the lump-sum taxes collected from the households in each period.

Note that, differently from Payne and Uren (2014), here the degree of openness is not considered to be the same one for the private and the public consumption (and so the level of home-bias will also be different). This innovation has been done following some literature such as Trionfetti (2000) and Brulhart and Trionfetti (2004), who state that for OECD countries, there is evidence of much stronger home bias in government procurement than in private consumption.

In order to be able to introduce shocks to government spending, this variable will be modelled as an AR(1) process of the form:

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g$$

where $g_t \equiv \log G_t$ and $0 < \rho_g < 1$.

Firms

Technology

There is a continuum of firms within the interval $[0, 1]$ that produce a differentiated good through the following production function with linear technology:

$$Y_t(j) = A_t N_t(j) \tag{1.12}$$

Note that the only production input that we account for, is labour; there is no capital in the model. Then technology follows an AR(1) process:

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a$$

where $a_t \equiv \log A_t$ and $0 < \rho_a < 1$.

Calvo price-setting

Since there is market power, if prices were flexible, firms would set a mark-up over the marginal costs equal to $\mu = \log\left(\frac{\epsilon}{\epsilon-1}\right)$. However in our setting prices are sticky and the model assumes a Calvo (1983) price-setting. In this framework firms will adjust prices every period with a probability $(1-\theta)$. In this way the optimal price-setting strategy for a representative firm changing its prices could be approximated by

$$\bar{p}_{H,t} = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t\left[mc_{t+k} + p_{H,t}\right]$$

where $\bar{p}_{H,t}$ is the log of newly set domestic prices. Thus firms' price decisions are forward-looking because once the price has been adjusted, it will remain unchanged for a number of periods. So the price is set as a mark-up over a weighted average of future expected marginal costs.

Open economy

There are three assumptions that link the analyzed economy to the rest of the world. The law of one price that determines that for each good j: $P_{i,t}(j) = \xi_{i,t} P_t^i(j)$ where $\xi_{i,t}$ is the bilateral nominal exchange rate defined as the price of country i's currency in terms of domestic currency and $P_t^i(j)$ is the price of country i's produced good j in terms of such country's currency. Then aggregating and taking logs we arrive at the expression:

$$p_{F,t}{=}e_t{+}p_t^*$$

where $p_{F,t}$ is the (log) price of the foreign goods, e_t is the (log) nominal exchange rate and p_t^* is the (log) world-price index. Combining the previous equation with the definition of the (log) effective terms of trade:

$$s_t{=}p_{F,t}{-}p_{H,t}$$

the following expression can be derived:

$$s_t{=}e_t{+}p_t^*{-}p_{H,t} \tag{1.13}$$

Also combining (1.2) with the definition of the (log) effective terms of trade:

$$p_t{=}p_{H,t}{+}\xi s_t \tag{1.14}$$

The second assumption is that financial markets are complete, thus the stochastic discount factor defined as $Q_{t,t+1}$ will be the same for all households across all countries. Thus, just as in (1.7) for the domestic economy, something similar must exist for any other country i:

$$\beta\left(\frac{C_{t+1}^{i}}{C_{t}^{i}}\right)^{-\sigma}\left(\frac{P_{t}^{i}}{P_{t+1}^{i}}\right)\left(\frac{\xi_{t}^{i}}{\xi_{t+1}^{i}}\right)=Q_{t,t+1} \tag{1.15}$$

It must then follow that combining (1.7) and (1.15) under this second assumption:

$$C_{t}=\Omega_{i}C_{t}^{i}Q_{i,t}^{\frac{1}{\sigma}} \tag{1.16}$$

where $Q_{i.t}=\frac{\xi_{i,t}P_{t}^{i}}{P_{t}}$ is the bilateral real exchange rate or, in log terms: $q_{t}=e_{t}+.p_{t}^{*}-p_{t}=(1-\xi)\,s_{t}$. And Ω_{i} is a constant depending on initial conditions of the net asset holdings.

Finally if symmetric initial conditions are assumed (basically zero initial net foreign asset holdings and identical starting environments) across all countries then $\Omega_{i}=1$.

All these assumptions put together lead us to the following relationship between domestic and world consumption:

$$c_{t}=c_{t}^{*}+\left(\frac{1-\xi}{\sigma}\right)s_{t} \tag{1.17}$$

Finally the uncovered interest rate parity will be determined by:

$$i_{t}-i_{t}^{*}=E_{t}\left[\Delta e_{t+1}\right] \tag{1.18}$$

Equilibrium

Demand side

The market clearing condition for good j is:

$$Y_{t}\left(j\right)=C_{H,t}^{1-sG}\left(j\right)+\int_{0}^{1}C_{H,t}^{i^{1-sG}}\left(j\right)+G_{H,t}^{sG}\left(j\right)+\int_{0}^{1}G_{H,t}^{i^{sG}}\left(j\right) \tag{1.19}$$

Then aggregating for the whole economy and taking logs total output produced in the economy equals the sum of the domestic and foreign consumption made by the private and public sectors. Here a first-order log-linear approximation around the steady state can be found:

$$y = (1 - s_G)\, c_t + s_G (1 - z)\, g_t + s_G z g_t^* + \frac{\alpha\omega}{\sigma} s_t \tag{1.20}$$

where $\omega = \sigma\gamma + [\sigma\eta - (1 - s_G)](1 - \xi) - \frac{\sigma\eta s_G(\alpha - z)}{\alpha}$, γ is the elasticity of substitution between foreign varieties and g_t^* is the (log) world government spending. Finally aggregating all the countries:

$$y_t^* = (1 - s_G)\, c_t^* + s_G g_t^* \tag{1.21}$$

Combining these last two equations with the previously defined international sharing-condition, we obtain:

$$y_t = y_t^* + s_G (1 - z)(g_t - g_t^*) + \frac{(1 - s_G)}{\sigma_\beta} s_t$$

where

$$\sigma_\beta = \frac{\sigma (1 - s_G)}{\sigma\omega + (1 - sG)(1 - \xi)}$$

The trade balance of the economy is defined as:

$$NX_t \equiv \left(\frac{1}{Y}\right) [Y_t - \left(\frac{P_t}{P_{H,t}}\right) (C_t^{1-sG} + G_t)]$$

the difference between total domestic production and total domestic (private and public) consumption expressed as a function of steady state output Y. Then a log-linear approximation yields:

$$nx_t = y_t - (1 - s_G)\, c_t - s_G g_t - \xi s_t$$

Supply side

Using the optimal price setting under Calvo we can see how the behaviour of domestic inflation depends on real marginal costs:

$$\pi_{H,t+1} = \beta E_t \left[\pi_{H,t+1}\right] + \lambda \left(mc_t - mc\right) \tag{1.22}$$

where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$, mc_t is the log of the marginal cost and mc is the natural level of the marginal cost in the absence of rigidities.

Given the production function faced by firms, the marginal cost satisfies:

$$mc_t = -\nu + \left(w_t - p_{H,t}\right) - a_t$$

where $\nu \equiv -\log(1-\tau)$ and in turn τ is an unemployment subsidy. Using this last equation together with (1.8), (1.14) and (1.17), we find that:

$$\begin{aligned} mc_t = -\nu + \left(\frac{\sigma_\beta}{1 - s_G} + \varphi\right) y_t + \left(\frac{\sigma - \sigma_\beta}{1 - s_G}\right) y_t^* - s_G \left(\frac{\sigma_\beta\,(1 - z)}{1 - s_G}\right) g_t \\ - s_G \left(\frac{\sigma - \sigma_\beta\,(1 - z)}{1 - s_G}\right) g_t^* - (1 + \varphi)\, a_t \end{aligned} \tag{1.23}$$

Canonical representation

Having defined the economy as a whole, we find a log-linear approximation of the model which is represented by a forward-looking NKPC and a dynamic IS curve. The former curve is of the form:

$$\pi_{H,t}=\beta E_t\left[\pi_{H,t+1}\right]+\kappa_\alpha x_t \tag{1.24}$$

where $x_t = y_t - \bar{y}_t$ is the output-gap between the real and the natural rate and

$$\kappa_\alpha=\lambda\left[\frac{\sigma_\beta}{(1-s_G)}+\varphi\right]$$

The natural rate of output, in turn, is determined for the case in which $mc_t = -\mu$:

$$y_t^n=\Sigma+\Gamma a_t+\Psi y_t^*+\Lambda_g g_t+\Lambda_{g^*} g_t^* \tag{1.25}$$

being

$$\begin{aligned}\Sigma &= \frac{(\nu-\mu)}{1+\varphi}\Gamma,\ \ \Gamma=\left(\frac{(1+\varphi)(1-s_G)}{\sigma_\beta+\varphi(1-s_G)}\right),\ \ \Psi=-\left(\frac{\sigma-\sigma_\beta}{\sigma_\beta+\varphi(1-s_G)}\right),\\ \Lambda_g &= s_G\left(\frac{\sigma_\beta(1-z)}{\sigma_\beta+\varphi(1-s_G)}\right),\ \ \Lambda_{g^*}=s_G\left(\frac{\sigma-\sigma_\beta(1-z)}{\sigma_\beta+\varphi(1-s_G)}\right).\end{aligned}$$

Knowing that $x_t = y_t - y_t^n$, the IS curve is defined by:

$$x_t=E_t\left[x_{t+1}\right]-\left(\frac{1-s_G}{\sigma_\beta}\right)\left(i_t-E_t\left[\pi_{H,t+1}\right]-r_t^n\right) \tag{1.26}$$

where

$$r_t^n=\rho+\left(\frac{\sigma_\beta}{1-s_G}\right)\left\{\begin{array}{c}\Gamma E_t\left[\Delta a_{t+1}\right]+\left(\Theta_{y^*}+\Psi\right)E_t\left[\Delta y_{t+1}^*\right]\\ +\left(\Theta_g+\Lambda_g\right)E_t\left[\Delta g_{t+1}\right]+\left(\Theta_{g^*}+\Lambda_{g^*}\right)E_t\left[\Delta g_{t+1}^*\right]\end{array}\right\} \tag{1.27}$$

is the natural interest rate or the rate attained when prices are fully flexible and where

$$\Theta_{y^*} = \frac{\alpha\omega - (1 - s_G)\,\xi}{(1 - s_G)}\ , \Theta_g = -(1 - z)s_G\ ,$$
$$\Theta_{g^*} = -s_G \frac{\alpha\omega - (1 - s_G)^2\,(\alpha - z)}{(1 - s_G)}\ .$$

Once we have this setup we will close the model with a description of the monetary policy. We will see two scenarios, one with a fixed exchange rate and a second scenario will be for the monetary policy to follow a Taylor rule instead, allowing for a flexible exchange rate:

$$i_t{=}i_0{+}\delta_\pi \pi_{H,t}{+}\delta_x x_t \tag{1.28}$$

where i_0 is the objective interest rate, and δ_π and δ_x are the weights given by the monetary authority to deviations of domestic inflation and output gap from the steady state.

Calibration

Parameters

We use calibration in order to assign values to the model's parameters, for which we will use information from different data sources such as the INE (Spanish National Institute of Statistics), the Bank of Spain and Eurostat. We use quarterly data for the period 1996-2013. β has been derived from the fact that $\rho = i^{SS}$ (nominal interest rate in steady state) and it equals 0.99, which is appropriate for a quarterly model. The parameter α has been calculated as the coefficient between

Spanish imports and real output. z will be considered as 0.1 and σ is derived from the first-order Euler equation and it is close to 0.5. Then in turn φ, which is the inverse of the Frisch labour elasticity, has been calibrated using the first-order labour-supply equation in order to match a labour elasticity of 0.4. The Calvo-price parameter has been set, following Álvarez and Burriel (2010), to 0.82. ϵ has been set equal to 6, following Galí and Monacelli (2005), in order to match a mark-up of 20%. We set the elasticities of substitution between domestic and foreign varieties and just between foreign varieties to be equal to 1. In these two last cases a robustness check might be necessary. Finally s_G is set equal to 0.18 as the average ratio of government spending to output. δ_π and δ_y are set to the standard values of 1.5 and 0.5 respectively.

Parameters	Description	Value
β	Quarterly subjective discount factor	0.99
α	Ratio of imports to output on priv. cons.	0.3
z	Ratio of imports to output for publ. spend.	0.1
ρ	Time discount rate	$-\log(\beta)$
φ	Calibr. to match a labour elast. of 0.4	2.6
σ	Inv. of the intertemporal elast. of subst.	0.5
θ	Calvo param. for a firm not resetting prices	0.82
ϵ	Calibr. to match a mark-up of 20%	6
η	Elast. of subst. between dom. and for. varieties	1
γ	Elast. of subst. between foreign varieties	1
s_G	Share of gov. spending to output	0.18
δ_π	Sensitiv. of monet. pol. to inflation	1.5
δ_y	Sensitivity of monet. pol. to output	0.5

Shocks

We model the four shocks that hit this economy (a, y^*, g and g^*) as AR(1) processes of the form:

$$z_t=\rho_z z_{t-1}+\varepsilon_t^z$$

where the errors of these processes are independently distributed and uncorrelated. In this way, and using quarterly data for the Spanish economy for the period 1996-2007, we estimate by least squares the following parameters:

$$\rho_a = \underset{(0.005)}{0.68}, \rho_{y^*} = \underset{(0.003)}{0.61}, \rho_g = \underset{(0.01)}{0.53} \text{ and } \rho_{g^*} = 0.320.002$$

Introducing fiscal policy

Effects of introducing fiscal policy

In figures 1.1 to 1.4 in Appendix A we compare the impulse responses of three different scenarios: a small open economy with no public sector (Galí and Monacelli, 2005), another in which the public sector is included (similar to Payne and Uren,2014) and a third case in which a different degree of openness for the private and the public sector is considered. The responses are to a shock to productivity and foreign output respectively under fixed or flexible exchange rates. The great similarity of the responses in terms of sign and volatility serves as proof of the fact that no big distortions have been introduced in the original model with the inclusion of the public sector.

Thus a positive productivity shock will lead in all models and under all exchange rate regimes to a negative response of both the output-gap and domestic inflation (being the latter measured in terms of the GDP deflator). The response of the output-gap is due to the fact that output increases by less than the natural level of output, widening in this way the gap. Under a fixed exchange rate, the nominal interest rate cannot accommodate such shock since the central bank has to focus on maintaining the exchange rate parity and thus the output-gap and domestic inflation react more strongly to the technological shock.

The shock also affects the domestic economy's relative competitiveness, which is reflected on the terms of trade. The fall in domestic prices will trigger an improvement of the terms of trade for the economy, however, under a fixed parity, there is a minimal response of this variable. Also this regime allows for stationarity of the price levels (both domestic and CPI) which in turn explains the hump-shaped responses of the output-gap and inflation. On the supply side of the economy such shock will lower marginal costs for domestic firms, leading to a fall in prices and an increase in domestic output .

Under a flexible exchange rate regime, on the other hand, the nominal interest rates can accommodate to induce a higher increase in both consumption and output compared to a peg. Following the Taylor rule imposed in the domestic economy, nominal interest rates are allowed to respond to the shock. In this way, a reduction of the interest rates will boost consumption and output and thus, in this second case, fluctuations in the output-gap and domestic inflation are minimized, compared to the previous case, while the economy will face higher fluctuations on the exchange-rate and the terms of trade.

Focusing now on the shock to world output, it can be seen how in all models two mechanisms offset each other. Firstly this positive shock leads to a deterioration of the terms of trade, this real appreciation affects consumption negatively (Expenditure-switching effect) and leads to a decrease in the economic activity. On the other hand there will be an increase in net exports and also in domestic consumption that will lead to the opposite effect, an increase in aggregate output. Following Galí and Monacelli (2005), which effect prevails depends directly on the value of ω. For our calibration $\omega < 1$ for all models so the expansionary effect to aggregate demand will dominate. In figures 1.3 and 1.4 we can observe how now output-gap, domestic inflation and output move in the same ascending direction.

So the introduction of the public sector does not seem to affect the main dynamics of the original Galí-Monacelli (2005) model.

Effects of a government spending shock under a different home-bias for the private and the public sector

Different exchange-rate scenarios

Figure 1.5 in Appendix A shows the effects of a shock to government spending. Note that for this analysis we have assumed an almost complete home bias in the public-sector spending. Thus, this shock increases both the output-gap and domestic inflation irregardless of the exchange-rate regime. Overall output increases and thus induces a rise in the labour supplied in the economy. This leads to a substitution of consumption for labour across households. Marginal costs and prices increase. This, in turn, raises inflation expectations. Under a Taylor rule, interest rates increase, offsetting partly the effect of the shock. Also there is a negative wealth effect on consumption, as higher government spending implies also higher taxes, which reduces disposable income. In this setting of flexible exchange-rates, higher prices imply a expenditure-switching effect from domestic goods to cheaper foreign goods which is reflected on the decrease of the terms of trade and the appreciation of the nominal exchange-rate. Finally, only a small part of such shock will spill over to the rest of the world since, by construction, most of the government purchases are of domestically produced goods.These results are in line with Obstfeld and Rogoff (1995), Ganelli (2005) and Di Giorgio et al. (2016).

Under a fixed exchange-rate a fiscal policy shock is more effective. The output-gap response more than doubles that of flexible exchange-rates but at the cost of higher domestic inflation since, under no Taylor rule, inflation is allowed to shift freely. Also the effects on consumption, even though still negative, are more muted in this scenario due to a similar effect on the terms of trade. This stems from the mean reverting properties of domestic prices under fixed exchange rates.Thus for stabilization purposes a flexible exchange-rate is preferred. However, it should also be noted that, under a fixed exchange-rate prices revert back to their mean after the shock whereas under flexible exchange-rates they change permanently. This implies a weaker effect of the shock on the terms of trade and thus consumption under fixed exchange-rates and a much larger one under the opposite regime.

Analyzing the effect of home-bias

In this subsection we recalibrate the model by setting both parameters α and z equal to the values of 0.1 and 0.5 respectively and then combining such values in pairs to see how such changes in the degree of openness affect the dynamics of the model subject to a government-spending shock.[1] Note that a degree of home-bias of 0.5implies that the

[1] Notice that the impulse-responses experience mostly a higher variation whenever the degree of openness is different for the private and the public sector (Note that when the degree of openness is the same one for both sectors the model collapses to an specification quite similar to that of the economy with the same degree of openness- Not shown).

public/private composite consumption is evenly distributed between foreign and domestic goods. Figures 1.6 and 1.7 in Appendix A show the responses of the main variables.

In line with Di Giorgio et al. (2016), and for both exchange rate specifications, a government spending shock raises domestic marginal costs more under a high degree of home bias, this triggers higher domestic prices, compared to abroad, that negatively affect the terms of trade and the real exchange rate. These two variables experience a high volatility and therefore allow for a greater reduction in consumption and shift of domestic demand towards foreign produced goods.

On the other hand an increase in the degree of openness of the public sector leads to a reduced response of all variables to a government spending shock. In fact, for both cases, such an increase reduces overall responses by slightly less than half. This allows for greater spillover effects to the rest of the world and could be seen as a factor that contributes to reduce the asymmetric effects of the shock, being this more evenly distributed between home and abroad. The moderation in the responses of home prices, the greater the degree of openness, in turn, allows for a lower correction of the terms of trade, that affects output and domestic inflation, this last one through the marginal costs. The same will happen with the exchange rate, thus the expenditure-switching effect towards foreign goods will be reduced.

Also under a government-spending shock, it is the degree of openness of the public sector that dictates the intensity of the response, while, under a productivity shock, the strength of the impulse-responses is lead by the degree of openness of the private sector, since its weight is greater in the economy (as stated by the fact that $s_G = 0.18$).

A final remark has to with the effects on consumption, for this variable displays greater responses whenever both degrees of openness are the same (both 0.1 or 0.5). This stems from the multiplier effect of the nominal and real exchange rates and the fact that for this, and by construction of the model, the degree of openness of the private sector leads the effects on consumption.

Analyzing the effect of trade openness

In Tables 1 and 2 we analyze the effects of different levels of trade openness, defined by the parameter η, with different degrees of openness for the public sector. Under flexible exchange rates and for low degrees of openness of the public sector there is a small change in the responses of the main variables depending on the degree of trade openness; the higher the trade openness the more softened the effects on variables. However as the public sector becomes more open, such different effects of trade openness get cancelled. Regarding the effect on output, as η increases the effects on this variable are lower as an increased substitution effect allows for a greater demand of foreign goods relative to domestic. Then regarding z, as it increases such changes in relative demand are reduced due to the effects of government spending. These results follow those of Faia and Monacelli (2008) and Blanchard et al. (2016) who perform the same analysis for the degree of openness of private consumption after a productivity shock. When the exchange rate is fixed the degree of trade openness is irrelevant in all cases.

Table 1. Effects of a government spending shock with fixed exchange rates under different values of z and eta

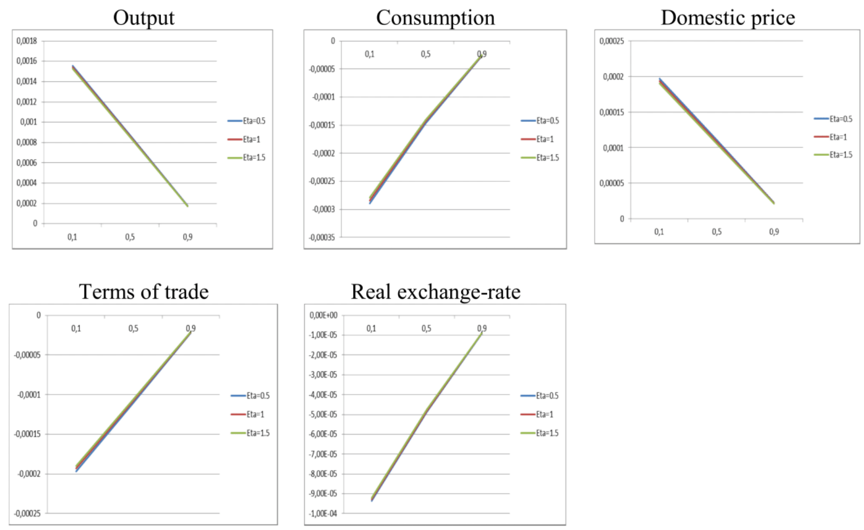
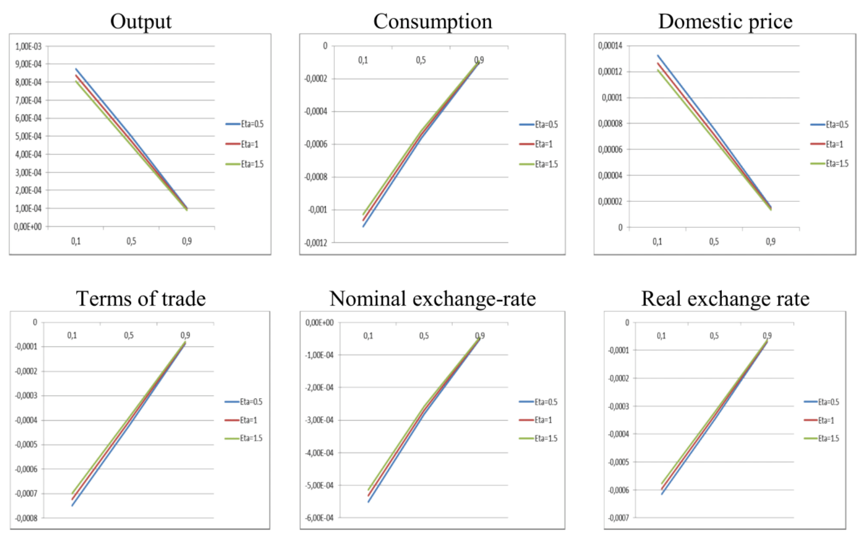


Table 2. Effects of a government spending shock with flexible exchange rates under different values of z and eta



Welfare considerations

The figures in Table 3 below describe deviations of discounted lifetime utility in terms of deviations from steady-state consumption under the different scenarios. Under both exchange-rate regimes deviations of utility from the steady state are higher the higher the degree of openness. This result goes in line with Ilzetzki et al (2010) and Karras (2014). Also it can be observed that under flexible exchange-rates, deviations of utility are smaller. Secondly, under such regime a higher degree of openness accounts for larger deviations from steady state and also it is the degree of openness of the public sector that leads this effect. For a fixed exchange-rate however, it would be, on the contrary, the degree of openness of the private sector. These findings are in line with the analysis made in the previous sections.

Table 3. Lifetime utility

	$\alpha = 0.1$	$\alpha = 0.5$	$\alpha = 0.1$	$\alpha = 0.5$
	$z = 0.1$	$z = 0.1$	$z = 0.5$	$z = 0.5$
Flexible exchange rates	0.90818832	0.90818837	0.90818844	0.90818846
Fixed exchange rates	0.90818855	0.90818859	0.90818853	0.90818855

Deviations of discounted lifetime utility in terms of consumption equivalent

Effects of a foreign government spending shock under different degrees of openness

Figures 1.8 and 1.9 in Appendix A analyze the effects of a shock to foreign government spending under fixed and flexible exchange rates. For the latter case and under high openness of the public sector, this shock increases output and the output-gap as the economy becomes more competitive and domestically-produced goods become more demanded abroad. This effect more than compensates the internal domestic loss of efficiency due to the increase in marginal costs and prices. Only for low degrees of openness is the case reverted.

Under fixed exchange rates the effect is negative over output and domestic inflation. This is a result of the adjustment process of the economy which is mainly done through quantities and so the increased competition through the terms of trade and real exchange rates becomes more muted and the higher prices and costs dominate the effect over output and domestic inflation.

Conclusion

This chapter has tried to develop a sensitivity analysis of the introduction of the public sector into a open-economy New-Keynesian model. Firstly it has been shown that, including such sector into the model and enhancing it with a differentiated degree of home-bias for the public sector, does not change it in any fundamental way. Secondly we have focused on analyzing the effects of shocks to government spending on the main economic variables under different exchange-rate regimes and degrees of home-bias. It was found, through an analysis of the impulse-responses, that following a shock to government expenditure, the output gap and the domestic inflation are less affected under a flexible exchange-regime framework, however this is not the case for consumption. The second main result in this line is that a different degree of openness for each sector has stronger effects indistinctly of the regime we analyze. Thirdly a large degree of openness lessens even further such variations, because of the spill-over effects of the fiscal policy into the rest of the world. Finally we performed a utility analysis for the representative consumer and found that only for high degrees of openness a shock to government expenditure affects consumers' utility less under a flexible exchange-rate framework, however such difference is decreasing in the degree of openness.

Chapter 2

The impact of fiscal policy and debt in an open economy

Introduction

One of the main results of traditional DSGE models, see for instance Galí and Monacelli (2005), is that the multipliers for fiscal policy are much larger under a fixed that under a flexible exchange rate policy, this has to do not only with the reaction of the real exchange rate but also with the response of monetary policy to such shock. Such theoretical predictions of a larger multiplier under a peg have been, later on, empirically proven by Ilzetzki et al. (2010a) and Corsetti et al. (2012). In the latter they also show that such multiplier depends also on the state of public finances. In this chapter we aim at analyzing the effects of such fiscal multiplier when introducing a risk premium to sovereign debt, and allowing for such debt to be issued either in domestic or in foreign currency. The motivation for this framework stems from the Great Recession and the increasing role played by sovereign debt and fiscal policies after this event, specially in an area such as the Euro zone, for which fiscal policy is the only tool left for national governments to counteract potential shocks hitting the economy.

Also the asset market structure is an important fact to understand the effects of a fiscal shock, as shown by Betts and Devereux (1999). These authors conclude that government spending shocks have no effects on the nominal and real exchange-rates only under complete international asset markets; thus such effects will only be present in a setting of incomplete financial markets. Here we will assume that increases in government debt raise the risk premium on bonds and affect the household's optimal intertemporal decisions through changes in the marginal real rate of return. Sovereign risk therefore generates an alternative to the traditional fiscal transmission mechanism.

In what follows we present a simple small open economy version of the New Keynesian Open Economy Model (NOEM) and compare two model specifications that differ in the assumption for the currency denomination of debt: a domestic and a foreign-currency denominated bond economy. In the latter case, all debt is issued in foreign currency. Comparing these two model specifications, we explain how effects of fiscal policy depend on the currency denomination of public debt. More broadly the key ingredients of the model include incomplete international financial markets, a country risk premium that is positively correlated with the exchange rate depreciation if debt is issued in foreign currency and distortionary taxation to analyze how such policies affect the economy depending on the initial setting.

Section 2 presents the literature review, section 3 the theoretical model, section 4 shows the calibration and estimation of the main parameters, section 5 describes the main results and section 7 concludes..

Literature review

We focus on the analysis of fiscal policy, which has always been used as one of the main stabilization tools in the face of economic fluctuations as well as to efficiently redistribute resources in the economy. Several authors such as Leeper (1991) and Sims (1994) analyzed the effects of the interaction between fiscal and monetary policies as stabilization tools and came to the conclusion that fiscal policy can influence the price level just as monetary policy does. Also the inherent limitations of the latter, such as the zero lower bound, when monetary policy does not have scope to provide sufficient stimulus to the economy, ensure the need for fiscal tools to procure stabilization in coordination with monetary policy. Such analyses were undertaken under a closed-economy setting, which is a restrictive assumption for a real economy. Betts and Devereux (1999) extend the analysis to a two-country setting and find that for the effects of fiscal policy, the structure of international asset markets is key. They conclude that under incomplete markets an expansionary fiscal policy increases output and consumption but leads to a depreciation of the nominal and real exchange rates. This contrasts with the traditional analysis of fiscal policy shocks in New-Keynesian DSGE models, which remark the positive effect of such shock on output, a negative effect on consumption and an appreciation of the exchange rate.

Another important reason why monetary policy must be coordinated with fiscal policy is the case in which a peg with another currency is established, such as the case of the Euro-area. Following Corsetti at al. (2011) the traditional assumption was that fiscal policies were always more effective under fixed than under flexible exchange rates. However these authors state that this need not be the case, and that the final effect rather stems from the policy mix and assumptions made about the economy.

Regarding empirical findings on this topic, Blanchard and Perotti (2002) and others showed that empirically exogenous increases in government spending have an expansionary effect over the business cycle. They use US data for their analysis. For the Euro Area Pappa (2009) develops a VAR analysis of government spending shocks and find similar results. A government spending shock causes output to increase as well as consumption. In order to get this latter positive effect on consumption, observed empirically, several authors have introduced innovations into the theoretical model such as the differenciation between Ricardian and non-Ricardian consumers (Galí et al., 2007) or the inclusion of habit persistence on consumption (Schmitt-Grohé and Uribe, 2006). We will abstract from introducing any of these specifications and thus consumption in our model will decrease after a government spending shock.

Due to the recent economic unfoldings, several authors have aimed at including in their analysis a richer public sector by including debt and distortionary taxation into the model. This last assumption implies that the Ricardian equivalence does not hold any longer and so the time path of debt financing will matter for the equilibrium dynamics. In the long run, any increase in government spending must be matched at some point by an increase in taxation when the public sector is committed to fulfling its intertemporal constraint. In the short run this will imply that increases in fiscal spending are followed large increases in debt. In this way Forni and Pisani (2014) , based in turn on Adolfson et al (2007) and Forni et al (2009), develop an open economy setting in which a set of fiscal rules is determined. Such rules are not optimal rules but, as they highlight, following Schmitt-Gohe and Uribe (2006), they can be a good approximation of such. We follow this assumption in our model.

The model

The model stems from Galí Monacelli (2005). In line with these authors, we assume a setting with a small open economy versus the rest of the world, thus decisions made within the former do not influence the world economy. We will assume that all parameters have the same value for both economies except for the degree of openness. In this setting a richer specification of the fiscal sector has been introduced following Forni and Pisani (2014) and Forni et al (2009). In this way we introduce two distortionary taxes (consumption and labor taxes) and feedback policy rules for each as well as for government spending and lump-sum taxes in order to achieve a better specification of the behaviour of the fiscal authority. The small open economy is populated by households, firms and a public sector that decides over fiscal and monetary policy. Finally we will assume that asset markets are incomplete and there is a risk-premium on debt.

Household behaviour

The economy consists of a continuum of infinitely-lived identical households employed in the domestic economy that consume both domestic and foreign goods and participate in international asset markets. The representative household chooses its preferences on consumption C and employment N, as to maximize the following intertemporal utility function:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right] \tag{3.1}$$

where β is the discount factor, σ the inverse of the intertemporal elasticity of substitution and φ is the inverse of the Frisch labour-elasticity. Consumption represents a composite index of nationally-produced and foreign-imported goods,

$$C_t \equiv \left((1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{3.2}$$

where α is a measure the economy's degree of openness for private consumption and η is the constant elasticity of substitution between home and foreign goods.

The household can choose to invest its savings from laboring for a nominal wage W_t in three different types of assets: domestic riskless bonds denominated in domestic and foreign currency respectively $B_{H,t}$

and $B_{F,t}$, which pay a nominal interest rate of R_t and R_t^F respectively or invest in an international bond F_t that pays the international rate R_t^*. Then it must also pay both lump-sum T_t taxes as well as taxes on consumption and labour, τ^C and τ^N. Finally ε_t is the nominal exchange rate expressed in terms of domestic currency (Following the Law of one price $P_t = \varepsilon_t P_t^*$) and P_t is the consumer price index equal to:

$$P_t \equiv \left[(1-\alpha) P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{3.3}$$

Thus the resulting intertemporal budget constraint has the form:

$$(1+\tau_t^C) P_t C_t + P_t T_t + B_{H,t} + \varepsilon_t B_{F,t} + \varepsilon_t R_{t-1}^* F_{t-1}$$

$$= (1-\tau_t^N) W_t N_t + R_{t-1} B_{H,t-1} + \varepsilon_t R_{t-1}^F B_{F,t-1} + \varepsilon_t F_t \tag{3.4}$$

The resulting optimal allocation of expenditures between domestic and imported goods for any given level of overall expenditures $P_t C_t$ will be as follows:

$$C_{H,t} = (1-\alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t, \;\; C_{F,t} = \alpha \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} C_t$$

and then

$$P_{H,t} C_{H,t} + P_{F,t} C_{F,t} = P_t C_t$$

A similar specification can be done for the foreign economy for which:

$$C^*_{H,t} = \alpha^* \left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta^*} C^*_t, C^*_{F,t} = (1-\alpha^*)\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\eta^*} C^*_t$$

Maximizing the utility function subject to the budget constraint above yields the following first order conditions for households:

$$RW_t = \frac{(1+\tau^C_t)}{(1-\tau^N_t)} C^\sigma_t N^\varphi_t \tag{3.5}$$

$$\beta R_t \left(\frac{E_t C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{1}{E_t \Pi_{t+1}}\right)\left(\frac{(1+\tau^C_t)}{(1+E_t\tau^C_{t+1})}\right) = 1 \tag{3.6}$$

$$\beta R^F_t \left(\frac{E_t C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{1}{E_t \Pi_{t+1}}\right)\left(\frac{(1+\tau^C_t)}{(1+E_t\tau^C_{t+1})}\right)\left(\frac{E_t\varepsilon_{t+1}}{\varepsilon_t}\right) = 1 \tag{3.7}$$

$$\beta R^*_t \left(\frac{E_t C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{1}{E_t \Pi_{t+1}}\right)\left(\frac{(1+\tau^C_t)}{(1+E_t\tau^C_{t+1})}\right)\left(\frac{E_t\varepsilon_{t+1}}{\varepsilon_t}\right) = 1 \tag{3.8}$$

where $RW_t = \frac{W_t}{P_t}$ is the real wage and $\Pi_t = \frac{P_t}{P_{t-1}}$ is the CPI inflation. Equation (3.5) is the labour supply which relate the optimal intertemporal decision between labour and consumption with real wages. Equations (3.6), (3.7) and (3.8) are the Euler equations or optimal decisions of asset holdings for domestic and international bonds..

We have assumed that markets are incomplete and thus, following Schmitt-Grohe and Uribe (2003), this gives rise to the need of introducing a risk-premium into the analysis to prevent an explosive consumption path. Such risk-premium will depend solely on the change of government debt from one period to the next, in the cases in which debt is denominated solely in domestic currency (so only B_H is issued) and, in the opposite case (so when only B_F is issued), the risk-premium will also depend on the evolution of the nominal exchange rate; so whenever the nominal exchange rate depreciates the risk-premium will increase as now the cost of repaying is higher and viceversa. However the risk-premium will not be affected by the amount of international debt (F). Thus algebraically it will be defined as :

$$RP_t = \chi_1 e^{(b_t - b_{t-1})} + \chi_2 e^{(e_t - e_{t-1})} \tag{3.9}$$

Combining equations (3.6) and (3.8) as well as (3.7) and (3.8) we get the following arbitrage conditions for the investment in these types of assets:

$$R_t = R_t^* \frac{E_t \varepsilon_{t+1}}{\varepsilon_t} RP_t \tag{3.10}$$

$$R_t^F \frac{E_t \varepsilon_{t+1}}{\varepsilon_t} = R_t^* \frac{E_t \varepsilon_{t+1}}{\varepsilon_t} RP_t \tag{3.11}$$

Firms

Technology

There is a continuum of monopolistically competitive firms within the interval $[0, 1]$ producing a differentiated good using the following production function:

$$Y_t(j) = A_t N_t(j) \tag{3.12}$$

where $Y_t(j)$ is the output produced by firm j in period , A_t is the economy-wide technology level and $N_t(j)$ is the labor force used by the firm. Note that the only production input that we account for is labour; there is no capital in the model. Technology is modelled as an AR(1) process:

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a \tag{3.13}$$

where $a_t \equiv \log A_t$ and $0 < \rho_a < 1$.

Then marginal cost, common across all firms, are:

$$MC_t = \frac{W_t}{P_{H,t}A_t} \tag{3.14}$$

Calvo price-setting

The existence of market power implies that if prices are flexible, firms would set a mark-up over the marginal costs equal to $\mu = \frac{\epsilon}{\epsilon-1}$. Here prices are sticky, following a Calvo (1983) price-setting and thus, only a fraction $(1-\theta)$ of firms can adjust prices every period in response to environment changes.

The aggregate price

$$P_t = \left[\theta P_{H,t-1}^{1-\epsilon} + (1-\theta)\,\bar{P}_{H,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{3.15}$$

is a combination of the general GDP deflator P_t and $\bar{P}_t$ the optimal price set by firms who are able to reoptimize in each period. In turn optimal price-settings for a representative firm changing its prices would be:

$$\bar{P}_{H,t} = \mu \frac{E_t \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} C_{t+k} P_{t+k}^{1+\epsilon} MC_{t+kt}^{r}}{E_t \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} C_{t+k} P_{t+k}^{\epsilon}} \tag{3.16}$$

So the optimal price is a mark-up over an average of future marginal costs. This implies that firms' price decisions are forward looking since once they are set, they will not be changed for certain periods.

Public sector

Government

The government spending funtion, G, is again a composite between domestic and foreign spending:

$$G_t \equiv \left((1-\alpha)^{\frac{1}{\eta}} G_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} G_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

We consider s_G as the steady-state government-spending to total-output ratio. Thus $(1-s_G)$ will determine the ratio of private consumption to output and, thus, these two measures approximate the size of each sector in the economy.

The government's intertemporal budget constraint is:

$$P_t G_t + R_{t-1} B_{H,t-1} + \varepsilon_t R_{t-1}^F B_{F,t-1} = \tau_t^C P_t C_t + \tau_t^N W_t N_t + T_t + B_{H.t} + \varepsilon_t B_{F,t} \tag{3.17}$$

or in real terms:

$$\begin{aligned} & G_t + \frac{R_{t-1}}{\Pi_t} RB_{H,t-1} + \frac{\varepsilon_t R_{t-1}^F}{\Pi_t} RB_{F,t-1} \\ = \; & \tau_t^C C_t + \tau_t^N RW_t N_t + RT_t + RB_{H.t} + \varepsilon_t RB_{F,t} \end{aligned} \tag{3.18}$$

where $RB_{H,t-1} = \frac{B_{H,t}}{P_t}$, $RB_{F,t-1} = \frac{B_{F,t}}{P_t}$ and $RT_t = \frac{T_t}{P_t}$. So government spending plus the amount of debt issued both in domestic and foreign currency must not exceed total taxes collected from the households in each period plus the issuing of new debt.

We will assume, following Forni et al (2009), that fiscal instruments are oriented at keeping real debt dynamics in check. In this way we will build up fiscal rules that, as stated by Schmitt-Grohe and Uribe (2006), are able to approximate optimal rules in the sense that both taxes and expenditures will depend on the level of debt in the economy. Thus the following log-linearized fiscal rules will ensure sustainability of the debt levels in every period:

$$g_t{=}\rho_g g_{t-1} + \phi_{g,b} b_t + \phi_{g,y} y_t{+}\varepsilon_t^g \tag{3.19}$$

$$rt_t{=}\rho_{rt} rt_{t-1} + \phi_{rt,b} b_t + \phi_{rt,y} y_t{+}\varepsilon_t^\tau \tag{3.20}$$

$$\tau_t^C{=}\rho_{\tau c} \tau_{t-1}^C + \phi_{\tau c,b} b_t + \phi_{\tau c,y} y_t{+}\varepsilon_t^{\tau c} \tag{3.21}$$

$$\tau_t^N{=}\rho_{\tau n} \tau_{t-1}^N + \phi_{\tau n,b} b_t + \phi_{\tau n,y} y_t{+}\varepsilon_t^{\tau n} \tag{3.22}$$

where $\phi_{gb} < 0$ measures the response of government spending to debt and $\phi_{gy} > 0$ to changes in output. For the feedback rules on taxes all parameters are assumed to be positive. Finally all the error terms follow standard i.i.d. processes.

Central bank

The central bank will either look after a fixed parity orl follow a Taylor rule instead of the following log-linearized form:

$$i_t{=}\delta_\pi \pi_{H,t}{+}\delta_y y_t \tag{3.23}$$

being δ_π and δ_y the positive weights given by the monetary authority to deviations of domestic inflation and output from target and steady-state levels respectively.

Equilibrium

The aggregate demand satisfies $Y_t = C_{H,t}^{1-sG} + C_{H,t}^{*1-sG} + G_{H,t}^{sG} + G_{H,t}^{*sG}$. If we substitute now both the domestic and foreign demand schedules the market clearing condition decomes:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \begin{bmatrix} (1-\alpha)C_t^{1-sG} + \alpha^* Q_t^\eta C_t^{*1-sG} \\ +(1-z)G_t^{sG} + z^* Q_t^\eta G_t^{*sG} \end{bmatrix} \tag{3.24}$$

Following Bonam and Lukkezen (2014) exports can be defined as the part of consumption and government spending that is adquired by the foreign economy. Thus we define exports as:

$$X_t = C_{H,t}^* + G_{H,t}^* \tag{3.25}$$

Then also the balance of payments is defined as:

$$\frac{P_{H,t}}{P_t} Y_t - C_t - G_t = Q_t\left(\frac{RF_{t-1}R_{t-1}^*}{\pi_t^*} - RF_t\right) + \varepsilon_t\left(\frac{RB_{F,t-1}R_{t-1}^F}{\pi_t} - RB_{F,t}\right) \tag{3.26}$$

so as the difference between total domestic savings in the economy and the net financial position where $RF_t = \frac{F_t}{P_t}$ and $RB_t = \frac{B_t}{P_t}$ (When government bonds are solely denominated in domestic currency then B_H would not be included into the previous equation). Q_t is the bilateral real exchange rate, defined as:

$$Q_t = \frac{\varepsilon_t P_t^*}{P_t} \tag{3.27}$$

Calibration

For the analysis of the model we have chosen Poland as the country of analysis. Poland is an economy in transition, member of the European Union but that still has not joined the Euro-area.The calibration stems from Kolasa (2009) and Grabek at al. (2011) who perform Bayesian estimation to find the main parameters defining the environment of the model. The parameter α represents the coefficient between Polish imports and real output and is set equal to 0.6. z will be considered as 0.1 to account for the low degree of openness that the government sector tends to have. Finally χ_1 is somewhat higher but similar to Bonam and Lukkezen (2014).

Results

In this section we will develop a comparison of the IRFs of the main variables under fixed or flexible exchange-rates, with domestic or foreign denominated public debt. The responses will be to 1 percent shocks and all are shown as percentage deviations from steady state. Dashed lines refer to a flexible exchange-rate setting, solid lines to a peg, then in turn, green lines imply the assumption of debt denomi-

Parameters	**Description**	**Value**
β	Quarterly subjective discount factor	0.99
α	Degree of openness of the priv. sector	0.6
z	Degree of openness of the publ. sector	0.1
α^*	Foreign degree of openness for the priv. sector	0.01
z^*	Foreign degree of openness for the publ. sector	0.01
φ	Inverse of the Frisch elasticity of labour supply	2.014
σ	Inv. of the intertemporal elasticity of substitution	1.9
θ	Calvo price param. for a firm not resetting prices	0.6
ϵ	Calibrated to match a mark.up of 20%	6
η	E.S. between domestic and foreigh goods	3.861
s_G	Share of government spending to output	0.18
ρ_g	Government spending AR coefficient	0.832
$\rho_{\tau c}$	Consumption tax AR coefficient	0.1772
$\rho_{\tau n}$	Labour tax AR coefficient	0.1312
ρ_a	Technology AR coefficient	0.749
$\phi_{rt,b}$	Elasticity of lump-sum taxes to debt	0.18
$\phi_{rt,y}$	Elasticity of lump-sum taxes to output	0
$\phi_{g,b}$	Government spending debt coefficient	0.01
$\phi_{g,y}$	Government spending output coefficient	0.5
$\phi_{\tau c,b}$	Consumption tax debt coefficient	0.0027
$\phi_{\tau c,y}$	Consumption tax output coefficient	0.46
$\phi_{\tau n,b}$	Labour tax debt coefficient	0.0022
$\phi_{\tau n,y}$	Labour tax output coefficient	0.76
δ_π	Sensitivity of monetary policy to CPI inflation	2.128
δ_y	Sensitivity of monetary policy to output	0.229
χ_1	Risk-premium elasticity w.r.t. debt	0.3
χ_2	Risk-premium elasticity w.r.t the exchange rate	0.1

nated exclusively in domestic currency and red lines are assigned to debt denominated solely in foreign currency.

Government Spending Shock

In figure 2.1, in Appendix B, we can see the effects of a shock to government spending. Under fixed exchange rates the initial response of output is negative contrasting the results of Corsetti et al (2011). This stems from the strong crowding-out on private consumption[1], being its effect stronger on output than the push of government spending plus the increase in exports due to the initial depreciation of the real exchange-rate. Nonetheless consumption recovers after a year leading to output following suit and then progressively going back to its baseline. All in all, the peak response of output under a peg is the highest of all scenarios, which would go in line with the previously referred findings. In general it should be noted that responses under fixed exchange-rates move quite close together in terms of size and sign irregardless of the denomination of public debt. Under a floating regime output does increase under both currency denominations for debt, however on impact the response when debt is denominated in domestic currency is higher. These responses seem lower than in the main literature but following Hebous (2011) the size ponse vary across theoretical and empirical studies. Also Ilzetzki et al (2013) state that economies with flexible exchange-rate regimes have rather small multipliers. In these cases a greater depreciation of the real exchange-rate leading to an expansion of exports backs such effects. For all cases the

[1]Note that in our theoretical setting we have not introduced any methodology to allow consumption to be crowded-in by a government spending shock. See Galí et al 2007.

decrease in consumption is due to a negative wealth effect associated with a tax burden increase as a result of the expected increase in future taxes that will affect the households' consumption decisions. After the increase in government spending, all taxes rise in response. The negative wealth effect induces households to increase hours worked. Then also the higher demand for goods and services raises the level of employment and labor income putting upward pressure on real wages. As a result real wages will increase, reflecting the higher labor demand. As mentioned, the net effect on output is positive as the increase in government spending dominates the fall in private demand.

Under flexible exchange rates CPI inflation increases moderately due to the expansionary effect of the shock only to progressively decline thereafter. Note that in the long.run it becomes negative since agents and specially firms foresee the previously mentioned needed adjustment of public finances after the increase in government spending. However initially such increase in inflation together with that of output leads to the monetary authority, following an active Taylor rule, increasing the nominal interest rate. Under fixed exchange rates there is no Taylor rule, though there is a clear increase of the interest rates, greater even than that under flexible exchange-rates when debt is denominated in domestic currency. This comes from the increase in the risk-premium of the country since debt levels rise after the expansionary fiscal policy and also that initially debt rises more under a peg regime. In turn such increase of the interest rate leads in all cases to a lagged appreciation of both the nominal and real exchange rate, that had depreciated on impact.

Sensitivity analysis

If we now turn to figure 2.2 in Appendix B, we can observe the effects of a government spending shock on output under different specifications of the risk premium. The left-hand graph shows a sensitivity of 0.15 of this variable to changes in the level of debt from one period to the next, the central graph accounts for the baseline calibration of 0.3 and finally the right-hand graph displays output results for a 0.5 sensitivity. It can be seen how for this former case of lower levels of risk premium the response of output follows conventional wisdom as it is now a positive response for both exchange-rate regimes and higher for the case of a peg, which is the standard result seen in most traditional literature. Then also as the risk premium sensitivity to changes in debt increases with respect to the baseline calibration, we can see how responses of output in all scenarios decrease and, as mentioned, for a fixed parity become negatve. Finally under high levels of risk premium almost all responses from output beecome negative or close to zero.

Shocks on taxes

Figures 2.3 and 2.4 in Appendix B show the effects on the main variables of a shock to labour and consumption tax respectively. Following Dungey and Fry (2009) a reduction in taxes, that is a negative shock on taxes, leads to a greater effect on output than a positive shock to government spending.

The decrease in the consumption tax leads to the greatest responses of variables. It leads to increases in both output and inflation for all cases on impact. This is due to the positive effect of the reduction in the tax on consumption and the increase in real wages and marginal costs respectively. All this causes nominal and real interest rates to increase. Note that debt in this scenario decreases for the case of fixed and flexible exchange rates with foreign-denominated debt because of the appreciation of the exchange rate. Then in the long run debt starts to increase again due to the inverted effects of the mentioned variables.

For the labour tax shock there is, as in Forni and Pisani (2014) an increase in output between 0.05 and 0.1 for the four cases in the short-run after the shock, however our responses a smaller due to the different parametrization of the persistence of the shocks. As before output strongly follows the response of consumption which in this case is positive since now households have more resources liberated from their wages to use in consumption. This is consistent with Blanchard and Perotti (2002) as well as Forni and Pisani (2014) for the case of Ricardian households. Inflation decreases and nominal interest rates increase on impact, this is consistent with Favero and Giavazzi (2007) for the US. Then also the responses of exports and the real exchange rate are rather similar to those of a government spending shock safe those of the case in which debt is denominated in foreign currency. In this case there is a somewhat greater appreciation of the exchange rate followed by a decrease in exports. Such appreciation must follow the decrease in prices that for this case is quite persistent in the medium and long-run. Debt increases after a reduction in taxes but its peak response is smaller than that of a government spending shock, again this is due to the behaviour of the public deficit. For the case of flexible exchange rates and debt denominated in foreign currency we observe the greatest increase in this variable triggered by the worsening of public finances.

Conclusion

In this chapter we have presented a DSGE model with a detailed fiscal policy in terms of debt and fiscal instruments. Then we have calibrated and simulated the model for the Spanish economy and have shown that different tax specifications play a role in determining fiscal policy effectiveness. Mainly effects of shocks on taxes seem greater than those of government spending. Also we have seen how differences arise for the case of flexible exchange rates depending on the currency denomination of sovereign debt. Also, under a foreign denomination of debt the responses of the main variables tend to be greater in almost all cases.

Chapter 3

Fiscal policy and the output costs of sovereign default

Introduction

The defining feature of sovereign debt is the absence of legal enforcement mechanisms. The presumption underlying formal models in the tradition of Eaton and Gersovitz (1981) is that sovereign debt can nevertheless be sustained via direct costs of default and the threat of financial autarky. The empirical literature, however, finds limited support for external punishment following default; instead, defaults appear to be deterred by domestic costs (Borensztein and Panizza, 2009; Panizza, Sturzenegger and Zettelmeyer, 2009). These costs have been found to be sizeable and potentially long-lasting. For example, De Paoli, Hoggarth and Saporta (2009) estimate a median output loss relative to pre-crisis output of at least 5% per year.

On the theoretical front, output costs of default are often incorporated in an ad-hoc fashion (Aguiar and Gopinath, 2006; Arellano, 2008). The important contribution made by Arellano (2008) was to introduce asymmetric costs of default which punish default more in good times; this exogenous feature proved essential to improve model performance in terms of the average debt levels that can be sustained at a reasonable default frequency, and in terms of the cyclical correlations of interest rate spreads and the trade balance with GDP. Against this background Mendoza and Yue (2012) endogenize the output costs of default with this asymmetric property in the context of a production economy where default causes disruptions of imports of intermediate inputs; this approach thus facilitates an integrated assessment of business cycles and sovereign default risk.

Importantly, however, Mendoza and Yue (2012) completely abstract from fiscal policy. Fiscal policy is distortionary, but also offers margins of adjustment that may constitute alternatives to outright sovereign default. Given the endogenous nature of the output costs of default, it is thus a priori unclear to what extent the findings in Mendoza and Yue (2012) are robust to the explicit consideration of fiscal policy, that is how the key properties of output costs of default survive when default is also associated with considerable fiscal adjustment, as it is observed empirically. This chapter makes a first attempt at assessing the role of fiscal policy for the determination of the output costs of default.[1] This

[1] Cuadra, Sánchez and Sapriza (2010) study fiscal policy in the context of a model with ad hoc default costs along the lines of Arellano (2008); by construction, there is thus no interaction between fiscal policy and default costs. In ongoing

is important because their structure has been identified as a key determinant of average debt levels and macroeconomic dynamics predicted by quantitative models.[2]

Finally the consideration of output costs of default in terms of output, instead of welfare considerations, goes directly at the problems discussed above and it also allows to experiment with the consequences of exogenous default in a straightforward way by looking at the static consequences of default without the need to consider subsequent dynamics.

Model and Calibration

Mendoza and Yue (2012) consider a small, open production economy with endogenous output costs of default driven by disruptions to the import of intermediate inputs. A sovereign government issues debt to international investors and default wipes out the entirety of the maturing liabilities. We extend the model by introducing fiscal policy in the form of a linear cosumption tax τ and government expenditure g.[3] Otherwise our model is identical; our exposition is thus confined to essential and new elements.

As is standard in the sovereign debt literature, households face a

work (Niemann and Pitchler, 2016), the cyclical behaviour of optimal fiscal policy is examined in a Mendoza-Yue-type economy with both fundamental and self-fulfilling sovereign default risk.

[2] Compare e.g. the discussion in Aguiar and Gopinath (2006), Arellano (2008) and Mendoza and Yue (2012)

[3] Tax systems in emerging economies tend to rely heavily on indirect taxation, i.e., taxes on goods and services rather than income; compare e.g. Vegh and Vuletin (2015)

static problem and do not participate in international financial markets. Decisions about consumption c and labour supply L are taken subject to a budget constraint linking private expenditure to income (gdp),

$$(1+\tau)c = wL + \pi^f + \pi^m \tag{2.1}$$

Preferences have a GHH-structure (Greenwood, Hercowitz and Huffman, 1988) and are specified as

$$u\left(c-\nu\left(L\right),g\right) = \pi\left(\frac{\left(c-\frac{L^\omega}{\omega}\right)^{1-\sigma}}{1-\sigma}\right) + (1-\pi)\left(\frac{g^{1-\sigma}}{1-\sigma}\right) \tag{2.2}$$

Accordingly, the contributions of public expenditures and the consumption-leisure composite to utility have an additively-separable CES structure and are aggregated with the relative weights π and $(1-\pi)$. The labor supply schedule is given by

$$\frac{u_l}{u_c} = \nu'\left(L\right) = \frac{w}{1+\tau} \tag{2.3}$$

where w are real wages. As seen, the consumption tax distorts labour supply, which can be devoted to the production of final (f) or intermediate (m) goods, $L = L^f + L^m$. The final goods production function is Cobb-Douglas and subject to productivity shocks ε,

$$y = \varepsilon\left(M\left(m^d, m*\right)\right)^{\alpha_M}\left(L^f\right)^{\alpha_L} k^{\alpha_k} \tag{2.4}$$

where M are intermediate inputs; k is the time-invariant stock; $\alpha_M, \alpha_L, \alpha_k \in (0,1)$ and $\alpha_M + \alpha_L + \alpha_k = 1$. The mix of intermediate inputs is determined by a CES Armington aggregator combining domestic (m^d) and imported $(m*)$ inputs,

$$M = \left[\lambda \left(m^d\right)^{\mu} + (1-\lambda)\left(m*\right)^{\mu}\right]^{\frac{1}{\mu}} \tag{2.5}$$

with $\lambda, \mu \in (0,1)$, implying an elasticity of substitution of $\eta^d = \mid \frac{1}{\mu-1} \mid$. Domestic inputs are produced according to the production function

$$m^d = A\left(L^m\right)^{\gamma} \tag{2.6}$$

where $A > 0$ and $\gamma \in [0,1]$. Imported inputs, in turn, are given by a Dixit-Stiglitz aggregator combining a continuum of differentiated varieties $m_j^*, j \in [0,1]$,

$$m* = [\int_{j\in[0,1]} \left(m_j^*\right)^{\nu} dj]^{\frac{1}{\nu}} \tag{2.7}$$

where $\nu \in (0,1)$. Thus, there is a finite elasticity of substitution of $\eta^j = \mid \frac{1}{\nu-1} \mid$ across imported input varieties. A subset Ω of the imported input varieties, defined by the interval $[0,\theta]$ with $\theta \in (0,1)$, must be financed in advance via working capital loans κ. The availability of working capital loans to firms conditions on the government's access to international financial markets. When the government repays its maturing debt, firms can contract loans at the risk-free world interest rate $r*$; in this case, their demand for working capital κ satisfies

$$\frac{\kappa}{1+r*} \geqslant \int_0^{\theta} p_j^* m_j^* dj \tag{2.8}$$

where p_j^*denotes the exogenous, time-invariant price of the imported input variety j. Following a sovereign default, instead, working capital loans become unavailable, preventing final goods firms from sourcing the optimally desired mix of imported inputs in (2.7). Since varieties in Ω must be replaced by imperfect substitutes, this induces an efficiency loss. The resulting output costs of default are increasing in productivity. This is because the complementarity embodied in the Cobb-Douglas production function (2.4) implies that distortions to firms' optimal factor demand are more costly at higher levels of productivity.

Final good producers maximize their profits taking w, r, $p*$and p^m as given:

$$\pi^f = y - p * m * -p^m m^d - wL^f \tag{2.9}$$

where p^m is the relative price of domestic inputs. Then intermediate goods producers profits given w and p^m

$$\pi^m = p^m m^d - wL^m \tag{2.10}$$

Introducing equations (2.9) and (2.10) into the household's budget constraint, equation (2.1), gives a constraint linking private expenditure with income (gdp),

$$(1+\tau)\, c = y - p * m* = gdp \tag{2.11}$$

Given productivity ε and some specification of fiscal policy (τ, g), factor allocations, factor prices and output in a competitive equilibrium can be determined from the above conditions. In order to quantify the output costs of default, numerical values must be assigned to the model parameters. Our assignment, detailed below, introduces π as a new parameter but is otherwise identical to the one in Mendoza and

Yue (2012) who calibrate their model to data from Argentina (1980Q1-2005Q4).

Parameters	**Description**	**Value**
ω	Frisch elasticity 1/(ω-1)=2.2	1.455
σ	Intertemporal elasticity 1/σ=0.5	2
π	Utility weight	0.9
α_M	Intermediate input share	0.43
α_L	Final sector labour share $\alpha_L/(1-\alpha_M) = 0.7$	0.40
α_k	Final sector capital share $\alpha_k/(1-\alpha_M) = 0.3$	0.17
γ	Intermediate sector labor share	0.7
A	Intermediate sector productivity	0.31
λ	Armington weight of domestic inputs	0.62
μ	Between elasticity $\eta^d = 1/(1-\mu) = 2.9$	0.65
ν	Within elasticity $\eta^j = 1/(1-\nu) = 2.44$	0.59
θ	Working capital parameter	0.7
$r*$	Risk-free interest rate	0.01

Output costs of default

In order to assess the importance of fiscal policy for the determination of the output costs of default, we subject the model economy to a comparative experiment under an exogenous, possibly suboptimal debt policy (cf. Section III of Mendoza and Yue, 2012). Given some debt policy, taxes and spending must satisfy the government budget constraint,

$$\frac{\tau}{1+\tau} = \frac{g + (1-d)\,\frac{r*}{1+r*}\bar{b}}{gdp} \tag{2.12}$$

where $d \in \{0,1\}$ is a default indicator and $\frac{r*}{1+r*}\bar{b}$ denotes the debt interest burden.[1] We then have the following result.

Proposition 1 *Given some debt policy, the government's optimal tax and spending policy is characterized by*

$$u_c \left\{ -\frac{\partial \frac{1}{1+\tau}}{\partial \tau} gdp - \frac{1}{1+\tau} \frac{\partial gdp}{\partial \tau} + \nu'(L) \frac{\partial L}{\partial \tau} \right\} = u_g \left\{ -\frac{\partial \frac{1}{1+\tau}}{\partial \tau} gdp + \frac{\tau}{1+\tau} \frac{\partial gdp}{\partial \tau} \right\} \tag{2.13}$$

which implies underprovision of public spending, $u_c < u_g$.

Given a debt interest burden of 3% of GDP, the preference weight $\pi = 0.9$ has been chosen such as to induce a level of public spending of 15% of GDP when the government honors its liabilities and productivity is at $\varepsilon = 1$. These numbers correspond roughly to their empirical counterparts in Argentina. Starting from there, we compare the output of final goods under default (y^d) and repayment (y^{nd}) for varying productivity. The output costs of default are then computed as $1 - y^d/y^{nd}$, whereby we contrast between three alternatives that differ in the fiscal adjustment in response to changing productivity and the exogenous repayment decision:

1. the repayment regime ($d = 0$) where both τ and g are adjusted optimally in line with (2.13);

2. the default regime ($d = 1$) where both instruments are again adjusted optimally;

[1] What matters for the determination of taxes and spending are not interest rates and debt separately, but only the resulting debt interest burden. Without loss of generality, the expression in (2.12) assumes that a stationary level of debt $\bar{b}$ is rolled over at the risk-free world interest rate $r*$.

3. the default regime ($d = 1$) where one of the fiscal instruments is constrained to replicate the state-contingent level chosen in regime (1.) while the other one must adjust residually to satisfy (2.12).[2]

The differences across fiscal regimes are most readily seen in figures 3.1 and 3.2 below, which plot the tax rate τ and the level of public spending relative to GDP, g/gdp, respectively against productivity. Under repayment, τ is decreasing in ε, while g/gdp is increasing, The reason is that higher productivity induces a higher tax base, which allows a more favorable reallocation from private to public consumption by means of taxation. By comparison, in regime (2.) τ is lower but g/gdp is higher for all productivity states. This is because of the fiscal relief coming from sovereign default. For the same reason, since tax revenues are no longer needed to finance the debt interest burden but used exclusively to provide public spending, both τ and g/gdp are now independent of ε.[3] Finally, fiscal relief through default is also present in regime (3.), but there are two distinct cases. When only taxes adjust, figure 3.1, τ is lower than in regime (1.) and increasing in ε. When only spending adjusts, figure 3.2, g/gdp is higher than in regime (1.) and decreasing in ε.

[2] This scenario arguably captures elements of fiscal sluggishness or other politico-economic considerations which prevent the optimal fiscal accommodation of sovereign default.

[3] That τ and g/gdp are constant follows from the absence of wealth effects under GHH-preferences and the fact that public expenditures and the consumption-leisure composite are subject to the same curvature parameter σ.

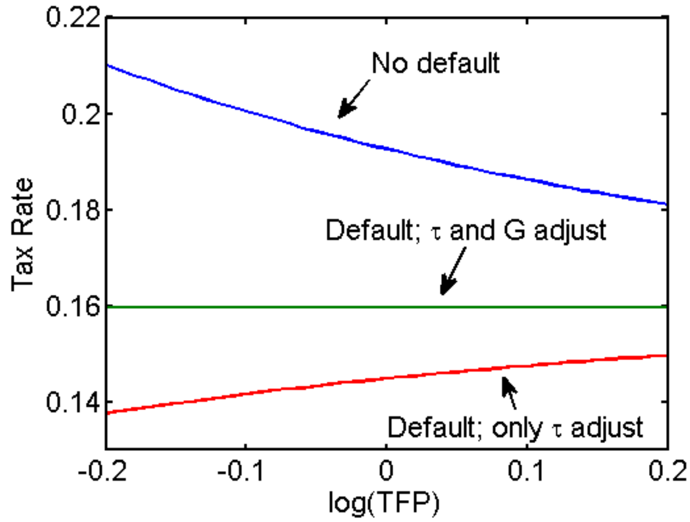


Figure 3.1 Taxes under different modes of fiscal adjustment

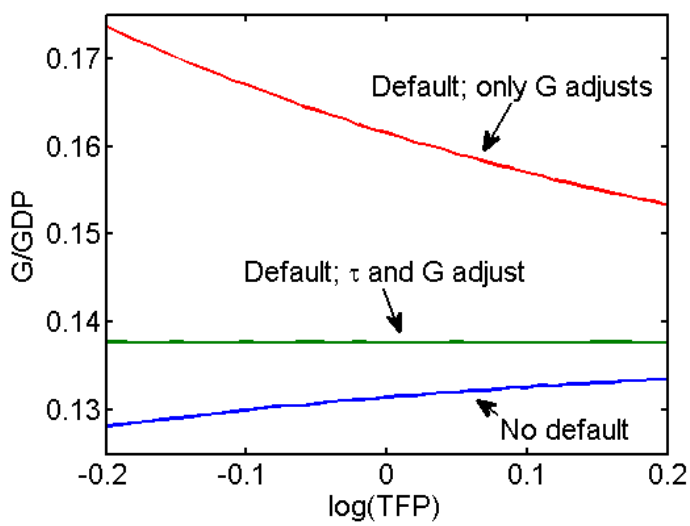


Figure 3.2 Public spending under different modes of fiscal adjustment

What does this imply for the output costs of default? Figure 3.3 plots these costs, contrasting the different scenarios for fiscal adjustment. We begin with the case of regime (3.) when taxes remain unchanged so that fiscal adjustment is exclusively in the form of changes in public spending. The resulting output costs of default are identical to those obtained in the model without fiscal policy studied by Mendoza and Yue (2012). This is because tax distortions are kept constant, while public spending enters utility in an additively-reparable fashion and hence does not affect allocations. Next, consider the case of regime (3.) when public expenditure is fixed and fiscal adjustment comes entirely in the form of tax changes. Compared to the other case - and thus also to the model without fiscal policy - the output costs of default are lower, and for sufficiently low productivity shocks even negative.; moreover, the output costs schedule in now steeper in ε. These two features are again due to the fact that debt repudiation through default relaxes the government budget constraint so that tax distortions are reduced. The relevance of this mechanism is higher in low productivity states because the underlying tax base is smaller so that default allows for a greater reduction of the tax rate. Finally, regime (2.) where both instruments are adjusted optimally generates output costs of default that average out the previous two scenarios in terms of level and slope.

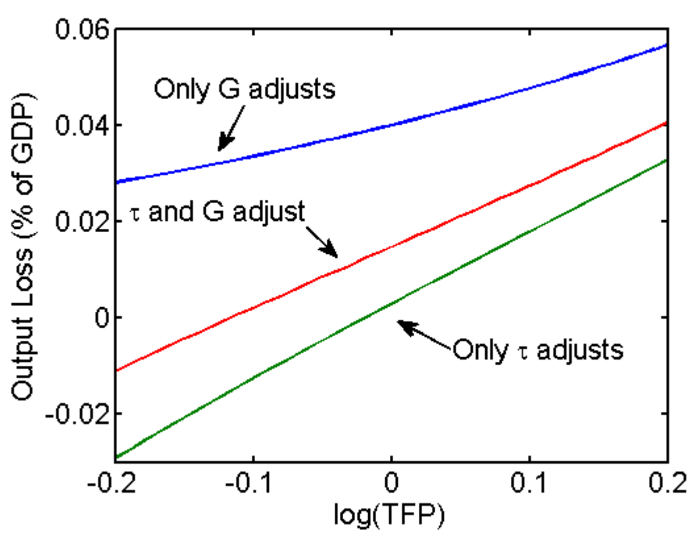


Figure 3.3 Output costs of default under different modes of fiscal adjustment

As seen, the consideration of fiscal policy in general, and the specification of details about the fiscal adjustment process in particular, have quantitatively relevant implications for the output costs of default. Fiscal activity matters due to its distortionary effect on labour supply. It is therefore interesting to examine the sensitivity of our findings to changes in the elasticity of labor supply $\frac{1}{1-\omega}$.[4] Figure 3.4 does this for regime (2.) where both fiscal instruments are adjusted optimally. In Mendoza and Yue (2012), a higher elasticity of labor supply dampens the wage response in the event of default, which implies stronger intersectoral reallocation effects and ultimately higher output costs of default. This comparative-static effect is actually reversed once fiscal policy is taken into account: a higher Frisch elasticity is now associated with lower (possibly even negative) output costs of default. To understand this, recall that default induces lower tax rates (c. figure 3.1). This has a positive effect on labor supply which is more pronounced the higher the elasticity of labour supply. In addition to their level effect on the output costs of default, induced changes in taxation can hence also affect important qualitative lessons from the model where fiscal policy is absent.

[4] The key role of the substitution elasticities $\eta^d = \mid \frac{1}{\mu-1} \mid$ and $\eta^j = \mid \frac{1}{\nu-1} \mid$ as determinants of the output costs of default already pointed out by Mendoza and Yue (2012) is preserved also in our modified model with fiscal policy.

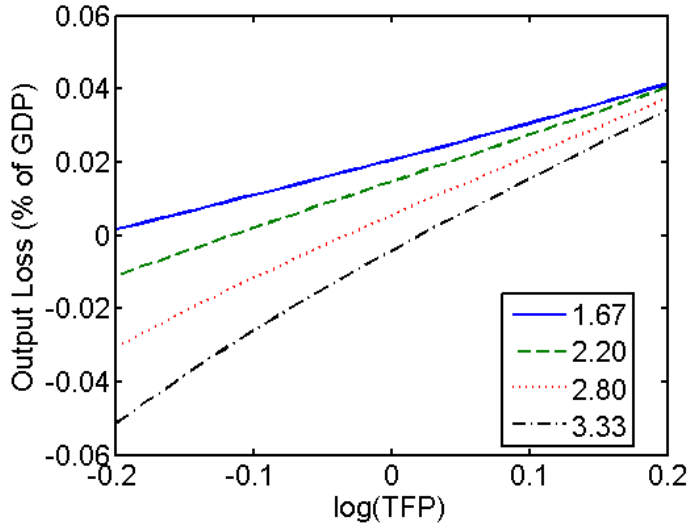


Figure 3.4 Regime (2.): Output costs of default under different labor supply elasticities

Conclusion

Fiscal policy has been introduced into a sovereign debt model with endogenous default costs and the implications for the determination of the output costs of default have been examined. We find that the quantitative properties of the output costs of default, an their dependence on primitives such as the elasticity of labor supply, are distinctly different depending on the margin of fiscal adjustment. While the exercise at hand has considered three distinct regimes under an exogenous debt and default policy, the relevant driving forces are likely preserved in the full model with variations in bond prices that induce cyclical dynamics in the government's debt, tax spending and default policy. The consideration of fiscal policy thus has potentially important implications for the quantitative properties of models of sovereign debt and default.

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Appendix A

Appendix - First chapter

Further specifications for the theoretical model

Household behaviour

Consumption in this setting represents an index of nationally-produced and foreign-imported goods of the form:

$$C_t \equiv \left((1-\alpha)^{\frac{1}{\eta}} \, C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

Also the consumption of each of these goods is set as:

$$C_{H,t} \equiv \left(\int_0^1 C_{H,t}\left(j\right)^{\frac{\epsilon-1}{\epsilon}} \, dj \right)^{\frac{\epsilon}{\epsilon-1}}, \;\; C_{F,t} \equiv \left(\int_0^1 \left(C_{i,t}\right)^{\frac{\gamma-1}{\gamma}} \, di \right)^{\frac{\gamma}{\gamma-1}}$$

where $j \in (0,1)$ determines the good variety, $\epsilon > 1$ is the elasticity of substitution between nationally-produced varieties and γ is the elasticity of substitution between foreign varieties. Finally $C_{i,t}$ is an index of all imported goods from country i with $i \in (0,1)$:

$$C_{i,t} \equiv \left(\int_0^1 \left(C_{i,t}(j) \right)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$$

Finally the household faces a constraint:

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj + \int_0^1 \int_0^1 P_{i,t}(j) C_{i,t}(j) dj di + E_t \left(Q_{t,t+1} D_{t+1} \right) \leq D_t + W_t N_t + T_t$$

for $t = 0, 1, 2, \ldots$,where $P_{H,t}(j)$ is the domestic price of the variety j, $P_{i,t}(j)$ is the price of variety j imported from country i and expressed in domestic currency, D_{t+1} is the pay-off at time $t+1$ of a portfolio held at time t and Q_{t+1} is the stochastic discount factor common to all countries. Lastly on the right-hand side (RHS) W_t is the nominal wage and T_t denotes lump-sum taxes/transfers.

The optimal allocation of resources within each variety of goods yields the following demand functions:

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\epsilon} C_{H,t} \quad , \quad C_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}} \right)^{-\epsilon} C_{i,t}$$

where

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}} \quad , \quad P_{i,t} = \left(\int_0^1 P_{i,t}(j)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}$$

are the domestic price index and the price index for goods imported from country i, again expressed in national currency respectively. This, in turn, implies that

$$\int_0^1 P_{H,t}(j)C_{H,t}(j)dj{=}P_{H,t}C_{H,t},\ \ \int_0^1 P_{i,t}(j)C_{i,t}(j)dj{=}P_{i,t}C_{i,t}$$

Also the optimal allocation of expenditures on imported goods by country of origin is:

$$C_{i,t}{=}\left(\frac{P_{i,t}}{P_{F,t}}\right)^{-\gamma}C_{F,t}$$

where

$$P_{F,t}{\equiv}\left(\int_0^1 {P_{i,t}}^{1-\gamma}di\right)^{\frac{1}{1-\gamma}}$$

is the price index for imported goods. Thus again:

$$\int_0^1 P_{i,t}C_{i,t}di{=}P_{F,t}C_{F,t}$$

Finally the allocation of resources between domestic and imported goods will be equal to:

$$C_{H,t}{=}\left(1-\alpha\right)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}C_t,\ \ C_{F,t}{=}\alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta}C_t$$

Government

The public sector is modelled as a composite good of:

$$G_{H,t}{\equiv}\left(\int_0^1 G_{H,t}\left(j\right)^{\frac{\epsilon-1}{\epsilon}}dj\right)^{\frac{\epsilon}{\epsilon-1}},\ \ G_{F,t}{\equiv}\left(\int_0^1 \left(G_{i,t}\right)^{\frac{\gamma-1}{\gamma}}di\right)^{\frac{\gamma}{\gamma-1}}$$

which are indexes for domestic government spending and for government spending on imported goods respectively. Being finally $G_{i,t}$ an index of the government spending on all imported goods from country i:

$$G_{i,t} \equiv \left(\int_0^1 \left(G_{i,t}(j)\right)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$$

Equilibrium

Demand side

The market clearing condition for good j is set at:

$$\begin{aligned} Y_t(j) &= C_{H,t}^{1-sG}(j) + \int_0^1 C_{H,t}^{i^{1-sG}}(j) + G_{H,t}^{sG}(j) + \int_0^1 G_{H,t}^{i^{sG}}(j) \\ &= \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\epsilon} \left\{ \begin{array}{c} \left[\begin{array}{c} (1-\alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t^{1-sG} \\ +\alpha \int_0^1 \left(\frac{P_{H,t}}{\xi_{i,t} P_t} \right)^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i} \right)^{-\eta} C_t^{i^{1-sG}} di \end{array} \right] \\ + \left[\begin{array}{c} (1-z) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} G_t^{sG} \\ +z \int_0^1 \left(\frac{P_{H,t}}{\xi_{i,t} P_t} \right)^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i} \right)^{-\eta} G_t^{i^{sG}} di \end{array} \right] \end{array} \right\} \end{aligned}$$

Then aggregating for the whole economy:

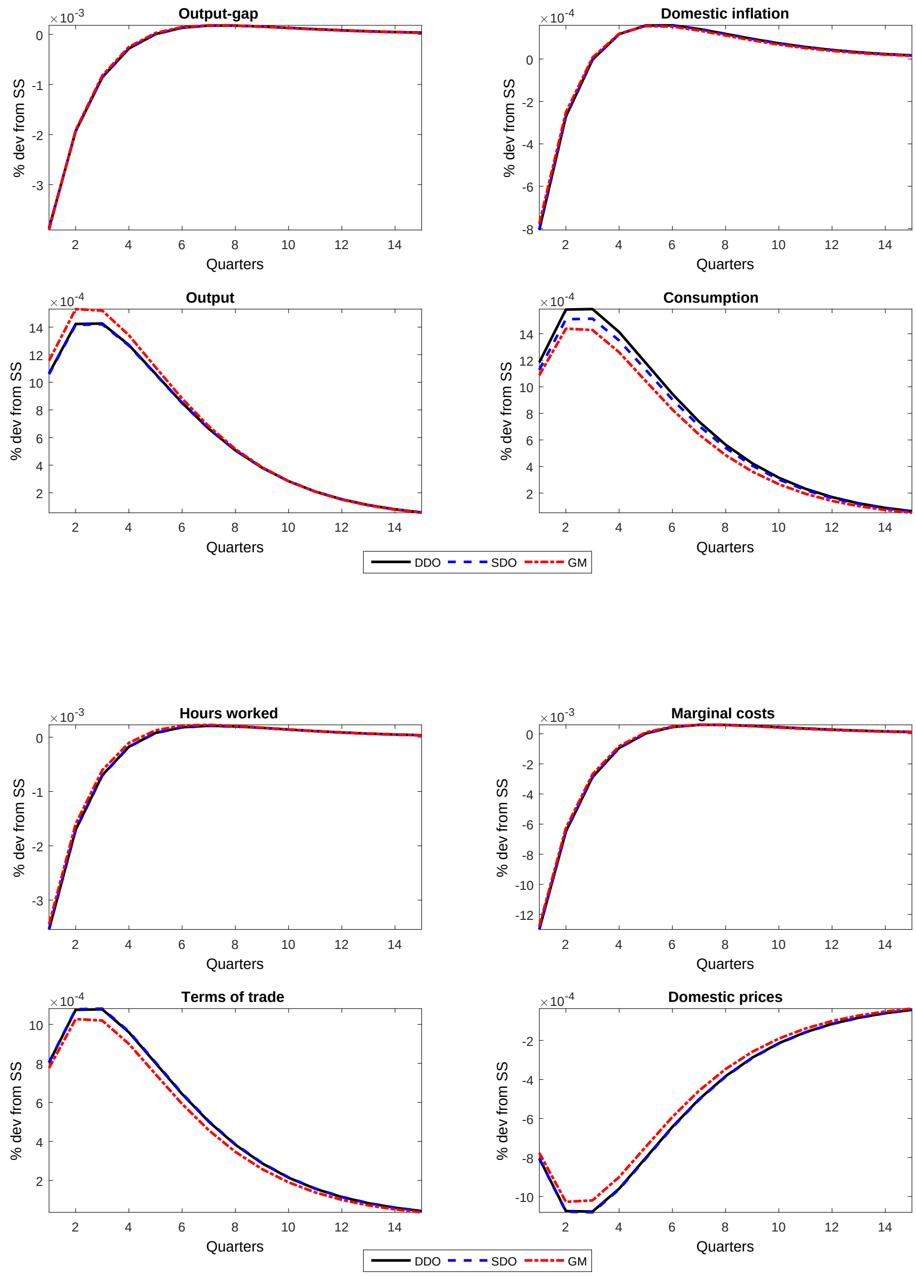
$$Y_t = \begin{array}{c} \left[\begin{array}{c} (1-\alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t^{sG} \\ +\alpha \int_0^1 \left(\frac{P_{H,t}}{\xi_{i,t} P_t} \right)^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i} \right)^{-\eta} C_t^{i^{sG}} di \end{array} \right] \\ + \left[\begin{array}{c} (1-z) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} G_t^{1-sG} \\ +z \int_0^1 \left(\frac{P_{H,t}}{\xi_{i,t} P_t} \right)^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i} \right)^{-\eta} G_t^{i^{1-sG}} di \end{array} \right] \end{array}$$

then taking logs we find:

$$\begin{aligned} y_t &= -\eta(p_{H,t} - p_t) + (1-s_G)c_t + \alpha(\gamma-\eta)s_t + \alpha\left(\eta - \frac{(1-s_G)}{\sigma}\right)q_t + (1-z)s_G g_t + z s_G g_t^* \\ &= (1-s_G)c_t + s_G(1-z)g_t + s_G z g_t^* + \frac{\alpha\omega}{\sigma}s_t \quad \text{(A.1)} \end{aligned}$$

Impulse responses

Figure 1.1 Shock to productivity under fixed exchange rates



Black line denotes different degrees of openness, blue line same degree of openness and red line the baseline model

Figure 1.2 Shock to productivity under flexible exchange rates

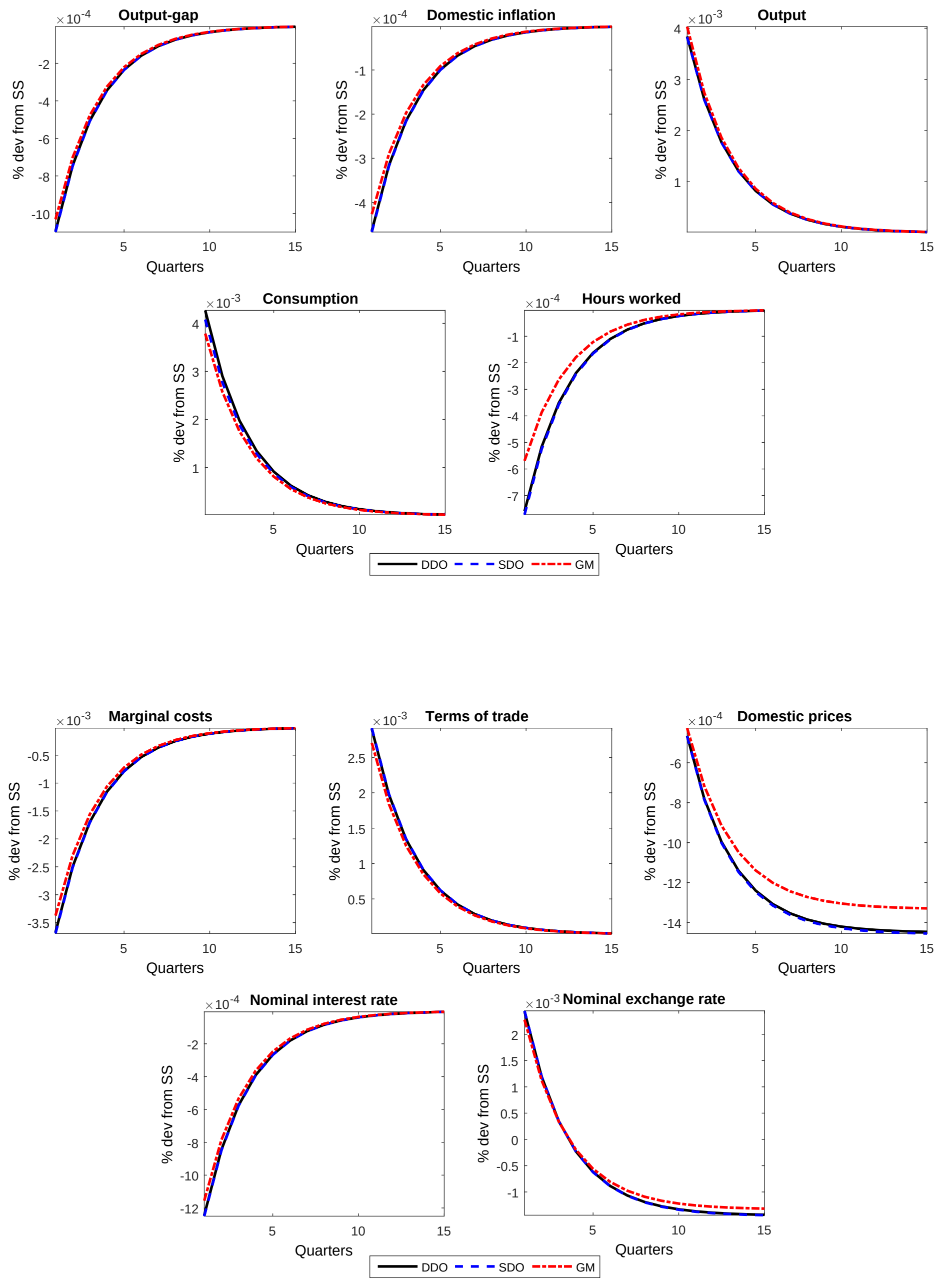
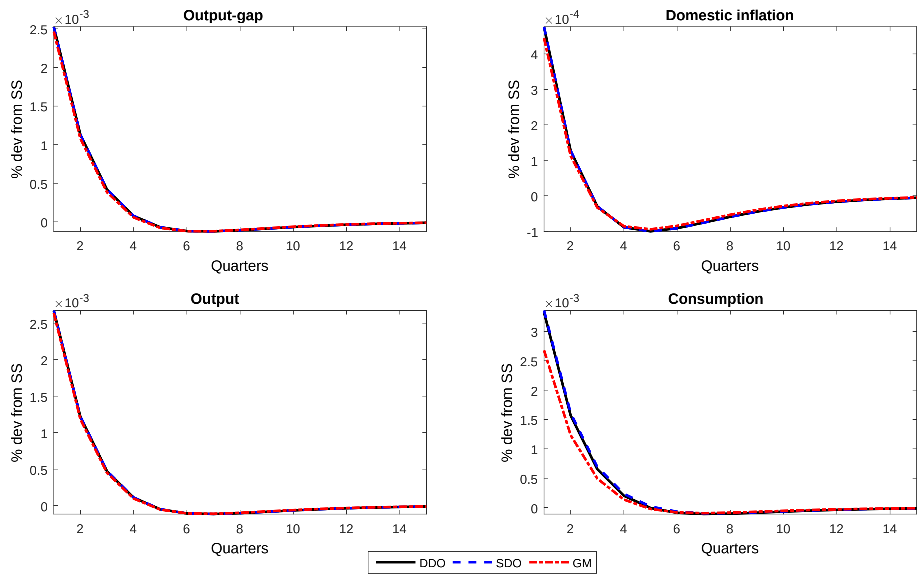


Figure 1.3 Shock to world output under fixed exchange rates



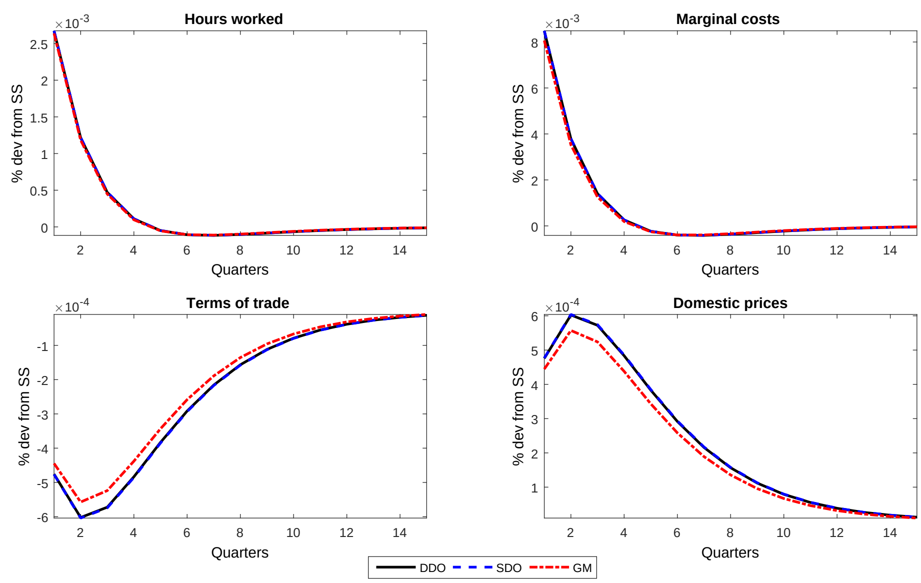


Figure 1.4 Shock to world output under flexible exchange rates

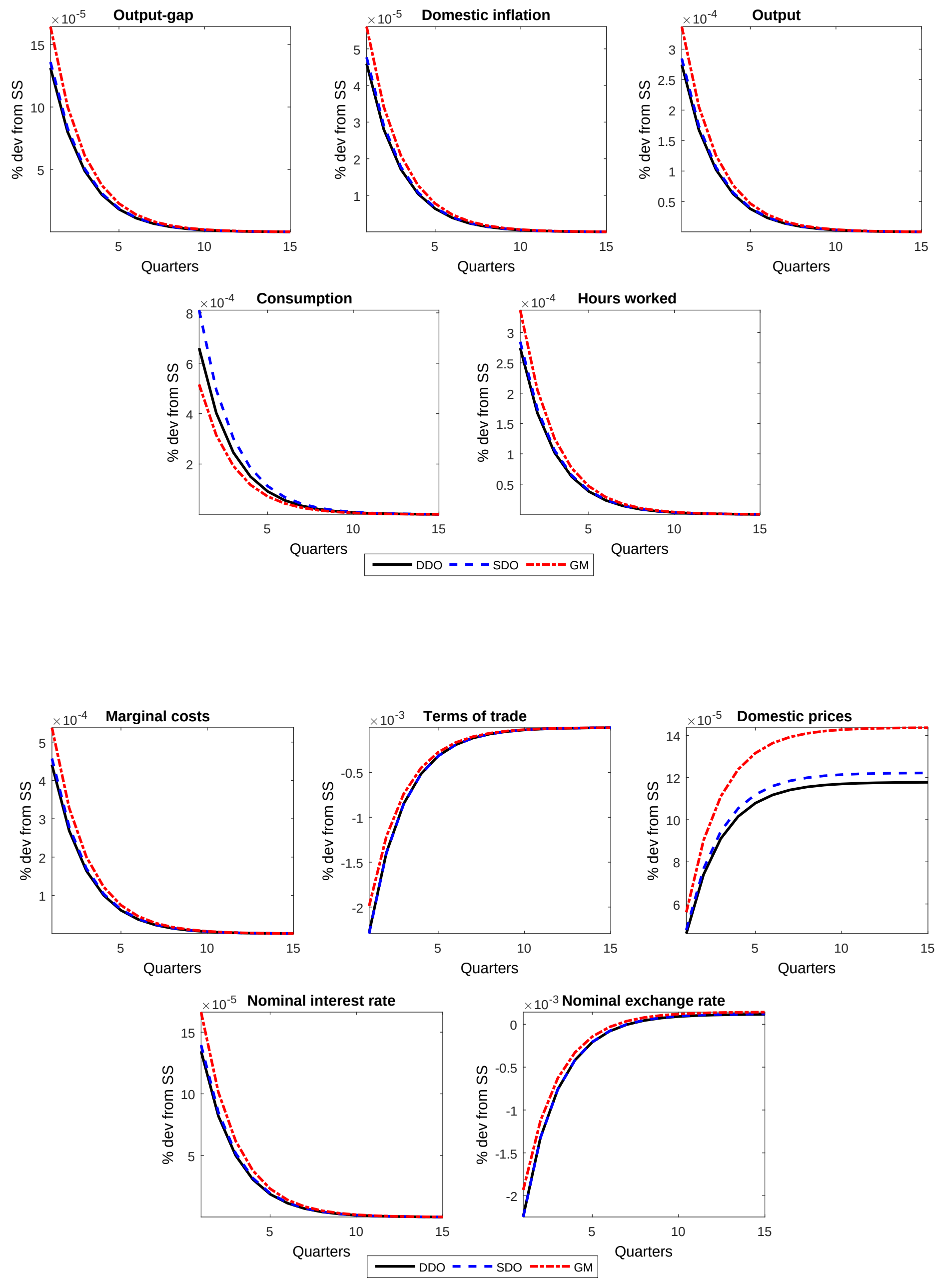
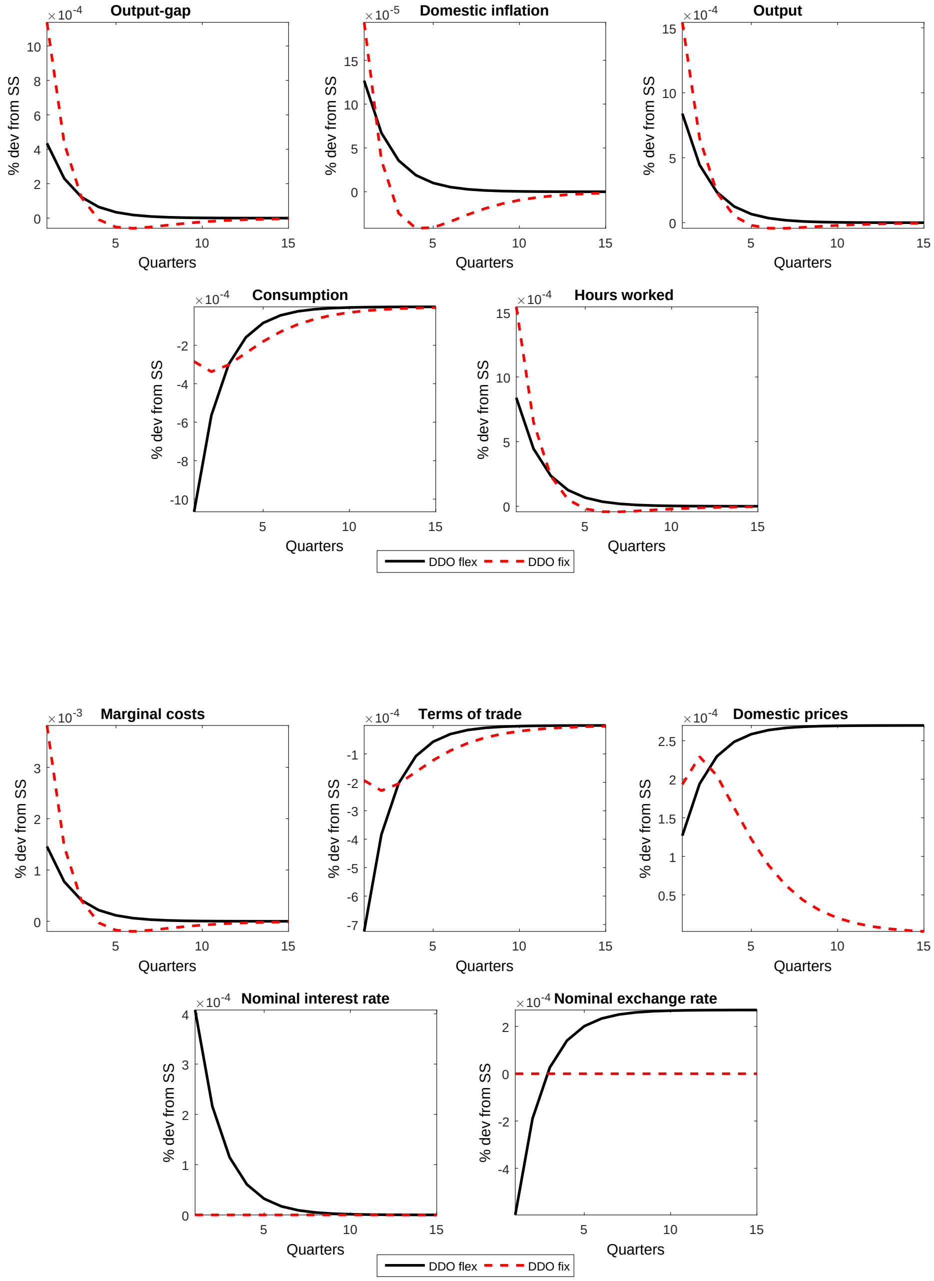
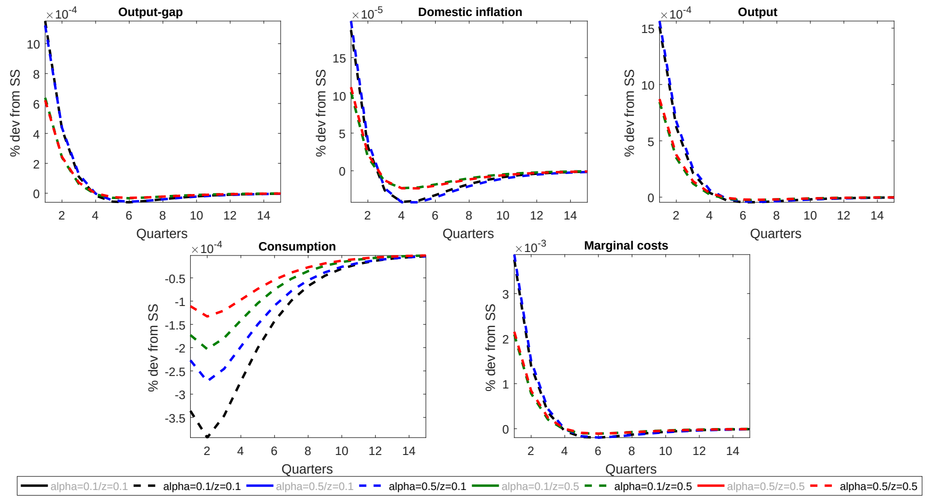


Figure 1.5 Shock to government spending



Black (red) line denotes flexible (fixed) exchange rates and different degrees of openness

Figure 1.6 Shock to government spending under fixed exchange rates with different degrees of openness



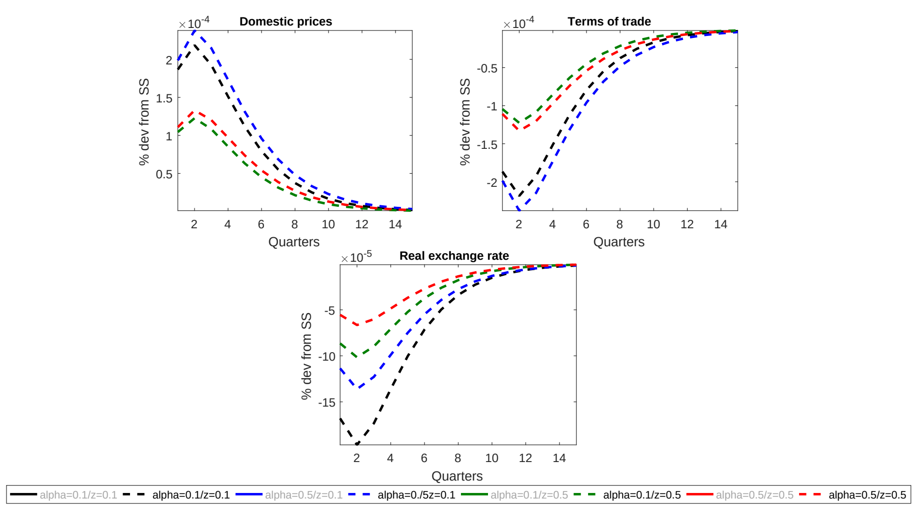
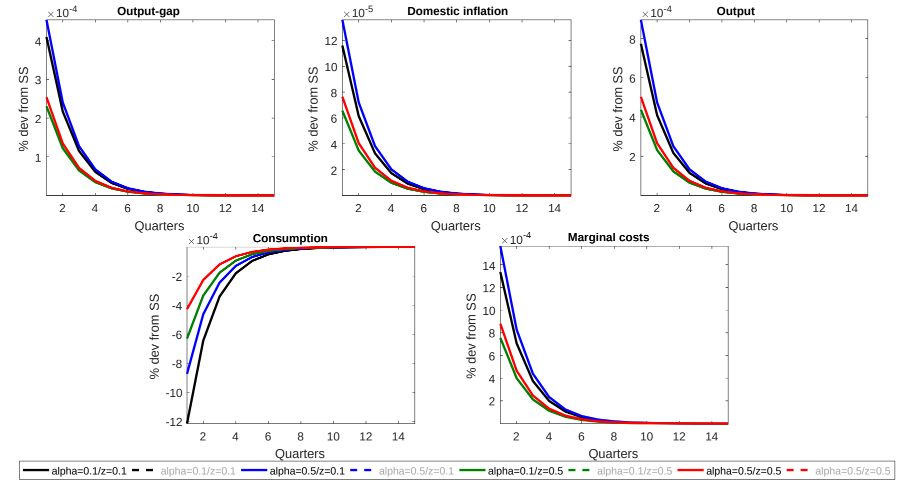


Figure 1.7 Shock to government spending under flexible exchange rates with different degrees of openness



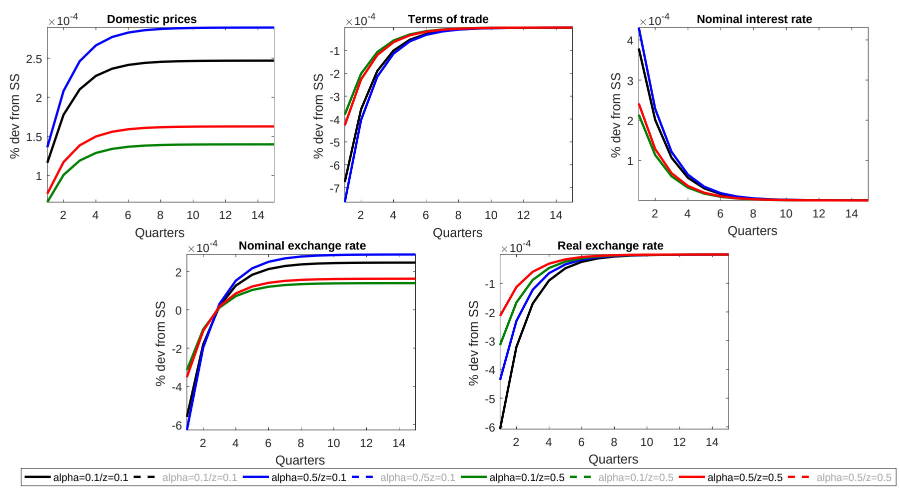
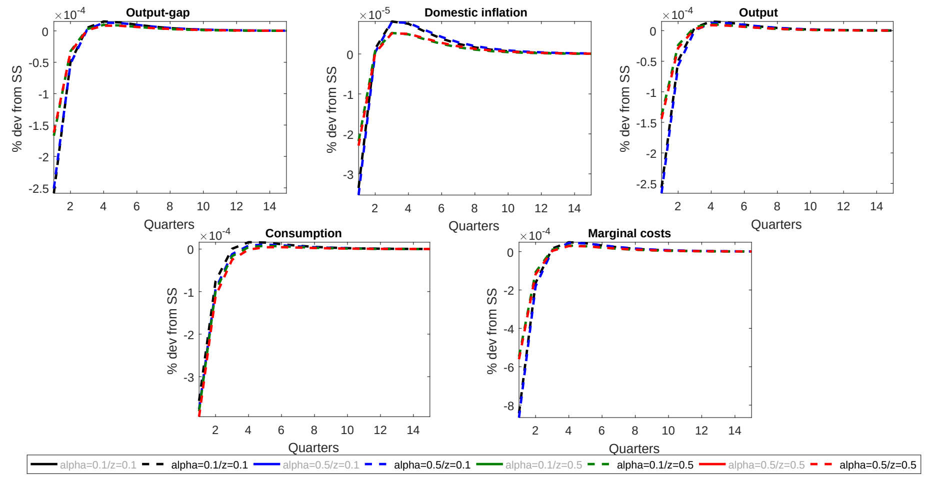


Figure 1.8 Shock to foreign government spending under fixed exchange rates with different degrees of openness



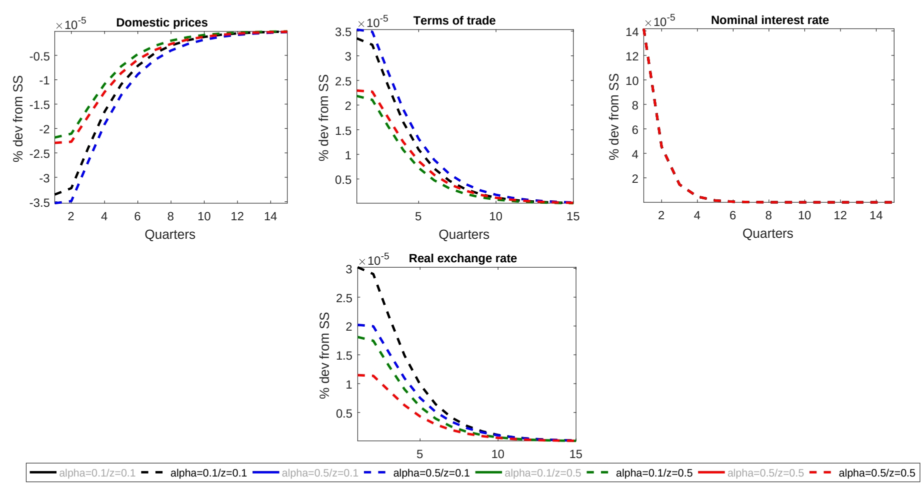
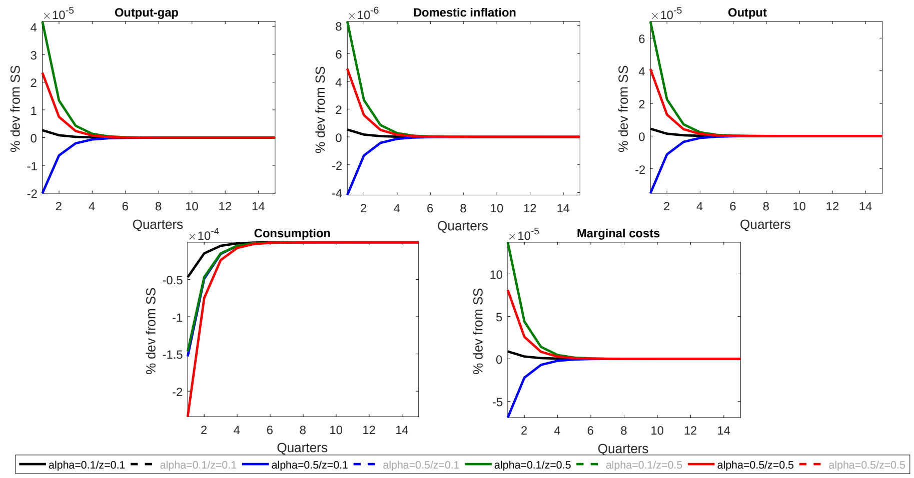
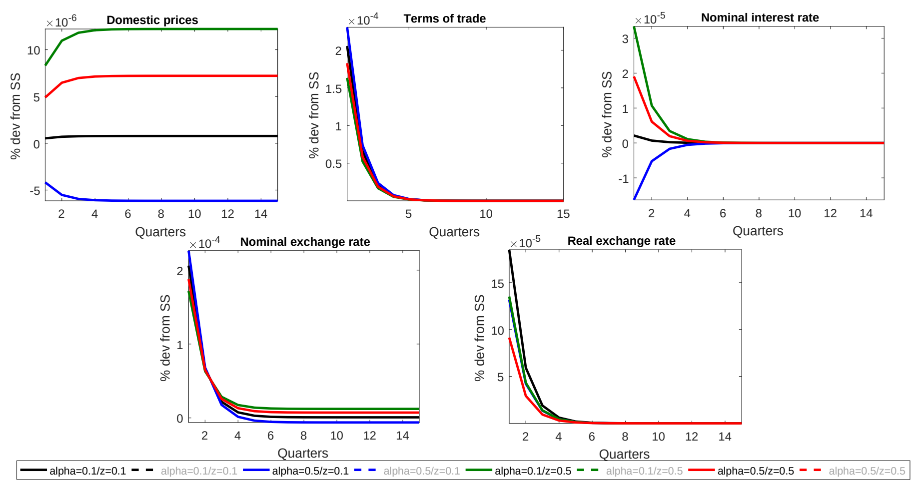


Figure 1.9 Shock to foreign government spending under flexible exchange rates with different degrees of openness





Appendix B

Appendix - Second chapter

Model log-linearization

As defined in the Calvo price setting section 3.2.2, dividing equation (3.16) by $P_{H,t-1}$ and taking logs gives:

$$\bar{p}_{H,t} = \mu + (1 - \theta\beta) E_t \sum_{k=0}^{\infty} (\theta\beta)^k \left(p_{H,t+k} - \hat{m}c^r_{H,t+k} \right)$$

so firms will set a price that corresponds to the desired markup,given by $\mu = -mc^r$, over a weighted average of their current and expected nominal marginal costs, with the weights being proportional to the probability of the price remaining effective each period θ^k . Then rearranging and substracting $p_{H,t-1}$ from each side:

$$\bar{p}_t - p_{H,t-1} = \theta\beta E_t\left(\bar{p}_{H,t+1} - p_{H,t}\right) + (1-\theta\beta)\,\hat{mc}^r_{H,t} + \pi_t \tag{A.1}$$

Then also dividing equation (3.15) by $P_{t-1}^{1-\epsilon}$ and taking logs:

$$\pi_t = (1-\theta)\left(\bar{p}_{H,t} - p_{H,t-1}\right) \tag{A.2}$$

Combining (A.1) and (A.2) gives the New Keynesian Phillips curve:

$$\pi_{H,t} {=} \beta E_t\left[\pi_{H,t+1}\right] {+} \lambda mc_t \tag{A.3}$$

where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

The effective terms of trade are defined as:

$$S_t = \frac{P_{F,t}}{P_{H,t}}$$

and taking logs as

$$s_t = p_{F,t} - p_{H,t} = e_t + p_t^* - p_{H,t} \tag{A.4}$$

since $P_{F,t} = e_t P_{F,t}^*$ and $P_{F,t} = P_t^*$ because the rest of the world work as a large economy.

The log-linearized version of the general price index equation (3.3) combined with the previous equation gives:

$$p_t = p_{H,t} + \alpha s_t \tag{A.5}$$

Then from equation (3.25) and taking logs:

$$q_t = e_t + p_t^* - p_t = p_{F,t} - p_t \tag{A.6}$$

Combining (A.4), (A.5) and (A.6) a relationship between the terms of trade and the real effective exchange rate of the following form follows:

$$q_t = (1-\alpha)\, s_t$$

Then finally writing equation (A.5) in differences results in:

$$\pi_t - \pi_{H,t} = \alpha\,(s_t - s_{t-1}) = \frac{\alpha}{1-\alpha}\,(q_t - q_{t-1}) \tag{A.7}$$

The complete system of log-linearized equations stems from equations (3.5), (3.6) or (3.7), (3.10) or (3.11), (3.12), (3.13), (3.17), (3.19), (3.20), (3.21), (3.22), (3.23), (3.24), (3.25), (3.26), (3.27), (A.3), (A.7) and (3.9) is as follows

A.1 $(w_t - p_t) = \sigma c_t + \varphi n_t + \left(\tau_t^C + \tau_t^N\right)$

A.2 $c_t{=}E_t\left[c_{t+1}\right]-\frac{1}{\sigma}\left(r_t - E_t\left[\pi_{t+1}\right] - \rho\right) + \frac{1}{\sigma}E_t\Delta\tau_{t+1}^C$

A.3 $r_t = r_t^* + (E_t e_{t+1} - e_t)$

A.4 $a_t{=}\rho_a a_{t-1}{+}\varepsilon_t^a$

A.5 $mc_t = rw_t + \frac{\alpha}{1-\alpha}q_t - a_t$

A.6 $g_t{+}\frac{1}{\beta}\left(rb_{H,t-1} + r_{t-1} - \pi_t\right){+}\frac{1}{\beta}\left(rb_{F,t-1} + r_{t-1} - \pi_t + e_t\right) =$

$$\left(\tau_t^C + c_t\right) + \left(\tau_t^N + rw_t + n_t\right) {+}rt_t{+}rb_{H.t}{+}\left(\varepsilon_t + rb_{F,t}\right)$$

A.7 $g_t{=}\rho_g g_{t-1} + \phi_{gb} b_t + \phi_{gy} y_t{+}\varepsilon_t^g$

A.8 $rt_t = \rho_\tau rt_{t-1} + \phi_{tb} b_t + \phi_{ty} y_t + \varepsilon_t^\tau$

A.9 $\tau_t^C = \rho_{\tau C} \tau_{t-1}^C + \phi_{tCb} b_t + \phi_{tCy} y_t + \varepsilon_t^{\tau C}$

A.10 $\tau_t^N = \rho_{\tau N} \tau_{t-1}^N + \phi_{tNb} b_t + \phi_{tNy} y_t + \varepsilon_t^{\tau N}$

A.11 $i_t = \delta_\pi \pi_{H,t} + \delta_y y_t + \delta_e e_t$

A.12 $y_t = (1 - s_G)[(1-\alpha)c_t + \alpha^* c_t^*] + s_G[(1-z)g_t + z^* g_t^*] + \eta[\frac{\alpha}{1-\alpha} + (1 - s_G)\alpha^* + s_G z^*]q_t$

A.13 $x_t = \alpha^* (1 - s_G) c_t^* + z^* s_G g_t^* + \eta \left(\frac{1}{1-\alpha}\right) q_t$

A.14 $\frac{f}{y} f_t = \frac{f}{y}[\frac{1}{\beta}(f_{t-1} + i_{t-1}^* - \pi_t^*)] + \frac{f}{y}[(\frac{1}{\beta} - 1)q_t] + \frac{b_F}{y}\frac{1}{\beta}(b_{F,t-1} + i_{t-1} - \pi_t) + \frac{b_F}{y}[(\frac{1}{\beta} - 1)e_t] - \frac{b_F}{y} b_{F,t} - nx_t$

A.15 $(q_t - q_{t-1}) = (e_t - e_{t-1}) + \pi_t^* - \pi_t$

A.16 $\pi_{H,t+1} = \beta E_t [\pi_{H,t+1}] + \lambda mc_t$

A.17 $\pi_t - \pi_{H,t} = \frac{\alpha}{1-\alpha} (q_t - q_{t-1})$

1. A.18 $rp_t = \chi_1 (b_t - b_{t-1}) + \chi_2 (e_t - e_{t-1})$

This system is completed with three equations defining the following foreign variables:

A.19 $\pi_t^* = 0$

A.20 $y_t^* = \rho_{y^*} y_{t-1}^* + \varepsilon_t^{y^*}$

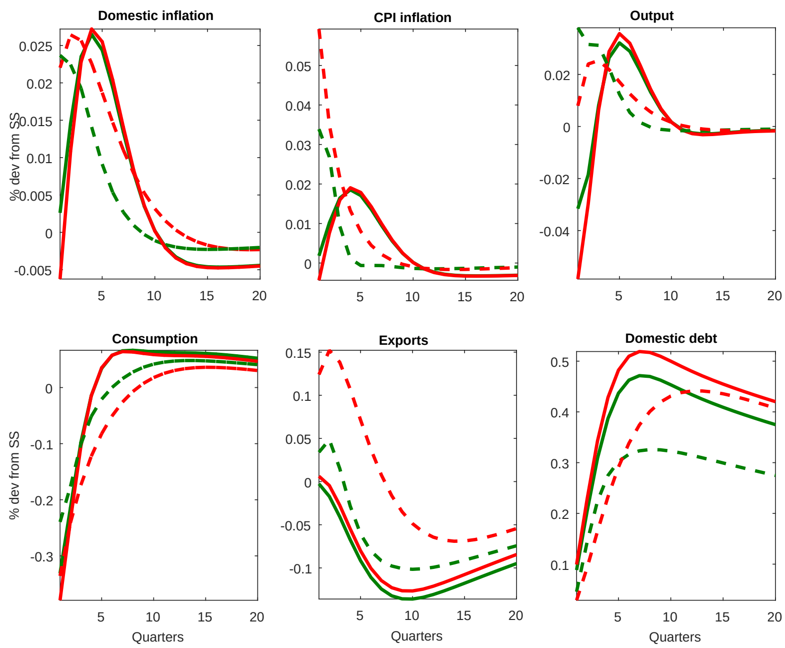
A.21 $g_t^* = \rho_{g^*} g_{t-1}^* + \varepsilon_t^{g^*}$

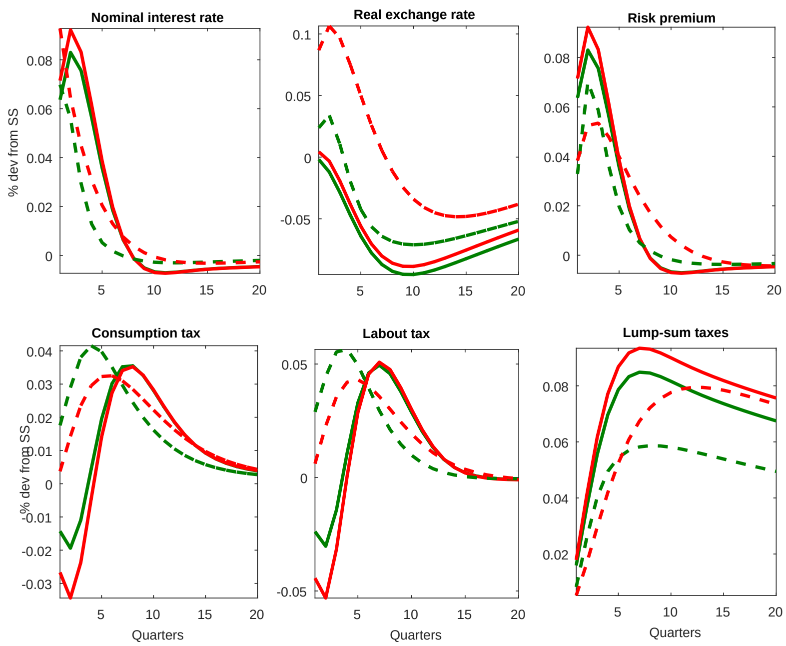
1. A.22 $r_t^* = \rho_r r_{t-1}^* + \varepsilon_t^{r*}$

or, in other words, we assume that the rest of the world has an inflation target as in A.19 and that the world output, government spending and interest rates behave as autoregressive processes of order 1.

Impulse responses

Figure 2.1 Government spending shock under fixed (solid lines) or flexible (dashed lines) exchange-rates with domestic (green lines) or foreign (red lines) denominated debt





Nominal interest rate
Real exchange rate
Risk premium
Consumption tax
Labout tax
Lump-sum taxes
% dev from SS
Quarters

Figure 2.2 Effects of a government spending shock under different risk premia

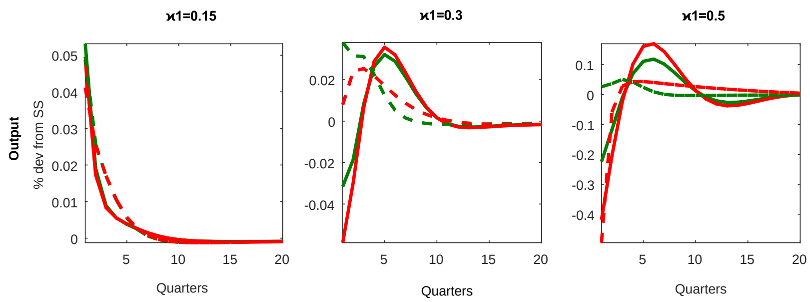


Figure 2.3 Consumption tax shock under fixed (solid lines) or flexible (dashed lines) exchange-rates with domestic (green lines) or foreign (red lines) denominated debt

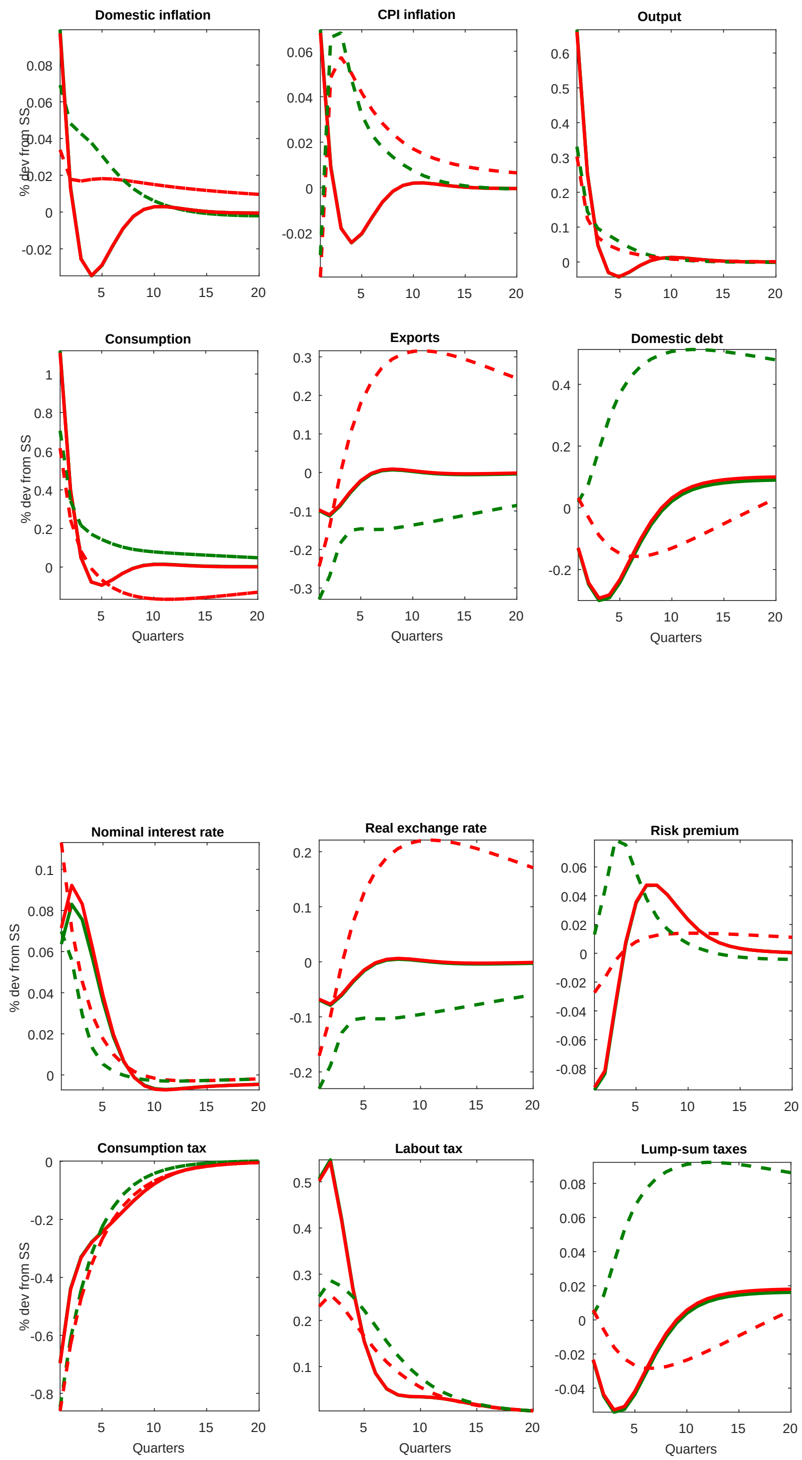
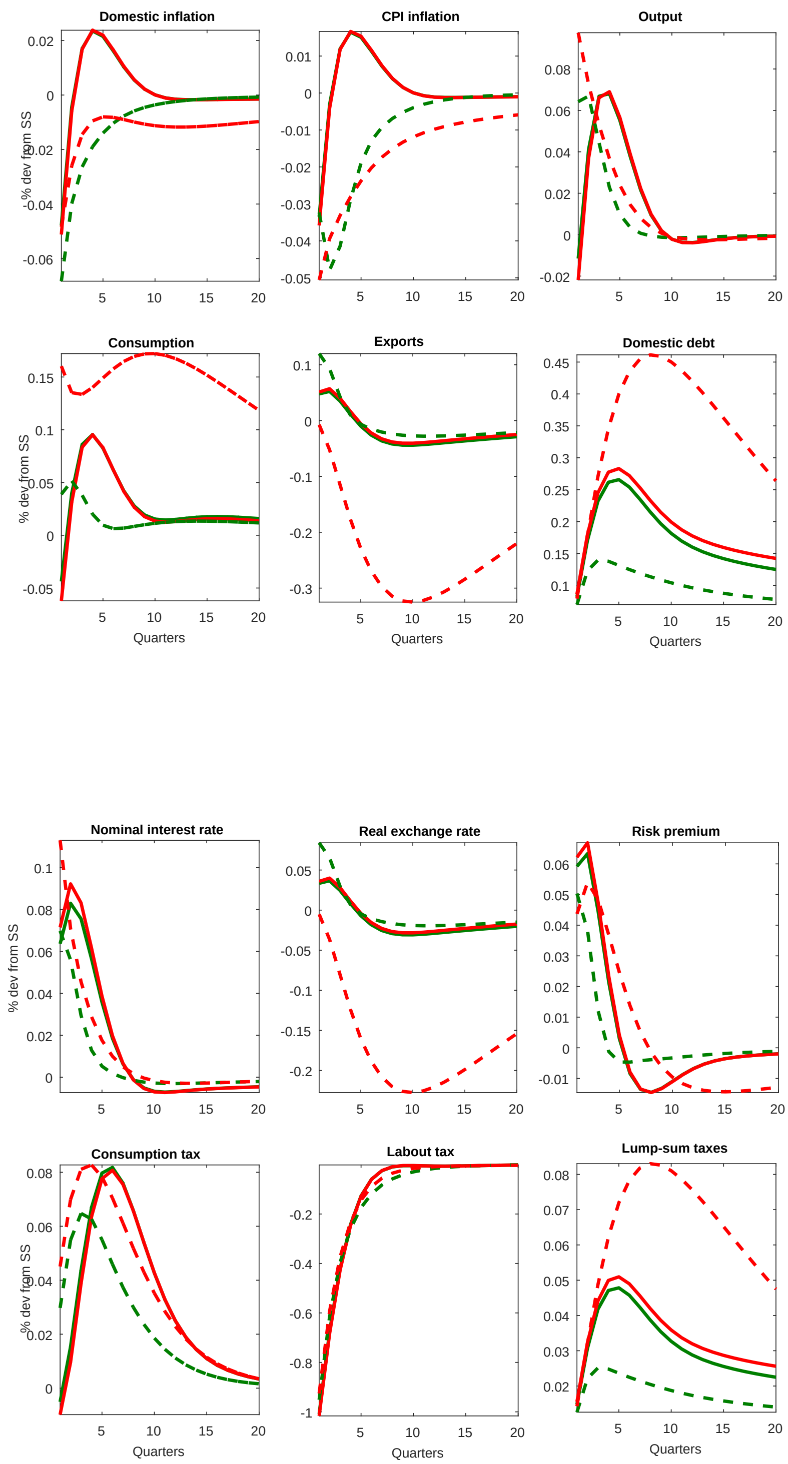


Figure 2.4 Labour tax shock under fixed (solid lines) or flexible (dashed lines) exchange-rates with domestic (green lines) or foreign (red lines) denominated debt



Appendix C

Appendix - Third chapter

Optimal tax and spending policy

Proof. *of Proposition 1.* Given some debt policy, the optimal tax and spending policy must satisfy (2.12) and

$$u_c \frac{\partial c}{\partial \tau} - u_l \frac{\partial L}{\partial \tau} + u_g \frac{\partial g}{\partial \tau} = 0$$

Using (2.11) and (2.3), the optimality condition for taxes becomes

$$0 = u_c \left[\frac{\frac{\partial gdp}{\partial \tau} (1+\tau) - gdp}{(1+\tau)^2} \right] - u_c \upsilon' (L) \frac{\partial L}{\partial \tau} + u_g \left[\frac{\left(gdp + \tau \frac{\partial gdp}{\partial \tau} \right) (1+\tau) - \tau gdp}{(1+\tau)^2} \right]$$

or equivalently,

$$u_c \left\{ -\frac{\partial \frac{1}{1+\tau}}{\partial \tau} gdp - \frac{1}{1+\tau} \frac{\partial gdp}{\partial \tau} + \upsilon' (L) \frac{\partial L}{\partial \tau} \right\} = u_g \left\{ -\frac{\partial \frac{1}{1+\tau}}{\partial \tau} gdp + \frac{\tau}{1+\tau} \frac{\partial gdp}{\partial \tau} \right\}$$

This condition has an interpretation in terms of marginal benefits and marginal costs of changing the tax rate. Variations in the government's tax policy are then seen to have three effects: a direct reallocation effect $\left(-\frac{\partial \frac{1}{1+\tau}}{\partial \tau} gdp > 0 \right)$, a budgetary effect $\left(\frac{\tau}{1+\tau} \frac{\partial gdp}{\partial \tau} < 0 \right)$ and an allocative effect $\left(-\frac{1}{1+\tau} \frac{\partial gdp}{\partial \tau} + \upsilon' (L) \frac{\partial L}{\partial \tau} > 0 \right)$. In detail, for given GDP, an increase in the tax rate allows to reallocate resouces from private to public consumption. However, this causes tax distortions which work to reduce GDP, the relevant tax base for the consumption tax, and thus has negative implications for the government's budget. Finally, there is an allocative effect, which trades off the tax implications in terms of reduced consumption and extra leisure. In conjunction, the three effects imply that the optimal fiscal policy limits distortions by keeping public expenditure below its first-best level: Since higher taxes affect GDP not only via lower labor supply, but also via lower imported inputs, the induced variation in GDP exceeds the variation in labor earnings (that is, the variation due to changes in labor supply for given w). Formally, from the labor supply condition (2.3),

$$-\frac{1}{1+\tau} \frac{\partial gdp}{\partial \tau} + \upsilon' (L) \frac{\partial L}{\partial \tau} = -\frac{1}{1+\tau} \frac{\partial gdp}{\partial \tau} + \frac{w}{1+\tau} \frac{\partial L}{\partial \tau} > 0$$

■

It is then immediate to verify that the above optimality condition for taxes implies $u_c < u_g$.