Fiscal policy in open economies: estimates for the Euro area

Lorenzo Forni and Massimiliano Pisani *

Abstract

We use a Bayesian open economy DSGE model to assess the quantitative effects of fiscal shocks on the trade balance in the euro area. We show that expansionary fiscal policy shocks - both those on the expenditure and revenue side - tend to deteriorate the trade balance while the effect on the real exchange rate depends on the specific shock. In particular, an increase in public consumption (1 percent of GDP) leads to an increase in the trade deficit by about 0.3 percentage points in the first year and to a real exchange rate appreciation. A comparable cut in labor income taxes (1 percent of GDP) leads to a slightly higher trade deficit (0.4 percentage points), driven by higher internal demand and import. In this case, the real exchange rate persistently depreciates. The effects of shocks to transfers and capital income taxes on the trade balance are instead rather small.

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*PRELIMINARY DRAFT. Usual disclaimers hold. E-mail address: lorenzo.forni@bancaditalia.it; massimiliano.pisani@bancaditalia.it.

1 Introduction

The analysis of the effects of fiscal shocks has recently attracted a vivid attention as the collapse of private demand has revived the use of discretionary fiscal policy in order to support aggregate demand. At the same time, there is still an open debate on the effectiveness of spending increase or tax cut in supporting private demand. These estimates have been made mainly on US data, as quarterly fiscal data for other countries are scarce. The uncertainty on the effects of fiscal shocks extend to the trade balance and the real exchange rate.

On this latter issues a number of studies on the US find some conflicting results. Kim and Roubini (2008) support the view that following a fiscal shock the real exchange rate depreciate (a result found also by Kollmann (2009) for G7 countries) and the trade balance improve. On the other, Monacelli and Perotti (2009), Ravn, Smitt-Groe and Uribe (2007) and, to a certain extent, Corsetti and Muller (2009) present evidence in favour of a worsening of the trade balance. Guerrieri et al(2005) using an open economy DSGE model calibrated to the US and the rest of the world, suggest that a fiscal expansion has a limited effect on the trade deficit as private sector consumption and investment (and therefore import) fall after the shock, partially compensating for the public stimulus.

The evidence regarding European or Euro area countries is more scarce. A recent contribution by Beetsma, Giuliodori and Klaassen (2008) present evidence on a panel of European countries using annual data. Their findings are in support of a worsening of the trade balance and a real exchange rate appreciation after a government expenditure shock. Moreover, the effect on the trade balance is be relevant: they estimate that an increase in public expenditures of 1% of GDP leads to a deterioration of the trade balance of between 0.5 and 1% in the first year.

This paper reconsiders the economic effects of fiscal policy in open economy. In particular, we try to understand what are the effects of fiscal shocks on the Euro area trade balance and real exchange rate. We build a new Keynesian small open economy model similar to Adolfson et al (2007) and Coenen et al (2009). Differently from them, and consistently with the goal of the paper, we introduce non-Ricardian agents that in each period consume all the available income, so to potentially account for Keynesian effects of public expenditure as in Gali et al (2007). We also introduce multiple fiscal rules, assuming that labor income tax rate, public consumption and public transfers to households can be appropriately and simultaneously modified by the fiscal authority to stabilize public debt. The range of tax rates includes also those on capital income and consumption, that follow a standard autoregressive process. To estimate the model we use the database on euro area fiscal variables (public expenditure and taxation) from Forni et al. (2009), while data for main aggregate variables are, consistently with similar contributions, from the Area Wide Model database.

Other features of the setup are standard. The small open economy is specialized in the production of a tradable good, produced under monopolistic competition regime using domestic labor and physical capital. We assume that the small open economy imports a tradable good from the rest of the world. Price of imports and exports are sticky in the currency of the destination market (we assume local currency pricing), so that the pass-through of nominal exchange rate into import prices is incomplete in the short-run. The small open economy trades a riskless bond, denominated in foreign currency, with the rest of the world. So the uncovered interest parity condition, linking the nominal interest rate differential to the expected nominal exchange rate depreciation, holds in the small open economy. For Ricardian households standard Euler equations determining interest-rate sensitive consumption and saving holds (Ricardian households accumulate physical capital and buy domestic and internationally traded bonds). As in Adolfson et al. (2007), we include all real and nominal frictions needed to guarantee a good fit of the data. We assume habit in consumption and adjustment costs on investment change, stickiness and indexation for nominal wage and prices. Finally, the monetary authority sets the nominal interest rate according to a standard Taylor rule.

Our results are the following. Expansionary fiscal policy shocks - both those on the expenditure and revenue side - tend to deteriorate the trade balance while the effect on the real exchange rate is ambiguous. In particular, our estimates suggest that an increase in public consumption (1 percent of GDP) leads to an increase in the trade deficit by about 0.3 percentage points in the first year. The main reason is a combination of real exchange appreciation, that strongly crowds out exports and of a relatively muted response of imports due to the gradual reduction in private demand. A comparable cut in labor income taxes (1 percent of GDP) leads to a slightly higher trade deficit (0.4 percentage points in the first year), driven by higher internal demand and import. In this case, the real exchange rate persistently depreciates. The effects of shocks to transfers and to capital income taxes on trade balance are rather small.

The remainder of this paper is organized as follows. Section 2 presents our basic open economy model. The calibration is discussed in Section 3. Section 4 reports our estimation results. Section 5 reports impulse response analysis. Section 6 discusses sentivity analysis. Section 7 concludes.

2 The Model

We develop a standard small open economy model, similar to recent contributions by Adolfson et al. (2007) and Coenen et al. (2008).[1] Differently from them, we include in the model rule-of-thumb agents and multiple fiscal policy rules on both expenditures and revenues, along the lines of Forni et al. (2009). Ricardian households maximize intertemporally an utility function consisting of consumption and leisure. Constrained agents, to the contrary, simply consume all their available income in each period. Consumption and investment baskets consist of domestically produced and imported goods. Pass-through of nominal exchange rate to import prices is incomplete in the short-run because of the assumption of nominal rigidities for imported and exported goods. Markets are incomplete, because we assume that only riskless bonds are traded domestically and at international level. In what follows, we initially describe the problems solved by firms and households

[1] Adolfson et al (2007) build on the work of Christiano et al. (2005) and extend their DSGE model to an open economy.

and then the behavior of the central bank, the fiscal authority, and the foreign economy.

2.1 Firms

Firms in the final goods sector produce three different types of goods under perfect competition. One type of good is used for private consumption, the other two respectively for private investment and public sector consumption.

Private consumption is a constant elasticity of substitution (CES) function consisting of domestically produced goods (C_H) and imported products (C_F):

$$C_t = \left[a_{HC}^{\frac{1}{\eta}} \left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + \left(1 - a_{HC}\right)^{\frac{1}{\eta}} \left(C_{F,t}\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{1}$$

where the parameter $0 < a_{HC} < 1$ is the share of domestic goods in consumption and the parameter η is the elasticity of substitution across consumption goods. Consumption C_H and C_F are composite of a continuum of, respectively, differentiated domestic (h) and imported (f) intermediate goods, each supplied by a different firm. They are produced according to the following CES functions, respectively

$$C_{H,t} = \left[\int_0^n C_{H,t}\left(h\right)^{\frac{\theta_{H,t}-1}{\theta_{H,t}}} dh \right]^{\frac{\theta_{H,t}}{\theta_{H,t}-1}}, \; C_{F,t} = \left[\int_n^1 C_{F,t}\left(f\right)^{\frac{\theta_{F,t}-1}{\theta_{F,t}}} df \right]^{\frac{\theta_{F,t}}{\theta_{F,t}-1}} \tag{2}$$

where $1 < \theta_{H,t} < \infty$ and $1 < \theta_{F,t} < \infty$ are the time-varying elasticity of substitution among domestic brands and among foreign brands, respectively. The parameter n is the size of the home economy (the size of the rest of the world is $(1 - n)$). The elasticities $\theta_{H,t}$ and $\theta_{F,t}$ are distributed according to the following log-linear autoregressive stochastic processes, respectively:[2]

$$\begin{aligned} \hat{\theta}_{H,t} &= \rho_{\theta_H} \hat{\theta}_{H,t-1} + \hat{\varepsilon}_{\theta_{H,t}}, \quad \hat{\varepsilon}_{\theta_{H,t}} \overset{iid}{\sim} N(0, \sigma^2_{\theta_H}) \\ \hat{\theta}_{F,t} &= \rho_{\theta_F} \hat{\theta}_{F,t-1} + \hat{\varepsilon}_{\theta_{F,t}}, \quad \hat{\varepsilon}_{\theta_{F,t}} \overset{iid}{\sim} N(0, \sigma^2_{\theta_F}) \end{aligned}$$

Similar bundles hold for investment:

$$I_t = \left[a_{HI}^{\frac{1}{\eta}} \left(I_{H,t}\right)^{\frac{\eta-1}{\eta}} + \left(1 - a_{HI}\right)^{\frac{1}{\eta}} \left(I_{F,t}\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{3}$$

$$I_{H,t} = \left[\int_0^n I_{H,t}\left(h\right)^{\frac{\theta_{H,t}-1}{\theta_{H,t}}} dh \right]^{\frac{\theta_{H,t}}{\theta_{H,t}-1}}, \; C_{F,t} = \left[\int_n^1 I_{F,t}\left(f\right)^{\frac{\theta_{F,t}-1}{\theta_{F,t}}} df \right]^{\frac{\theta_{F,t}}{\theta_{F,t}-1}} \tag{4}$$

For public expenditure, we assume it is fully biased towards domestic goods. The implied basket is:

[2] A hat denotes log-deviation from the corresponding steady-state level: $\hat{X}_t = \ln X_t - \ln \bar{X}$.

$$G_t = \left[\int_0^n G_{H,t}(h)^{\frac{\theta_{H,t}-1}{\theta_{H,t}}} dh \right]^{\frac{\theta_{H,t}}{\theta_{H,t}-1}}$$

The production function for the generic intermediate good h is

$$Y_{H,t}(h) = z_t^{1-\alpha} \epsilon_t K_t(h)^\alpha L_t(h)^{1-\alpha} \tag{5}$$

where z_t is a unit-root technology shock capturing world productivity, ϵ_t is a domestic stationary technology shock, both common to all firms. The variable $K(h)$ denotes physical capital stock, rented from domestic households in a competitive market. The stationary technology shock ϵ, expressed in log-deviations from its steady state value, follows an autoregressive process:

$$\hat{\epsilon}_t = \rho_\epsilon \hat{\epsilon}_{t-1} + \hat{\varepsilon}_{\epsilon,t}, \quad \hat{\varepsilon}_{\epsilon,t} \overset{iid}{\sim} N(0, \sigma_\epsilon^2)$$

The growth rate of the unit-root technology follows a similar log-linear process:

$$\hat{\mu}_{z,t} = \rho_z \hat{\mu}_{z,t} + \hat{\varepsilon}_{z,t}, \quad \hat{\varepsilon}_{z,t} \overset{iid}{\sim} N(0, \sigma_z^2)$$

where

$$\hat{\mu}_{z,t} \equiv \frac{z_t}{z_{t-1}} - 1$$

The variable $L(h)$ is a composite of a continuum of differentiated labor inputs, each supplied by a different domestic household under monopolistic competition:

$$L_t(h) = \left[\int_0^n L_t(i)^{\frac{\theta_{L,t}-1}{\theta_{L,t}}} di \right]^{\frac{\theta_{L,t}}{\theta_{L,t}-1}} \tag{6}$$

where $1 \leq \theta_{L,t} < \infty$ is the time-varying elasticity of substitution between labor varieties, which is distributed accordingly to the following log-linear autoregressive process:

$$\hat{\theta}_{L,t} = \rho_{\theta_L} \hat{\theta}_{L,t-1} + \hat{\varepsilon}_{\theta_L,t}, \quad \hat{\varepsilon}_{\theta_L,t} \overset{iid}{\sim} N(0, \sigma_{\theta_L}^2)$$

Each firm i minimizes its production costs. The resulting nominal marginal cost is:

$$MC_t = \frac{1}{z_t^{1-\alpha} \epsilon_t \alpha^\alpha (1-\alpha)^\alpha} \left(R_t^K\right)^\alpha W_t^{1-\alpha} \tag{7}$$

where R_t^k is the gross nominal rental rate of capital and W_t the nominal wage rate (corresponding to the price of the bundle $L_t(h)$).

Each of the domestic goods is sold domestically and abroad subject to market specific cost of adjusting the price à la Rotemberg (1982).[3] Prices are sticky in the currency of the destination market (local currency pricing) and so exchange rate pass-through into

[3]Adolfson et al (2007) use a variant of the Calvo (1983) model. It is possible to show that, up to first order, there is a one-to-one mapping between Calvo and Rotemberg models (see [..]). So results are not affected by the choice of the pricing scheme.

import prices is incomplete in the short run.[4] In any period, each intermediate firm can reoptimize its domestic and foreign prices, $P_{H,t}(i)$ and $P^*_{H,t}(i)$ respectively, subject to quadratic adjustment costs in the form of a CES basket of all goods in the same (domestic and exporting) sector of the economy:

$$AC_{H,t}(h) \equiv \frac{\kappa_H}{2}\left(\frac{P_{H,t}(h)/P_{H,t-1}(h)}{\pi_{H,t-1}^{\alpha_H}\bar{\pi}_t^{1-\alpha_H}} - 1\right)^2 Y_{H,t} \tag{8}$$

$$AC_{H,t}(h) \equiv \frac{\kappa_H^*}{2}\left(\frac{P^*_{H,t}(h)/P^*_{H,t-1}(h)}{\left(\pi^*_{H,t-1}\right)^{\alpha_H^*}\left(\bar{\pi}_t^*\right)^{1-\alpha_H^*}} - 1\right)^2 Y^*_{H.t} \tag{9}$$

where $\kappa_H, \kappa_H^*, \geq 0$ are price adjustment cost parameters in the domestic and foreign economy, respectively. The parameters $0 \leq \alpha_H \leq 1$ and $0 \leq \alpha_H^* \leq 1$ measures the degree of indexation, respectively in the Home and Foreign economy. Specifically, we assume $(1-\alpha_H)$ measures the degree of indexation to the current period central bank time-varying inflation target $(\bar{\pi})$ and α_H to last period's sector-specific inflation rate $\pi_{H,t-1}$ $(\pi_{H,t} = P_{H,t}/P_{H,t-1})$. A similar interpretation holds for α_H^*.

The profit maximization problem yields two standard log-linearized market-specific Phillips curve:

$$\hat{\pi}_{H,t} - \alpha_H \tag{10}$$

$$hatpi_{H,t-1} - (1-\alpha_H)\,\hat{\bar{\pi}}_t \tag{11}$$

$$\begin{aligned}
&= \beta E_t\left(\hat{\pi}_{H,t+1} - \alpha_H\hat{\pi}_{H,t} + (1-\alpha_H)\,\hat{\bar{\pi}}_{t+1}\right) \\
&\quad -\frac{(\theta_H - 1)}{p_H\kappa_H^p}\widehat{p}_{H,t} + \frac{(\theta_H-1)}{\kappa_H^p}\widehat{rmc}_t + \hat{\lambda}_{\theta_H,t}
\end{aligned}$$

$$\hat{\pi}^*_{H,t} - \alpha_H^*\pi^*_{H,t-1} - (1-\alpha_H^*)\,\hat{\bar{\pi}}^*_t \tag{12}$$

$$\begin{aligned}
&= \beta E_t\left(\hat{\pi}^*_{H,t+1} - \alpha_H^*\hat{\pi}^*_{H,t} + (1-\alpha_H^*)\,\hat{\bar{\pi}}^*_{t+1}\right) \\
&\quad -\frac{(\theta_H - 1)}{p_H^*\kappa_H^{p*}}\widehat{p}^*_{H,t} + \frac{(\theta_H-1)}{\kappa_H^{p*}}\widehat{rmc}_t - \frac{(\theta_H-1)}{\kappa_H^{p*}}\widehat{rer}_t + \hat{\theta}^*_{H,t}
\end{aligned}$$

where β is the discount factor of the home Ricardian representative household (see next sections for more details), $\widehat{p}_{H,t}$ $(\widehat{p}^*_{H,t})$ is the relative price, with respect to local consumption basket of home tradable in the home (foreign) market, $\widehat{rmc}_t$ is the real marginal cost and $\widehat{rer}_t$ is the real exchange rate, defined (in levels) as the ratio of consumption prices expressed in the same currency:

$$RER_t \equiv \frac{S_t P_t^*}{P_t} \tag{13}$$

where S_t is the bilateral nominal exchange rate (expressed in home currency units) and P_t (P_t^*) is the home (foreign) consumption-based price level.

[4] See also Smets and Wouters (2002).

2.2 Ricardian Households

There is a continuum ($0 \leq j \leq \left(1-\lambda^{NR}\right)n$, with $0 \leq \lambda^{NR} \leq 1$) of households that maximize utility subject to a standard budget constraint. The preferences of household j are given by

$$E_t\left[\sum_{k=0}^{\infty}\beta^k\left(\xi_{t+k}^C\log\left(C_{t+k}(j)-bC_{J,t+k-1}\right)-\frac{\xi_{t+k}^L}{1+\sigma_L}\left(L_{t+k}(j)\right)^{1+\sigma_L}\right)\right] \tag{14}$$

where $C(j)$ and $L(j)$ are respectively the j-th household's levels of consumption and labor supply, each of them subject to a persistent preference shock, ξ^C and ξ^Lrespectively. The parameter b ($0 \leq b \leq 1$) measures the degree of external habit formation in consumption (C_J is the consumption level of the home ricardian representative agent), while $1/\sigma_L$ is the labor Frisch elasticity. The two shocks are distributed according to the following autoregressive processes:

$$\begin{aligned}
\hat{\xi}_t^C &= \rho_{\xi^C}\hat{\xi}_t^C+\hat{\varepsilon}_{\xi^C,t}, \quad \hat{\varepsilon}_{\xi^C,t}\overset{iid}{\sim}N(0,\sigma_{\xi^C}^2) \\
\hat{\xi}_t^L &= \rho_{\xi^L}\hat{\xi}_t^L+\hat{\varepsilon}_{\xi^L,t}, \quad \hat{\varepsilon}_{\xi^L,t}\overset{iid}{\sim}N(0,\sigma_{\xi^L}^2)
\end{aligned}$$

Ricardian households can save in domestic and foreign riskless bonds, respectively $B_{H,t}$ and $B_{F,t}$ as well as in physical capital K_t. Domestic bonds are denominated in domestic currency and are traded with domestic government, while foreign bonds are denominated in foreign currency and are traded between domestic ricardian households and the rest of the world. The resulting budget constraint is as following:

$$\begin{aligned}
& B_t(j)+S_tB_t^*(j)-B_{t-1}(j)R_{t-1}-S_tB_{t-1}^*(j)R_{t-1}^*\Phi\left(a_{t-1},\tilde{\phi}_{t-1}\right) \\
= & \left(1-\tau_t^w\right)W_t(j)N_t(j)+\left(1-\tau_t^k\right)\left(R_{K,t}K_{i,t-1}(j)+\frac{\Pi_t}{n\left(1-\lambda^{NR}\right)}\right) \\
& +TR_t(j)-\left(1+\tau_t^c\right)P_{C,t}C_{i,t}(j)-P_{I,t}I_{i,t}(j)-\Gamma_W(j)
\end{aligned}$$

where R and R^* are respectively the gross nominal interest rates on domestic and foreign bonds. The term Φ is a premium that depends on the net foreign asset position of the home economy (a, see below) and ensures a well-defined steady-state.[5] The variables τ_t^w, τ_t^k, τ_t^c represent taxes on labor income (W_tN_t), capital income ($R_{K,t}K_{t-1}$, where R_k is the gross rental rate of capital and Π_t are total profits for ownership of domestic firms, equally distributed across households) and consumption, respectively. The variable $TR_t(j)$ represents lump-sum transfers from the public sector. The households can invest ($I_{i,t}$) in additional physical capital ($K_{i,t}$) undertaking a quadratic adjustment cost. The implied capital accumulation equation is

[5] See Benigno (2009) and Schmitt-Grohé and Uribe (2001). The cost implies that domestic households are charged a premium over the foreign interest rate R_t^* if the net foreign asset position of the country is negative, and receive a lower remuneration if the net foreign asset position is positive.

$$K_t(j) = (1-\delta) K_{t-1}(j) + \left(1 - \frac{\gamma_I}{2}\left(\frac{\Upsilon_t I_t(j)}{I_{t-1}(j)} - 1\right)^2\right) I_t(j) \tag{15}$$

where Υ_t is a stationary autoregressive investment-specific technology shock. Finally, each household is a monopoly supplier of a differentiated labor service. He choose its own wage given labor demand by domestic firms and subject to Rotemberg-type wage adjustment costs Γ_W, whose functional form is:

$$\Gamma_W(j) \equiv \frac{\kappa_W}{2}\left(\frac{W_t(j)/W_{t-1}(j)}{\pi_{W,t-1}^{\alpha_W}\bar{\pi}_t^{1-\alpha_W}} - 1\right)^2 L_t$$

where $\kappa_W \geq 0$ is the wage adjustment cost parameter , α_W $(0 \leq \alpha_W \leq 1)$ is a parameter that measures indexation to the wage inflation rate in the previous period and the current inflation target of the central bank, while L is the bundle of labor varieties (6).

From the two first order conditions with respect to the two bond positions $B_t(j)$ and $B_t^*(j)$ we get a modified uncovered interest parity condition. The latter links the interest rate differential, comprehensive of the premium $\Phi\left(a_{t-1}, \tilde{\phi}_{t-1}\right)$ on the foreign bond holdings, to the expected exchange rate changes. The premium $\Phi\left(a_t, \tilde{\phi}_t\right)$ is given by

$$\Phi\left(a_t, \tilde{\phi}_t\right) = \exp\left(-\tilde{\phi}_a(a_t - \bar{a}) + \tilde{\phi}_t\right)$$

where $a_t \equiv S_t B_t^* / (P_t z_t)$ is the net foreign asset position and $\tilde{\phi}_t$ is a shock to the risk premium distributed as follows:

$$\widehat{\tilde{\phi}}_t = \rho_{\xi^C}\tilde{\phi}_t + \hat{\varepsilon}_{\xi^{\tilde{\phi}},t}, \quad \hat{\varepsilon}_{\xi^{\tilde{\phi}},t} \overset{iid}{\sim} N(0, \sigma^2_{\xi^{\tilde{\phi}}})$$

2.3 Non-Ricardian Agents

We assume a share of Home households $(\left(1-\lambda^{NR}\right) n < j' < n)$ are non-Ricardian. Non-Ricardian households are modeled in various ways in the literature, leading to different responses of their consumption to changes in their current disposable income. Some authors have assumed that non-Ricardian households cannot participate in capital markets, but they can still smooth consumption by adjusting their holding of money (consumption smoothing will be less than complete as the return from money holding has a negative real return).[6] Other authors have shown that assumptions implying stronger responses of non-Ricardian agent's consumption to variations in disposable income are necessary in order to allow for the possibility of obtaining a positive response of private consumption to government expenditure shocks. In particular, following Campbell and Mankiw (1989), Gali' *et al.* (2007) assume that in each period non-Ricardian agents consume their current income; in their work, the strong response of non-Ricardian consumption to disposable

[6] In this latter case, Coenen, McAdam and Straub (2008) show it is very difficult to get a non negative response of private consumption to a government expenditure shock as the response of non-Ricardian consumers is very similar to that of Ricardian households.

income variations is a necessary condition (but not sufficient) to obtain a positive response of total consumption to government spending shocks. In this paper we follow this latter approach and assume that non-Ricardian households simply consume their after-tax disposable income, as originally proposed by Campbell-Mankiw (1989), which consists of labor income plus net lump-sum transfers from the government:

That is, their budget constraint is simply:

$$P_t C_t(j') = (1 - \tau_t^W) W_t(j^{'}) L_t(j') + TR_t(j') \tag{16}$$

Note that this modeling of non-Ricardian households does not impose a positive response of total private consumption to government expenditure shocks. The response will depend, among other things, on the value of the share of non-Ricardian households, λ_t^{NR} (see the below robustness section for a discussion of this point). The composition of the consumption bundle is the same as in equation (1). The NR households set their wage to be the average wage of the optimizing households. Since NR households face the same labor demand schedule as the optimizing households, each NR household works the same number of hours as the average for optimizing households.

2.4 Central bank

The monetary policy specification is in line with Smets and Weuters (2003) and assumes that the central bank follows an augmented Taylor interest rate feedback rule characterized by a response of the nominal rate R_t to its lagged value, to the gap between lagged gross consumer price inflation inflation π_t^c ($\pi_t^c = P_t/P_{t-1}$) and steady state (or targeted) inflation $\bar{\pi}_t^c$, to the gap between contemporaneous (detrended) output y_t and its steady state value, to changes in inflation $\Delta\pi_t^C = \pi_t^c/\pi_{t-1}^c$ and to output growth $\Delta y_t = y_t/y_{t-1}$.In log-linearized form we have:

$$\begin{aligned} \hat{R}_t &= \rho_R \hat{R}_{t-1} + (1-\rho_R)\left(\hat{\bar{\pi}}_t^c + r_\pi\left(\hat{\pi}_{t-1}^c - \hat{\bar{\pi}}_t^c\right) + r_y \hat{y}_t\right) \\ &\quad + r_{\Delta\pi}\Delta\hat{\pi}_t^C + r_{\Delta y}\Delta\hat{y}_t + \varepsilon_{R,t} \end{aligned} \tag{17}$$

where $\varepsilon_{R,t}$ is an uncorrelated monetary policy shock with variance σ_R^2 and $\hat{\bar{\pi}}_t^c$ is a shock to the monetary authority target, distributed according to the following AR(1) process:

$$\hat{\bar{\pi}}_t^c = \rho_{\bar{\pi}} \hat{\bar{\pi}}_t^c + \hat{\varepsilon}_{\bar{\pi},t}, \quad \hat{\varepsilon}_{\bar{\pi},t} \overset{iid}{\sim} N(0, \sigma_{\bar{\pi}}^2)$$

2.5 Fiscal Policy

We consider the following budget constraint:

$$\left[B_t^G - B_{t-1}^G R_{t-1}\right] = P_{H,t}\left(1 + \tau_t^C\right) G_t + TR_t - T_t \tag{18}$$

where $B_t^G > 0$ is the public debt. We assume it is traded with domestic Ricardian agents only. The variable G_t is government consumption (we assume that the public sector buys only domestic goods and that pays the related consumption tax rate τ_t^C), TR_t are transfers to households and T_t are taxes. We assume that the stationary components of government purchases and transfers expressed in real terms (deflated by domestic consumer prices), respectively g an tr, follows the rules below:

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + (1-\rho_g)\eta_g \widehat{\widetilde{B}}_t + \varepsilon_{g,t}, \quad \hat{\varepsilon}_{g,t} \overset{iid}{\sim} N(0,\sigma_g^2) \tag{19}$$

$$\widehat{tr}_t = \rho_{tr} \widehat{tr}_{t-1} + (1-\rho_{tr})\eta_{tr} \widehat{\widetilde{B}}_t + \varepsilon_{tr,t}, \quad \hat{\varepsilon}_{tr,t} \overset{iid}{\sim} N(0,\sigma_{tr}^2) \tag{20}$$

where $\widehat{\widetilde{B}}_t = (\ln B_t^G/P_t - \ln(B^G/P))$ is the (stationary component of) public debt expressed in real terms, the parameters $0 \leq \rho_g \leq 1$ and $0 \leq \rho_{tr} \leq 1$ measure the inertia in changing the correspondent fiscal variables and both $\varepsilon_{g,t}$ and $\varepsilon_{tr,t}$ are i.i.d. innovations. Finally, the parameters $\eta_g > 0$ and $\eta_{tr} > 0$ measure the response of, respectively, government consumption and public transfers to public debt. Consistently with the existing empirical evidence on euro area, we assume that the labor income tax rate is determined according to the following rule:

$$\hat{\tau}_t^w = \rho_{\tau^w} \hat{\tau}_{t-1}^w + (1-\rho_{\tau^w})\eta_{\tau^w} \widehat{\widetilde{B}}_t + \hat{\varepsilon}_{\tau^w,t}, \quad \hat{\varepsilon}_{\tau^w,t} \overset{iid}{\sim} N(0,\sigma^2_{\varepsilon_{\tau^w,t}}) \tag{21}$$

while tax rates on capital income and consumption follow an exogenous AR(1) process

$$\hat{\tau}_t^k = \rho_{\tau^k} \hat{\tau}_{t-1}^k + \hat{\varepsilon}_t^{\tau^k}, \quad \hat{\varepsilon}_{\tau^k,t} \overset{iid}{\sim} N(0,\sigma^2_{\varepsilon_{\tau^k,t}}) \tag{22}$$

$$\hat{\tau}_t^c = \rho_{\tau^c} \hat{\tau}_{t-1}^c + \hat{\varepsilon}_t^{\tau^c}, \quad \hat{\varepsilon}_{\tau^c,t} \overset{iid}{\sim} N(0,\sigma^2_{\varepsilon_{\tau^c,t}}) \tag{23}$$

Total taxes T are given by the following identity:

$$\begin{aligned} T_t \equiv\ & \tau_t^w W_t n L_t + \tau_t^c \left(P_t\left(1-\lambda^{NR}\right) nC_t + P_t \lambda^{NR} nC_t + P_{H,t} G_t\right) \\ & + \tau_t^k R_t^k \left(1-\lambda^{NR}\right) K_{t-1} + \tau_t^k \Pi_t \end{aligned} \tag{24}$$

where Π_t are total profits in the economy. Note we assume that τ_t^w is the same for both Ricardian and non-Ricardian households.

2.6 Foreign Economy

The setup of the foreign economy is stylized so to get a parsimonious model. We assume there is a Euler equation for aggregate demand (without making any distinction between consumption and investment), two Philips curves (one holds domestically and the other in the Home country, because we assume that local currency pricing holds also for foreign firms) a Taylor rule reacting to domestic inflation and total output. Finally, we also assume that the foreign aggregate demand is a CES bundle of foreign and home goods, with weights respectively a_{F^*} and $(1-a_{F^*})$ and elasticity of substitution η. The chosen calibration (see next section) implies that the foreign economy is substantially closed and spillovers from the euro area are small, consistently with the assumption of small open economy.

Specifically, we add the following set of log-linear equations to those holding for the home economy:[7]

$$\hat{\lambda}_t^* = \hat{\lambda}_{t+1}^* + \hat{r}_t^* - \hat{\pi}_{t+1}^* \tag{25}$$

$$\hat{\lambda}_t^* = \frac{1}{1-h^* g_z^{-1}}\widehat{ad}_t^* + \frac{h^* g_z^{-1}}{1-h^* g_z^{-1}}\widehat{ad}_{t-1}^* - \frac{h^* g_z^{-1}}{1-h^* g_z^{-1}}\hat{\mu}_{z,t} + \hat{\epsilon}_t^{ad*} \tag{26}$$

$$(1-n) y_F^* \hat{y}_{F,t}^* = -\phi(1-n) y_F^* \hat{p}_{F,t}^* + \gamma_F^* ad^* \widehat{ad}_t^* \tag{27}$$

$$n y_H^* \hat{y}_{H,t}^* = -\phi n y_H^* \hat{p}_{H,t}^* + (1-\gamma_F^*)\, ad^* \widehat{ad}_t^* \tag{28}$$

$$\begin{aligned} \hat{R}_t^* &= \rho_R^* \hat{R}_{t-1}^* + (1-\rho_R^*)\left(\widehat{\overline{\pi}}_t^{c*} + r_\pi^* \left(\hat{\pi}_{t-1}^{c*} - \widehat{\overline{\pi}}_t^{c*}\right) + r_y^* \hat{y}_t^*\right) \\ &\quad + r_{\Delta\pi}^* \Delta\hat{\pi}_t^{C*} + r_{\Delta y}^* \Delta\hat{y}_t^* + \varepsilon_{R,t}^* \end{aligned} \tag{29}$$

$$\begin{aligned} &\hat{\pi}_{F,t} - \alpha_F \hat{\pi}_{F,t-1} - (1-\alpha_F)\widehat{\overline{\pi}}_t \\ = \ &\beta E_t\left(\hat{\pi}_{F,t+1} - \alpha_F \hat{\pi}_{F,t} + (1-\alpha_F)\widehat{\overline{\pi}}_{t+1}\right) \\ &- \frac{(\theta_F - 1)}{\kappa_F^p}\widehat{p}_{F,t} - \frac{(\theta_F - 1)}{\kappa_F^p}\lambda_t^* + \frac{(\theta_F - 1)}{\kappa_F^p} ad_t^* + \hat{\theta}_{F,t} \end{aligned} \tag{30}$$

$$\begin{aligned} &\widehat{\pi}_{F,t}^* - \alpha_F^* \hat{\pi}_{F,t-1}^* - (1-\alpha_F^*)\widehat{\overline{\pi}}_t^* \\ = \ &\beta E_t\left(\hat{\pi}_{F,t+1}^* - \alpha_F^* \hat{\pi}_{F,t}^* + (1-\alpha_F^*)\widehat{\overline{\pi}}_{t+1}^*\right) \\ &- \frac{(\theta_F^* - 1)}{\kappa_F^*}\widehat{p}_{F,t}^* - \frac{(\theta_F^* - 1)}{\kappa_F}\lambda_t^* + \frac{(\theta_F^* - 1)}{\kappa_F^*} ad_t^* - \frac{(\theta_F^* - 1)}{\kappa_F^{p*}}\widehat{rer}_t + \hat{\theta}_{F,t}^* \end{aligned} \tag{31}$$

The first equation is the euler condition for foreign aggregate demand (we do not distinguish between foreign consumption and investment). The second equation defines the Lagrange multiplier λ^* in terms of foreign aggregate demand and a shock $\hat{\epsilon}_t^{ad*}$following a standard AR(1) process. The parameter h^* measure habit in aggregate demand. The third and fourth equations are market clearing conditions for foreign and home good in the foreign country, respectively. The fifth equation is the monetary policy rule. Finally, the last two equations are the Phillips curves of the foreign good in the home and foreign market, respectively. We assume that the marginal cost is directly proportional to foreign aggregate demand (the weight of exports to the home country in the total demand of foreign good is negligible) and inversely proportional to the Lagrange multiplier. We assume that the shocks to foreign aggregate demand, to foreign good markup in the home and foreign market and to foreign monetary target follow log-linear AR(1) processes. The monetary policy shock is assumed to be i.i.d.

[7] Our main results do not change when we assume a VAR representation of the foreign economy as in Adolfson et al. (2007).

2.7 The trade balance of the Home economy

The trade balance is obtained by consolidating the private sector aggregate budget constraint and the government budget constraint, taking into account that the public debt is traded only with home Ricardian households and it's not internationally traded. Assuming that a symmetric equilibrium holds (so that there is a representative agent for each type of households, Ricardian and non-Ricardian), the resulting trade balance is as follows:

$$\begin{aligned} TB_t &= S_t n B_t^* - S_t n B_{t-1}^* - S_t n B_{t-1}^* (j) R_{t-1}^* \Phi \left(a_{t-1}, \tilde{\phi}_{t-1} \right) \\ &= P_{H,t} n Y_{H,t} + S_t P_{H,t}^* n Y_{H,t}^* - P_t n \left(1 - \lambda^{NR} \right) C_t - P_{I,t} n \left(1 - \lambda^{NR} \right) I_t - P_H G_t \\ &= S_t P_{H,t}^* n Y_{H,t}^* - P_{F,t} (1-n) Y_{F,t} \end{aligned}$$

The first equality expresses the trade balance as the result of the change in the net foreign asset position. The second equality as the difference between total aggregate revenues from production and total aggregate expenditures. Finally, the third equality is net exports, both expressed in domestic currency. The ratio of import-to-export prices, both expressed in home currency, defines the home terms of trade:

$$tot_t \equiv \frac{P_{F,t}}{S_t P_{H,t}^*} = \frac{p_{F,t}}{rer_t p_{H,t}^*}$$

where rer is the home real exchange rate (see equation (13)) while $p_{F,t}$ and $p_{H,t}$ are prices of home imports and exports expressed respectively in terms of home and foreign consumption.

3 Data

We use quarterly Euro area data for the period 1980:1–2005:4 to estimate the model. We match the following twenty variables: GDP, consumption, investment, government consumption, exports, imports, the real exchange rate, the short-run interest rate, wage inflation, employment, the GDP deflator, the consumption deflator, the investment deflator, transfers to families, public transfers, average effective tax rate on labor, average effective tax rate on capital, foreign output, foreign inflation and the foreign interest.

Data are from the Area Wide Model data set and, for fiscal variables, from Forni et al. (2009).[8] In the AWM data set export and import series include both intra- and extra-area trade and there is no series on aggregate hours worked. The exchange rate is the ECB's official effective exchange rate for the 12 main trading partners of the Euro area with weights based on 1995–1997 manufactured goods trade.[9] The data set also includes foreign output and prices (weighted average of, respectively, the GDP and GDP deflator series for the U.S., the United Kingdom, Japan and Switzerland). It does not include

[8] For details on the AWM dataset see Fagan et al.(2005).

[9] See Adolfson et al. (2006).

data on foreign interest rate and euro area hours worked. Regarding the former, the Fed funds rate is used as a proxy. For hours worked we use employment, which we model using a Calvo-rigidity equation:[10]

$$\hat{E}_t = \frac{\beta}{1+\beta} E_t \left[\hat{E}_{t+1} \right] + \frac{1}{1+\beta} \hat{E}_{t-1} + \frac{(1-\beta\xi_E)(1-\xi_E)}{(1+\beta)\xi_E} \left(\hat{N}_t - \hat{E}_t \right)$$

where $1 - \xi_E$ is the fraction of firms that can adjust the (log-linear) level of employment $\hat{E}$ to the preferred amount of total labor input $\hat{N}$.

Estimates concerning the effects of fiscal policy for the Euro area are usually constrained by the lack of quarterly data on government accounts. Eurostat has recently started to release quarterly data on general government accounts, but only starting from 1999, i.e. a period too short to be used for our purposes. As we use quarterly data for government consumption, transfers to families and average effective tax rates, we can model the fiscal policy block with more detail than previous work. First, we can distinguish within expenditures and revenues. Moreover, estimating average effective tax rates allows us to use proportional distortionary taxation, a feature that is more realistic, and more appropriate for estimation purposes than assuming lump-sum taxes.

The assumption of non stationary technology shock implies a common stochastic trend in the real variables. We make them stationary by using first log-differences. We remove a linear trend from the employment and public expenditures. We also remove an excessive trend of import and export (with respect to output) series, to make the correspondent shares stationary.[11] Employment, tax rates, public expenditure and the real exchange rate are measured as percentage deviations around the mean. For all other variables, we use the seasonally adjusted series, without demeaning.

Finally, consumption and investment aggregates in the model are CES composites of domestic and imported goods. This assumption does not hold in the data. We take into account of it when estimating the model by constructing data-consistent consumption and investment variables.[12]

4 Estimation

In what follows we describe calibrated parameters and the prior distributions of estimated parameters. The model is estimated with Bayesian methods (a posterior distribution of the model is obtained by updating the information contained in the prior distribution with the information in the observed data).

[10]See Smets and Wouters (2003).
[11]See Adolfson et al. (2005).
[12]See Adolfson et al. (2005) for details.

4.1 Calibrated parameters

We calibrate parameters that allow to match the sample mean of observed variables and those that are weakly identified. In Table 1 we report both the calibrated parameters and in Table 2 the implied steady state values of main variables.

Following Coenen et al. (2008), we set private home consumption, investment and government consumption as a ratio to home GDP respectively to 59, 23 and 20 percent. To match the investment-to-GDP ratio, we calibrate the depreciation rate δ of physical capital to 0.025 and the share α of capital in the production function to 0.31.

The home-bias parameters (a_H in the Home consumption bundle, a_{HI} in the Home final investment bundle and $a_F^\star$ in the foreign country) are set to values that allow to match the import content of consumption and investment spending— roughly 10 and 6 percent, expressed as shares of nominal GDP— in line with Coenen et al (2008) and that imply that the foreign country is substantially a closed economy. The elasticity of substitution between domestic and imported goods, η, is set to 4.5, in line with Adolfson et al (2007). The steady state elasticity of substitution between brands ($\theta_H, \theta_F, \theta_H^\star, \theta_F^\star$) is set to 6, consistently with a steady state markup equal to 1.2. The substitution elasticity between labor varieties, θ_L, to 4.33.

We assume that the steady state growth rate of the world economy is 2.0 percent per annum (consistently with the average sample real GDP growth). The steady state trade balance and the net foreign asset position are set to zero. The discount factor β is calibrated consistently with an annualized equilibrium real interest rate of 2.0 percent. The monetary authority's long-run annualized gross inflation objective π is set to 2.0 percent. The inverse of the labor supply elasticity, σ^L, is set to 2, consistently with the existing literature.

On the fiscal side, as for steady state values, based on sample averages we set public expenditures for consumption goods at 20 percent of output, debt at 60 percent (on a yearly basis). Steady state values for tax rates are assumed to be simply the averages over the sample period of our estimates of average effective tax rates (approximately equal to 16 percent for consumption taxes, 19 percent for capital income taxes, 45 percent for labor income taxes). Given these figures, the steady state value for transfers is set residually so as to satisfy the government budget constraint.

4.2 Prior distributions of the estimated parameters

Table 3 shows the prior distribution of the estimated parameters (first fourth columns from the left hand side). The location of the prior distribution corresponds to a large extent to that in Adolfson et al (2007) and Forni et al. (2009). Parameters bounded between 0 and 1 are distributed according to a beta distribution (habit persistence b, indexation parameters α and coefficients of shock autocorrelation ρ). Positive parameter have an inverse gamma distribution (wage and price stickiness parameters κ, adjustment cost on investment γ_I, standard deviations of the shocks σ, tax rate and public expenditure responses to public debt in the fiscal rules η_b). Finally unbounded parameters are distributed according to the normal distribution (interest rate response to output and output growth in the Taylor rule ρ_y and $\rho_{\Delta y}$).

The (domestic, imported and exported goods) price and wage stickiness parameters are set so that the average length between price, or wage, adjustments is four quarters. The range covered by the prior distributions of both parameters is chosen so as to span approximately from less than one fifth to more than double the mean frequency of adjustment, therefore including very low degrees of nominal rigidity. Parameters measuring the degree of price and wage indexation are set to 0.5. Investment adjustment coefficient has a mean of 7.694 and a standard deviation equal to 1.5. Regarding the monetary policy rule, the prior mean on the the lagged interest rate coefficient is set to 0.8, those on inflation and inflation growth coefficients respectively to 1.7 and 0.3. Finally, the coefficient responding to output (deviation from steady state) and output growth are set respectively to 0.125 and 0.0625. All the autocorelated shocks have an autoregressive coefficent set to 0.85. The prior on the risk premium parameter, $\tilde{\Phi}$, is set to 0.01.

Tax policies are a priori taken to be quite persistent, with autoregressive coefficients having a prior mean set to 0.8 (standard deviation equal to 0.1). Labor income tax rate and public expenditures (for consumption and transfers) elasticities with respect to debt are all assumed to have a mean equal to 0.02 (standard deviation equal to 0.005). Innovations to all shocks are assumed to be white noise with standard deviation having mean set to 0.1 percent.

4.3 Posterior distributions of the estimated parameters

Given priors, we estimate the posterior distributions of the parameters using the Metropolis–Hastings algorithm with two hundred thousand iterations. Table 3 shows the posterior mode of all the parameters, the posterior standard deviation, the mean along with the 5th and 95th percentiles of the posterior distribution.

On the fiscal policy side, tax rate processes appear to be highly persistent. The autoregressive parameter for government purchases, and transfers to households are estimated at respectively 0.984 and 0.986, pointing to a high persistence of fiscal policy innovations.

The estimate for price stickiness suggests that in the euro area prices are more sticky than wages (a similar result is obtained by Adolfson et al. (2007). Habit parameter is estimated to be relatively low

The posterior mode of the persistence parameter in the unit-root technology process is estimated to be 0.99. We find a similar value for the stationary technology shock. For other shocks, the persistence coefficients are substantially lower.

Table 4 compares estimates of the benchmark model with those obtained by calibrating in different way some key parameters. Specifically, we consider the case of a high share of non-Ricardian agents (0.45, against 0.35 in the benchmark), of a low elasticity of intratemporal substitution between domestic and imported goods (1.2 against 4.5 in the benchmark). Finally, we also estimate the closed economy version of the model. Estimates seem to be robust across the different open economy models. The main differences appear in the estimated closed economy. For this model, the estimated persistence of the shocks, in particular the fiscal ones, decreases. This result suggests that the high persistence of the shocks is needed to fit open economy specific data, such as the volatile export and import quantities as well real exchange rate.

In Figure 1 we report the data and the correspondent fitted values obtained from the benchmark model estimated at the mode. The insample fit of the model appears to be satisfactory.

5 Impulse response Functions

5.1 Public expenditure shocks

We now discuss the implications of our estimates for the effects of government spending shocks on the economy, in particular on the trade balance and the public deficit. Fig. 2 shows impulse responses with respect to a shock to real detrended government purchases of goods and services while Fig. 3 with respect to real detrended transfers. The solid line shows median values, while the dotted ones the 5th and 95th percentile based on posterior distributions. The magnitude of the shocks is set in order to have an increase in expenditures equal to one percent of steady state output. Impulse responses are expressed as percent deviation from steady state values. The exceptions are the interest rate and the inflation rate, expressed as annualized percentage points, and fiscal and trade balance reported as a ratio to domestic steady state output (percentage points from steady state).

The shock to public government purchases (Figure 2) increases employment by increasing the demand for goods and services which, in turn, brings about an increase in labor income. This sustains consumption of non-Ricardian households, to an extent that, however, is not enough (also in view of their share) to compensate for the decrease in Ricardian consumption due to the negative wealth effect of debt-financed spending and the higher real interest rates (that crowds out also investment). On impact, the government spending multiplier does not exceeds unity.

The higher public expenditure implies an initial increase in the government budget deficit by about 0.6 percentage point of GDP. After the initial period, the deficit gradually decreases, because labor income taxes and transfer adjust to make the public debt stable.

Imports decrease, following the decrease in the home private demand. The public expenditure is fully biased towards the domestic good, so its increase induces an improvement in the home terms of trade and the appreciation of the real exchange rate. The increase in the home goods relative prices favors a decrease in export. The trade deficit-to-GDP ratio deteriorates by about 0.4 percentage points in the first quarter (the peak level). Overall, the effect of public deficit on the external balance is rather strong.

Figure 3 reports the effects of a shock to transfers to households. It has a big and persistent impact on consumption as it translates one to one into an increase in disposable income of non-Ricardian households. Demand-driven output and employment also increase, while real wages are initially unchanged. Higher labor effort stimulates physical capital accumulation and hence investment. Consumption and capital accumulation by Ricardian agents decrease, because of the negative wealth effect of debt-financed spending (due to distortionary taxation) and to higher real interest rate. The higher public transfer implies an initial increase in the government budget deficit by about 0.8 percentage point of GDP on impact. Subsequently, the deficit decreases very slowly.

Higher private consumption favors higher demand for domestic goods and higher imports. The trade balance-to-output ratio response is instead, differently from the case of the shock to government purchases, rather muted (around 0.1 percent). The higher private aggregate demand induces an increase in imports and an improvement in the terms of trade (consistently with the exchange rate depreciation, given the assumption of local currency pricing and incomplete pass-through in the short run).

5.2 Shocks to tax rates

Next we look at the effects of tax rates innovations. Figures 4-6 plot the impulse responses of a shock to the tax rate on, respectively, labor income, capital income and consumption, all calibrated in order to achieve a decrease in revenues equal to 1% of steady state output.

The reduction in labor income tax rate leads to an outward shift of labor supply, consumption and higher accumulation of physical capital by Ricardian agents. Also non-Ricardian agents increase consumption, given the higher available income (lower taxes and higher number of hours worked more than compensate for the reduction in real wage). The monetary authority increases the nominal interest rate, given the higher economic activity. In the first period the public deficit increases by 0.6 percentage points. Higher aggregate demand drives up imports. The real exchange rate depreciates on impact because of higher supply of home goods, whose production is driven up by higher labor supply. Exports increase as well, contributing to reduce the high supply of home goods. The trade balance deteriorates by 0.3 points in the first quarter and continues to deteriorate thereafter, up to a maximum value of 0.6 percentage points in the 8th quarter.

Figure 5 reports the effects of a decrease in capital income tax rate. Ricardian intertemporal choice starts favoring investment rather than consumption. Labor hardly moves, given the incentive to substitute capital for labor. Similarly, consumption of non-Ricardian agents hardly moves, because their disposable income is relatively constant. Overall, aggregate consumption falls, and inflation do as well. On impact the public deficit increases by 1 percent point. Higher aggregate demand for investment favors higher imports. Exports initially slightly decrease and subsequently gradually increase, following the smooth increase in domestic good supply. The trade balance slightly deteriorates, up to -0.02 percentage points in the 7th quarter.

Figure 6 shows that a decrease in consumption tax rate brings about a one time decrease in inflation (around 5% on annual terms). The lower tax rate stimulates households to increase consumption, while investment in physical capital increases only slightly. Firms increase output to meet the additional demand and they do so by increasing employment. The strong increase in economic activity limits the loss of public revenues. The deterioration is rather the same in the following periods, given the extremely high persistence of the negative consumption tax shock. Higher aggregate demand favors the improvement of the home terms of trade and higher imports. Higher aggregate supply is absorbed not only through the higher domestic demand, but also through higher exports, contributing to a persistent surplus of the trade balance.

5.3 Fiscal multipliers

To summarize the quantitative effects of our five fiscal shocks we report in Table 5 the fiscal multipliers on output, consumption, investment, imports, exports, real exchange rate and inflation implied by our estimates. We report the average effects in the first 1 and 4 quarters (first two lines) and from 4th to 8th quarters (third line) respectively, expressed in percentage points (annualized in the case of inflation).

Fiscal multipliers on output and consumption are quite sizeable, although generally smaller than one. The average effect on output in the first quarter is, as expected, greatest for a shock to purchases of good and services (these being part of aggregate demand); the other shocks all have multipliers between zero and 0.6. The effect on private consumption is higher for innovations to consumption taxes, labor taxes and transfers. The effect, in all cases, works through an increase in household real income (this is true in particular for non-Ricardian agents). For Ricardian agents an intertemporal substitution effect is at work in the case of consumption and labor taxes.

The fiscal multipliers on imports mimics the multiplier on consumption and investment, depending on the considered fiscal shock. The highest value is reached in correspondence of shocks to labour income tax, consumption tax and transfer (that stimulates private consumption). The effect is somewhat smaller for capital income (that stimulates private investment). The effects on the real exchange rate and inflation are generally mild. The only notable exception are the innovations in consumption taxes, as they translate one to one to prices and therefore affect strongly the real exchange rate.

6 Sensitivity Analysis

We have performed sensitivity by looking at the impulse responses to our fiscal shocks allowing one single parameter to move at a time while leaving the other parameters set at their estimated values. We focused on the following parameters: among calibrated ones, the share of non-Ricardians and the elasticity of intratemporal substitution between domestic and imported goods; among estimated one, the parameters of the fiscal and monetary rules (in particular, the persistence of the Fiscal rules). These are the parameters that most can impact on private consumption, and therefore imports, and on the composition of final demand in domestically produced and imported goods.

Overall results are robust to variations in these parameters within reasonable bounds. Two relevant cases, that we discuss below, are the effect of the share of non-Ricardian consumers on domestic consumption and imports (and therefore trade balance) and the response of the real exchange rate for values of the elasticity of intratemporal substitution between domestic and imported goods higher that the one we assume. We will discuss these two cases with reference to a government expenditure shock.

Figure 7 reports the impact responses of private consumption, investment and imports (upper panel), and of the terms of trade and real exchange rate (lower panel) following a government expenditure shock for values of λ^{NR} between zero and one. The response of consumption and imports is significantly increasing in the share of non-Ricardian agents. Note that the consumption response becomes positive for values of λ around 0.5. Consistently with the response of domestic consumption, that induce a stronger increase in demand for domestic goods, the terms of trade appreciates to a bigger extent and the real exchange rate appreciates less.

Figure 8 shows the response to a government expenditure shock of the same variables, now moving the value of the elasticity of substitution between domestic tradables and imported goods. The impact responses highlight that real variables (consumption, investment and imports) tend to remain relatively stable, while the relative prices (terms of trade and real exchange rate) move significantly. In particular, the real exchange rate appreciate less. When we also assume that the expenditure shock is not very persistent - as in the figure where we set ρ_G=0.8 - then we can have also that the real exchange rate depreciates for values of the elasticity approximately higher than 4.5. This is interesting, as we have already discussed that several authors have found evidence in favour of a depreciation of the real exchange rate following an expenditure shock, although with reference to US data. The figure shows that the model we are considering allows in principle for depreciations after an expenditure shock, although our estimates does not find support for this result.

Figure 9 shows the responses to a spending shock for values of the persistence of the fiscal shock (ρ_G) between 0.8 and 1. A more persistent process produces a stronger negative wealth effect on Ricardian agents that drives down imports. The exchange rate appreciate less.

Finally the response of variables is inversely proportional to the tightness of monetary policy. These effects however are not very strong and therefore we do not show any particular figure on this point. Higher consumption and import responses are obtained when the coefficient of response to CPI inflation in the Taylor rule is low, so that there is a lower reaction of the nominal interest rate to the fiscal stimulus (so the increase in the real interest rate is lower, and the implied depressing effect on Ricardian aggregate effect is lower as well).

7 Conclusions

TO BE WRITTEN

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Table 1 Calibrated parameters

Parameter	Description	Value
β	Discount factor	0.999
α	Capital share in production	0.31
η	Substitution elasticity btw tradables	4.5
σ^L	Labor supply elasticity	2.0
δ	Depreciation rate of capital	0.025
$\theta_i(i = H, F, H^*, F^*)$	Substitution elasticity btw brands	6.0
θ^L	Substitution elasticity btw labor varieties	4.3
$1 - a_{HI}$	Imported investment share	0.40
$1 - a_H$	Imported consumption share	0.32
λ^{NR}	Share of rule-of-thumb agents	0.35
τ^w	Labor income tax rate	0.45
τ^k	Capital and dividend income tax rate	0.19
τ^c	Private consumption tax rate	0.16
n	Size of the home economy	0.20

Table 2 Steady state relationships

Parameter	Description	Value
$\bar{\pi}$	Inflation rate	2.00
gr	Growth rate	2.16
R	Nominal interest rate	4.00
$C/(p_Y Y)$	Consumption-to-output ratio	0.59
$I/(p_Y Y)$	Investment-to-output ratio	0.23
$M(X)/(p_Y Y)$	Imports (Exports)-to-output ratio	0.16
$B^F/(p_Y Y)$	Net foreign asset	0.00
$B^G/(p_Y Y)$	Public debt	2.40
$bb/(p_Y Y)$	Public deficit-to-output ratio	0.00
$P_H G/(p_Y Y)$	Public expenditure-to-output ratio	0.20
$tr/(p_Y Y)$	Lump sum transfers-to-output ratio	0.18
$\tau^w wl/(p_Y Y)$	Revenues on labor income tax-to-output ratio	0.23
$\tau^{r^k} r^k k/(p_Y Y)$	Rev. on capital income tax-to-output ratio	0.04
$\tau^c C/(p_Y Y)$	Rev. on consumption tax-to-output ratio	0.07

Table 3. Prior and posterior distributions

	Prior distribution			Posterior distribution				
Parameter	Type	Mean	S.D.	Mode	S.D.(Hessian)	Mean	5 %	95 %
Habit in formation b	Beta	0.65	0.1	0.600	0.055	0.600	0.578	0.621
Calvo employment ξ_E	Beta	0.675	0.1	0.869	0.054	0.868	0.858	0.878
Invest. adj. cost γ_I	Normal	7.694	1.5	8.507	0.079	8.521	7.536	9.638
Risk premium Φ	Gamma	0.01	0.05	0.068	0.149	0.068	0.053	0.083
Interest rate smoothing ρ_R	Beta	0.8	0.05	0.843	0.081	0.843	0.826	0.859
Inflation response ρ_π	Normal	1.7	0.1	1.768	0.063	1.773	1.675	1.873
Difference inflation response $\rho_{\Delta\pi}$	Normal	0.3	0.1	0.313	0.042	0.313	0.247	0.379
Output response ρ_y	Normal	0.125	0.05	-0.028	0.005	-0.028	-0.036	-0.021
Difference output response $\rho_{\Delta y}$	Normal	0.0625	0.05	0.059	0.015	0.060	0.036	0.084
Public expenditure debt resp. η_{G_b}	Gamma	0.02	0.005	0.010	0.085	0.010	0.009	0.012
Lump-sum transfers debt response η_{tr_b}	Gamma	0.02	0.005	0.012	0.012	0.012	0.012	0.012
Wage tax rate debt resp. $\eta_{\tau^w_b}$	Gamma	0.02	0.005	0.007	0.133	0.007	0.005	0.008
Public expenditure shock ρ_g	Beta	0.8	0.1	0.984	0.033	0.984	0.983	0.985
Lump-sum transfers shock ρ_{tr}	Beta	0.8	0.1	0.986	0.033	0.986	0.985	0.986
Wage tax persistence ρ_{τ^w}	Beta	0.8	0.1	0.988	0.042	0.988	0.987	0.988
Capital income tax rate pers. ρ_{τ^k}	Beta	0.8	0.1	0.980	0.006	0.980	0.979	0.980
Consumption tax rate pers. ρ_{τ^c}	Beta	0.8	0.1	0.979	0.020	0.979	0.978	0.979
Public expenditure shock σ_g	Invgamma	0.001	0.01	0.005	0.021	0.005	0.005	0.005
Lump-sum transfers shock σ_{tr}	Invgamma	0.001	0.01	0.005	0.009	0.005	0.005	0.005
Wage tax rate shock σ_{τ^w}	Invgamma	0.001	0.01	0.006	0.016	0.006	0.006	0.006
Capital income tax rate shock σ_{τ^k}	Invgamma	0.001	0.01	0.009	0.009	0.009	0.009	0.009
Consumption tax rate shock σ_{τ^c}	Invgamma	0.001	0.01	0.007	0.020	0.007	0.006	0.007
Rotemberg domestic prices κ_H	Gamma	100	31.623	151.51	0.057	151.528	138.329	165.305
Rotemberg import prices κ_F	Gamma	100	31.623	172.919	0.060	173.836	158.247	191.230
Rotemberg wages κ_W	Gamma	100	31.623	129.97	0.069	130.364	116.272	145.324
Indexation domestic good prices α_H	Beta	0.5	0.15	0.216	0.080	0.215	0.194	0.235
Index. imported prices α_F	Beta	0.5	0.15	0.143	0.060	0.144	0.133	0.156
Index. wages α_W	beta	0.5	0.15	0.104	0.034	0.104	0.099	0.109
habit in formation b^*	Beta	0.65	0.1	0.878	0.036	0.878	0.871	0.884
Interest rate smoothing ρ_{R^*}	Beta	0.8	0.05	0.753	0.060	0.753	0.735	0.771
Inflation response ρ_{π^*}	Normal	1.7	0.1	1.718	0.019	1.719	1.688	1.751
Difference inflation response $\rho_{\Delta\pi^*}$	Normal	0.3	0.1	0.329	0.044	0.326	0.256	0.396
Output resp. ρ_{y^*}	Normal	0.125	0.05	0.003	0.014	0.002	-0.021	0.024
Difference output resp. $\rho_{\Delta y^*}$	Normal	0.0625	0.05	0.156	0.032	0.156	0.105	0.208
Rotemberg domestic prices κ^*_F	Gamma	100	31.6228	125.35	0.069	125.929	113.001	139.299
Rotemberg import prices κ^*_H	Gamma	100	31.623	136.202	0.061	136.357	123.416	149.438
Index. domestic good prices α^*_F	Beta	0.5	0.15	0.284	0.016	0.284	0.278	0.290
Index. imported prices α^*_H	Beta	0.5	0.15	0.110	0.009	0.110	0.108	0.112

Table 3 continued

Parameter	Prior distribution			Posterior distribution				
	Type	Mean	S.D.	Mode	S.D.(Hessian)	Mean	5 %	95 %
Stationary technology shock ρ_{ϵ}	Beta	0.85	0.1	0.991	0.237	0.991	0.988	0.994
Unit root technology shock ρ_{μ}	Beta	0.85	0.1	0.989	0.051	0.989	0.988	0.990
Invest. spec. tech. shock ρ_{Υ}	Beta	0.85	0.1	0.463	0.061	0.462	0.438	0.485
Consumption preference shock ρ_{ξ^c}	Beta	0.85	0.1	0.928	0.150	0.928	0.912	0.943
Risk premium shock $\rho_{\tilde{\phi}}$	Beta	0.85	0.1	0.963	0.072	0.963	0.959	0.967
Domestic good markup shock ρ_{θ_H}	Beta	0.85	0.1	0.928	0.112	0.928	0.916	0.940
Imported good markup shock ρ_{θ_F}	Beta	0.85	0.1	0.921	0.042	0.921	0.916	0.926
Labor supply shock ρ_{θ_L}	Beta	0.85	0.1	0.716	0.071	0.717	0.694	0.740
Inflation target shock $\rho_{\overline{\pi}}$	Beta	0.85	0.1	0.744	0.109	0.741	0.707	0.772
Domestic good markup shock $\rho_{\theta_{F^*}}$	Beta	0.85	0.1	0.852	0.008	0.853	0.850	0.855
Imported good markup shock $\rho_{\theta_{H^*}}$	Beta	0.85	0.1	0.949	0.029	0.949	0.947	0.952
Demand shock ρ_{ad^*}	Beta	0.85	0.1	0.913	0.051	0.913	0.906	0.919
Inflation target shock $\rho_{\overline{\pi}^*}$	Beta	0.85	0.1	0.364	0.013	0.365	0.359	0.370
Stationary technology shock σ_{ϵ}	Invgamma	0.001	0.01	0.016	0.086	0.016	0.014	0.018
Unit root technology shock σ_{μ}	Invgamma	0.001	0.01	0.001	0.026	0.001	0.001	0.001
Invest. spec. tech. shock σ_{Υ}	Invgamma	0.001	0.01	0.075	0.086	0.076	0.066	0.087
Monetary policy shock σ_R	Invgamma	0.001	0.01	0.001	0.026	0.001	0.001	0.001
Consumption preference shock $\sigma_{\xi c}$	Invgamma	0.001	0.01	0.020	0.057	0.020	0.018	0.022
Risk premium shock $\sigma_{\tilde{\phi}}$	Invgamma	0.001	0.01	0.004	0.064	0.004	0.003	0.004
Domestic good markup shock σ_{θ_H}	Invgamma	0.001	0.01	0.112	0.063	0.112	0.101	0.123
Imported good markup shock σ_{θ_F}	Invgamma	0.001	0.01	0.208	0.048	0.208	0.192	0.224
Labor supply shock σ_{θ_L}	Invgamma	0.001	0.01	0.054	0.058	0.054	0.049	0.060
Inflation target shock $\sigma_{\overline{\pi}}$	Invgamma	0.001	0.01	0.002	0.107	0.002	0.002	0.003
Monetary policy shock σ_{R^*}	Invgamma	0.001	0.01	0.002	0.024	0.002	0.002	0.002
Domestic good markup shock $\sigma_{\theta_{F^*}}$	Invgamma	0.001	0.01	0.001	0.012	0.001	0.001	0.001
Imported good markup shock $\sigma_{\theta_{H^*}}$	Invgamma	0.001	0.01	0.174	0.048	0.175	0.161	0.188
Demand shock σ_{ad^*}	Invgamma	0.001	0.01	0.052	0.036	0.052	0.049	0.055
Inflation target shock $\sigma_{\overline{\pi}^*}$	Invgamma	0.001	0.01	0.005	0.024	0.005	0.004	0.005

Table 4. Sensitivity with respect to some calibrated parameters, posterior estimates

Parameter	Benchmark	Low elasticity	High share of non-Ricardian	Closed economy
Habit in formation b	0.600	0.607	0.520	0.698
Calvo employment ξ_E	0.869	0.874	0.869	0.884
Invest. adj. cost γ_I	8.507	8.680	8.477	8.153
Risk premium Φ	0.068	0.037	0.075	
Output response ρ_y	-0.028	-0.024	-0.027	
Interest rate smoothing ρ_R	0.843	0.851	0.838	0.861
Inflation response ρ_π	1.768	1.750	1.779	1.751
Difference inflation response $\rho_{\Delta\pi}$	0.313	0.312	0.313	0.269
Difference output response $\rho_{\Delta y}$	0.059	0.056	0.059	0.004
Lump-sum transfers debt response η_{tr_b}	0.012	0.013	0.012	0.015
Public expenditure debt resp. η_{g_b}	0.010	0.011	0.010	0.017
Wage tax rate debt resp. $\eta_{\tau^w_b}$	0.007	0.007	0.007	0.028
Public expenditure shock ρ_g	0.984	0.984	0.985	0.899
Lump-sum transfers shock ρ_{tr}	0.986	0.985	0.986	0.982
Wage tax persistence ρ_{τ^w}	0.988	0.988	0.988	0.921
Capital income tax rate pers. ρ_{τ^k}	0.980	0.980	0.980	0.978
Consumption tax rate pers. ρ_{τ^c}	0.979	0.978	0.978	0.976
Public expenditure shock σ_g	0.005	0.005	0.005	0.013
Lump-sum transfers shock σ_{tr}	0.005	0.005	0.005	0.005
Wage tax rate shock σ_{τ^w}	0.006	0.006	0.006	0.005
Capital income tax rate shock σ_{τ^k}	0.009	0.009	0.009	0.009
Consumption tax rate shock σ_{τ^c}	0.007	0.007	0.007	0.007
Rotemberg domestic prices κ_H	151.505	133.065	142.925	87.243
Rotemberg import prices κ_F	172.919	101.139	172.872	
Rotemberg wages κ_W	129.967	107.175	127.890	106.676
Indexation domestic good prices α_H	0.216	0.153	0.210	0.163
Index. imported prices α_F	0.143	0.114	0.141	
Index. wages α_W	0.104	0.114	0.106	0.094
habit in formation b^*	0.878	0.872	0.879	
Interest rate smoothing ρ_{r^*}	0.753	0.759	0.752	
Inflation response ρ_{π^*}	1.718	1.667	1.719	
Difference inflation response $\rho_{\Delta\pi^*}$	0.329	0.331	0.328	
Output resp. ρ_{y^*}	0.003	-0.003	0.004	
Difference output resp. $\rho_{\Delta y^*}$	0.156	0.150	0.155	
Rotemberg domestic prices κ^*_F	125.353	117.439	125.284	
Rotemberg import prices κ^*_H	136.202	75.939	135.326	
Index. domestic good prices α^*_F	0.284	0.265	0.284	
Index. imported prices α^*_H	0.110	0.092	0.110	

Table 4. ...continued

Parameter	Benchmark	Low elasticity	High share of non-Ricardian	Closed economy
Stationary technology shock ρ_{ε}	0.991	0.994	0.992	0.996
Invest. spec. tech. shock ρ_{Υ}	0.463	0.435	0.489	0.214
Consumption preference shock ρ_{ζ_c}	0.928	0.877	0.957	0.863
Demand shock ρ_{ad^*}	0.913	0.929	0.911	
Domestic good markup shock ρ_{θ_H}	0.928	0.916	0.934	0.935
Labor supply shock ρ_{θ_L}	0.716	0.804	0.713	0.880
Unit root technology shock ρ_{μ}	0.989	0.992	0.988	0.885
Risk premium shock $\rho_{\tilde{\phi}}$	0.963	0.978	0.967	
Imported good markup shock ρ_{θ_F}	0.921	0.892	0.915	
Imported good markup shock $\rho_{\theta_H^*}$	0.949	0.881	0.947	
Inflation target shock $\rho_{\overline{\pi}}$	0.744	0.858	0.752	0.994
Domestic good markup shock $\rho_{\theta_F^*}$	0.853	0.850	0.851	
Inflation target persistence $\rho_{\overline{\pi}^*}$	0.364	0.348	0.369	
Stationary technology shock σ_{ε}	0.016	0.016	0.015	0.012
Invest. spec. tech. shock σ_{Υ}	0.075	0.080	0.073	0.090
Monetary policy shock σ_R	0.001	0.001	0.001	0.001
Consumption preference shock $\sigma_{\zeta c}$	0.020	0.018	0.020	0.001
Demand shock σ_{ad^*}	0.052	0.053	0.052	
Domestic good markup shock σ_{θ_H}	0.112	0.129	0.106	0.084
Labor supply shock σ_{θ_L}	0.054	0.044	0.054	0.035
Unit root technology shock σ_{μ}	0.001	0.001	0.001	0.003
Risk premium shock $\sigma_{\tilde{\phi}}$	0.004	0.003	0.004	
Imported good markup shock σ_{θ_F}	0.208	0.271	0.211	
Imported good markup shock $\sigma_{\theta_H^*}$	0.174	0.279	0.174	
Inflation target shock $\sigma_{\overline{\pi}}$	0.002	0.001	0.002	0.001
Domestic good markup shock $\sigma_{\theta_F^*}$	0.001	0.001	0.001	
Inflation target shock $\sigma_{\overline{\pi}^*}$	0.005	0.004	0.005	
Monetary policy shock σ_{R^*}	0.002	0.002	0.002	
Log-likelihood	-5180.79	-5622.41	-5164.39	-4275.96

Table 5. Fiscal multipliers

Increase in	Quarters	Pub Def	Trade Bal	Terms of Tr	CPI Infl	Output	Cons	Inv	Exp	Imp	Real Exch
pub. expend.	1	0.56	-0.36	0.02	0.24	0.83	-0.10	-0.08	-0.21	0.05	-0.10
	4	0.64	-0.28	-0.07	0.22	0.60	-0.37	-0.19	-0.40	0.00	-0.09
	8	0.70	-0.16	-0.16	0.13	0.30	-0.65	-0.45	-0.56	-0.13	-0.07
pub. transfers	1	0.86	-0.12	-0.05	0.08	0.23	0.57	-0.06	-0.02	0.35	0.04
	4	0.87	-0.09	-0.05	0.08	0.17	0.47	-0.14	-0.03	0.28	0.04
	8	0.82	-0.04	-0.05	0.04	0.06	0.34	-0.33	-0.02	0.13	0.03
Reduction of											
labor tax rate	1	0.71	-0.27	0.01	0.06	0.62	1.09	0.32	0.23	0.63	0.08
	4	0.58	-0.38	0.12	0.09	0.94	1.39	0.76	0.58	0.71	0.11
	8	0.32	-0.54	0.28	0.18	1.46	1.76	1.69	1.18	0.82	0.19
capital tax rate	1	0.99	-0.01	-0.03	0.07	0.01	-0.03	0.16	0.00	0.04	0.03
	4	0.95	-0.01	-0.02	0.08	0.03	-0.07	0.33	-0.01	0.09	0.02
	8	0.84	-0.02	-0.01	0.07	0.04	-0.11	0.61	-0.02	0.18	0.00
cons. tax rate											
	1	0.41	0.07	-1.50	-4.69	0.60	1.07	0.29	0.25	0.63	1.59
	4	0.35	0.01	-0.93	-0.77	0.70	1.24	0.39	0.29	0.79	1.03
	8	0.43	0.06	-0.27	0.25	0.49	0.97	0.19	0.13	0.72	0.29

Note: Fiscal multipliers are computed as averages of percent responses over the specified number of quarters. Expenditure innovations are set equal to 1% of steady state output. Tax rates innovations are such that the reduction of revenues is equal to 1% of steady state output. The change in inflation is expressed in annualized percentage points

Fig. 1 Data (thick) and one-sided predicted values from the model (thin)

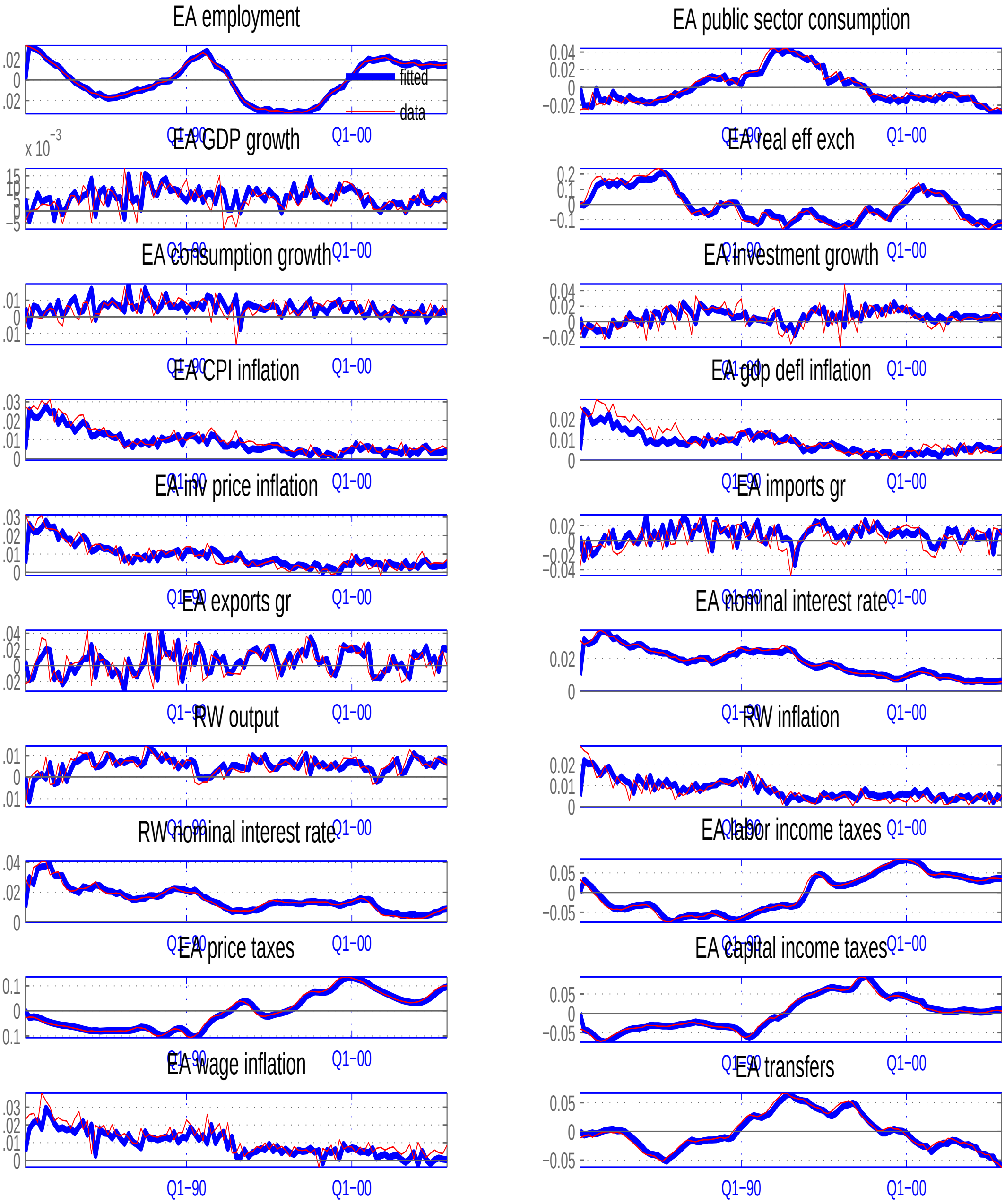


Figure 2 Increase in public expenditure

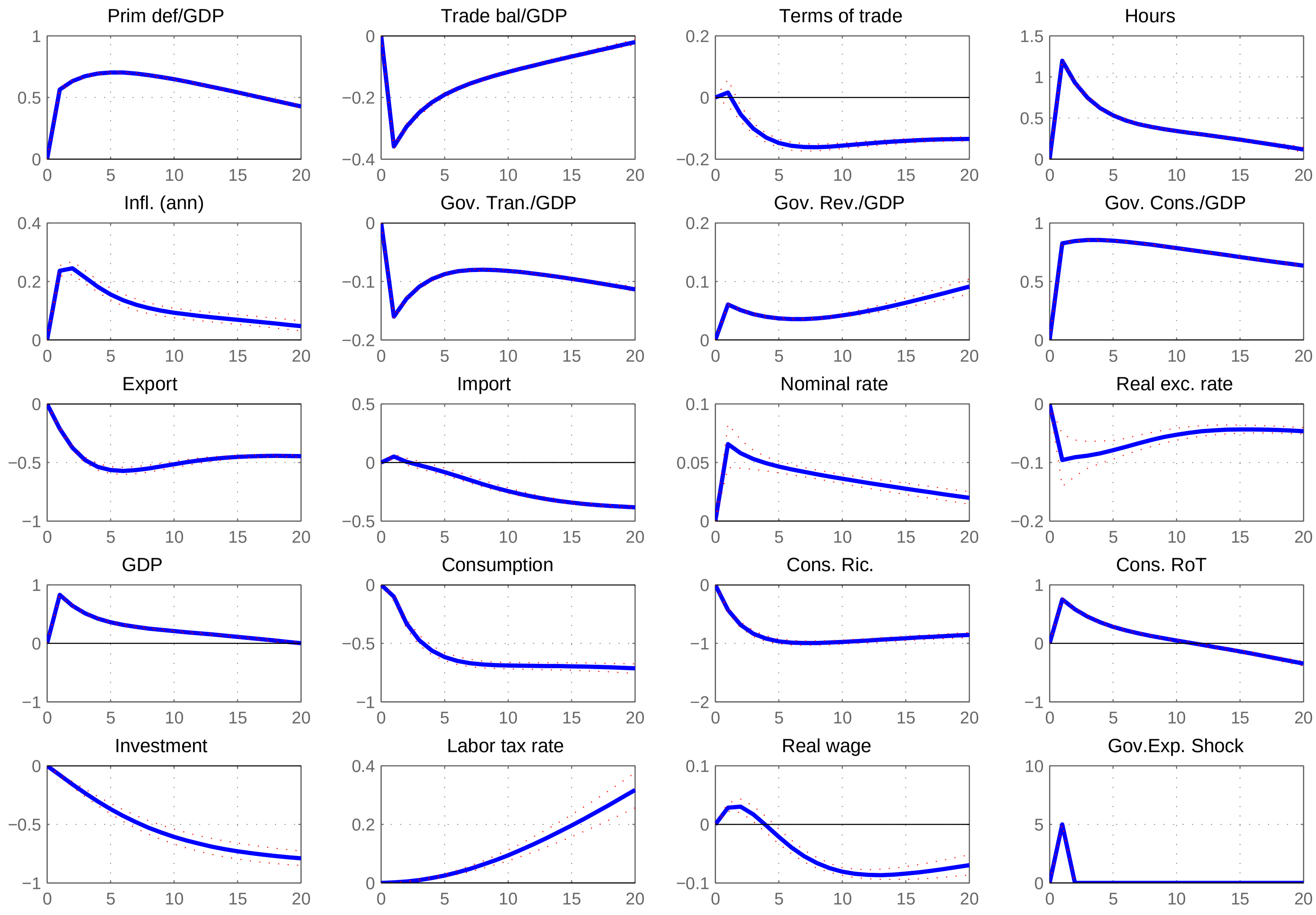


Figure 3 Increase in public transfers

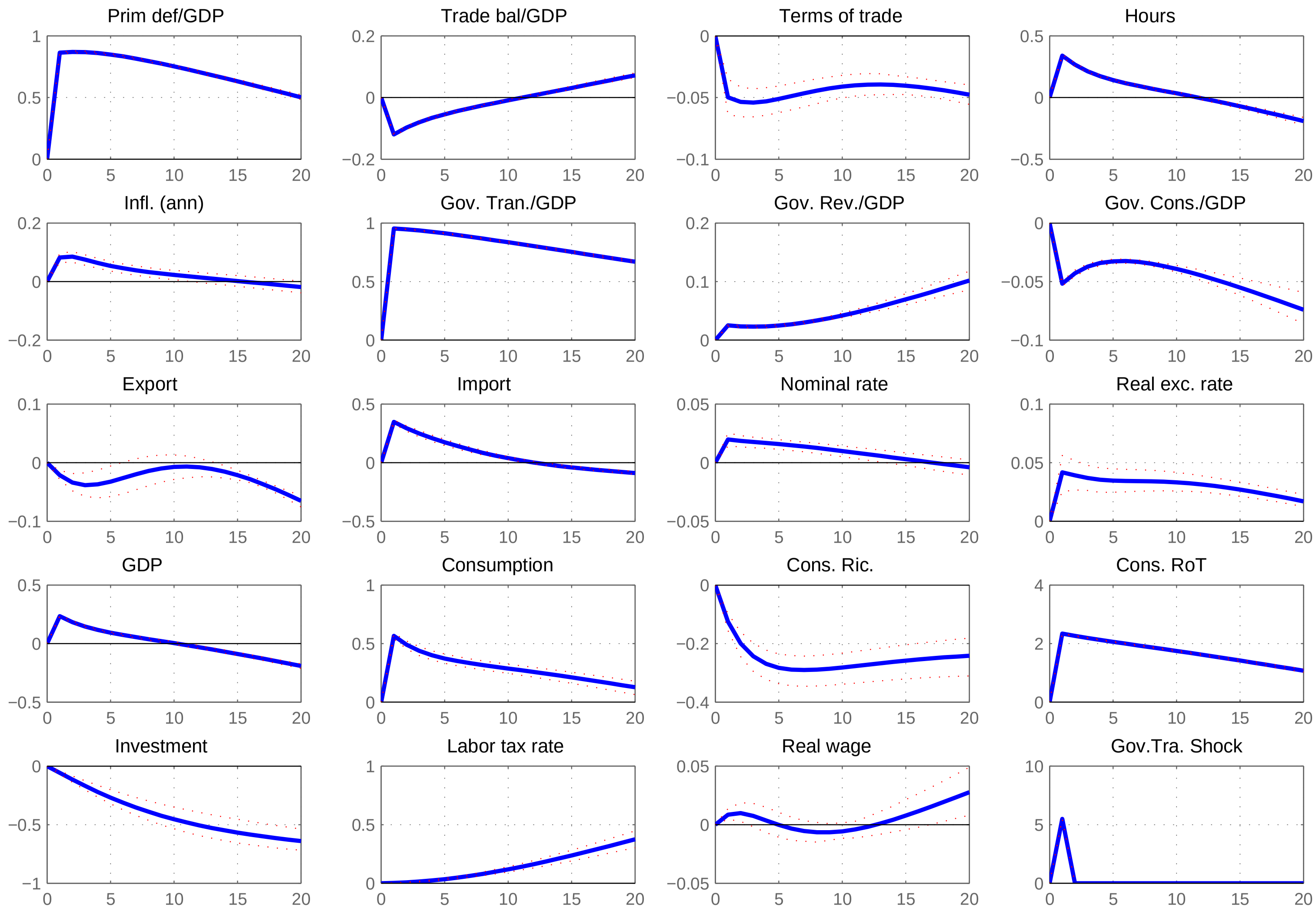


Figure 4 Reduction of wage income tax rate

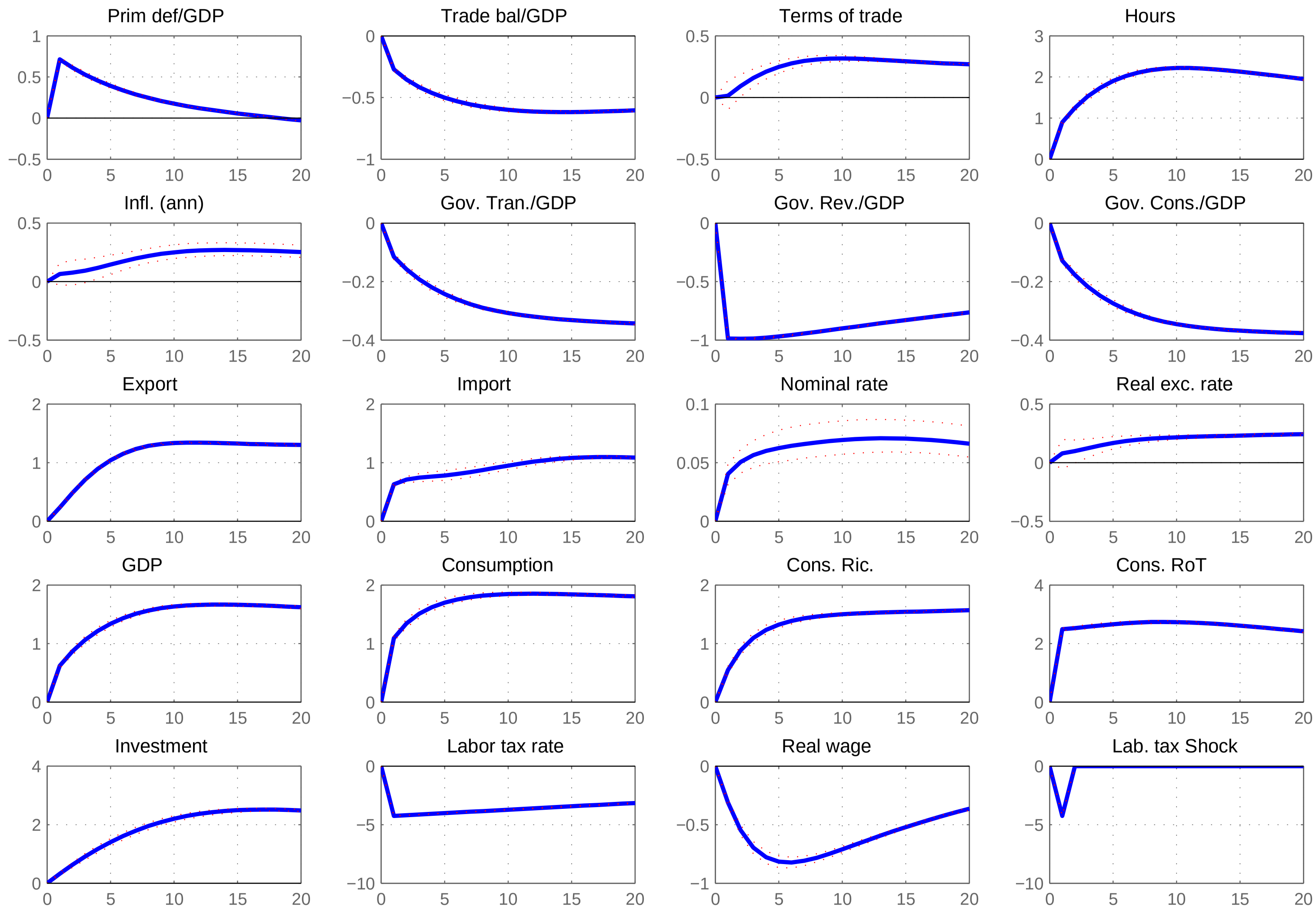


Figure 5 Reduction of capital income tax rate

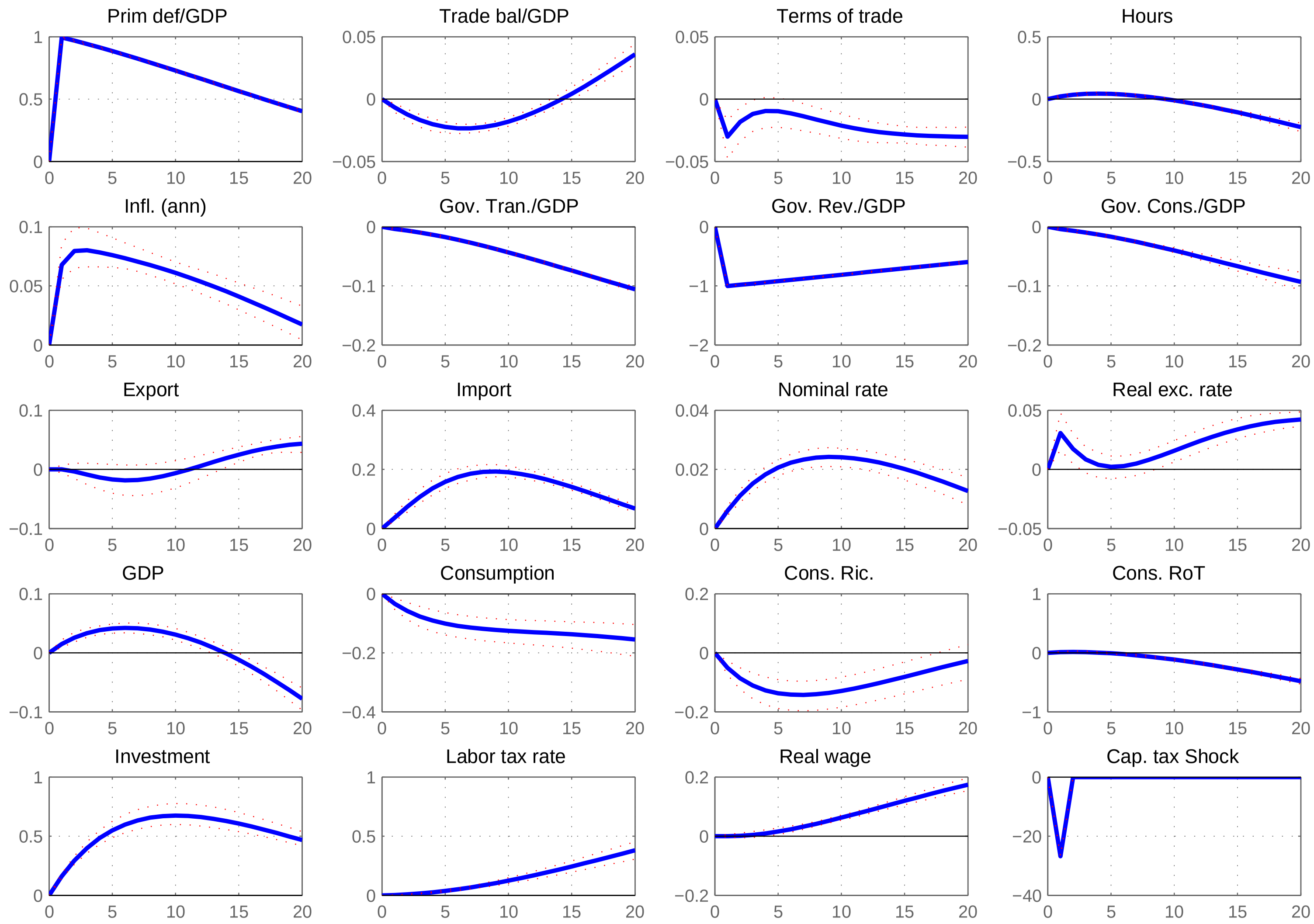


Figure 6 Reduction of consumption tax rate

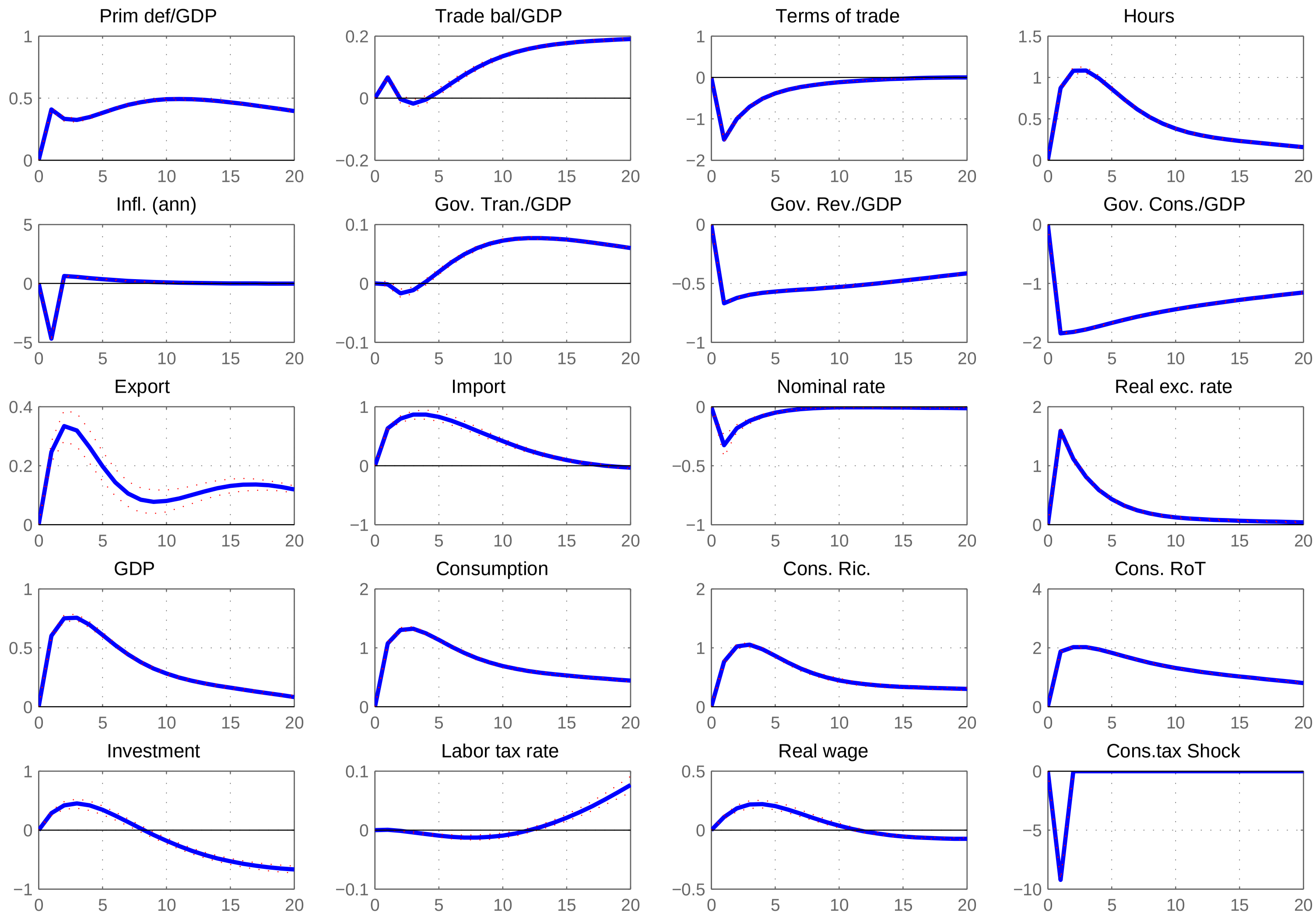
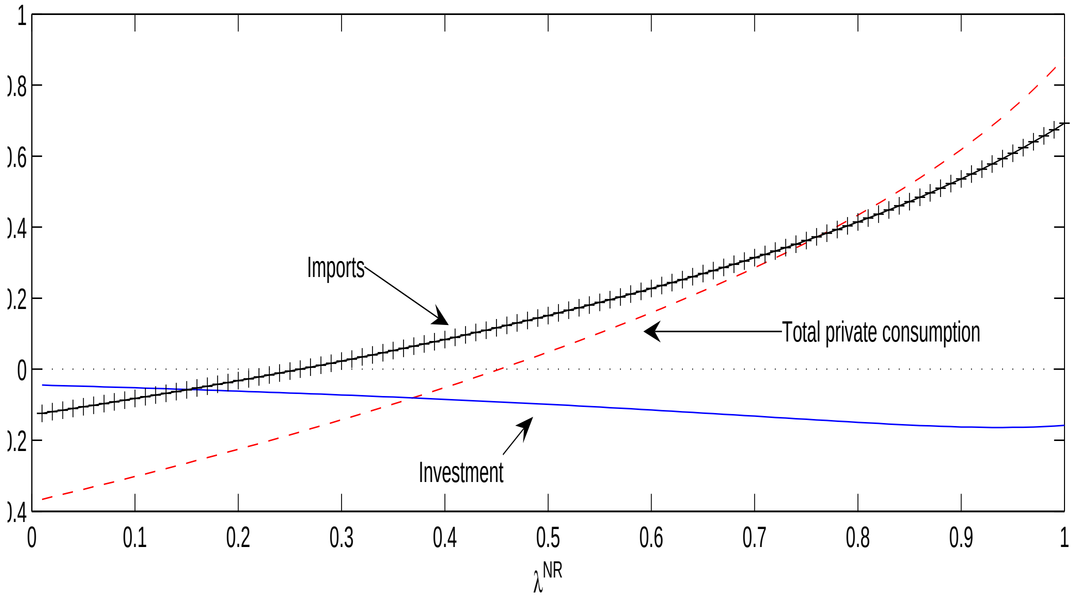


Figure 7 Sensitivity - Impact responses to a public expenditure shock of main variables for different values of the non-Ricardian households share



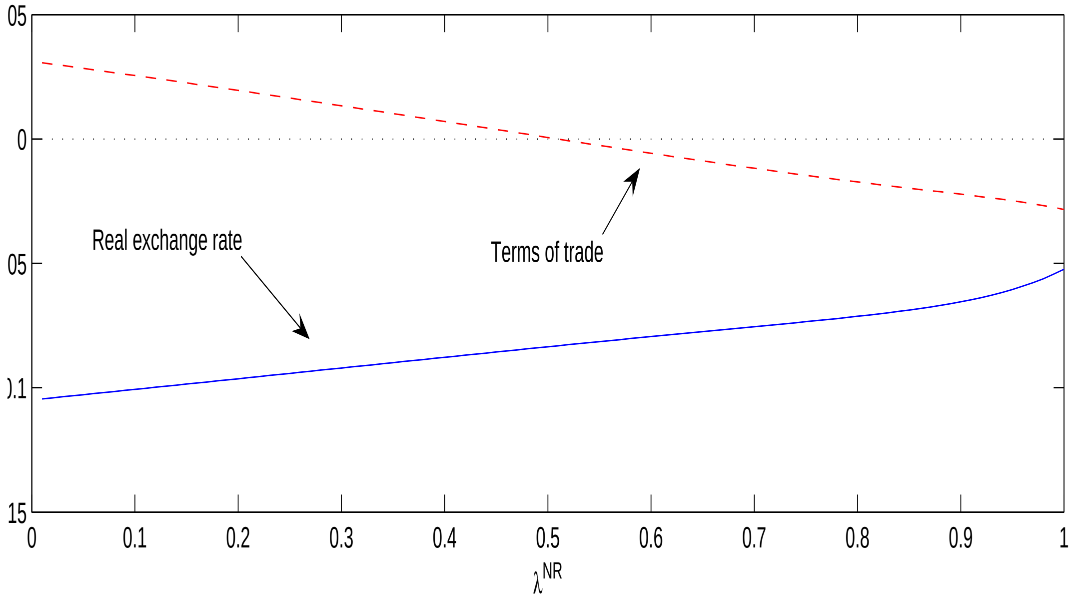


Figure 8 Sensitivity - Impact responses to a public expenditure shock of main variables for different values of the elasticity of substitution between domestic and imported goods

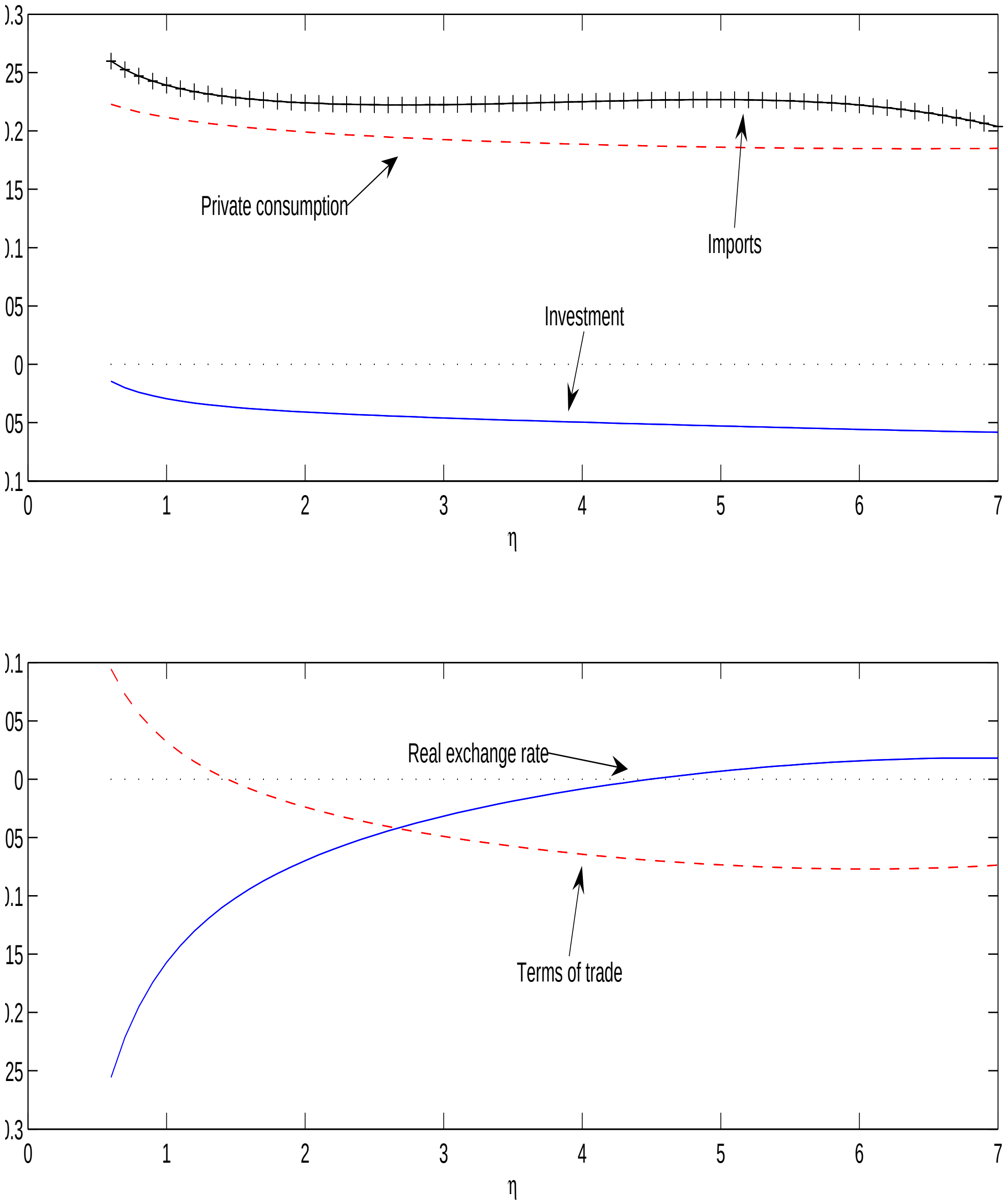


Figure 9 Sensitivity - Impact responses to a public expenditure shock of main variables for different values of the shock persistence