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by Lorenzo Forni, Libero Monteforte and Luca Sessa

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THE GENERAL EQUILIBRIUM EFFECTS OF FISCAL POLICY: ESTIMATES FOR THE EURO AREA

by Lorenzo Forni*, Libero Monteforte* and Luca Sessa*

Abstract

This paper describes a dynamic stochastic general equilibrium model featuring a fraction of non-Ricardian agents in order to estimate the effects of fiscal policy in the euro area by means of Bayesian techniques. The model accounts for distortionary taxation on labor and capital income and on consumption, while expenditures are broken down into purchases of goods and services, compensation of public employees, and transfers to households. A newly computed quarterly dataset of fiscal variables is used. Our results point to a prevalence of mild Keynesian effects of fiscal policy. In particular, although innovations in fiscal policy variables tend to be rather persistent, government purchases of goods and services and compensation of public employees have small and short-lived expansionary effects on private consumption, while innovations in transfers to households show a slightly more sizeable and lasting effect. On the revenue side, decreases in labor income and consumption tax rates have a sizable effect on consumption and output, while a reduction in capital tax favors investment and output in the medium run. Finally, with the exception of transfers to households and labor income tax rates, most fiscal policy variables contribute little to the cyclical variability of the main macro variables.

JEL Classification: E32, E62.
Keywords: fiscal policy, distortionary taxation, DSGE modeling, Bayesian estimation.

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* Bank of Italy, Economics and International Relations.

Contents

1 Introduction

This paper reconsiders the economic effects of fiscal policy using an estimated dynamic stochastic general equilibrium model for the euro area. We try to better understand how these effects depend on the composition of expenditures and revenues, as well as on the interaction with monetary policy.

Recent years have witnessed significant changes in the fiscal position of both the United States and the euro area. The main motivation behind these shifts has been related with cyclical considerations as policy makers have tried to support economic activity through fiscal stimulus. Most of the discretionary measures undertaken, both on the spending and on the revenue side, were backed by little consensus among economists on their short to medium run effects. This lack of consensus stems from the difficulty economists have in building models able to replicate the main empirical regularities concerning fiscal variables.

Frictionless models with optimizing forward-looking agents, as RBC models, for example, seem to be ill suited to study the effects of government spending. In this context, Baxter-King (1993) have shown that any increase in expenditures will bring about - as the government intertemporal budget constraint has to be satisfied - an increase in the discounted value of future taxes. This will amount to a negative wealth effect on households which will induce a decrease in their private consumption, a contemporaneous increase in labor supply, and therefore a decrease in the marginal productivity of labor and in real wages; as in the model the steady state capital labor ratio does not change, investment will increase. These theoretical correlations are at odds with empirical evidence. A number of studies, mainly in the context of VAR analysis, have shown that in most developed countries over most sample periods private consumption tend to respond positively to government spending shocks.[1] Also employment and real

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[1]Among the others, the 5 OECD countries study by Perotti (2005) supports this view. Galí *et al.*

wages tend to grow, while the response of private investment is generally negative.[2]

The new-keynesian paradigm, which mainly adds real frictions and nominal rigidities to an RBC framework, displays the same wealth-effect mechanism that leads to a reduction in private consumption and an expansion in labor supply following a government spending shock.[3] In this context, however, real wages may increase, as a result of an outward shift of the labor demand induced by the expanding demand in the presence of sticky prices (with a reduction in price markups).

In order to fill the gap with the evidence, the literature has recently moved away from the representative infinitely-lived rational agent. In particular Mankiw (2000) has argued that a model where Ricardian and non-Ricardian agents (that cannot save or borrow and therefore consume their income period by period) coexist is better suited for fiscal policy analysis with respect to both neoclassical and overlapping generations models.[4] Building on this framework, Galí, López-Salído and Vallés (2007, henceforth GLSV) add rule-of-thumb agents to a standard new-keynesian model. They show that both price stickiness and the presence of rule-of-thumb consumers are necessary elements in order to get a positive response of private consumption for reasonable calibrations of the parameters. As they put it: "Rule-of-thumb consumers partly insulate aggregate demand from the negative wealth effects generated by the higher levels of (current and future) taxes needed to finance the fiscal expansion, while making it more sensitive to current disposable income. Sticky prices make it possible for real wages to increase (or, at least, to decline by a smaller amount) even in the face of a drop in the marginal product of labor, as the price markup may adjust sufficiently downward to absorb the resulting gap. The combined effect of a higher real wage and higher employment raises current labor income and hence stimulates the consumption of rule-of-thumb households".[5,6]

(2007) provide an extensive review of the literature on the topic.

[2]On the response of employment and real wages, see Pappa (2005) for an analysis on US data. On the response of investment, Alesina *et al.* (2002) have shown, on a large sample of OECD countries over the period 1960-2002, the negative effect on investment of a variety of government spending shocks (in particular related to transfers to households and to the public wage bill). Also Perotti (2005) shows that the response of investment is negative in the US and, after 1980, also in Germany.

[3]On this see Goodfriend-King (1997) and Linnemann-Schabert (2003).

[4]As Mankiw (2000), pg. 124, puts it "A better model would acknowledge the great heterogeneity in consumer behavior that is apparent in the data. Some people have long time horizons, as evident by the great concentration of wealth and the importance of bequests in aggregate capital accumulation. Other people have short time horizon, as evidenced by the failure of consumption-smoothing and the prevalence of households with near zero net worth."

[5]GLSV pg. 260.

[6]As another alternative to a model with a representative infinitely-lived rational agent, Romanov

In this paper we contribute to the debate on the macroeconomic effects of fiscal policy by estimating on euro area data a DSGE model which puts the idea of GLSV into the framework of Christiano-Eichenbaum-Evans (2005). The latter includes a number of frictions proved to be useful for estimation purposes, as shown in particular on euro area data by Smets-Wouters (2003, henceforth SW).[7]

We extend this framework with a relatively rich description of the fiscal policy side. In particular, for government revenues we consider and estimate fiscal policy rules defined on distortionary tax rates, while previous literature (GLSV, and Coenen-Straub, 2005, henceforth CS) had essentially focused on lump-sum taxes. In order to do so, we compute quarterly average effective tax rates on labor income, capital income and consumption for the euro area following the methodology of Mendoza *et al.* (1994).[8]

On the expenditure side, we take into consideration the fact that the variable generally used in the literature as a proxy for government purchases of goods and services, that is government consumption from National Accounts data, includes both purchases of goods and services and compensations for government employees, as early recognized by Rotemberg-Woodford (1992) and later by Finn (1998). In fact, in the case of the euro area in the last twenty five years (the sample period we consider), the employees compensations share of government expenditure averaged 60% approximately. While government purchases of goods and services is a component of aggregate demand, compensations for government employees affect the economy mainly through their effects

(2003), Sala (2004) and Cavallo (2007), among others, consider agents with a finite horizon by introducing a constant probability of dying *à la* la Blanchard (1985). The idea is that, although higher government expenditures will increase the level of expected future taxes, agents - while fully benefiting from the expansion in expenditures - will not likely live long enough to pay their entire share of the financing. Since the keynesian effects of expenditures shocks depend essentially on the probability of (or share of the population) dying before paying taxes and this probability is reasonably small over the short to medium term, these models cannot replicate the positive response of private consumption after a government spending shock.

[7]Differently from GLSV and due to the fact that we are interested in estimating the model, we assume sticky wages. Sticky wages might be thought to work against the positive response of private consumption after a government expenditure shock, as wages would increase less after the shock or even decrease. Our estimates confirm a more muted response of real wages, but still positive. This goes along with a lower increase in marginal costs and inflation, triggering a smaller increase in the real interest rate and a reduced impact decrease in Ricardians' consumption. Therefore, as Furlanetto (2006) shows in the GLSV model, sticky wages are not bound to reduce the effect of government expenditure innovations on total private consumption.

[8]Appendix D provides a detailed description of the data used, including the methodology we have employed, the sources and some comparison between our data and alternative sources.

on employment and wages. We therefore define government consumption excluding compensations for public employees and model public employment separately.

The model is estimated using Bayesian inference methods on the euro area data from 1980 to 2005. Bayesian technique - as forcefully claimed by Fernandez-Villaverde and Rubio-Ramirez (2006) - is now the standard tool for the estimation of DSGE models. Fernandez-Villaverde and Rubio-Ramirez (2004) show how, in practical applications, the Bayesian approach delivers very strong performance, especially on small samples. As we are estimating a relatively large model on a relatively short time span, we opted for the standard linear approximation solution of the model.

To our knowledge this is the first paper that estimates a medium scale DSGE model with a detailed role for the fiscal policy (featuring both distortionary taxes and detailing expenditures in its main components) on euro area data. We use both state of the art econometric techniques for the estimation and a newly computed quarterly data set for fiscal policy variables (as government sector data in the euro area are mainly available on an annual basis). We believe that the use of a rich set of data (especially for the government sector that is the focus of our paper) is necessary for a proper identification of parameters and shocks.[9]

Our results point to a significant share of non-Ricardian agents (about 40%) and to the prevalence of mild Keynesian effects of fiscal policy. In particular, although innovations in fiscal policy variables tend to be rather persistent, government purchases of goods and services and compensations for public employees have small and short lived expansionary effects on private consumption, while innovations to transfers to households show a slightly more sizable and lasting effect. Among revenues, decreases in labor income and consumption tax rates have a sizable effect on consumption and output, while a reduction in the capital income tax favors investment and output in the medium run. Finally, with the exception of transfers to households and labor income tax rates, most fiscal policy variables contribute little to the cyclical variability of the main macro variables.[10]

[9]For example, having data on distortionary taxes makes us more confident in our estimates of certain shocks: it helps disentangling the effects of a shock to the consumption-leisure intratemporal trade-off from those due to a change in the labor income tax rate, or the effects of a technology shock from those of a capital income tax rate shock.

[10]CS introduce non-Ricardian agents and fiscal policy elements in the SW framework. They do not include fiscal variables other than government consumption (the only variable available from official sources at a quarterly frequency) nor detail the fiscal policy as we do (they include only government expenditures, G, and a fiscal rule on lump-sum taxes). Their main results are that the estimated mean share of rule-of-thumb consumers is around 1/4 and that the model is unable to deliver a positive response of private consumption to a government expenditure shock.

The paper is organized as follows. Section 2 describes in detail the model and our assumptions regarding policies. Section 3 sketches the techniques we use to solve and to estimate the model, and describes the data and the assumptions regarding prior distributions. Section 4 presents our estimated parameter distributions, that are then used in section 5 to discuss the effects of government shocks. In section 6 we briefly address the issue of the interaction between monetary and fiscal policies, while in section 7 we summarize our results.

2 The setup

The economy is populated by a measure one of households of which a fraction γ are non-Ricardians. Non-Ricardian agents do not have access to financial or capital markets. Asset markets (not modelled) are assumed to be complete. Ricardian households are the only owners of assets, including capital, which is rented to firms.

Non-Ricardian households have been modelled 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 to capital markets, but they can still smooth consumption by adjusting their holding of money (for example, Coenen *et al.*, 2007). In this case non-Ricardian agents' consumption does not respond one to one to variations in disposable income. Consumption smoothing will still be less than complete, as the real return of money is generally negative.[11] Other authors have made assumptions implying stronger responses of non-Ricardian agents' consumption to variations in disposable income. In particular, following Campbell and Mankiw (1989), GLSV assume that each period non-Ricardian agents consume their current income; in their work, the strong response of non-Ricardian consumption to disposable income variations is a necessary condition in order to obtain a positive response of total consumption to government spending shocks.

Regarding the behavior of non-Ricardian agents in the labor market, Coenen *et al.* (2007) assume that for each labor type they are wage setters for their own labor effort which is only partially substitute to the one of the Ricardian households. In this case, non-Ricardian agents' labor supply will essentially depend on their static trade-off between consumption and leisure. On the other hand, both GLSV and CS assume that, for each labor type, efforts of the two groups are perfectly substitutable

[11] However, as Coenen *et al.* (2007) show in the case of a monetary policy shock, the dynamics of aggregate consumption is not very different from that in SW, where only Ricardian agents exist.

and are therefore equally remunerated, with all workers working the same amount of hours. In this paper we will follow this latter approach.

2.1 Consumers Problem

All consumers have a preference for variety: for each household i, the consumption index is

$$c_t(i) = \left[\int_0^1 c_t(i,j)^{\frac{\theta_c - 1}{\theta_c}} dj \right]^{\frac{\theta_c}{\theta_c - 1}} \tag{1}$$

where $c_t(i,j)$ is i's consumption of the good produced by firm j. The maximization of $c_t(i)$ w.r.t. $c_t(i,j)$ for a given total expenditure leads to a set of demand functions of the type

$$c_t(i,j) = \left(\frac{p_t(j)}{P_t} \right)^{-\theta_c} c_t(i) \tag{2}$$

where $p_t(j)$ is the price of the good produced by firm j gross of consumption taxes. Moreover, the appropriate price deflator is given by

$$P_t = \left[\int_0^1 p_t(j)^{1-\theta_c} dj \right]^{\frac{1}{1-\theta_c}} \tag{3}$$

An aggregator identical to (1) is also assumed both for real public consumption c_t^g and investment I_t, and for each of them isoelastic demand functions of the form (2) obtain.

Conditional on such optimal behavior, it will be true that $\int_0^1 p_t(j)c_t(i,j)dj = P_t c_t(i)$, and similarly for public consumption and investment, although for the latter it is assumed that no indirect tax is levied, so that the relevant price index is $\widetilde{P}_t = P_t/(1+\tau^c)$.

2.1.1 Ricardian households

Lifetime utility of the i-th Ricardian household (R) is a separable function of his consumption $c_t^R(i)$ and labor $l_t^R(i)$ given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left[\frac{1}{1-\sigma_c} \left(c_t^R(i) - h c_{t-1}^R \right)^{1-\sigma_c} - \varepsilon_t^l \frac{1}{1+\sigma_l} l_t^R(i)^{1+\sigma_l} \right] \tag{4}$$

Ricardian households have group-specific external habits in consumption with parameter $h \in [0,1)$: c_{t-1}^R is lagged aggregate per capita Ricardian consumption. Two demand shifters are assumed: ε_t^b affects the overall level of utility in period t while ε_t^l affects the consumption-leisure intratemporal trade-off. The nominal flow budget constraint for Ricardian agent i is given by

$$
\begin{aligned}
&(1-\tau_t^w)w_t(i)l_t^R(i) + (1-\tau_t^k)\Big[R_t^k\overline{k}_t^R(i)u_t(i) + D_t^R(i)\Big] + B_t^R(i) + Tr_t^R(i) + \frac{\tau_t^c}{1+\tau_t^c}P_tI_t^R(i) = \\
&= P_tc_t^R(i) + P_tI_t^R(i) + \frac{B_{t+1}^R(i)}{R_t} + P_t\psi(u_t(i))\overline{k}_t^R(i) + \frac{\phi}{2}\left(\frac{w_t(i)}{w_{t-1}(i)} - \pi\right)^2 W_t \qquad (5)
\end{aligned}
$$

where $(1-\tau_t^w)w_tl_t^R$ is net labor income, $(1-\tau_t^k)R_t^k\overline{k}_t^R u_t$ is net nominal income from renting capital services $k_t^R = \overline{k}_t^R u_t$ (where the bar indicates physical units of capital, while u_t is utilization intensity) to firms at the rate R_t^k, D_t^R are dividends distributed by firms to Ricardians (by assumption, the only firms' owners). The fiscal authority makes net lump-sum transfers Tr_t and finances its expenditures by issuing one period maturity discount nominal bonds B_t and by levying taxes on labor income (τ_t^w), capital income (τ_t^k) and consumption (τ_t^c). Consumption tax introduces a wedge between the producer price index $\widetilde{P}_t$ and the consumers one $P_t = (1+\tau_t^c)\widetilde{P}_t$. We assume that no indirect taxes are paid on purchases of investment goods, so that the price index of investment goods is the wholesale price $\widetilde{P}_t$. Instead of having two price levels in the consumers' problem, we include among the uses (r.h.s. of the budget constraint) the investment expenditure expressed in prices gross of taxes $P_tI_t^R$ and compensate it with a rebate equal to $\frac{\tau_t^c}{1+\tau_t^c}P_tI_t^R$, so that the difference between the two is equal to the actual expenditure on investment goods $\widetilde{P}_tI_t^R$. Uses also feature the amount of government bonds that Ricardian households carry over to the following period, discounted by the nominal interest rate $R_t = 1 + i_t$. Finally, adjustment costs are introduced on the households choices of the nominal wage w_t and of capacity utilization u_t. The first is incurred if the nominal wage deviates from the steady state path (on which gross wage inflation π^W is assumed equal to gross price inflation π) and is expressed in terms of the equilibrium wage rate W_t (see Kim, 2000). The second is incurred if the level of capital utilization changes with respect to its steady state value of 1; this cost is described by an increasing convex function $\psi(u_t)$, with $\psi(1) = 0$. Hence $\psi(u_t)\overline{k}_t^R$ denotes the cost (in terms of consumption units) associated with the utilization level u_t.

The physical capital accumulation law is

$$
\overline{k}_{t+1}^R(i) = (1-\delta)\,\overline{k}_t^R(i) + \left[1 - s\left(\frac{\varepsilon_t^i I_t^R(i)}{I_{t-1}^R(i)}\right)\right] I_t^R(i) \qquad (6)
$$

where not all new investment gets transformed into capital and the term $s\left(\frac{\varepsilon_t^i I_t^R}{I_{t-1}^R}\right) I_t^R$ describes (in terms of capital loss) the cost of adjustment the agent incurs if he varies the investment level with respect to the previous period, a cost which is subject to a specific efficiency shock ε_t^i.[12]

2.1.2 Non Ricardian households

Non-Ricardian households (NR) are assumed to simply consume their after-tax disposable income, as originally proposed by Campbell-Mankiw (1989). That is, their budget constraint is simply:

$$P_t c_t^{NR}(i) = (1-\tau_t^w) w_t(i) l_t^{NR}(i) + Tr_t^{NR}(i) \tag{7}$$

2.2 Firms problem

In the private sector there is a continuum of firms j each producing one differentiated final good with the following Cobb-Douglas technology defined in terms of homogeneous labor input l_t^p (where the index p refers to the employment level in the private sector) and rented capital services:

$$y_t(j) = k_t(j)^{\alpha} (l_t^p(j)\, \varepsilon_t^z)^{1-\alpha} \tag{8}$$

where ε_t^z is a stationary labor-augmenting technology shock.

From the solution of firm j's static cost minimization problem, we have inputs demands

$$k_t(j) = y_t(j) \left(\frac{W_t}{R_t^k} \frac{\alpha}{1-\alpha} \right)^{1-\alpha} \varepsilon_t^{z\ \alpha-1} \tag{9}$$

$$l_t^p(j) = y_t(j) \left(\frac{W_t}{R_t^k} \frac{\alpha}{1-\alpha} \right)^{-\alpha} \varepsilon_t^{z\ \alpha-1} \tag{10}$$

and, defining $\zeta = (1-\alpha)^{\alpha-1}\, \alpha^{-\alpha}$, an expression for the nominal marginal cost (here equal to the average one and hence common to all firms)

$$MC_t = \zeta W_t^{1-\alpha}\, R_t^{k\ \alpha} \varepsilon_t^{z\ \alpha-1}\ . \tag{11}$$

Each firm chooses its own net price $\widetilde{p}_t\,(j)$ to maximize intertemporal profits defined as the difference between total revenues and total costs (inclusive of a price adjustment cost, which is scaled in terms of wholesale total output)

$$\max_{\{\widetilde{p}_t(j)\}} E_0 \sum_{t=0}^{\infty} Q_{0,t} \left(\widetilde{p}_t(j) y_t(j) - MC_t y_t(j) - \frac{\kappa}{2} \left(\frac{\widetilde{p}_t(j)}{\widetilde{p}_{t-1}(j)} - \pi \right)^2 \widetilde{P}_t y_t \right) \tag{12}$$

[12] As in Christiano *et al.* (2005), $s\,(.)$ has the general properties $s\,(1) = s'\,(1) = 0$ and $s''\,(1) > 0$

subject to the fact that output is demand-determined. From aggregation over agents, aggregate demand for each component still has the form of (2): being total demand for good j equal to $y_t(j) = c_t(j) + c_t^g(j) + I_t(j)$, each firm will face an isoelastic demand function with price elasticity θ_c for its total demanded output. $Q_{0,t}$ is the stochastic discount factor for Ricardian households (the only share-owners).

2.3 The labor market

For each type of differentiated labor service, supply comes from both Ricardian and non-Ricardian households and demand gets uniformly allocated among them. Labor is an input for both the public and the private sector, $l_t = l_t^g + l_t^p$. Public sector labor demand is assumed to be uniformly met by supply, so that $l_t^g = \int_0^1 l_t^g(i)di$; it is modelled as an autoregressive exogenous shock in logs with i.i.d. error term, of the form

$$\log l_t^g = \rho_{lg} \log l_{t-1}^g + \left(1 - \rho_{lg}\right) \log l^g + \varepsilon_t^{lg} \tag{13}$$

We assume that the wage rate in the public sector is equal to the one prevailing in the private sector.[13] In fact, hours can be moved costlessly across the two sectors and l_t^g and l_t^p are perfect substitutes in the utility function. This setup is very similar to the one considered by Cavallo (2007), although in a different context.

In the private sector labor market, a perfectly competitive firm buys the differentiated individual labor services supplied by households and transforms them into an homogeneous composite labor input that, in turn, is sold to good-producing firms. The 'labor packer' is a CES aggregator of differentiated labor services which solves:

$$\max_{l_t^p(i)} \; l_t^p = \left[\int_0^1 l_t^p(i)^{\frac{\theta_L - 1}{\theta_L}} di\right]^{\frac{\theta_L}{\theta_L - 1}} \tag{14}$$

$$\text{s.t.} \quad \int_0^1 w_t(i) l_t^p(i) di = \overline{E}_t$$

for a given level of the wage bill $\overline{E}_t$. The solution gives the demands for each kind of differentiated labor service in the private sector $l_t^p(i)$:

$$l_t^p(i) = \left(\frac{w_t(i)}{W_t}\right)^{-\theta_L} l_t^p \tag{15}$$

where l_t^p is total private sector labor and W_t is given by

$$W_t = \left[\int_0^1 w_t(i)^{1-\theta_L} di\right]^{\frac{1}{1-\theta_L}}$$

[13]This assumption is not far from reality. In fact, hourly wages in the public sector tend to track private sector ones, at least over medium terms horizons.

The representative Ricardian household sets optimally his wage for his type i labor, having regard of the labor demand constraint (15). For simplicity, and following Erceg *et al.* (2005), it is assumed that non-Ricardian households cannot choose a wage, but for each of them the wage rate is equal to the average one of Ricardians. Since all households face the same labor demand, each non-Ricardian household will work the same number of hours as any Ricardian.

2.4 Fiscal policy

Estimates concerning the effects of fiscal policy are usually constrained by the lack of quarterly data on government accounts. For the euro area, Eurostat has recently started to release quarterly data on general government accounts, but only from 1999 onward, i.e. a period too short to be used for our purposes. The only quarterly data series easily available is the National Account definition of government consumption (G). As we have computed quarterly data for government purchases of goods and services, transfers to families, total revenues and average effective tax rates,[14] 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. Finally, having data on distortionary taxes makes us more confident in our estimates of certain shocks: in particular, it helps disentangling the effects of a shock affecting the consumption-leisure intratemporal trade-off from those of a change in the labor income tax rate, or the effects of a technology shock from those of a capital income tax rate shock.

We consider the following budget constraint:

$$\left[\frac{B_{t+1}}{R_t} - B_t\right] = C_t^g + W_t l_t^g + Tr_t - T_t \tag{16}$$

where C_t^g is nominal government purchases of goods and services (assumed to be pure waste), $W_t l_t^g$ is compensation for public employees (such that $C_t^g + W_t l_t^g = G_t$) and Tr_t are transfers to households. Total government revenues T_t are given by the following identity:

$$T_t = \tau_t^w W_t l_t + \frac{\tau_t^c}{1+\tau_t^c}\left[P_t c_t + C_t^g\right] + \tau_t^k \left[R_t^k k_t + D_t\right] \tag{17}$$

[14]For government employment, the Eurostat NA series is already quarterly.

where tax rates on labor income, capital income and consumption are assumed to be determined according to the following rules (where hats denote log-linearized form):

$$\widehat{\tau}_t^w = \rho_{\tau^w}\widehat{\tau}_{t-1}^w + (1-\rho_{\tau^w})\eta_{\tau^w}\widehat{b}_t + \widehat{\varepsilon}_t^{\tau^w} \tag{18}$$

$$\widehat{\tau}_t^c = \rho_{\tau^c}\widehat{\tau}_{t-1}^c + (1-\rho_{\tau^c})\eta_{\tau^c}\widehat{b}_t + \widehat{\varepsilon}_t^{\tau^c} \tag{19}$$

$$\widehat{\tau}_t^k = \rho_{\tau^k}\widehat{\tau}_{t-1}^k + (1-\rho_{\tau^k})\eta_{\tau^k}\widehat{b}_t + \widehat{\varepsilon}_t^{\tau^k} \tag{20}$$

where $b_t = \log(B_t/P_t)$ and each ε_t^τ is an i.i.d. innovation.

Expenditure items in real terms, $c_t^g \equiv C_t^g/P_t$ and $tr_t \equiv Tr_t/P_t$, are assumed to follow exogenous log linear AR(1) processes as for l_t^g :

$$\log c_t^g = \rho_{cg}\log c_{t-1}^g + \left(1-\rho_{cg}\right)\log c^g + \varepsilon_t^{cg} \tag{21}$$

$$\log tr_t = \rho_{tr}\log tr_{t-1} + (1-\rho_{tr})\log tr + \varepsilon_t^{tr} \tag{22}$$

where c^g and tr are steady state values, and ε_t^{cg} and ε_t^{tr} are i.i.d. error terms.

As for steady state values, based on sample averages we set $C^g = 10\%$ of output, $B = 60\%$ (on a yearly basis) and l^g equal to 20% of total employment. Steady state values for tax rates are assumed to be simply the averages over the sample period of our estimates of effective average tax rates (approximately equal to 16% for consumption taxes, 19% for capital income taxes, 45% for labor income taxes). Given these figures, the steady state value for transfers is set residually so to satisfy the government budget constraint (it turns out to be equal to 16.5% of output).

2.4.1 Some remarks on the fiscal policy rules

In our benchmark specification we assume that taxes are set in order to keep real debt dynamics under control. This is consistent with the idea that debt stabilization is an important motive in the conduct of fiscal policy. Debt stabilization, however, might not be the only motive driving tax rates. In particular, one might want to allow taxes to respond also to the cyclical position of the economy or to changes in expenditure levels.

Regarding cyclical conditions, economic theory suggests that tax rates should not respond to output fluctuations (the tax smoothing result). To explore this issue we have added to our policy rules the gap of output from its steady state value. The estimates show that the coefficients relating tax rates to the output gap are in general positive (suggesting pro-cyclical changes in tax rates) but too small to affect significantly the results.[15] This implies also that our results do not depend on whether we use as a measure of debt the real debt (as we do) or to the debt/output ratio.We have also experimented adding measures of expenditures (transfers, government consumption of good and services, government wage bill) in the tax rules and found that the corresponding coefficients are not well identified and in general not sizable.

As for expenditures, we are assuming they are all exogenous AR(1) processes. In general, expenditures tend to be rather stable in nominal terms across the business cycle, with the notable exception of transfers to households, as they include also welfare and unemployment benefits. The inclusion of measures of economic activity in the process describing expenditures is potentially important, as an expansionary fiscal shock could bring about an increase in activity or employment and therefore a reduction in transfers to households. The latter could in turn offset the increase in disposable income of non-Ricardian households coming from the increase in labor income. We have therefore experimented adding in the equation describing transfers the deviation of output and of private employment from their own steady state values. The estimated response of transfers to both measures of gap, although well identified, is relatively mild and overall not able to change in any significant way our estimated response of private consumption to government expenditure shocks.

Finally, another relevant issue is whether we are able to properly identify fiscal policy innovations, in particular tax rates innovations. In this respect, we follow the approach that is standard in the literature on monetary policy, that is to augment the tax rules with an i.i.d. error term and to assume that this error represents an unexpected change in policy. However, it might be argued that fiscal policy is different, as it suffers more than monetary policy from announcement effects and implementation lags. Although this criticism cannot be entirely disregarded, it is difficult to believe that changes in effective tax rates on a quarterly basis could be fully anticipated. Moreover, we assume that a share of agents consume their current disposable income. For these agents, even changes that are announced in advance will not have any effect prior to their realization.

[15]There is some evidence on the response of the overall budget to the cycle (as measured for example by the output gap) on a yearly basis, although Galí-Perotti (2003) document that the response is at best weak. The evidence is more supportive of the stabilization role of fiscal policy when estimates are conducted using real time data; see on this Forni-Momigliano (2004).

2.5 Monetary policy

The monetary policy specification is in line with SW 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 lagged inflation π_{t-1}, to contemporaneous output, to changes in inflation $\Delta\pi_t = \pi_t - \pi_{t-1}$, and to output growth $\Delta y_t = y_t - y_{t-1}$; that is, in log-linearized form:

$$\widehat{R}_t = \rho_R \widehat{R}_{t-1} + (1-\rho_R)(\rho_\pi \widehat{\pi}_{t-1} + \rho_y \widehat{y}_t) + \rho_{\Delta\pi} \widehat{\Delta\pi}_t + \rho_{\Delta y} \widehat{\Delta y_t} + \widehat{\varepsilon}_t^m \tag{23}$$

The monetary policy shock ε_t^m is assumed to be i.i.d.[16]

2.6 Aggregations and market clearing

The aggregate per-capita level of any household quantity variable $x_t(i)$ is given by

$$x_t = \int_0^1 x_t(i)di = (1-\gamma)x_t^R + \gamma x_t^{NR}$$

as households within each of the two groups are identical. Therefore, aggregate consumption is given by

$$c_t = (1-\gamma)c_t^R + \gamma c_t^{NR} \tag{24}$$

Moreover, since only Ricardian households hold bonds, accumulate physical capital through investment and receive dividends, related per-capita aggregate variables will be given by:

$$\begin{aligned} B_t &= (1-\gamma)B_t^R \\ \overline{k}_t &= (1-\gamma)\overline{k}_t^R \\ I_t &= (1-\gamma)I_t^R \\ D_t &= (1-\gamma)D_t^R \end{aligned}$$

[16] In new-keynesian models with non-Ricardian agents the *Taylor principle* (that states $\rho_\pi > 1$ as a sufficient condition for local determinacy) might not hold. For example, Bilbiie (2006) argues, in a model without capital, that determinacy requires a muted (less than one for one) response of nominal rate to inflation (the so called *inverted Taylor principle*). On the other hand, Galí *et al.* (2004, 2007) show that, when both price stickiness and the share of non-Ricardians are high, the Taylor principle should be reinforced (*reinforced Taylor principle*), that is determinacy requires a response of nominal rate to inflation much greater than one. Both Bilbiie (2006) and Galí *et al.* (2004, 2007) assume flexible wages. However, Colciago (2006) shows that with (reasonable amounts of) wage stickiness the Taylor principle is restored as both the *inverted Taylor* and the *reinforced Taylor* regions disappear.

Equilibrium in the goods market requires:

$$y_t = k_t{}^{\alpha}(l_t^p \varepsilon_t^z)^{1-\alpha} = c_t + I_t + c_t^g + ADJ_t \tag{25}$$

where ADJ_t stands for adjustment costs in real terms,

$$ADJ_t = \frac{\phi}{2}\left(\pi_t^W - \pi\right)^2 \frac{W_t}{P_t} + \psi(u_t)\overline{k}_t + \frac{\kappa}{2}\left(\widetilde{\pi}_t - \pi\right)^2 \frac{y_t}{1+\tau_t^c}$$

with $\pi_t^W \equiv W_t/W_{t-1}$ and $\widetilde{\pi}_t \equiv \widetilde{P}_t/\widetilde{P}_{t-1}$. Market clearing conditions in capital and private labor markets are obtained by setting firms' demands (9) and (10) equal to households' supplies:

$$k_t = \left(\frac{W_t}{R_t^k}\frac{\alpha}{1-\alpha}\right)^{1-\alpha} \varepsilon_t^{z\ \alpha-1} y_t \tag{26}$$

$$l_t^p = \left(\frac{W_t}{R_t^k}\frac{\alpha}{1-\alpha}\right)^{-\alpha} \varepsilon_t^{z\ \alpha-1} y_t$$

3 Solution and estimation

We solve the model using linear techniques. First order conditions and their log-linearizations around the deterministic steady state are reported in Appendix A and C, respectively. Stacking all the endogenous variables of the model in the vector X_t and using lower-case to denote log deviations from the steady state (i.e. $x_t \equiv \log X_t - \log X$) we can write the model as

$$AE_t\left(x_{t+1}\right) = Bx_t + Cz_t \tag{27}$$

$$E_t\left(z_{t+1}\right) = Sz_t \tag{28}$$

where z_t are the exogenous variables (i.e., the shocks) and the entries in the matrices A, B and C depend on the structural coefficients in the model and on the steady state values of X_t. The recursive solution has a state-space representation:

$$s_{t+1} = Ms_t + Nz_t$$
$$v_t = Ps_t + Qw_t$$

where s_t and v_t contain the predetermined and non-predetermined variables in the model, respectively, and w_t is a vector of measurement errors, which in our case will be nonzero only in the entry for total public revenues. That is, we consider a (i.i.d.) measurement error ε^t when estimating equation (17), as it is unlikely that the total revenues obtained from the sum of the three tax rates times their tax bases (the r.h.s.

of equation (17)) could ever match exactly the total revenue data (the l.h.s. of equation (17)).

We map the solution with a matrix of observables and estimate the model using Bayesian inference methods. First, relying on information from earlier studies, we specify a prior distribution for each parameter to be estimated. Using prior information seems very reasonable, in particular when the period covered by the data is not very long as in our case; moreover, it helps reducing the numerical difficulties associated with a highly non-linear estimation problem such as ours.

3.1 Estimation methodology

Let $P(\vartheta|m)$ be the prior distribution of the parameter vector $\vartheta \in \Theta$ for some model $m \in M$ and let $L(Y_T|\vartheta, m)$ be the likelihood function for the observed data $Y_T = \{y_t\}_{t=1}^{T}$, conditional on the parameter vector ϑ and the model m. The likelihood is computed starting from the log-linear state-space representation of the model by means of the Kalman filter and the prediction error decomposition. The posterior distribution of the parameter vector ϑ is then obtained combining the likelihood function for Y_T with the prior distribution of ϑ, that is:

$$P(\vartheta|Y_T, m) = \frac{L(Y_T|\vartheta, m)P(\vartheta|m)}{\int L(Y_T|\vartheta, m)P(\vartheta|m)d\vartheta}$$

The computation of the integral at the denominator becomes rapidly an impossible task as the number of parameters increases (and we have 45 parameters to estimate). In order to obtain numerically a sequence from this unknown posterior distribution, we follow Schorfheide (2000) and SW and employ the Metropolis-Hastings algorithm.

3.2 Data and prior distributions

We use data on consumption, investment, wages, inflation and nominal interest rate. As for public sector variables, we use government purchases of goods and services, transfers to households, public employment, tax rates on labor income, on capital income, on consumption and total tax revenues. In Appendix D we report sources and description of each series, we describe in detail the methodology that we have employed to compute effective average tax rates and to obtain quarterly variables from annual ones. We provide also some comparisons with alternative sources.

We detrend the logarithm of real variables with a linear trend. For tax rates, we simply subtract sample means for the variables in logarithm. As for the inflation trend, we fit a linear spline until 1999:Q1 and assume a 2% target for annual inflation thereafter. The trend for the interest rate is assumed to be equal to that of the inflation rate divided by the discount factor β, consistently with the steady state relation of the model. The series that we use in estimation (together with the fit of the model) are plotted in figure 3.

We calibrate four parameters: $\beta = 0.9926$ (so that the annual steady state real interest rate is 3%), $\delta = 0.025$ (so to imply a 10% annual depreciation rate of capital), $\alpha = 0.3$ (which makes the steady state labor share in income approximately equal to 70%), $\theta_c = 6.0$ (which implies a steady state price mark-up approximately equal to 20%). We calibrate θ_c as it is difficult to jointly identify it and the adjustment cost parameter on prices κ.

Table 1 shows the main prior distributions for the remaining parameters. Prior distributions are also reported, together with posteriors, in figure 4. As for the preference parameters, a Gamma distribution is assumed for the coefficients of risk aversion σ_c and of Frisch elasticity σ_l, with a mean of 2 and 3, respectively, and a standard deviation for both parameters equal to 0.5, so that both prior masses are concentrated on values higher than a logarithmic specification. The fraction of non-Ricardian consumers γ, whose mean is set at 0.5 as in the baseline setting in GLSV, and the habit coefficient h, whose mean is set at 0.7 as in SW, are distributed according to a Beta distribution with standard deviations of 0.1. The labor wage elasticity θ_L is assumed to follow a Gamma distribution centered on a value of 6.5, which yields a steady state wage mark-up slightly lower than the one for prices; a prior variance of 1 is assumed, so that the markup prior ranges from 10% to 50% approximately.

A Gamma distribution is chosen for the four frictions parameters. Since there is some uncertainty on whether prices or wages are more rigid (for example, SW claim that, despite common belief, a very robust result of their estimated model for the euro area is the greater stickiness in prices relative to wages), we set the mean of both adjustment costs coefficients on prices and wages, κ and ϕ, at an equal of 100. Given mean values for the other parameters, this assumption corresponds approximately to an adjustment frequency of five quarters[17] (approximately the frequency at which the median firm changes its prices in the euro area according to the evidence presented in Fabiani *et al.* (2006) and the average wage duration estimated for the euro area by SW, respectively). The range covered by the prior distributions of both parameters

[17]The mapping between cost of adjustment parameters and adjustment frequency can be obtained comparing coefficients in the respective expectational Phillips curves, as sketched in Corsetti *et al.* (2005).

is chosen so 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. Investment and capital utilization adjustment coefficients, s'' and ψ''/ψ', have a mean, respectively, of 5 and 0.2 and a standard deviation equal to 0.25 and 0.1, in line with the priors of SW.

All non-policy shocks are assumed to be characterized by an AR(1) process of the type

$$\log \varepsilon_t = (1 - \rho_\varepsilon) \log \varepsilon + \rho_\varepsilon \log \varepsilon_{t-1} + \eta_t \tag{29}$$

with steady state value ε and i.i.d. error term η_t. A Beta distribution is chosen for the autoregressive coefficients ρ, with mean and standard deviation set at 0.85 and 0.1, respectively, as in SW. For these shocks, the standard deviations of the innovations are assumed to be distributed as Gamma with a 10% mean and 0.02 standard deviation.

Monetary policy parameters are assumed to have the same distribution type, mean and standard deviation as in SW, the only exception being that ρ_π, the coefficient measuring the response of the nominal rate to lagged inflation, is assumed to be Gamma rather than Normal-distributed. Innovations to monetary policy are assumed to be white noises with standard deviation distributed as Gamma with mean 0.1 and standard deviation equal to 0.02.

Tax policies are a priori taken to be quite persistent, with autoregressive coefficients distributed as a Beta with mean 0.8 and standard deviation equal to 0.1. Tax rates elasticities with respect to debt are all assumed to be distributed as a Gamma with mean 0.5 and standard deviation equal to 0.1 (so that they will range approximately between 0.2 and 0.8). Innovations to tax rates are assumed to be white noises with standard deviation distributed as Gamma with mean 0.1 and standard deviation equal to 0.02.

4 Estimation results

Given priors, we estimate the posterior distributions of the parameters using the Metropolis-Hastings algorithm with one million iterations, a number which seems to be sufficient to achieve convergence (as measured by the cumulated mean and standard deviation of the parameters). Figure 4 plots prior and posterior distributions for a selection of parameters.[18]

[18] The percentage of accepted draws is 26%. Since we initialize the MH with the estimated mode and Hessian, evaluated at the mode, of the posterior distribution, we have carried out several diagnostic checks on the properties of the mode. In particular, we have checked the gradient and the conditioning

Overall, most parameters seem to be well identified, as shown by the fact that either the posterior distribution is not centered on the prior or it is centered but with a smaller dispersion. Some parameters however are not: this is the case for those related to investment adjustment cost, s'', the monetary response to inflation, ρ_π, and to a certain degree the parameters capturing the response of the consumption and capital income tax rates to the debt level. The fact that the labor income tax rate coefficient on debt seems to be well identified is not surprising, as labor income tax rates include social security contributions, that have been increasing in the last twenty years in order to keep under control social security deficits (which have been an important determinant of public debt growth in most European countries).

Right columns of table 1 summarize estimated means and standard deviations for a selection of the parameters. The top panel reports estimates for preference and technology ones. The estimated fraction of non-Ricardian households γ turns out to be 0.38, which is higher than in CS but not so high as to reach more than half of the population as in the U.S. estimate of Campbell-Mankiw (1989).

Among preference parameters, those related to risk aversion, σ_c, habit, h, and the elasticity of labor supply with respect to real wage, $1/\sigma_l$, are estimated to be higher with respect to both SW and CS. Also the elasticity of labor demand with respect to the real wage, θ_L, is estimated to be quite higher than the calibrated value of SW and CS, implying a much lower steady state wage markup, at about 20%.

With respect to both SW and CS, the estimate for price stickiness confirms the result that it exceeds the one of wages by a factor of three. Based on a Rotemberg-Calvo equivalence, it can be computed as a price duration of about 8 quarters, i.e. lower than in the two above papers, though comparable with the estimate in Galí *et al.* (2001).

Estimated policy coefficients feature, on the monetary side, a lower smoothing and a higher weight on inflation and, particularly, on inflation change with respect to both SW and CS. On the fiscal side, tax rate processes appear to be highly persistent, although the reaction to debt is quite sizeable and large enough to be stabilizing. The autoregressive parameter for government purchases, public employment and transfers to households are estimated at respectively 0.87, 0.97 and 0.96 (levels similar to the one estimated for government consumption G by both SW and CS), pointing to a high persistence of fiscal policy innovations.

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number of the Hessian, the covariance among parameters implicit in the estimated Hessian and plotted slices of the likelihood around the mode. The Hessian is in general well conditioned and does not imply any correlation among parameters higher that 0.8, and the likelihood at the mode shows a significant curvature for almost all parameters. This latter result, in particular, is evidence of the fact that the data contain useful information to identify the parameters.

As a robustness check, we re-estimated the model using the same series detrended with an HP filter rather than subtracting linear trends. In line with expectations, we obtain lower estimates for the autoregressive coefficients on the fiscal policy variables. In particular, the autoregressive parameter for government purchases, public employment and transfers to households drop to, respectively, 0.54, 0.77 and 0.82, while the ones on tax rates to 0.86 for labor income taxes, to 0.90 for consumption taxes and to 0.94 for capital income taxes. There are not major differences for the estimates of the other parameters (with the notable exception of the habit parameter that drops from 0.84 to 0.72). Notwithstanding these differences, results in terms of impulse responses are hardly affected. In the following we will present results based only on linear detrending.

As for the fit of the model, we have already showed in figure 3 that the model is able to replicate the data used for estimation. In figure 5 we report the cross-covariance functions of the model variables against the data. We consider four lags and four leads. We plot the 90% confidence bands of the cross-covariance functions obtained on 10,000 random samples generated by the DSGE model. The samples are obtained by randomly drawing 100 times from the parameter posterior distribution and running the model 100 times for each parameter draw. Generally, and despite some notable exceptions, as the cross-covariance between private consumption and investment, the data covariances fall within the confidence intervals suggesting that the model is able to mimic the cross-covariance in the data within a one year horizon. Most cross-covariances involving fiscal policy variables fall within confidence bands.

5 General equilibrium effects of fiscal policy

5.1 Government spending shocks

We now discuss the implications of our estimates for the effects of government spending shocks on the economy. Figure 6 shows impulse responses with respect to a shock to real government purchases c_t^g, figure 7 with respect to a shock to government employment l_t^g, while figure 8 with respect to real transfers tr_t. The solid line reports 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 private output (i.e. excluding the government wage bill).[19] Impulse responses are for each variable the deviation from its steady state value expressed in percentage points (i.e. 1 means 1%). The deviations of real interest rate and inflation (gross of consumption taxes) are reported in annualized percentage points. Total revenues and debt are expressed as a percentage of output. For the different components of revenues (from labor income, capital income and consumption taxes), we report their contribution to the change of total real revenues (so that the sum of the responses of labor income, capital income and consumption tax revenues minus the response of output is equal to the response of total tax revenues/output ratio). The bottom right panel of each figure reports the path of the shock.

We can immediately observe that on impact all three shocks increase employment and aggregate private consumption. The shock to purchases does that by increasing the demand for goods and services which, in turn, brings about an increase in employment and labor income. This sustains consumption of non-Ricardians, to an extent able (also in view of their share) to more than compensate the decrease in Ricardian consumption due to the negative wealth effect of debt-financed spending. Adjustments occur mainly on quantities: real wages, marginal costs, inflation and the nominal interest rate all increase mildly: the limited increase of the real rate contains the impact decrease of Ricardian consumption. The overall increase in consumption, together with the increase in the real interest rate, induce a decrease in investment. However, employment rises, making the use of capital services more profitable and leading to a more intensive use of capacity.

The shock to government employment increases total labor demand and determines an increase in both total employment and labor income. On the private labor market, overall supply contracts despite some increase induced by the negative wealth effect of debt-financed government hiring; labor demand expands following the higher demand for goods by non-Ricardians, which firms mostly accommodate by decreasing unitary markups on their prices due to price adjustment costs. Overall, private employment increases. Labor income is higher for all households, but Ricardian consumption is depressed by the negative wealth effect, despite a decrease in the real interest rate. With respect to a c_t^g shock, the l_t^g shock has a greater positive impact effect on private aggregate consumption, as non-Ricardian consumption hikes (after the boost in labor income), but lower on output, as the hiring from the government tends to crowd out employment in the private sector.

Finally, the shock to transfers to households has the biggest and more persistent

[19] In particular, the shock to l_g is calibrated in order to have an increase in the public wage bill, using the steady state level of wages, equal to 1% of steady state output.

impact on consumption as it translates one to one into an increase in disposable income of non-Ricardians. Demand-driven output and employment also increase, and so do capacity utilization and investment, while real wages fall.

These estimated responses are consistent with a new-keynesian framework but not with an RBC-style model. Inconsistencies with the latter lie not only in the positive response of private consumption following a government expenditure shock, but also in the (mild) increase of real wages after a shocks to c_t^g, as the wealth effect brings about an increase in employment that in turn should imply a decrease in the marginal productivity of labor and in real wages. The increase (or stability) in real wage that we find is therefore possible only if there is an outward shift in labor demand. Finally, after a government employment shock, private employment increases on impact, although mildly, reflecting the keynesian effect on labor demand via an increase in consumption and output. In fact, in an RBC-style model, for reasonable calibrations of the parameters, the increase in labor supply due to the standard wealth effect after an increase in public spending cannot compensate for the increased labor demand from the government, so that private sector employment would decrease on impact. The increase in private sector employment that we find is therefore due to the contemporaneous shift in labor demand as price markups get reduced (to accommodate a higher goods demand under sticky prices). This keynesian effect, however, does not last long and after roughly four quarters employment in the private sector starts reducing.

5.2 Shocks to tax rates

Next we look at the effects of tax rates innovations. Figures 9-11 plot the impulse responses of a shock to, respectively, the tax rate on labor income, capital income and consumption, all calibrated in order to achieve a decrease in revenues equal to 1% of steady state private output.

The main effect of the reduction in labor income tax (approximately 1.6 percentage points) is to lead to an increase in employment. The latter, on the one hand, leads to an increase in output; on the other hand, together with the decrease in labor taxes, induces an increase in non-Ricardian disposable income and consumption, which further reinforces the increase in output. As the nominal rate stays virtually unchanged, investment gradually increases.

The decrease in capital income taxes (slightly less than 3 percentage points) leads on impact to a reallocation from labor to capital, whose utilization spikes up. Ricardian intertemporal choice starts favoring investment rather than consumption. The decrease in employment reduces non-Ricardian labor income. Therefore, aggregate consumption falls, and inflation do as well. Over time, however, physical capital builds up, leading also employment back towards its steady state value. In the case of changes in capital income taxes, therefore, the presence of non-Ricardian consumers has a stabilizing effect on output. In fact, the expansionary effect (via an increase in capacity utilization and investment) of a reduction in τ_t^k is partially compensated by a reduction in employment and disposable income of non-Ricardians.

The main effect of a decrease in consumption taxes (around 1.4 percentage points) is a one time decrease in inflation (5% on annual terms) that brings about an increase in the real interest rate. Nevertheless, the wealth effect prevails and Ricardian consumption of the cheaper goods basket increases, although mildly, while much sharper is the increase in non-Ricardian one. A lower price level also leads to a substantial increase in real wages, implying that the expansion in demand-determined output is implemented by firms mainly through a higher capacity utilization rather than labor. As the real interest rate spikes back, Ricardian consumption keeps increasing (though slowing down as the tax gradually returns to its steady state level), shifting away resources from investment.

5.3 Fiscal multipliers

To summarize the quantitative effects of our six fiscal shocks we report in table 2 the fiscal multipliers on private output, consumption, investment and inflation implied by our estimates. We report the average effect in the first 1, 4, 8 and 12 quarters respectively, expressed in percentage points (annualized in the case of inflation).

We first note that fiscal multipliers on consumption and output are sizable, although generally less than one, while the effect on inflation is in general mild. The average effect on output in the first year is, as expected, greatest for a shock to purchases of good and services: the other shocks have all multipliers between 0.2 and 0.4. The keynesian effect on consumption is higher for innovations to transfers and labor taxes.

It is interesting to note that the impact effect on consumption and output of a reduction in labor income or consumption tax rates is similar to an increase in transfers or in public employment. The effect in all cases works through an increase in households' (in particular non-Ricardian) real labor income, which drives the increase in consumption and output. However, the innovation in public employment tends to crowd out private employment and therefore output and consumption: after 12 quarters the average effect on output of an increase in government employment becomes negative.

The effects on prices are generally mild, the notable exception being innovations to consumption taxes (as they translate almost one to one to prices).

These results are broadly in line with available empirical evidence, coming from both VAR analyses and large scale macroeconomic models, i.e. models which are either not microfounded at all or not in the same way as in the DSGE literature. In addition simulation exercises run with large scale models usually assume as exogenous the path of certain variables, as the interest rates or the fiscal variables themselves. This obviously complicates the comparison with our results. Moreover, analyses with both VAR and econometric models have usually focused on a small set of variables. Henry *et al.* (2004) compare output and inflation responses from a selection of large scale macro models of euro area countries institutions with respect to four fiscal shocks: purchases of good and services, personal income tax, indirect taxes and social security contributions.[20]

As reported by Henry *et al.* (2004), the first year effect on output of a 1% of GDP increase in purchases of good and services ranges between 1.18 for the Deutsche Bundesbank model to 0.87 for the model of the National Bank of Belgium. The average of the models considered is 0.97, slightly higher than our number. However, the results for the second year after the shock - on the average of the countries considered - is 1.19, higher than what we find. The corresponding estimates for the first and second years obtained from the Area Wide Model (AWM) of the ECB are 1.04 and 1.53. As for prices, the effect on inflation in the first year for the Bundesbank model is 0.04 percentage points, while for the simple average of the countries considered is 0.11. The corresponding multiplier for the AWM is 0.16. Therefore, our number (0.15) lies in the higher range of estimates.

As for the other shocks considered by Henry *et al.* (2004), we can make a reasonable comparison only for the one to indirect tax rates.[21] They report an average effect in the first year of 0.35 on GDP and -1.19 percentage points on prices, not far from our estimates (0.43 and -1.51).

To get a sense of how sensitive these quantitative effects are to the specific parameters values, in figures 12-17 we plot the average first year response of output,

[20]Perotti (2005) presents a VAR analysis of the effects of fiscal policy in five OECD countries (USA, Germany, UK, Canada, Australia). He considers innovations to two variables: government spending (including purchases of good and services, the public wage bill and government investment) and net taxes (i.e., taxes net of transfers to households). These definitions are different from ours and therefore any quantitative comparison with his work would not be appropriate.

[21]In fact, personal income taxes include taxes on both labor and capital income, while we consider them separately. Social security contributions are, in our framework, included in τ^w as we assume that in the bargaining process firms care for the cost of labor (w, that includes all social security contributions) while workers do for the take-home pay ($w(1-\tau^w)$, that is net of all social security contributions and personal income taxes on labor).

consumption and investment to each of our six fiscal shocks, moving one important parameter at a time. We focus on those parameters that are most likely to have an influence on the responses of consumption, investment and output, that is the share of non-Ricardian agents (γ), the inverse of the labor supply elasticity (σ_l), the habit persistence perimeter (h), the autoregressive coefficient for the shocks (ρ_{cg}, ρ_{tr} and ρ_{lg} depending on the shock), the debt coefficient in the labor income tax rule (η_{τ^w}) and the inflation coefficient in the Taylor rule (ρ_{π}). For example, in figure 12 top left panel we plot the average first year response of output, consumption and private investment to a 1% of GDP government purchases shock allowing the parameter γ to move between 0 and 1, while leaving the other parameters unchanged.[22]

Regarding spending shocks, we note that results are most sensitive to γ and to the autoregressive coefficients. A positive response of private consumption following shocks to purchases and government employment obtains only for shares of non-Ricardians higher than about 20% (less for transfers). The large effect on responses of a greater persistence in expenditures shocks is of no surprise: as the autoregressive parameter becomes higher, the negative wealth effect on Ricardian consumption is more and more exacerbated, and the impact response of total private consumption is diminished.

As for taxes, the effects of labor income tax shocks are very sensitive to parameter values. To a large extent this result is due to the fact that we are moving preference parameters (as h and σ_l). For example, it is to be expected that the effect of a labor income tax change will be higher the higher is the labor supply elasticity (the smaller is σ_l), given that labor income is key for the increase in consumption demand by non-Ricardians.

Finally, we briefly comment on the contribution of each of the structural fiscal shock to the variance of the endogenous variables at various horizon (at the first and fourth quarters, and asymptotically; see table 3). Focusing on the long term horizon, we see that government purchases and employment shocks have almost no explanatory power for the variance of any of the macro variables considered. Among expenditures, only transfers do have a role, in particular in explaining private consumption and inflation. Among revenues, the labor income tax rate explains a non-trivial component of private consumption, inflation and total revenues. The reason why both transfers and labor income taxes have a more prominent role - among fiscal shocks - in partially driving some macro variables (in particular private consumption) is mainly related to their effects on disposable income of non-Ricardian consumers and the role of the latter in

[22]Notice that, consistently with note 15 and differently from GLSV, the equilibrium is determined over the whole range of γ.

affecting the variability of total consumption and inflation.

6 Interaction of fiscal and monetary policy

Perotti (2005), in the context of a VAR analysis, argues that controlling for monetary policy is not very important when estimating the effects of fiscal policy on output. In our estimated model, fiscal shocks do have effects on output and prices, and in general the monetary authority does respond to output and prices variations originating from fiscal policy shocks.[23] However, our parameter estimates imply that a 1% increase in the short-term real interest rate has an impact effect on Ricardian consumption of -0.1%, and that the responses of the real interest rate to our fiscal shocks (with the exception of shocks to consumption taxes) range from -0.3 to 0.6% on annual basis: therefore, the effect on consumption of a restrictive monetary policy after a fiscal shock is limited.

We have also experimented with different specifications of the monetary policy rule. Our baseline model has the Taylor rule with interest rate smoothing used by SW, specified in terms of (deviations from steady state values of) lagged inflation and contemporaneous output and their first differences: monetary policy reacts to the output gap, defined as the gap from the steady state value rather than the deviation of output from the level obtained in the equilibrium with flexible prices and wages. Holding SW priors fixed in the monetary rule, we first experimented different timing (contemporaneous versus lagged) for both inflation and output. Subsequently, holding SW timing of both inflation and output fixed, we assumed alternative priors for the inflation coefficient ρ_π (lower and higher mean, higher variance, original SW normal distribution) or we calibrated at zero the reaction coefficients on inflation variation and output growth. In all cases parameters estimates do not substantially differ from our baseline. In particular, γ is as high as in the baseline case. As parameters estimates do not substantially differ, and hence monetary policy remains 'aggressive', neither the shape of the response of the real interest rate nor the one of the consumption of Ricardian agents after a government expenditure or employment shock vary in any significant way.

[23]On this issue, see also Canova and Pappa (2005) or Henry *et al.* (2004).

7 Concluding remarks

In this paper we have presented new evidence regarding the macroeconomic effects of fiscal policy. To this end, we have developed a general equilibrium model and estimated its structural parameters through Bayesian techniques. As most of the euro area official data on government accounts are available only at an annual frequency and given the importance for our purposes of including detailed information on government variables, we have also computed quarterly data for important fiscal policy series.

Our results point to a significant share of non-Ricardian agents and to the prevalence of mild Keynesian effects of fiscal policy. In particular, although innovations in fiscal policy variables tend to be rather persistent, government purchases of goods and services and compensations for public employees have small and short lived expansionary effects on private consumption, while innovations to transfers to households show a slightly more sizable and lasting effect. Among revenues, decreases in labor income and consumption tax rates have a sizable effect on consumption and output, while a reduction in the capital income tax favors investment and output in the medium run. Finally, with the exception of transfers to households and labor income tax rates, most fiscal policy variables contribute little to the cyclical variability of the main macro variables.

While our model is rather general, we have restricted our focus to a closed economy setup. Although we believe this is a good approximation for an economic area as the euro area, as SW have shown, we might still be missing some effects coming from the external channel. This, however, is a topic for future research.

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Appendix

A F.O.C.s

A Ricardian household maximizes (4) subject to (5) and (6) with respect to c_t^R, B_{t+1}, w_t, I_t, $\bar{k}_{t+1}$, u_t, and the two lagrangian multipliers, λ_t and μ_t respectively. In the symmetric equilibrium, the corresponding first order conditions are

$$\varepsilon_t^b (c_t^R - hc_{t-1}^R)^{-\sigma_c} = \lambda_t P_t \tag{30}$$

$$\lambda_t = \beta R_t E_t[\lambda_{t+1}] \tag{31}$$

$$\theta_L \varepsilon_t^b \varepsilon_t^l l_t^{\sigma_l} \frac{l_t^p}{w_t} + \beta\phi E_t\Big[\lambda_{t+1}\big(\pi_{t+1}^W - \pi\big)\pi_{t+1}^{W\,2}\Big] = \lambda_t\Big[\phi\big(\pi_t^W - \pi\big)\pi_t^W + (1-\tau_t^w)(\theta_L l_t^p - l_t)\Big] \tag{32}$$

$$\lambda_t \frac{P_t}{(1+\tau_t^c)} = \mu_t\left\{[1 - s_t\,(.)] - s_t'\,(.)\,\frac{\varepsilon_t^i I_t}{I_{t-1}}\right\} + \beta E_t\left[\mu_{t+1} s_{t+1}'(.)\varepsilon_{t+1}^i \left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{33}$$

$$\mu_t = \beta E_t\big\{\lambda_{t+1}\left[(1-\tau_{t+1}^k)R_{t+1}^k u_{t+1} - \psi(u_{t+1})P_{t+1}\right] + \mu_{t+1}(1-\delta)\big\} \tag{34}$$

$$\psi'(u_t)P_t = R_t^k(1-\tau_t^k) \tag{35}$$

plus constraints (5) and (6). Defining $mc_t \equiv MC_t/P_t$ and $\chi_t \equiv \lambda_t/P_t$, firms' price choice f.o.c. is in turn

$$\kappa(\widetilde{\pi}_t - \pi)\widetilde{\pi}_t = \beta E_t\left[\frac{\chi_{t+1}}{\chi_t}\kappa(\widetilde{\pi}_{t+1} - \pi)\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\widetilde{\pi}_{t+1}\frac{y_{t+1}}{y_t}\right] + \theta_c mc_t(1+\tau_t^c) + 1 - \theta_c \tag{36}$$

where Ricardians' stochastic discount factor is computed from their f.o.c. w.r.t. c^R.

B Steady state

We solved in closed form for steady state values for all variables, with the exception of fiscal policy variables as debt, government consumption and employment levels. In steady state we have by assumption $u = 1$, $\psi(1) = 0$ and $s = s' = 0$. From (31) we have $R = \pi/\beta$, with π the long run objective of the monetary authority (that we identify with the trend). From (33) and (34) we obtain the real rental rate of capital:

$$r^k = \frac{R^k}{P} = \frac{1 - \beta(1-\delta)}{\beta(1-\tau^k)(1+\tau^c)} \tag{37}$$

From the solution of the firm's price problem (36) we have

$$mc = \frac{\theta_c - 1}{\theta_c(1+\tau^c)}$$

which can be equalized to the steady state version of (11) to obtain the real wage

$$\omega = \varepsilon^z \left[\frac{(\theta_c - 1)}{\zeta\theta_c(1+\tau^c){r^k}^{\alpha}}\right]^{\frac{1}{1-\alpha}} . \tag{38}$$

Having obtained factor prices, we now recover aggregate quantities. Start from the steady state consumption level of non-Ricardian households in aggregate terms (with $l = l^R = l^{NR}$ and $tr = tr^R = tr^{NR}$)

$$c^{NR} = (1-\tau^w)\omega l + tr\,. \tag{39}$$

Real transfers can be obtained from the steady state version of the government budget constraint

$$tr = b\left(\frac{\pi - R}{R}\right) + t - c^g - \omega l^g \tag{40}$$

Moreover, using also (lower case variables are in real terms)

$$t = \tau^w \omega l + \frac{\tau^c}{1+\tau^c}(c + c^g) + \tau^k\left(r^k k + d\right)$$

where $d = \frac{1}{1+\tau^c}\frac{1}{\theta_c}y$, $\;k = Al^p$, $\;y = A^{\alpha}l^p$ and $A = \frac{\alpha}{1-\alpha}\frac{\omega}{r^k}$, we are able to rewrite non-Ricardian consumption as

$$c^{NR} = D \cdot l^p + \frac{\tau^c}{1+\tau^c}c \tag{41}$$

where $D = \omega + \frac{b}{y}\frac{\pi - R}{R}A^{\alpha} + \tau^k\big(r^k A + \frac{A^{\alpha}}{(1+\tau^c)\theta_c}\big) - \frac{A^{\alpha}}{1+\tau^c}\frac{c^g}{y}$ is a function only of exogenous parameters and steady state values. Defining $E = \frac{\gamma D}{(1-\gamma\frac{\tau^c}{1+\tau^c})}$ and $F = \frac{1-\gamma}{(1-\gamma\frac{\tau^c}{1+\tau^c})}$, from (24) total private consumption c can then be rewritten as

$$c = E \cdot l^p + F \cdot c^R \tag{42}$$

In order to solve for c^R in terms of l^p, c and exogenous parameters, take the steady state versions of the budget constraint of Ricardian households in aggregate terms

$$(1-\gamma)c^R = (1-\tau^w)(1-\gamma)\omega l^R + (1-\tau^k)\big(r^k k + d\big) + \frac{R-\pi}{R}\,b + (1-\gamma)tr^R - \frac{I}{1+\tau^c} \tag{43}$$

and of the capital accumulation equation

$$I = \delta k = \delta A l^p \,;$$

after some simple algebra, we obtain an expression for c^R as a function of l^p and c:

$$c^R = G \cdot l^p + \frac{\tau^c}{1+\tau^c} c \tag{44}$$

where $G = \omega + (1-\gamma\tau^k)\left(\frac{r^k A}{1-\gamma} + \frac{1}{1+\tau^c}\frac{1}{\theta_c}\frac{A^\alpha}{1-\gamma}\right) + \gamma\frac{b}{y}(\frac{R-\pi}{R})\frac{A^\alpha}{1-\gamma} - \frac{\delta}{1+\tau^c}\frac{A}{1-\gamma} - \frac{A^\alpha}{1+\tau^c}\frac{c^g}{y})$. Plugging (42) in (44), and defining $H = \left(G + \frac{\tau^c}{1+\tau^c}E\right)/\left(1 - \frac{\tau^c}{1+\tau^c}F\right)$, one gets

$$c^R = H \cdot l^p \tag{45}$$

In steady state, l^p is a given fraction of total labor l. In particular we assume that government employment in steady state is equal to 20% of total employment, i.e. we set $l^g_{ss} = (\frac{l^g}{l}) = 0.2$. Hence

$$l^p = l - l^g = (1 - l^g_{ss}) \cdot l$$

and therefore

$$c^R = H \cdot (1 - l^g_{ss}) \cdot l \tag{46}$$

We now have to solve for l. Combining the first order conditions (evaluated in the steady state) with respect to c and l of the Ricardian households we obtain:

$$\theta_L l^{\sigma_l} \frac{l^p}{\omega} + \left[c^R(1-h)\right]^{-\sigma_c}(1-\tau^w)(\theta_L l^p - l) = 0$$

which can be used to solve for c^R as a function of l:

$$c^R = \frac{1}{1-h}\left[\frac{(1-\tau^w)(\theta_L l^p - l)\,\omega}{\theta_L l^{\sigma_l} l^p}\right]^{\frac{1}{\sigma_c}} \tag{47}$$

Equating (47) and (46) allows us to solve for l, which will allow to solve backward for all the other variables:

$$l = \left[\frac{1}{(1-h)H}\right]^{\frac{\sigma_c}{\sigma_c+\sigma_l}} \left\{\frac{(1-\tau_w)\omega[\theta_L(1-l^g_{ss}) - 1]}{\theta_L(1-l^g_{ss})^{1+\sigma_c}}\right\}$$

C Log-linearizations

Ricardian consumers are all identical, which, after aggregation, allows simplification when log-linearizing (30) so to have

$$\widehat{\chi}_t = -\frac{\sigma_c}{1-h}\left(\widehat{c}^R_t - h\widehat{c}^R_{t-1}\right) + \widehat{\varepsilon}^b_t \tag{48}$$

where $\chi_t \equiv \lambda_t P_t$, which is of use also in log-linearization of (31)

$$\widehat{\chi}_t = \widehat{R}_t + E_t[\widehat{\chi}_{t+1}] - E_t[\widehat{\pi}_{t+1}]\,. \tag{49}$$

Defining $\pi_t^W \equiv W_t/W_{t-1}$ one has

$$\widehat{\pi}_t^W = \widehat{\omega}_t - \widehat{\omega}_{t-1} + \widehat{\pi}_t \tag{50}$$

and also, log-linearizing (32),

$$\widehat{\pi}_t^W = \beta E_t[\widehat{\pi}_{t+1}^W] + \frac{1-\tau^w}{\phi\pi^2}\left[(\theta_L l^p - l)\left(\widehat{\chi}_t - \frac{\tau^w}{1-\tau^w}\widehat{\tau}_t^w\right) + \left(\theta_L l^p \widehat{l^p}_t - l\widehat{l}_t\right)\right] + \frac{\theta_L l^{\sigma_l} l^p}{\chi\phi\pi^2\omega}\left[\sigma_l \widehat{l}_t + \widehat{l^p}_t - \widehat{\omega}_t + \widehat{\varepsilon}_t^b + \widehat{\varepsilon}_t^l\right] \tag{51}$$

Defining $q_t = \frac{\mu_t(1+\tau_t^c)}{\chi_t}$, log-linearization of (33) and (34) yields

$$\widehat{I}_t = \frac{\widehat{I}_{t-1}}{1+\beta} + \frac{\beta}{1+\beta}E_t[\widehat{I}_{t+1}] + \frac{\widehat{q}_t}{s''(1+\beta)} - \frac{\beta}{1+\beta}E_t[\widehat{\varepsilon}_{t+1}^i] + \frac{\widehat{\varepsilon}_t^i}{1+\beta} \tag{52}$$

and

$$\widehat{\chi}_t + \widehat{q}_t - \frac{\tau^c}{1+\tau^c}\widehat{\tau}_t^c = E_t[\widehat{\chi}_{t+1}] + \tag{53}$$
$$+\beta\left[(1-\delta)E_t[\widehat{q}_{t+1}] + r^k(1+\tau^c)(1-\tau^k)E_t[\widehat{r}_{t+1}^k] - r^k\tau^k(1+\tau^c)E_t[\widehat{\tau}_{t+1}^k] - \frac{(1-\delta)\tau^c}{1+\tau^c}E_t[\widehat{\tau}_{t+1}^c]\right]$$

where we used the steady state equalities $q = 1$, $s(.) = s'(.) = 0$, $u = 1$, $\psi(1) = 0$, $\psi'(1) = r^k(1-\tau^k)$, and $r^k = [1-\beta(1-\delta)]/\beta(1-\tau^k)(1+\tau^c)$. Log-linearization of (35) directly follows:

$$\frac{\psi''(u)}{\psi'(u)}\widehat{u}_t = \widehat{r}_t^k - \frac{\tau^k}{(1-\tau^k)}\widehat{\tau}_t^k\,. \tag{54}$$

Zero steady state adjustment costs imply also that the log-linearized version of constraint (6) is

$$\widehat{\overline{k}}_{t+1} = (1-\delta)\,\widehat{\overline{k}}_t + \delta\widehat{I}_t \tag{55}$$

where

$$\widehat{k}_t = \widehat{u}_t + \widehat{\overline{k}}_t\,, \tag{56}$$

and, from the capital market equilibrium (26),

$$\widehat{k}_t = \widehat{y}_t + (1-\alpha)\left[\widehat{w}_t - \widehat{r}_t^k - \widehat{z}_t\right]\,. \tag{57}$$

As for budget constraints, it is enough to log-linearize (7), the one of non-Ricardians

$$c^{NR}\widehat{c}_t^{NR} = \omega l[(1-\tau^w)(\widehat{\omega}_t + \widehat{l}_t) - \tau^w\widehat{\tau}_t^w] + tr\,\widehat{tr}_t \tag{58}$$

and the aggregate resource constraint (25)

$$y\widehat{y}_t = c\widehat{c}_t + I\widehat{I}_t + c^g\widehat{c^g}_t + \psi'(1)\overline{k}\widehat{u}_t \tag{59}$$

where

$$c\widehat{c}_t = (1-\gamma)\, c^R\widehat{c}_t^R + \gamma c^{NR}\widehat{c}_t^{NR} \tag{60}$$

and

$$\widehat{y}_t = (1-\alpha)\,\widehat{z}_t + (1-\alpha)\,\widehat{l}_t^p + \alpha\widehat{k}_t \tag{61}$$

with

$$l\,\widehat{l}_t = l^p\,\widehat{l}_t^p + l^g\,\widehat{l}_t^g\,. \tag{62}$$

No adjustment in the steady state also imply that in (36) $mc = \frac{\theta_c - 1}{\theta_c(1+\tau^c)}$, so that its log-linearized version turns out to be

$$\widehat{\widetilde{\pi}}_t = \beta E_t[\widehat{\widetilde{\pi}}_{t+1}] + \frac{\theta_c - 1}{\kappa\widetilde{\pi}^2}\left[\widehat{mc}_t + \frac{\tau^c}{1+\tau^c}\widehat{\tau}_t^c\right] \tag{63}$$

where from (11)

$$\widehat{mc}_t = (1-\alpha)\,(\widehat{w}_t - \widehat{z}_t) + \alpha\widehat{r}_t^k\,. \tag{64}$$

and, from the relation between P_t and $\widetilde{P}_t$,

$$\widehat{\pi}_t = \widehat{\widetilde{\pi}}_t + \frac{\tau^c}{1+\tau^c}(\widehat{\tau}_t^c - \widehat{\tau}_{t-1}^c)\,. \tag{65}$$

Recalling that $R = \pi/\beta$, the log-linearized government budget constraint is

$$\beta b\left(E_t[\widehat{b}_{t+1}] + E_t[\widehat{\pi}_{t+1}] - \widehat{R}_t\right) = b\widehat{b}_t + c^g\widehat{c^g} + wl^g(\widehat{w}_t + \widehat{l}_t^g) + tr\,\widehat{tr}_t - t\,\widehat{t}_t \tag{66}$$

where

$$t\,\widehat{t}_t = \tau^w\omega l\left[\widehat{\tau}_t^w + \widehat{\omega}_t + \widehat{l}_t\right] + \left[\frac{\tau^c}{(1+\tau^c)^2}(c+c^g) - \frac{d\tau^k y}{(1+\tau^c)}\right]\widehat{\tau}_t^c + \tag{67}$$

$$+\frac{\tau^c}{1+\tau^c}c\widehat{c}_t + \frac{\tau^c}{1+\tau^c}c^g\widehat{c^g} + \tau^k r^k k\left[\widehat{r}_t^k + \widehat{k}_t\right] + \widehat{\tau}_t^k\left[\tau^k r^k k + d\tau^k\right] +$$

$$d^2\tau^k\widehat{y}_t - d\tau^k y\; mc\;\widehat{mc}_t \tag{68}$$

The set of this equations, plus the processes for the shocks and the policy functions in the main text, already specified in terms of log-deviations, make up the system of equations to be solved.

D Data sources and description

D.1 General description

The model is estimated using quarterly data over the period from 1980:1 to 2005:4. The National Accounts (NA) and the government sector series are seasonally adjusted and, when available, working day adjusted.

Data for NA variables (households' consumption, capital accumulation, private compensations and public employment) are taken from the Eurostat ESA95 data base. Euro area NA data have a break in 1991 because of the German unification: for years before 1991, we use the series reconstructed by the ECB for the Area Wide Model (ECB-AWM).[24]

A large part of the euro area information for the government sector is available only on annual basis.[25]

Annual fiscal data for Cg, T and Tr are mainly obtained from the AMECO data base of the European Commission.[26] To construct series from 1980 we had to join three different subsets of the AMECO database because of discontinuities: the governments statistics, based on the current system of accounts ESA95, from 1995; from 1991 to 1995 data of the former standard of accounts (ESA79); previous to 1991, ESA79 data for the euro area excluding East Germany. In each of these joins, we removed level discontinuities by applying the growth rates of the old series to the levels of the new series, as done by most data providers.

Concerning implicit tax rates we construct annual series from 1980 following the methodology of Mendoza *et al.* (1994, henceforth MRT). In the original paper of MRT, series were computed for the period 1965-1988 and, among euro area countries, only for Germany, France and Italy. Eurostat provides official tax rate series starting from 1995, using a modified version of the MRT methodology. This latter is at the basis also of the OECD paper by Carey and Rabesona (2002, henceforth CR), where time series for OECD countries covering the years 1975-2000 are presented.

We obtain quarterly series from annual ones for all series by applying standard techniques commonly adopted by national statistical offices to estimate high frequency

[24]In particular we refer to the release of the ECB-AWM updated to the 2005:4, available on the web site of the Euro Area Business Cycle Network-EABCN.

[25]Recently Eurostat has released a number of quarterly series for the principal items of the government accounts, but only for a short time span (from 1999:1) and not adjusted either for seasonality or for working days.

[26]In alternative to AMECO some variables, as documented in the following section, are extracted from ECOUT, the data base of the OECD Economic Outlook.

series using proxy indicators. In particular, we followed the Chow and Lin (1971) method, as modified by Barbone *et al.* (1981).[27] We use a particular care in the choice of the quarterly indicators for each series, as detailed in the following section. In particular we use quarterly Eurostat NA data as they guarantee at least two advantages. First, the intra annual profile of the reconstructed series incorporate the same seasonal adjustment. Second, NA series are on accrual basis, therefore do not require additional adjustments typically needed when cash basis indicators are used. For tax rates we use NA indicators for each of the variable entering in the computation of the rate, as documented in the next section.

D.2 Data sources and methodology for the individual data series

In the following we document series by series the sources and the data processing that we have done.

Households' consumption (c) = real private consumption; source: AWM-ECB data set up to 1990:4 and NA-ESA95 thereafter.

Investment (I) = real investments; source: AWM-ECB up to 1990:4 and NA-ESA95 thereafter.

Interest rate (i) = three-months nominal interest rate; source: AWM-ECB.

Inflation rate (π) = annual percentage changes of the Harmonized Index of Consumer Price (HICP); source: AWM-ECB.

Private per-capita compensations (w) = private sector per-capita compensations, computed as the ratio between private compensations and private employees (private variables are computed as difference between whole economy and public sector values); source: AWM-ECB up to 1990:4 and NA-ESA95 thereafter.

Government consumption less compensations (c^g) = real government purchases of good and services; source for annual series: ECOUT. The quarterly indicator is the difference between government consumption and non market compensations; source for the quarterly indicator: AWM-ECB up to 1990:4 and NA-ESA95 thereafter. HICP-deflated.

Government transfers (Tr) = real government transfers to households; source for annual series: AMECO. The quarterly indicator is the unemployment rate.

Total revenues (T) = real government total revenues; source for annual nominal

[27] This methodology provides an efficient way to estimate the linear relationship between low frequency data and the low frequency values of the indicator. This low frequency model coefficients are then properly used with the high frequency indicators to disaggregate (in time) the original (low frequency) data.

series: AMECO. The quarterly indicator is a sum of three components: 1) a series of direct taxes, with the annual data from AMECO and the quarterly data reconstructed using as indicator the NA data on value added in the market sector; 2) a series of indirect taxes, with the annual data from AMECO and the quarterly data reconstructed using as indicator the NA data on private and public consumption; 3) a series of social contributions, with the annual data from AMECO and the quarterly data reconstructed using as indicator the NA data for social contributions. HICP-deflated.

Government employment (l^g) = public employees; source: AWM-ECB up to 1990:4 and ECOUT thereafter.

Tax rate on labor income (τ^w) = the annual series is computed in two steps: 1) an average direct tax rate (thh) is computed as :

$$thh = \frac{TD_h}{(OSPUE + PEI + W)} \tag{69}$$

2) the labor tax rate is given by

$$\tau^w = \frac{(thh\ W + SC + T_w)}{(W + SC_e)} \tag{70}$$

where:

TD_h = households direct taxes

$OSPUE$ = Operating surplus of private unincorporated firms

PEI = household's property and entrepreneurial income

W = wages

SC = social contributions

T_w = taxes on payroll and workforce

SC_e = employers social contributions

τ^w is therefore a measure on how taxes and social contributions on labor (the numerator) affect the labor cost (the denominator). Sources for annual series: OECD Revenue Statistics and AMECO. The quarterly indicator for TD_h is the same series on direct taxes used as indicator for T (see above). For wages and social contributions the indicators are the corresponding NA series. For $OSPUE + PEI$ we use the NA profit series.

Tax rate on consumption (τ^c) = the annual series is given by the ratio

$$\tau^c = \frac{TI_1 + TI_2}{(C + C^g - TI_1 - TI_2)} \tag{71}$$

where:

TI_1 = general taxes on goods and services

TI_2 = excise taxes

C = private consumption

C^g = government purchases of good and services

τ^c is therefore the tax rate on private and public consumption. Sources for annual series: OECD Revenue Statistics, AMECO and ECOUT. The quarterly indicator for TI is the same series on indirect taxes used as indicator for T (see above). For C and C^g the indicators are the corresponding NA series.

Tax rate on capital income (τ^k)= the series is computed in two steps: 1) an average direct tax rate (thh) is computed as for τ^w; 2) the capital tax rate is therefore the ratio

$$\tau^k = \frac{(thh\ (OSPUE + PEI) + TD_k + TP + TTR)}{NOS} \tag{72}$$

where:

TD_k = direct taxes on corporations

NOS = net operating surplus of the economy

TP = taxes on immovable property

TTR = taxes on financial and capital transactions

τ^k is therefore a measure on how taxes on all kind of firms (the numerator) affect profits (the denominator). Sources for annual series: OECD Revenue Statistics and AMECO. The quarterly indicator for TD_k is the same series on direct taxes used as indicator for T (see above). Given the lack of suitable quarterly indicators for TP and TTR we use a linear trend. For NOS and $OSPUE + PEI$ we use the NA profit series.

D.3 Comparison of our fiscal series with alternative sources

Although coverage and definitions are slightly different, we can compare our fiscal policy series with those of alternative data set. In particular, we can compare our T and Tr series with the corresponding ones from the ECB-AWM and with the ones from Eurostat on a quarterly basis; as for tax rates, we will comment on the differences of annual series as both MRT and CR compute tax rates only at annual frequency.

Eurostat series for T and Tr are short (start in 1999:1) and not seasonally adjusted, therefore for comparison with our series we adjust them for seasonality using TRAMO-SEATS. On the other hand quarterly fiscal series of ECB-AWM are longer (start in 1970:1) but are obtained interpolating annuals data.

The top panel in figure 1 shows total revenues as a percent of GDP. Our series has a similar profile to that of the ECB, with a correlation coefficient close to 90%. We also see that our series has the same profile as the Eurostat one. The discrepancies with the quarterly profile of the Eurostat series are related to the different adjustment for seasonality.

The bottom panel of figure 1 plots the series for government social transfers as a share of GDP. The correlation coefficient with the ECB series is around 75% and the larger discrepancies are in the last decade. Our series appears less smoothed, consistently with the different method adopted to estimate quarterly values. The differences with the Eurostat series are mainly due to differences in series coverage.[28]

Turning to the tax rates, our series are basically an updated version for the euro area of the rates computed by MRT. On an annual basis these rates can be compared with those provided by Eurostat and those in MRT and in CR. In principle, all of these rates are based on the MRT methodology but still there are some differences in the definitions adopted. CR use the same data definitions as MRT with slight modifications in the methodology. On the other hand, Eurostat uses country data not always of public domain.

In terms of coverage, among euro area countries MRT computed rates from 1965 to 1988 only for Germany, France and Italy. CR have longer series (from 1975 to 2002) for seven countries in the euro area.[29] To compute figures for the euro area, we aggregated these national rates using fixed GDP weights. Eurostat computes tax rate for each European country since 1995 and provides two euro area series with different aggregation methods : 1) an arithmetic average; 2) a weighted average using country GDP weights. We choose GDP weighted series as in the case of MRT and CR.

The top panel in figure 2 shows labor income tax rates. Our series is the highest but is comparable with MRT.

The central panel of figure 2 plots tax rates on consumption. Our series tracks closely the MRT one in the first part of the eighties, and almost overlaps with that of CR thereafter. The difference with the Eurostat series is due to a different definition of the denominator, as Eurostat does not include government consumption of goods and services among the tax base.

The bottom panel of figure 2 shows capital income tax rates. Our series is about four points lower than the others, but with a similar profile. In particular, it captures the slight decrease in the 80's as in MRT and the increase in the nineties as in the other two series.

[28]In particular, the Eurostat series is higher as it includes also services funded by government that are produced and delivered to households by market units and by non-government non-profit institutions serving households (NPISHs).

[29]The countries are Germany, France, Italy, Austria, Belgium, Finland and Spain. The series in CR are from 1980 to 2000, but we refer to an update to 2002 kindly provided by the authors.

Table 1: Selected prior and posterior distributions

Parameter		**Prior distribution**			**Posterior**	
		Type	*Mean*	*St.Dev.*	*Mean*	*St.Dev.*
Preferences and technology						
inverse intertemporal subst. elasticity	σ_c	Γ	2	0.5	2.02	0.19
inverse labor supply wage elasticity	σ_l	Γ	3	0.5	1.70	0.16
fraction of non-Ricardian	γ	β	0.5	0.1	0.38	0.03
habit parameter	h	β	0.7	0.1	0.84	0.02
labor demand wage elasticity	θ_L	Γ	6.5	1	6.43	0.56
Frictions						
investment adjustment cost	s''	Γ	5	0.25	5.02	0.25
wage adjustment cost	ϕ	Γ	100	$1000^{\frac{1}{2}}$	122.68	14.96
price adjustment cost	κ	Γ	100	$1000^{\frac{1}{2}}$	306.85	33.57
capital utilization adjustment cost	ψ''/ψ'	Γ	0.2	0.1	0.11	0.02
Monetary policy						
interest rate AR coefficient	ρ_R	β	0.8	0.1	0.90	0.01
inflation coefficient	ρ_π	Γ	1.7	0.1	1.75	0.10
output coefficient	ρ_y	N	0.125	0.05	0.13	0.02
inflation change coefficient	$\rho_{\Delta\pi}$	N	0.3	0.1	0.36	0.08
output growth coefficient	$\rho_{\Delta y}$	N	0.0625	0.05	0.07	0.02
Fiscal policy						
labor tax rate AR coefficient	ρ_{τ^w}	β	0.8	0.1	0.96	0.01
labor tax rate debt coefficient	η_{τ^w}	Γ	0.5	0.1	0.35	0.04
consumption tax rate AR coeff.	ρ_{τ^c}	β	0.8	0.1	0.97	0.01
consumption tax rate debt coeff.	η_{τ^c}	Γ	0.5	0.1	0.41	0.07
capital tax rate AR coefficient	ρ_{τ^k}	β	0.8	0.1	0.96	0.01
capital tax rate debt coefficient	η_{τ^k}	Γ	0.5	0.1	0.55	0.06

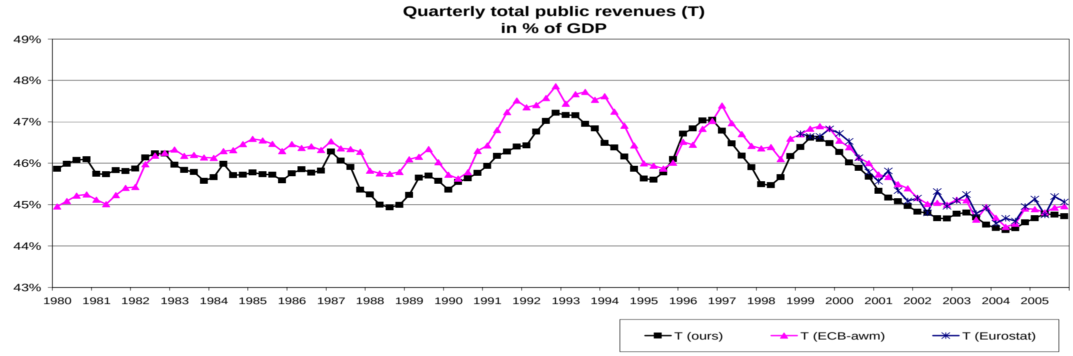
Table 2: Fiscal multipliers

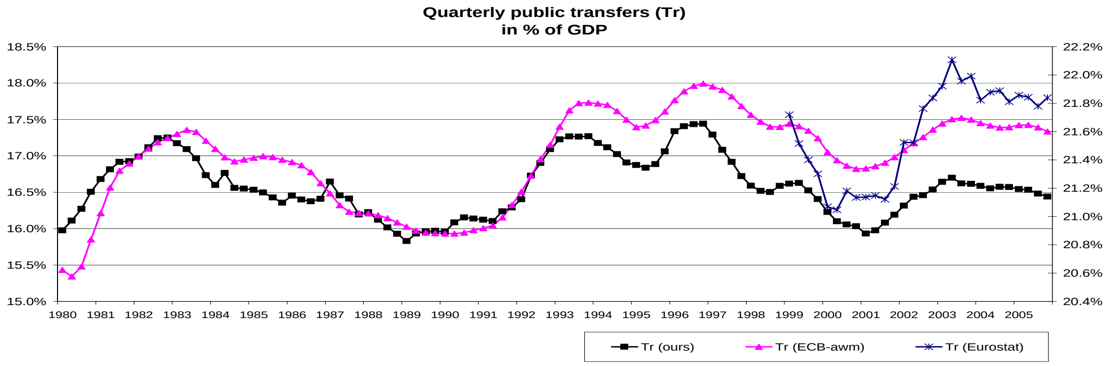
		Quarters	$\frac{\Delta y}{y}$	$\frac{\Delta c}{c}$	$\frac{\Delta I}{I}$	$\Delta \pi$
Increase in	c^g	1	1.27	0.16	-0.28	0.16
		4	0.88	0.06	-0.53	0.15
		8	0.55	-0.03	-0.67	0.15
		12	0.34	-0.08	-0.69	0.16
	l^g	1	0.28	0.30	-0.05	0.70
		4	0.20	0.21	-0.22	0.68
		8	0.05	0.09	-0.49	0.66
		12	-0.09	-0.01	-0.71	0.63
	Tr	1	0.42	0.46	0.19	0.15
		4	0.32	0.31	0.46	0.17
		8	0.23	0.17	0.77	0.22
		12	0.15	0.07	1.00	0.27
Reduction of	τ^w	1	0.39	0.45	0.28	-0.59
		4	0.32	0.33	0.81	-0.54
		8	0.33	0.26	1.50	-0.44
		12	0.37	0.22	2.05	-0.33
	τ^k	1	0.35	-0.18	0.40	-0.64
		4	0.36	-0.24	1.04	-0.53
		8	0.41	-0.28	1.82	-0.38
		12	0.44	-0.30	2.40	-0.25
	τ^c	1	0.42	0.35	-0.31	-5.18
		4	0.43	0.45	-0.79	-1.51
		8	0.41	0.52	-1.31	-0.91
		12	0.38	0.55	-1.68	-0.72

Note: Fiscal multipliers are computed as averages of the 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.

Table 3: Variance decomposition

					after 1 period								
	ε^z	ε^b	ε^l	ε^m	ε^{cg}	ε^{tr}	$\varepsilon^{\tau w}$	$\varepsilon^{\tau c}$	$\varepsilon^{\tau k}$	ε^i	ε^{lg}	ε^t	Tot
c	8.4	81.2	6.1	1.4	0.2	0.6	1.0	0.2	0.0	0.9	0.0	0.0	100
I	2.8	3.3	1.4	3.0	0.1	0.0	0.0	0.0	0.0	89.3	0.0	0.0	100
π	59.5	2.3	15.4	0.9	0.1	0.0	0.8	20.6	0.3	0.1	0.1	0.0	100
R	24.6	10.6	8.2	50.3	1.5	0.1	0.0	3.7	0.0	1.0	0.0	0.0	100
τ^w	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	0.0	100
τ^c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	100
τ^k	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	100
ω	0.2	19.3	77.2	1.1	0.0	0.0	0.4	0.9	0.0	1.0	0.0	0.0	100
T	4.3	4.9	3.1	0.2	0.5	0.0	1.1	0.0	0.4	0.1	0.0	85.2	100
					after 4 periods								
	ε^z	ε^b	ε^l	ε^m	ε^{cg}	ε^{tr}	$\varepsilon^{\tau w}$	$\varepsilon^{\tau c}$	$\varepsilon^{\tau k}$	ε^i	ε^{lg}	ε^t	Tot
c	3.1	70.6	3.1	9.4	0.2	0.2	0.5	0.6	0.1	12.2	0.0	0.0	100
I	6.0	2.7	1.5	1.3	0.1	0.0	0.2	0.0	0.1	88.2	0.0	0.0	100
π	73.4	1.4	11.5	0.7	0.3	0.2	1.1	10.9	0.3	0.1	0.2	0.0	100
R	39.5	9.5	9.5	19.0	1.0	0.2	0.3	1.3	0.0	19.6	0.1	0.0	100
τ^w	0.2	0.0	0.0	0.3	0.0	0.0	99.3	0.0	0.0	0.0	0.0	0.0	100
τ^c	0.2	0.0	0.0	0.2	0.0	0.0	0.0	99.4	0.0	0.0	0.0	0.0	100
τ^k	0.2	0.0	0.0	0.4	0.0	0.0	0.1	0.0	99.2	0.0	0.0	0.0	100
ω	0.8	14.1	70.4	7.9	0.0	0.2	2.7	1.2	0.0	2.6	0.0	0.0	100
T	4.3	9.4	6.0	4.0	0.5	0.0	3.7	0.2	1.1	4.4	0.1	66.3	100
					asymptotic								
	ε^z	ε^b	ε^l	ε^m	ε^{cg}	ε^{tr}	$\varepsilon^{\tau w}$	$\varepsilon^{\tau c}$	$\varepsilon^{\tau k}$	ε^i	ε^{lg}	ε^t	Tot
c	19.7	27.4	2.7	16.2	2.5	11.0	3.8	1.6	2.6	11.4	1.1	0.0	100
I	10.3	1.3	0.8	1.3	0.2	0.6	0.5	0.1	0.2	84.6	0.1	0.0	100
π	35.9	0.8	4.9	10.4	2.2	12.6	6.2	3.6	3.1	19.1	1.2	0.0	100
R	21.3	3.7	3.7	13.6	1.9	9.2	4.1	1.5	2.1	38.1	0.9	0.0	100
τ^w	5.9	0.2	0.7	20.3	4.0	22.1	21.5	1.6	6.0	16.1	1.7	0.0	100
τ^c	4.9	0.1	0.6	17.4	3.4	19.3	10.8	22.8	5.2	14.0	1.4	0.0	100
τ^k	5.8	0.2	0.7	20.1	3.9	22.0	12.4	1.6	15.6	16.0	1.6	0.0	100
ω	19.6	9.6	47.4	9.4	0.6	3.7	4.5	1.7	0.4	2.9	0.2	0.0	100
T	12.9	11.8	8.4	7.5	1.1	3.2	6.0	0.4	2.0	10.7	0.3	35.6	100





NOTE:
The right hand scale, in the chart for transfers refers to the official quarterly ESA 95 series.

Fig. 1: Quarterly fiscal policy series

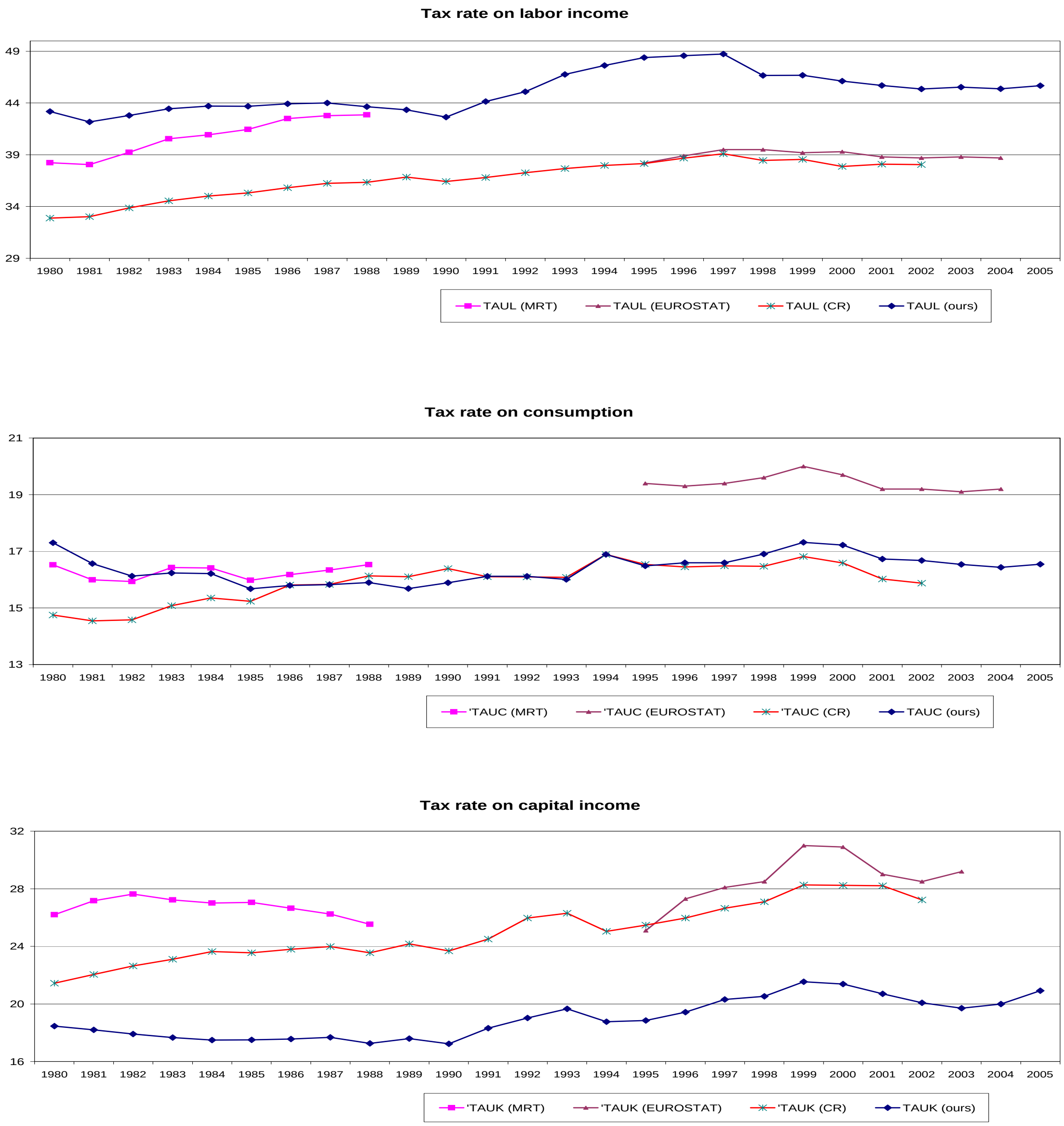


Fig. 2: Annual implicit tax rates

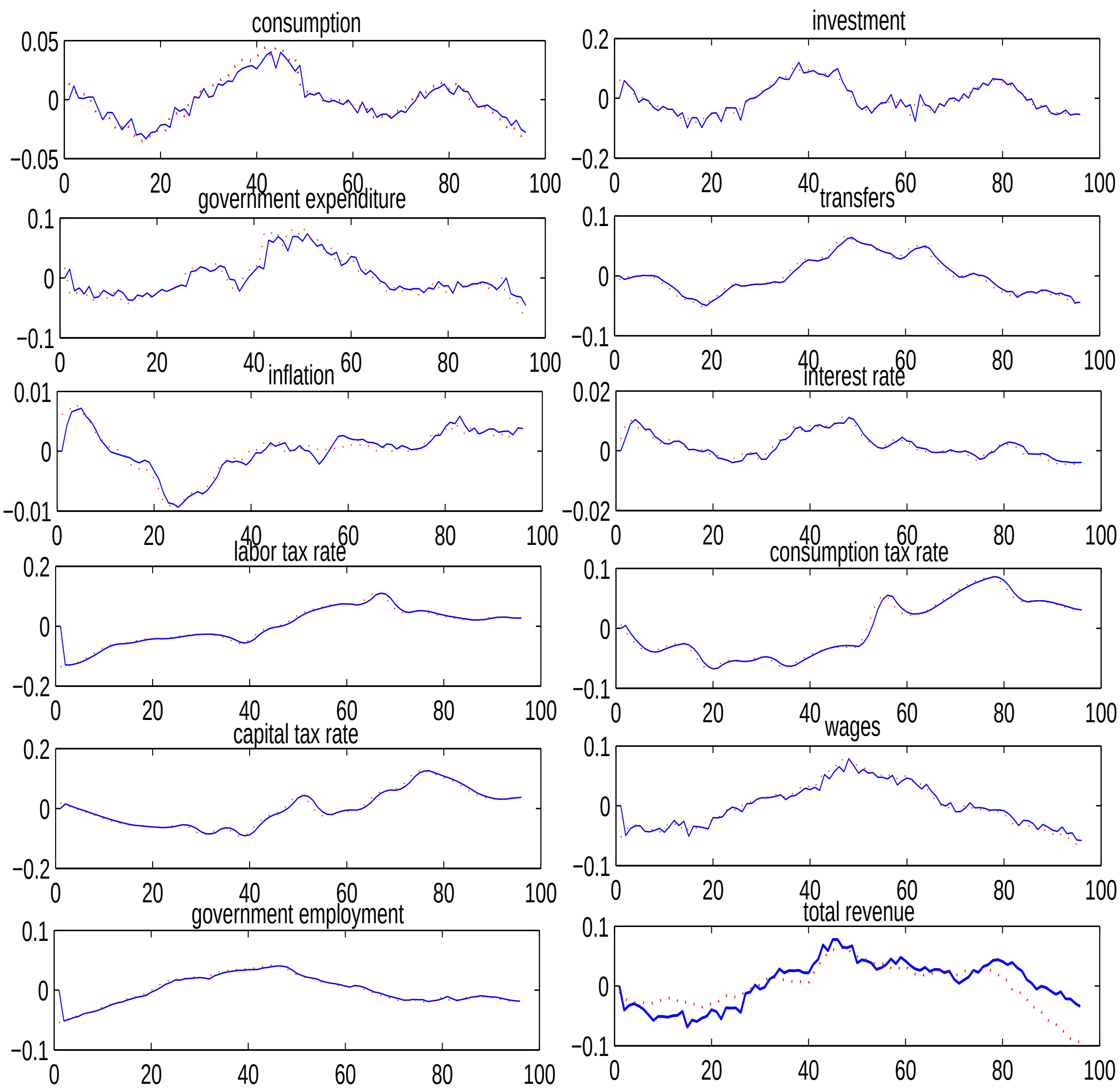


Fig. 3: Model fit after MH procedure: data (blue/solid) vs. model (red/dotted)

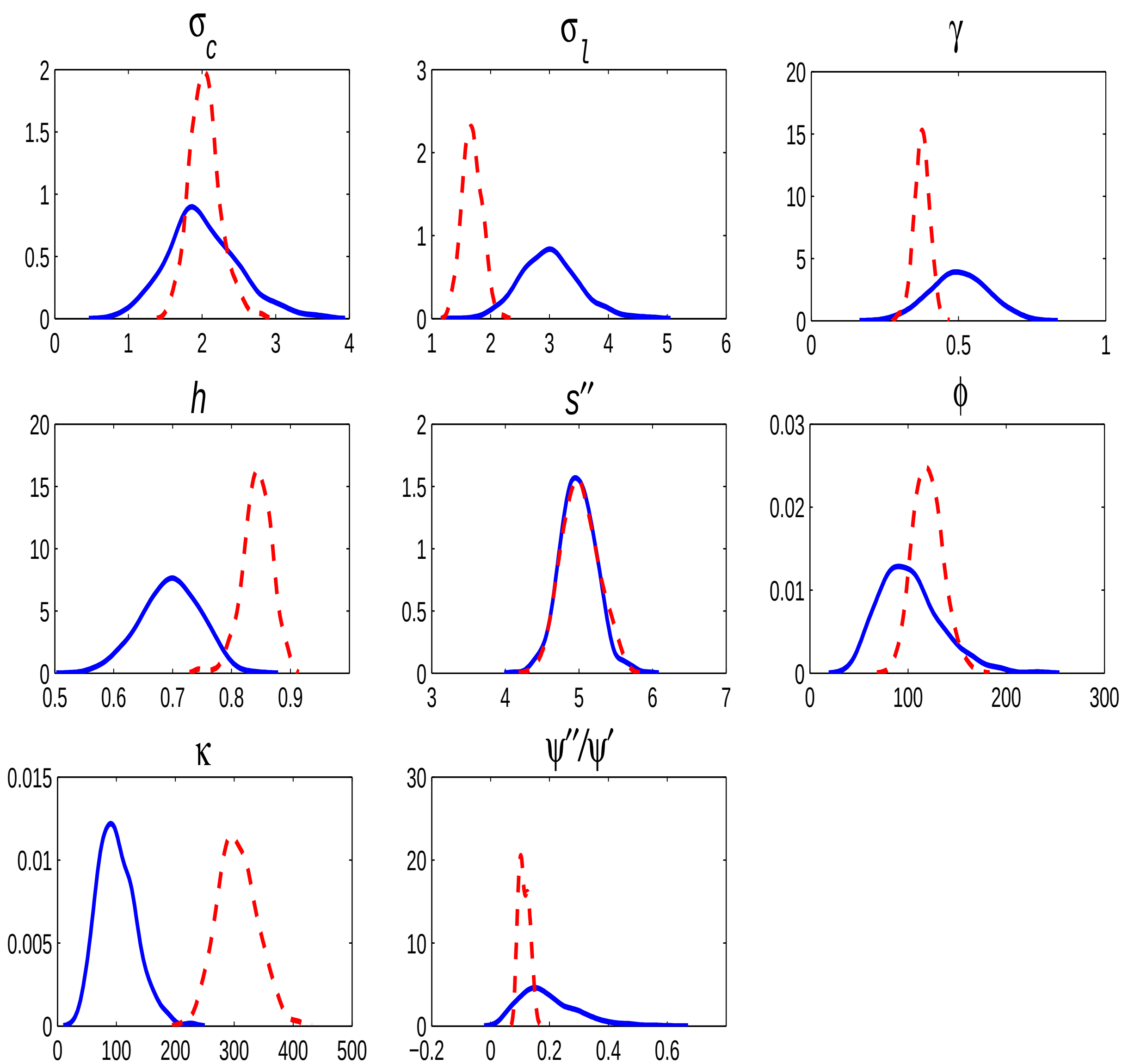


Fig.4.1: Prior (blue/solid) vs. posterior (red/dashed) distributions in MH procedure

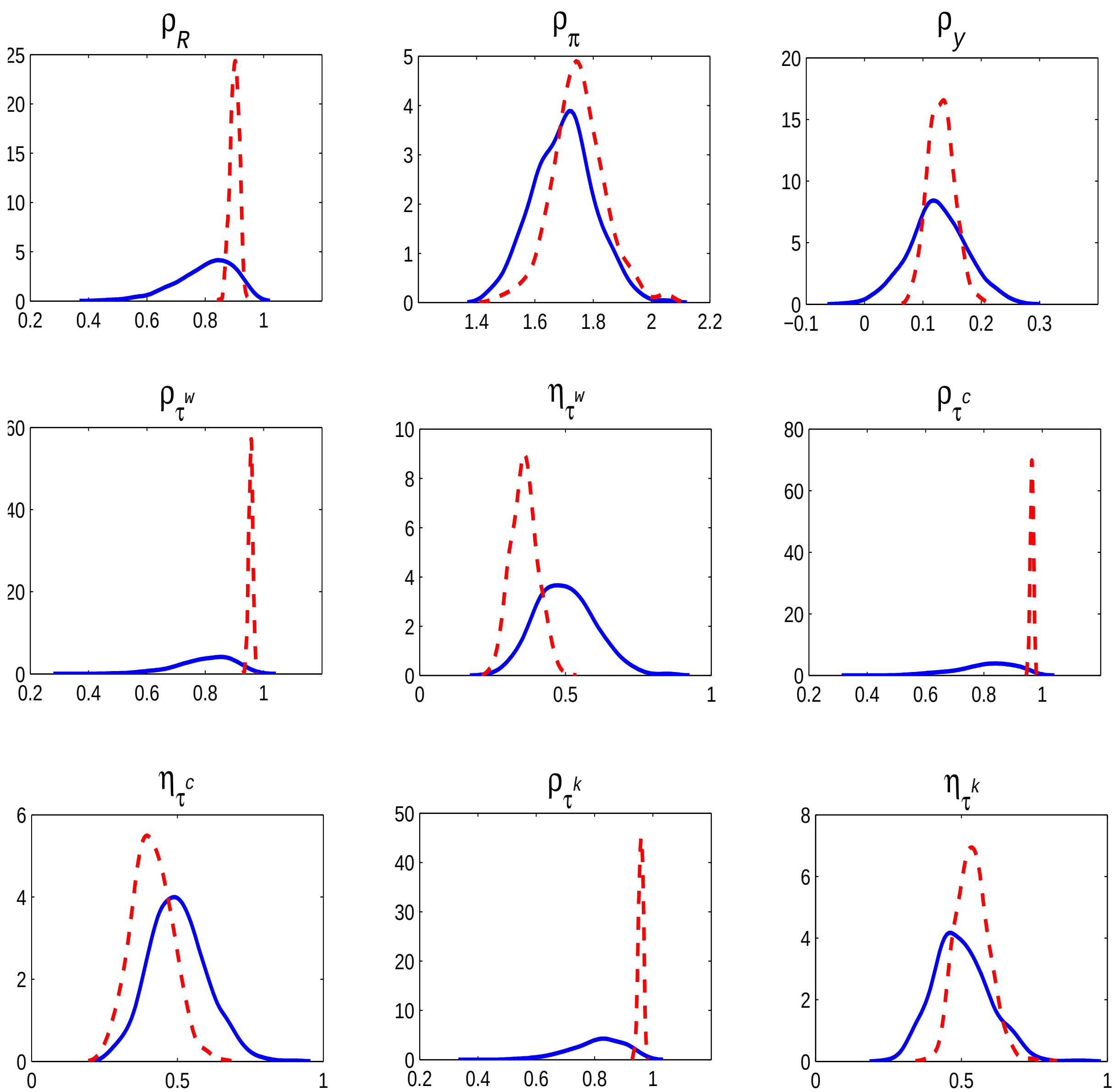


Fig.4.2: Prior (blue/solid) vs. posterior (red/dashed) distributions in MH procedure

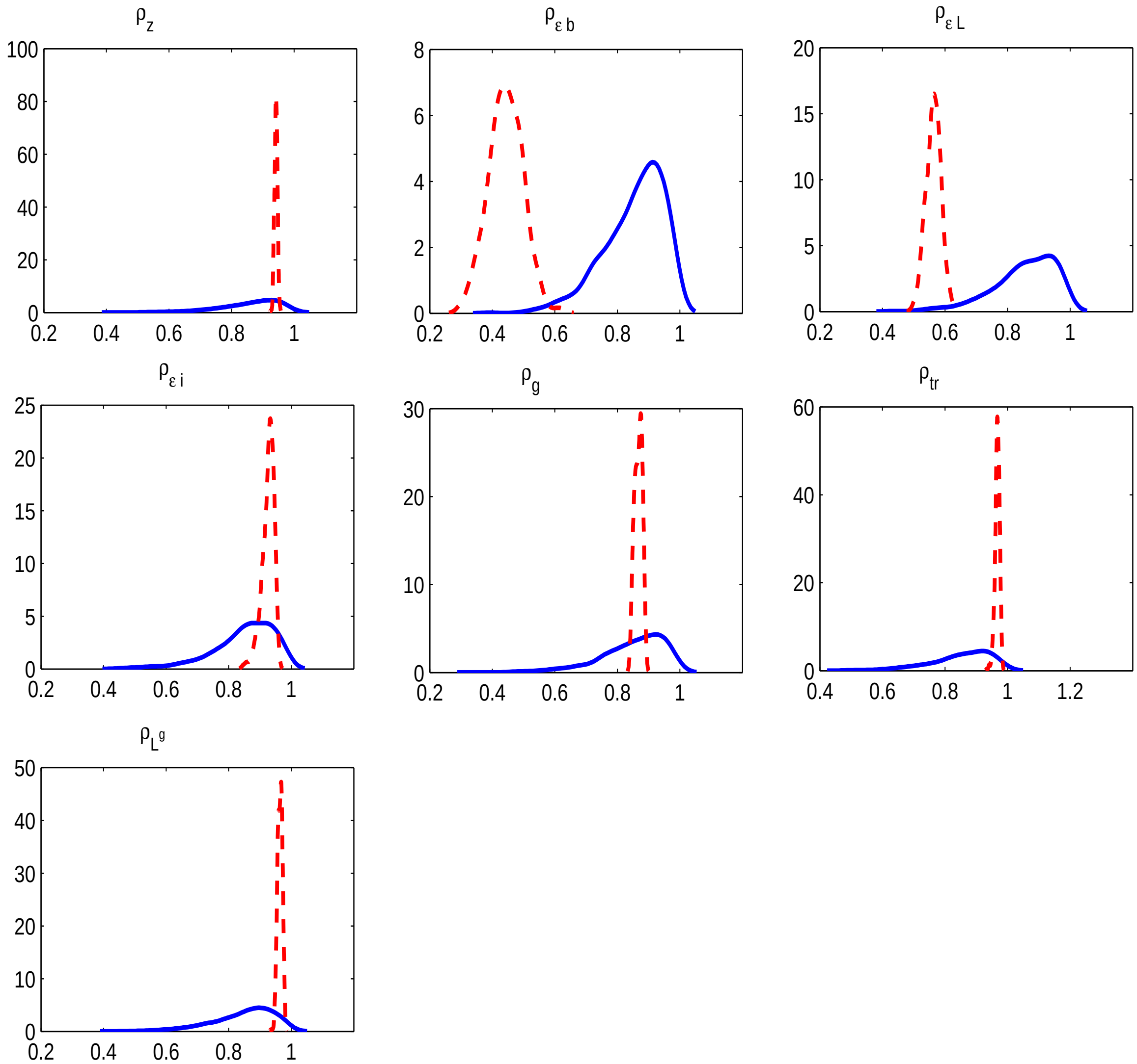


Fig.4.3: Prior (blue/solid) vs. posterior (red/dashed) distributions in MH procedure

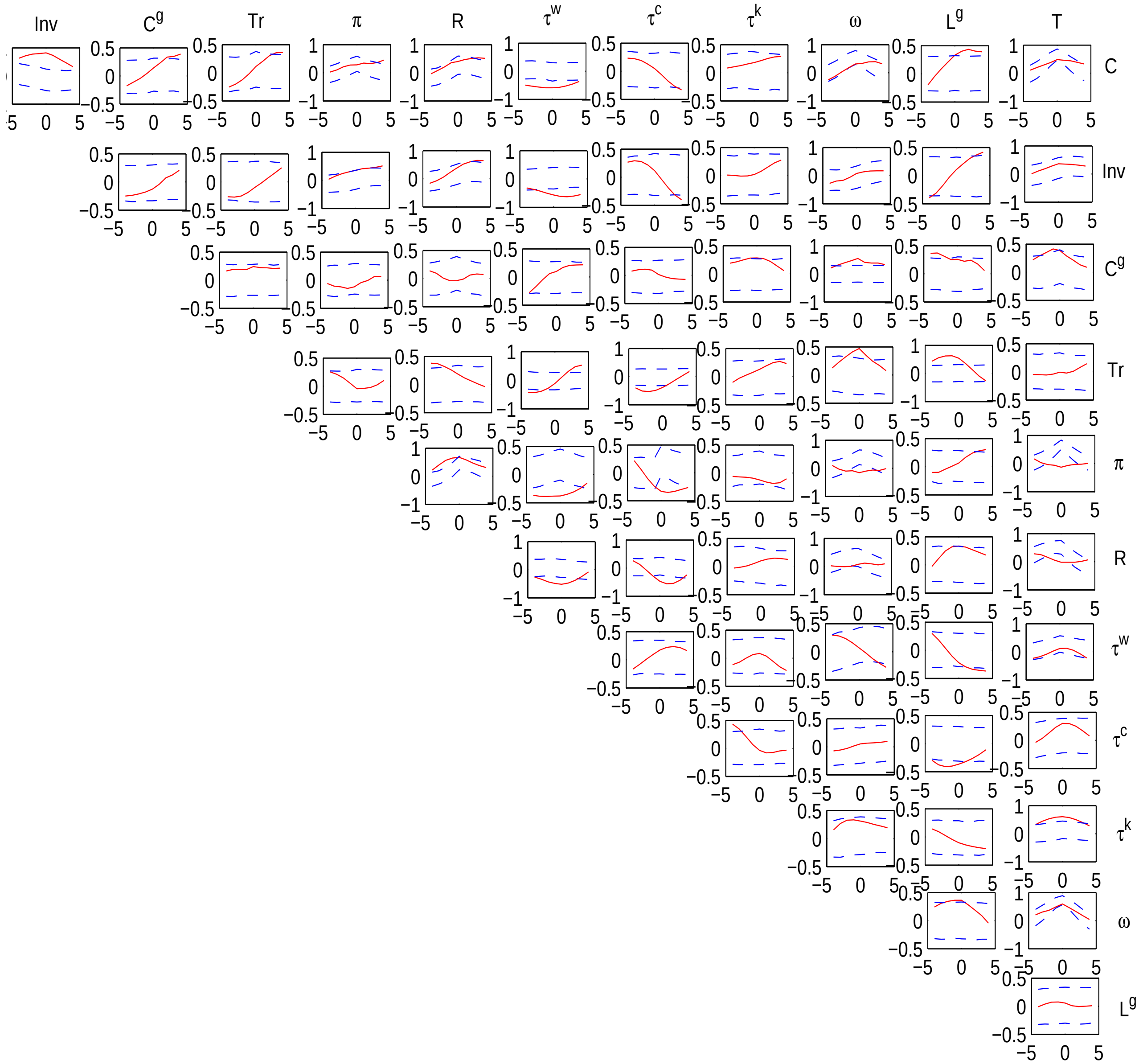


Fig. 5: Cross-correlations at +/- 4 periods;
data (red/solid) vs. model (blue/dashed 90% confidence bands)

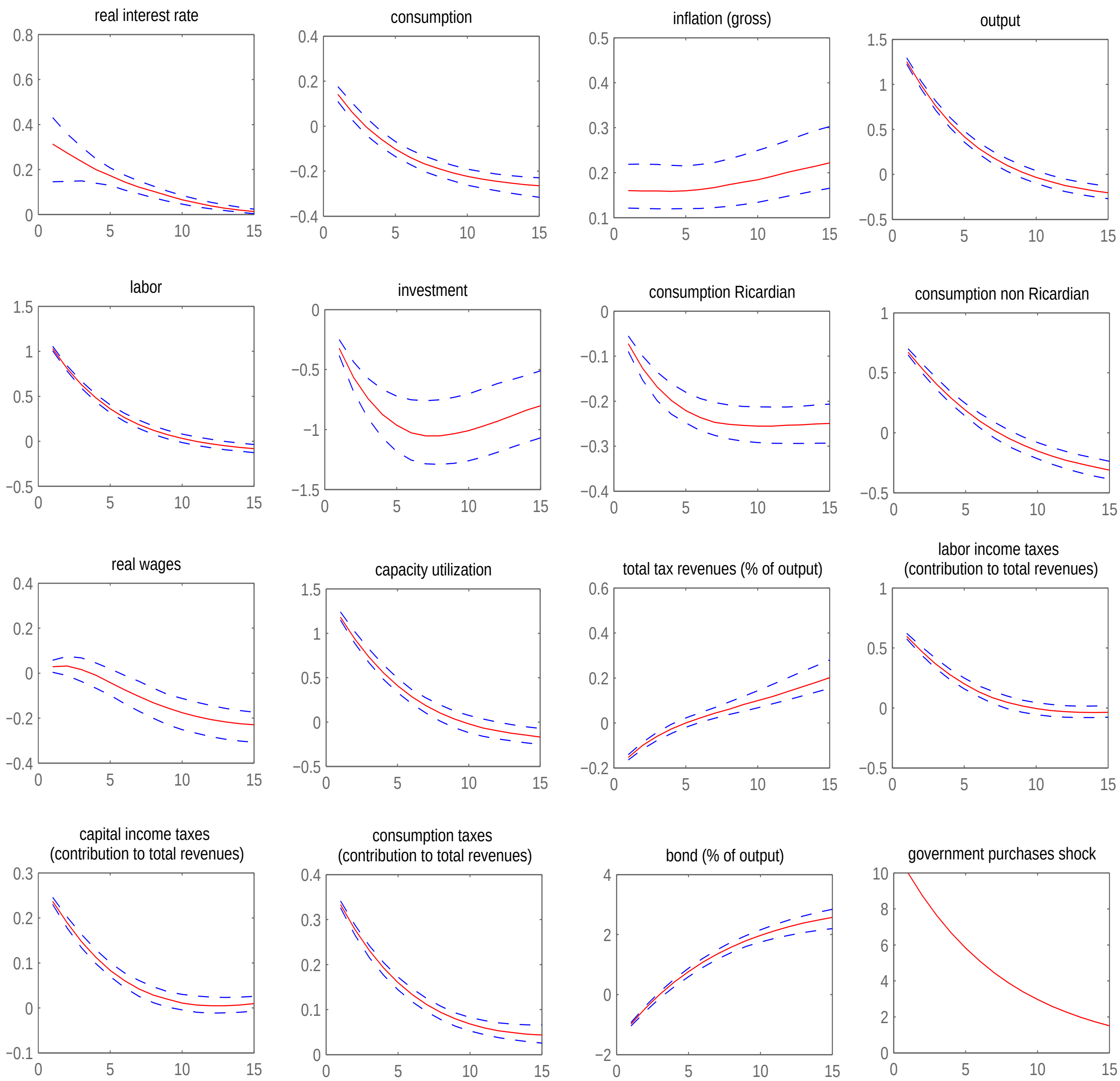


Fig. 6: Impulse responses after a government purchases shock

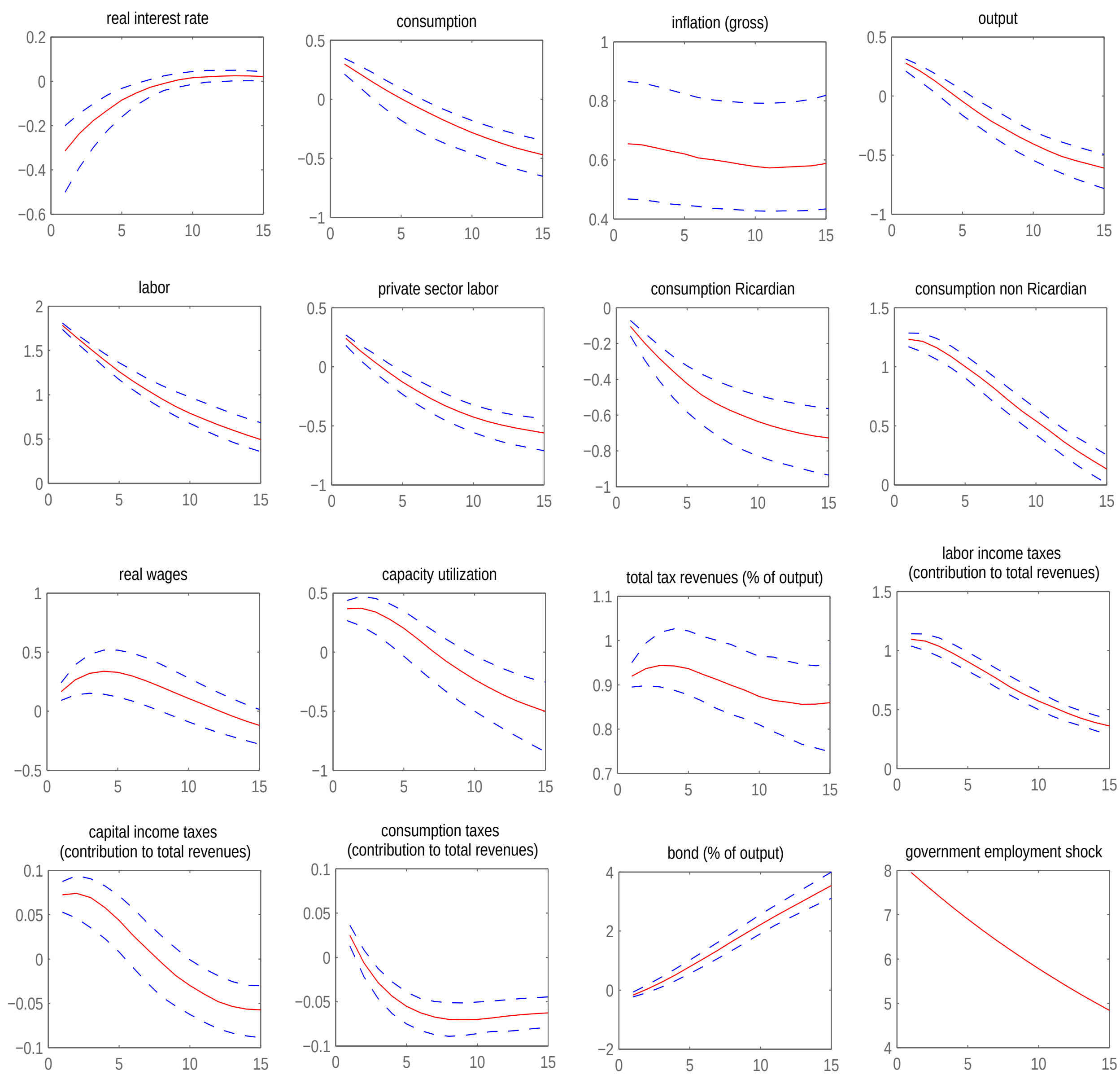


Fig. 7: Impulse responses after a government employment shock

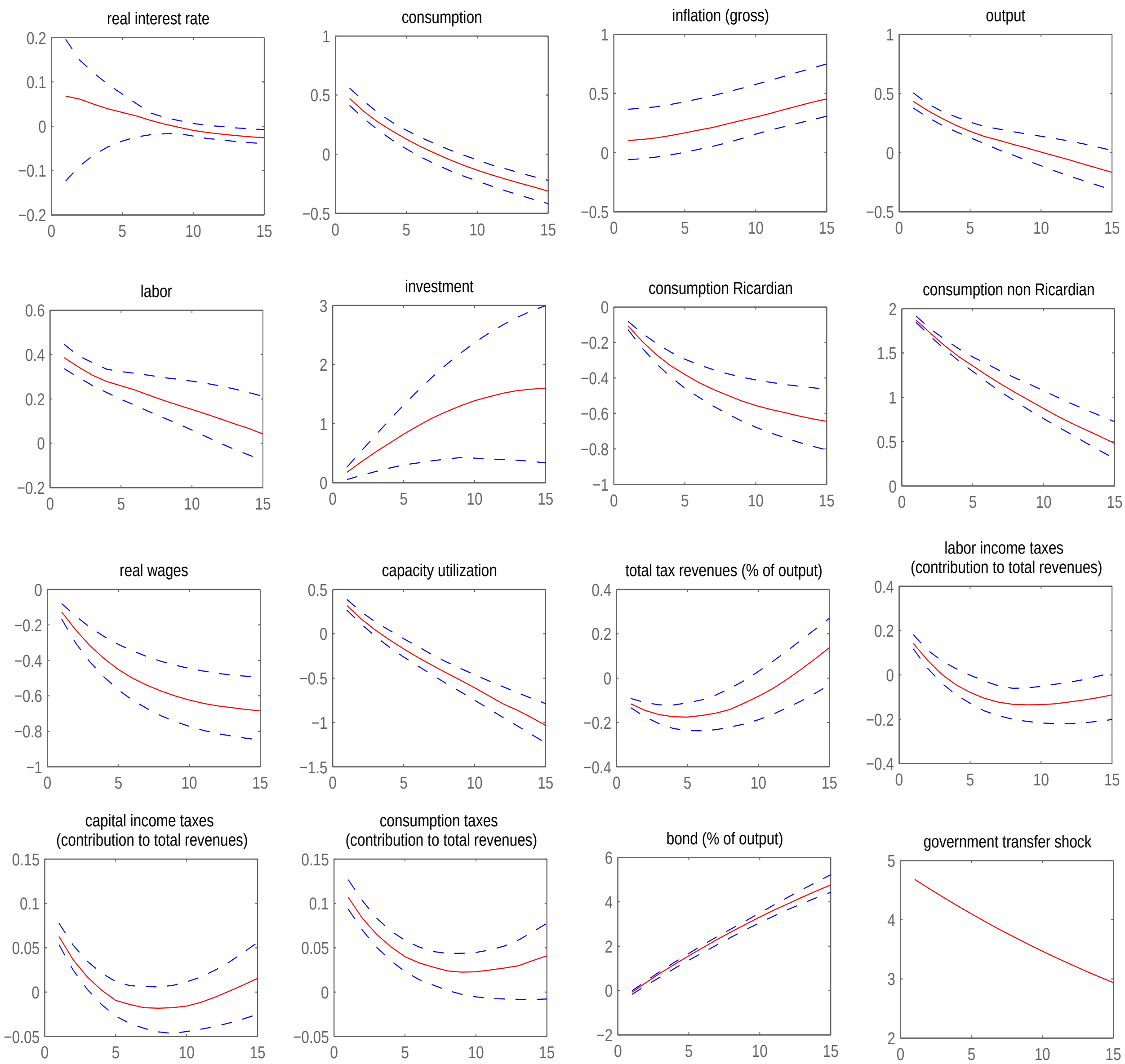


Fig. 8: Impulse responses after a transfers shock

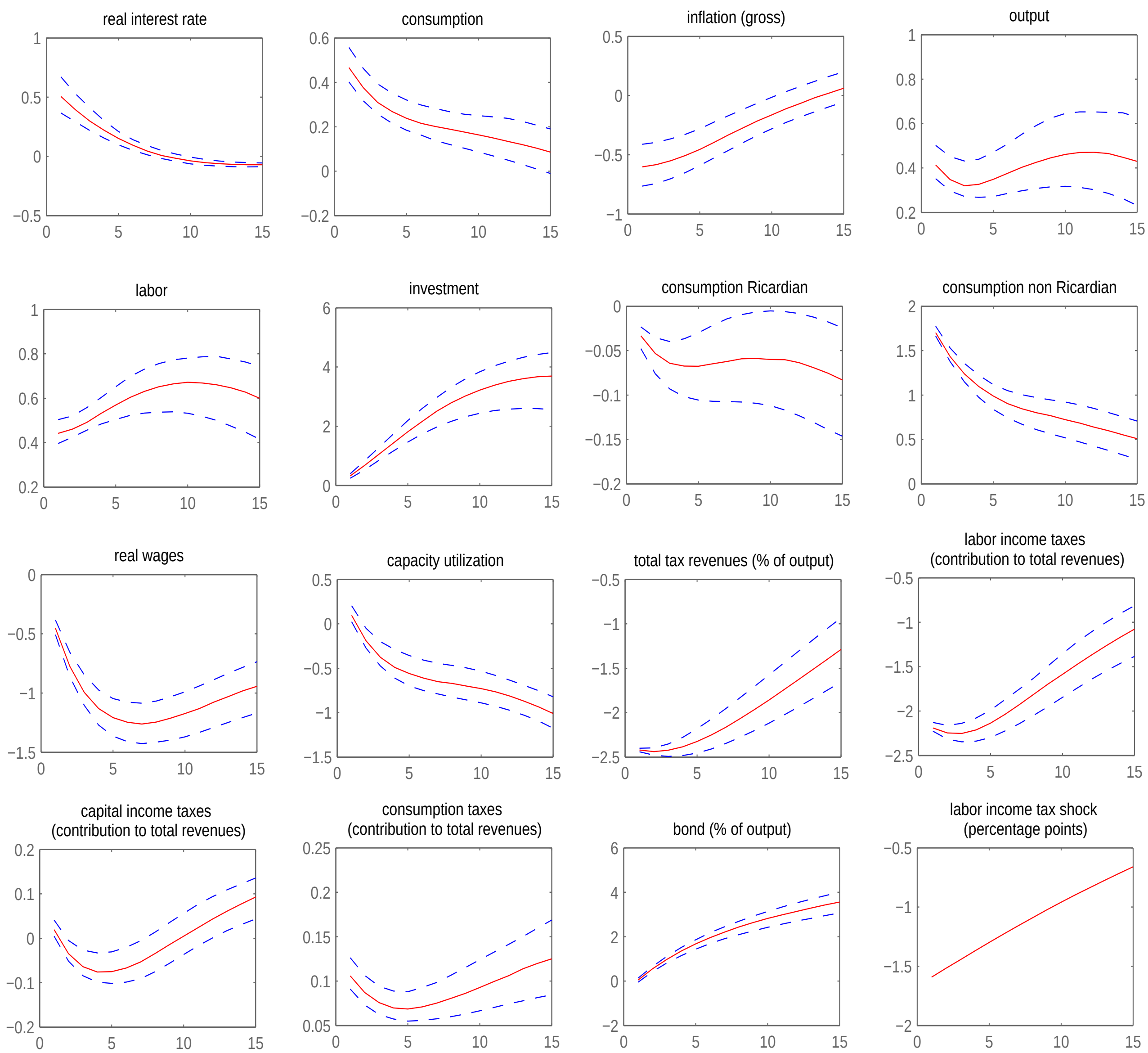


Fig. 9: Impulse responses after a labor income tax shock

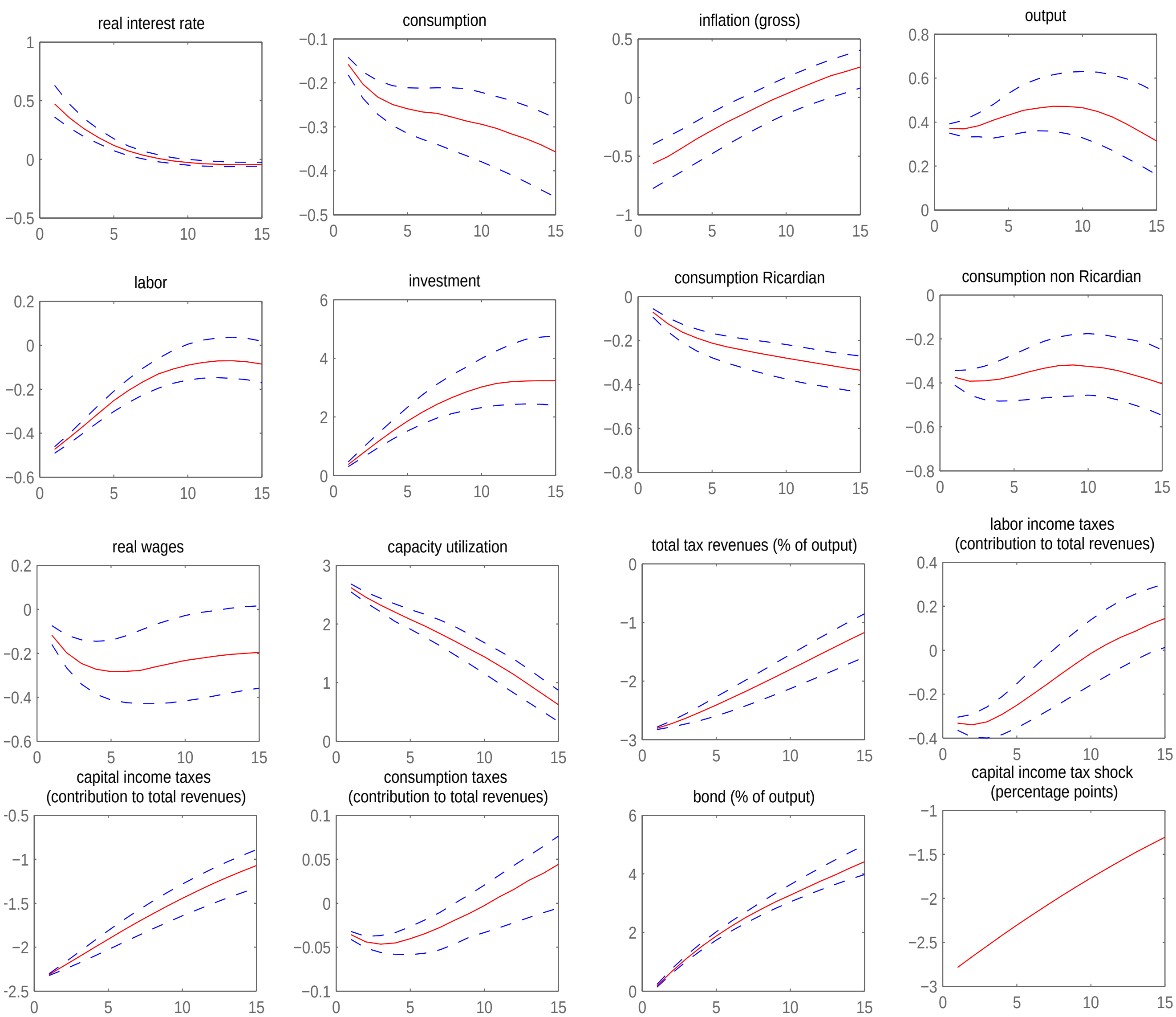


Fig. 10: Impulse responses after a capital income tax shock

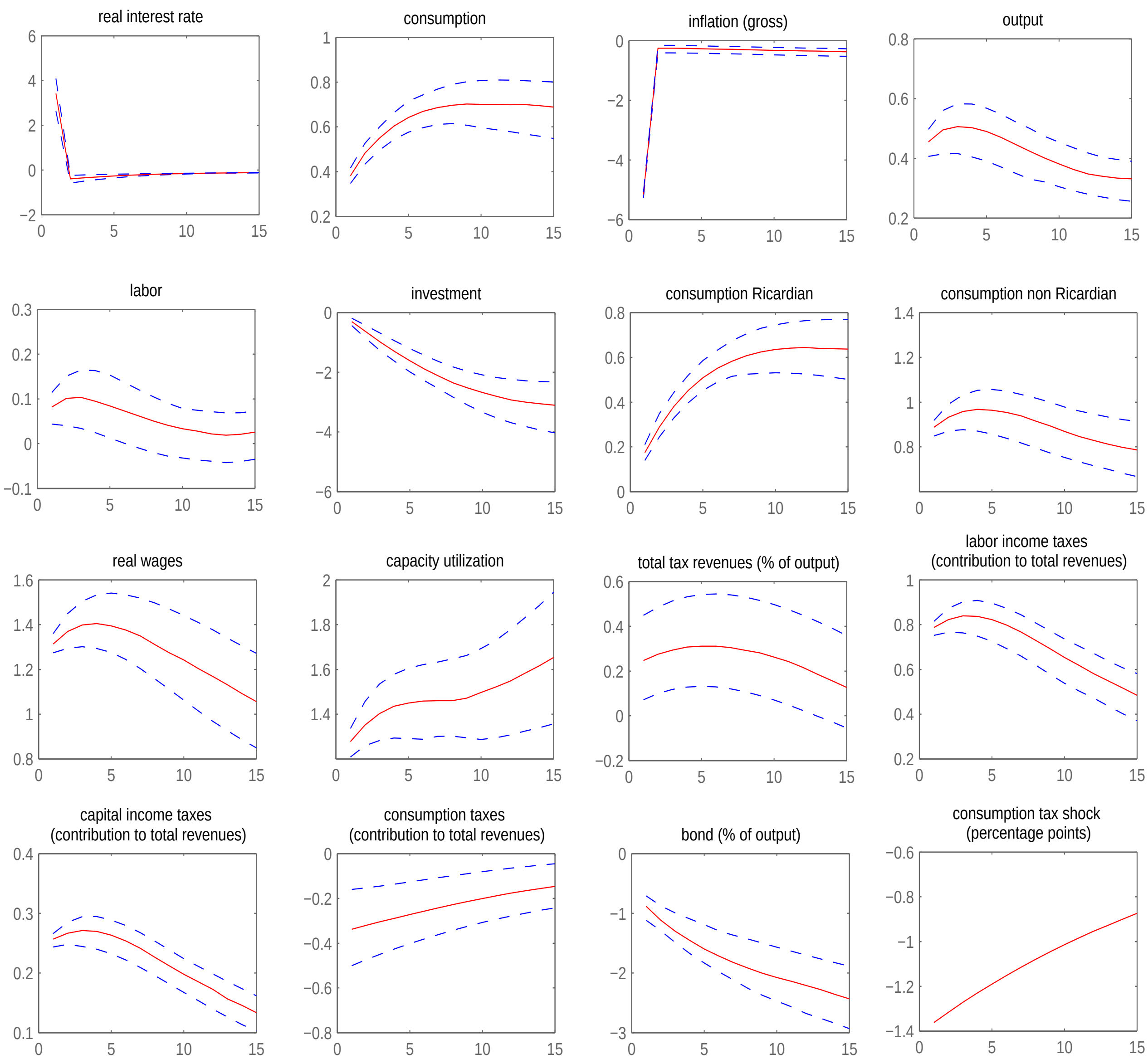


Fig. 11: Impulse responses after a consumption tax shock

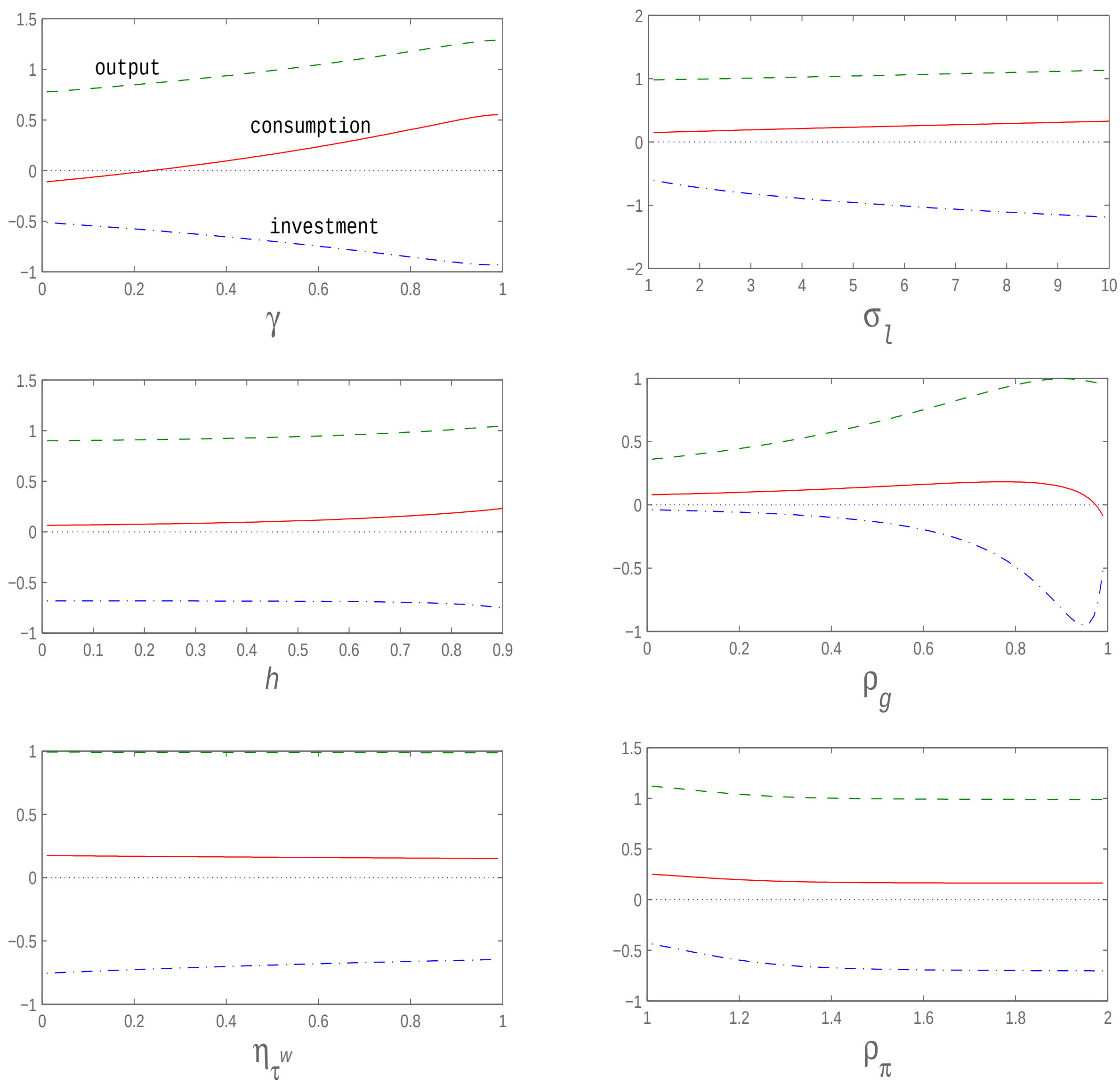


Fig. 12: Robustness - First year average responses to a government purchases shock of output, consumption and investment for parameters ranges

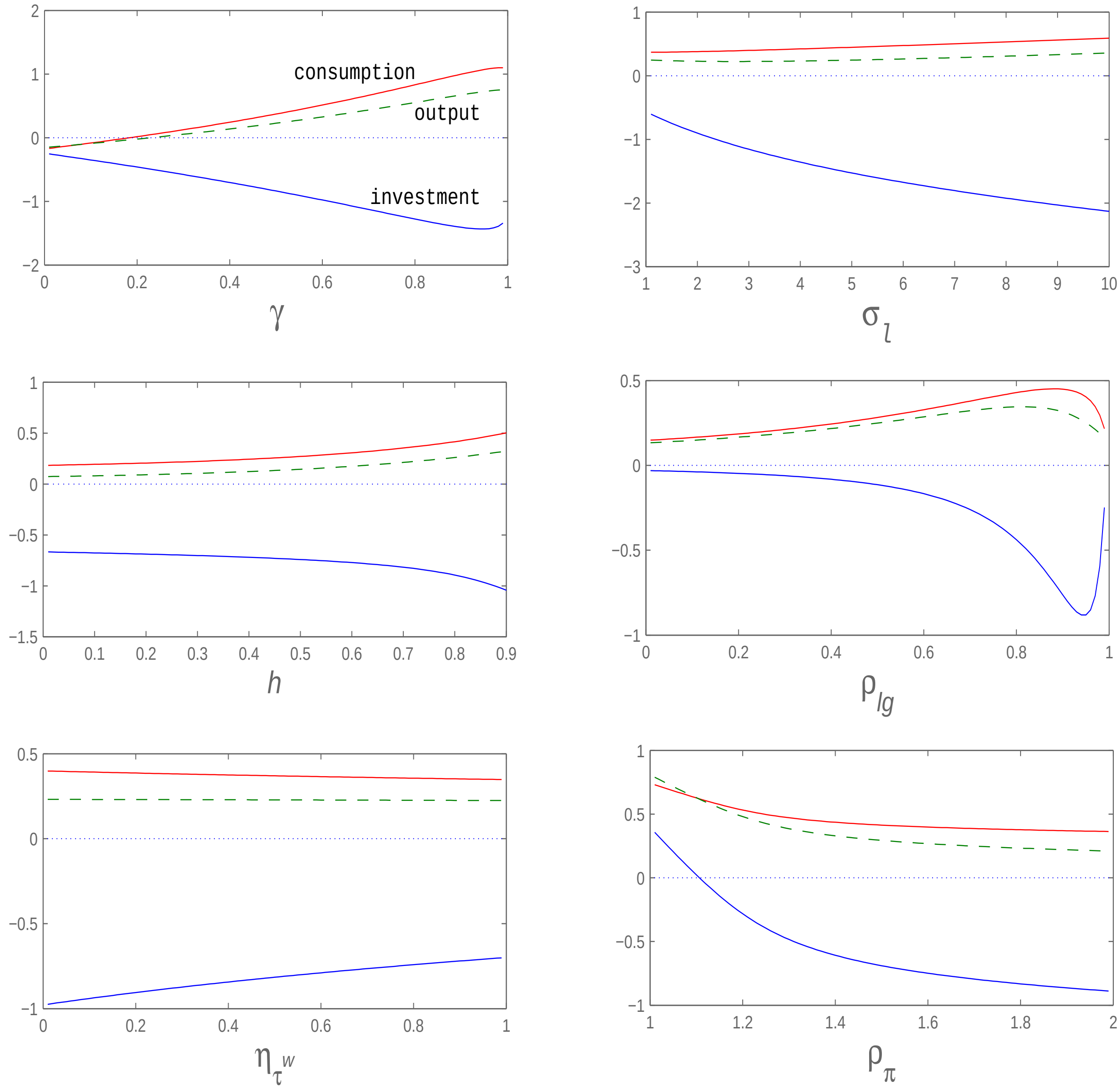


Fig. 13: Robustness - First year average responses to a government employment shock of output, consumption and investment for parameters ranges

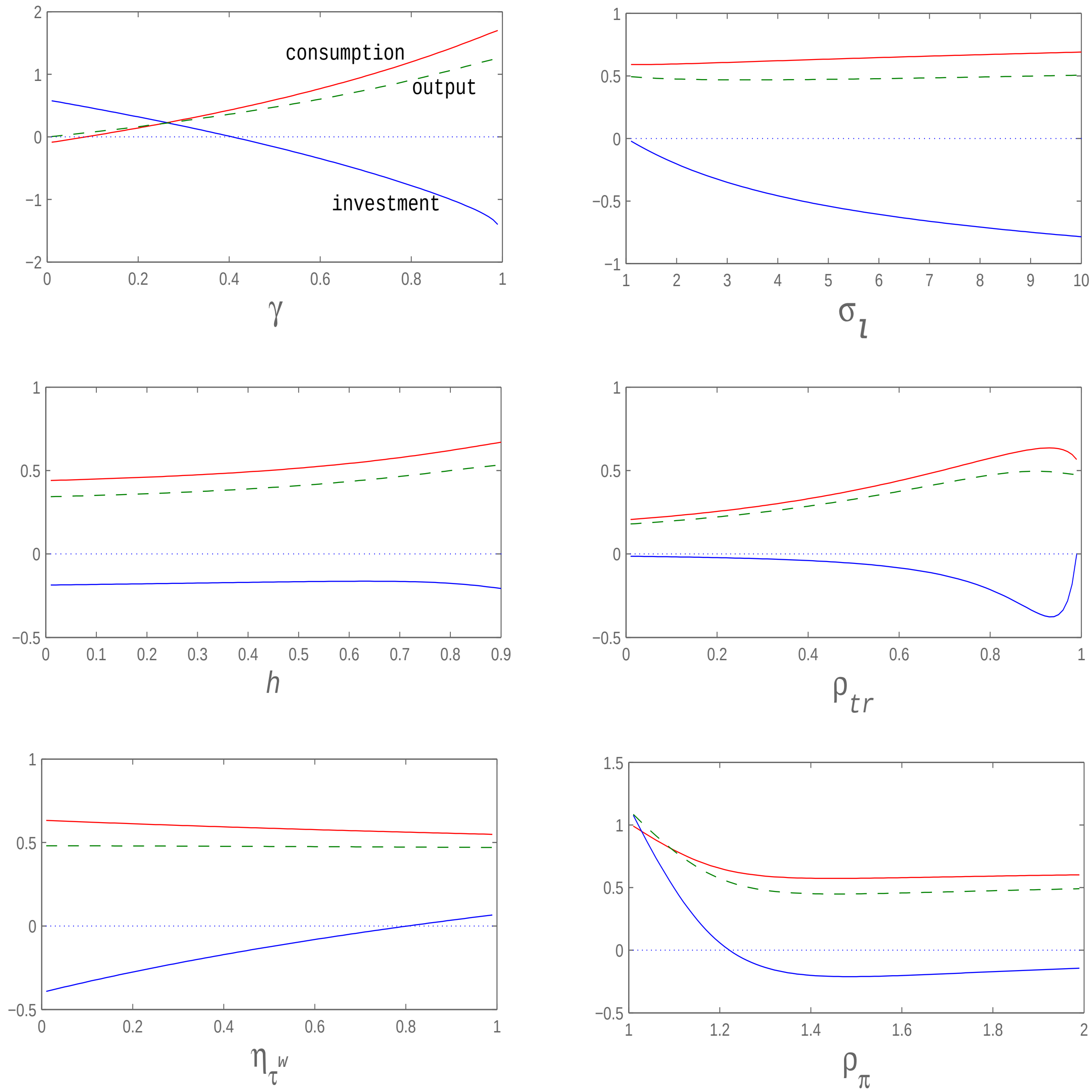


Fig. 14: Robustness - First year average responses to a government transfers shock of output, consumption and investment for parameters ranges

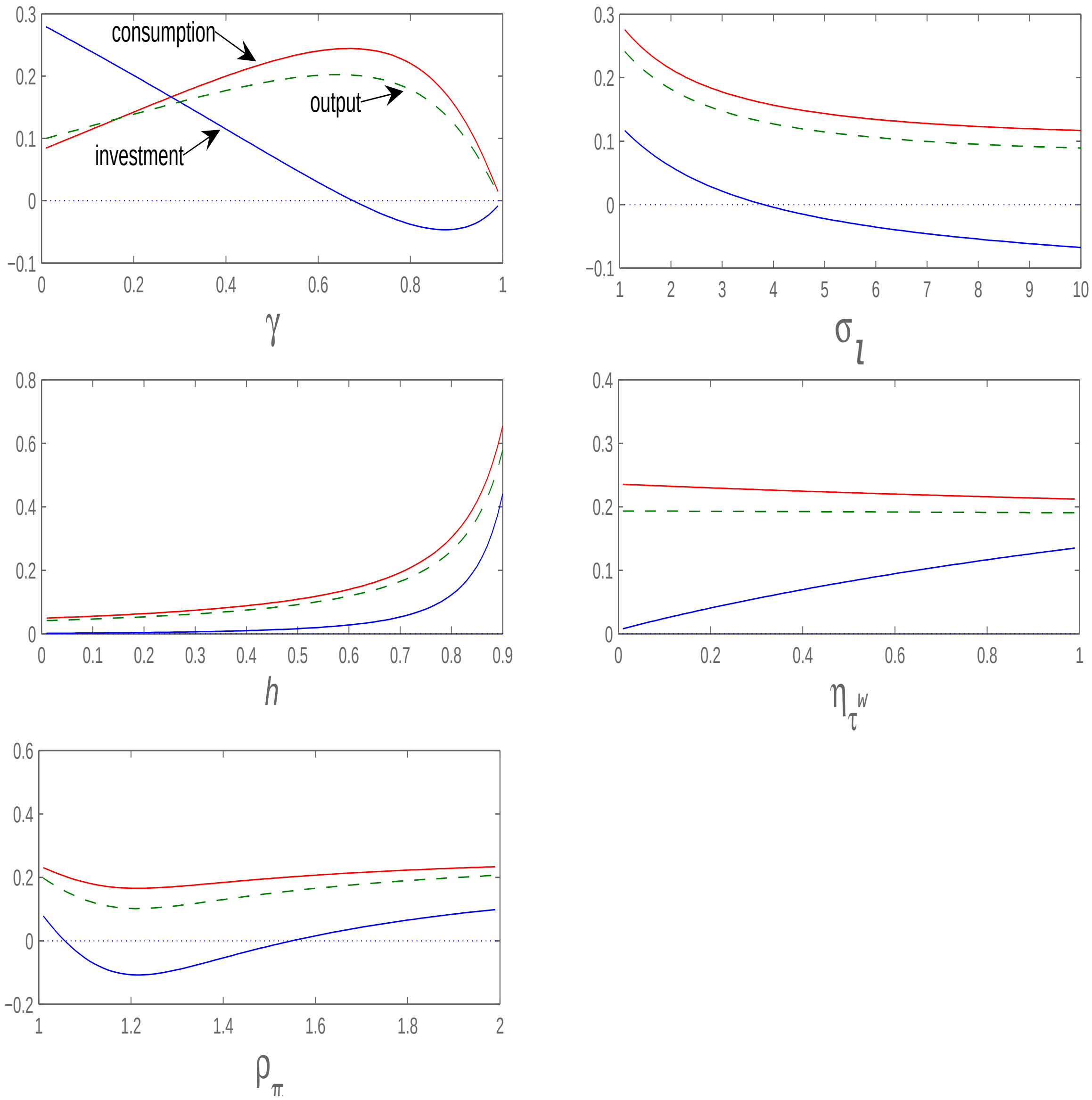


Fig. 15: Robustness - First year average responses to a labor income tax shock of output, consumption and investment for parameters ranges

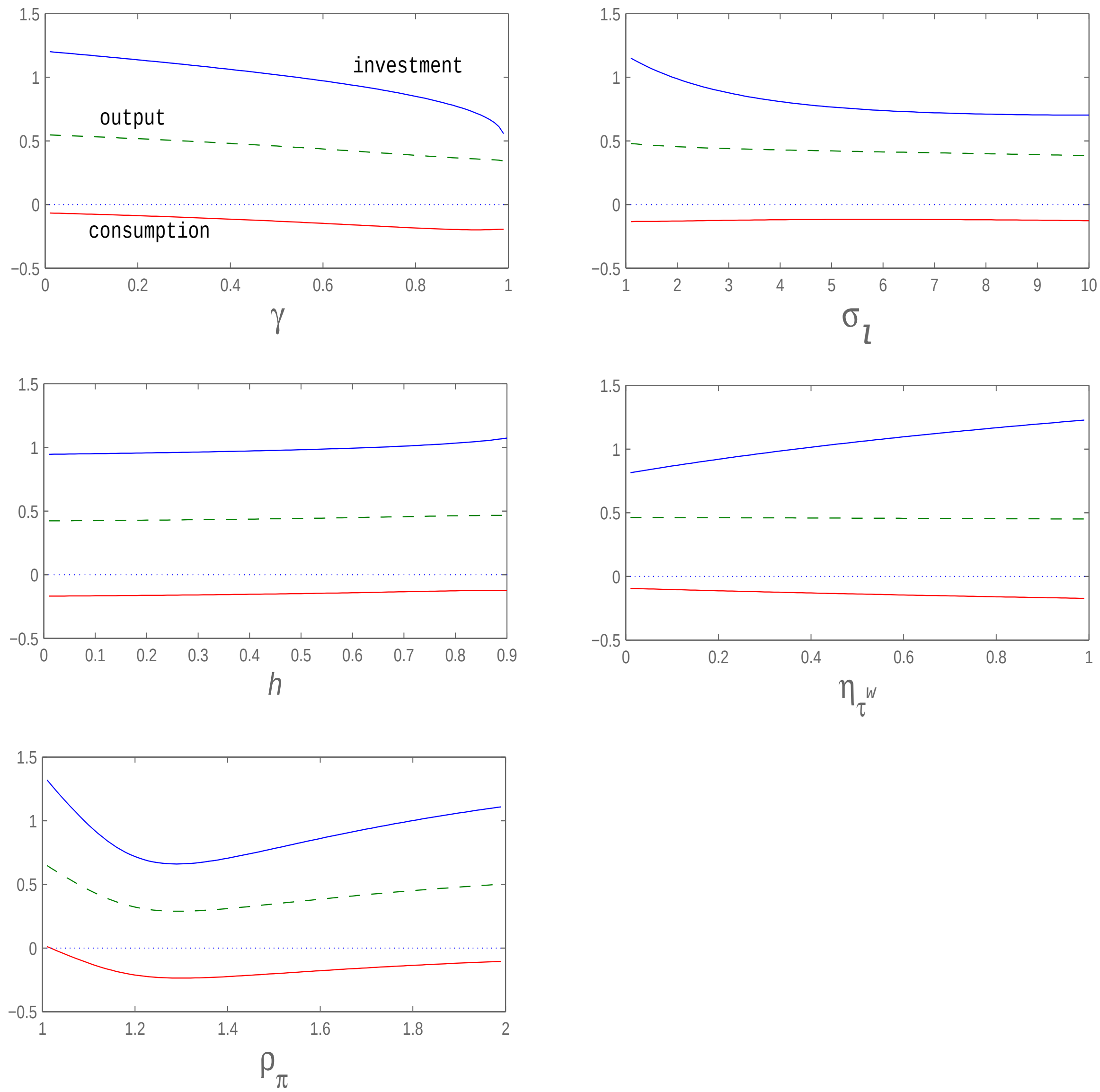


Fig. 16: Robustness - First year average responses to a capital income tax shock of output, consumption and investment for parameters ranges

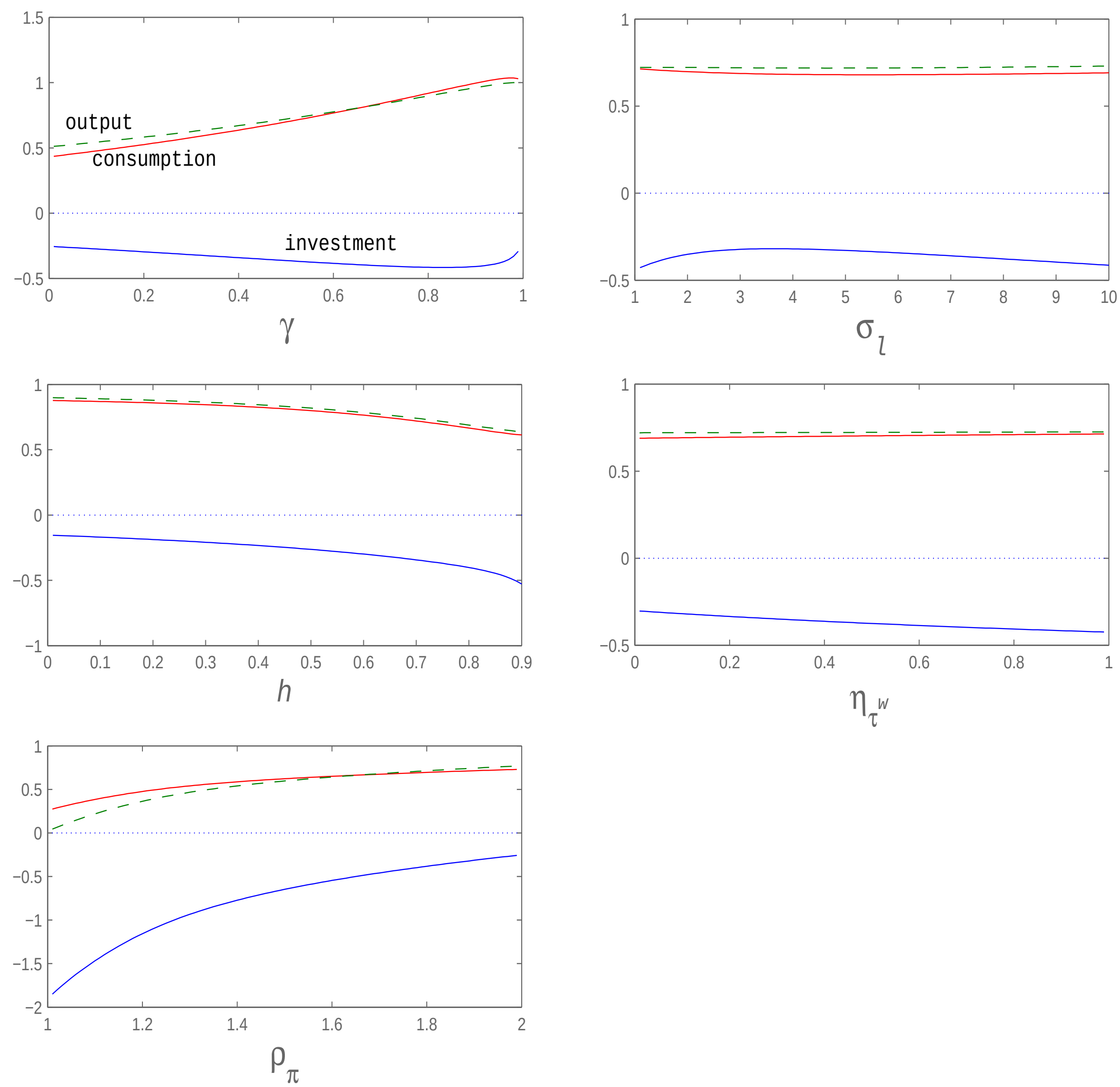


Fig. 17: Robustness - First year average responses to a consumption tax shock of output, consumption and investment for parameters ranges

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